



DevTreks –social budgeting that improves lives and livelihoods

## CTA-Prevention (CTAP)

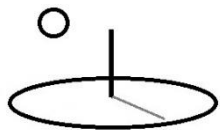
**Last Updated: September 18, 2018; First Released: July 30, 2015**

**Author: Kevin Boyle, President, DevTreks (1\*)**

**Version: 2.1.6**

This tutorial uses online datasets to illustrate how to carry out Disaster Risk Management Analysis. Version 2.1.4 upgraded this reference to make it part of the Social Performance Analysis tutorial. That tutorial includes 3 references that introduce tools that support the monitoring and evaluation of the SDG and Sendai DRR Targets and Indicators. This reference also supports these Monitoring and Evaluation business and community accounting systems by using introductory disaster risk management algorithms to further achieve the Sendai DRR targets at local scale.

<b>Sections and Examples</b>	<b>Page</b>
• CTAP Examples Introduction	39
• Appendix A. Disaster Risk Reduction (DRR) Algorithms	40
• Algorithm1. Subalgorithm 9. Disaster Risk Reduction	60
• Example 1. Hurricanes, St. Lucia, Caribbean	65
• Example 2. Floods, Semarang, Indonesia	97
• Appendix B. Risk Management Indicator (RM) Algorithms	117
• Algorithm 1. Subalgorithm 10. Disaster Risk Index	125
• Example 3. Earthquakes, Bogota, Columbia	128
• Algorithm 1. SubAlgorithm 11. Risk Management Index (RMI)	142
• Example 4. Risk Management Index	146
• Algorithm 1. SubAlgorithm 12. Resiliency Index (RI)	156
• Example 5. Generic RI Indicators	164
• Appendix C. Decision Support System Algorithms	168
• Example 8. Drought, Uttar Pradesh, India and Sana'a Water Basin, Yemen	170
• Example 9. Drought Vulnerability Index	211
• Appendix D. Integrated Local, National, and International CTAP Systems	217
• Appendix E. Resource Stock and M&E Analyzers Example 6. Stock Analyzers and Example 7. M&E Analyzers	218
• Appendix F. Testing on localhost	257



DevTreks –social budgeting that improves lives and livelihoods

All of the algorithms in this reference were tested using the upgraded Version 2.1.6 calculator patterns.

## **A. Introduction**

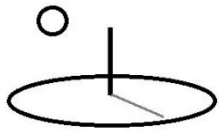
People want to know how to prevent climate change from wrecking their one and only world. Many U.S. residents have seen their houses destroyed by hurricanes, their ranges dry up from drought, their cities finances stretched from snow storms, their watersheds mangled by forest fires, their reservoir levels drop from less snowmelt, and their farm jobs disappear from irrigation water shortfalls.

At an international scale, people have seen their villages wiped out from typhoons, their children become stunted from disruptions in food supplies, their elderly relatives die from heat waves, and their livelihoods disrupted from agricultural losses due to drought.

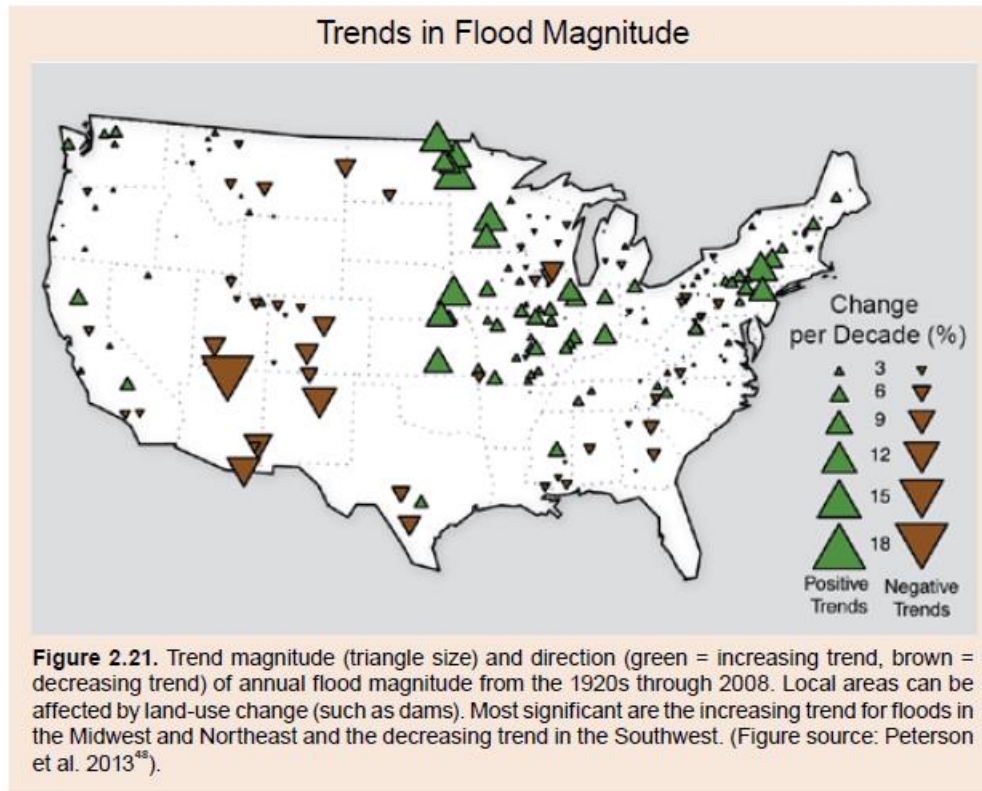
Walsh et al. (2014) find that the following natural resource trends in the United States will reinforce people's perception of impending peril to their planet:

- Temperatures are expected to continue to rise.
- The growing season [for agriculture] is projected to continue to rise.
- Average precipitation has increased since 1900.
- Heavy downpours are increasing.
- The intensity, frequency, and duration of hurricanes are projected to continue increasing.
- Changes in extreme weather events is occurring.
- Winter storms have increased in frequency and intensity since the 1950s, and their tracks have shifted northward.
- Oceans will continue becoming more acidic causing disruptions to marine ecosystems.
- Global sea levels are projected to continue increasing.

The following image (Walsh et al, 2014) demonstrates that, although these types of damages have always occurred, climate change is making them worse.



DevTreks –social budgeting that improves lives and livelihoods

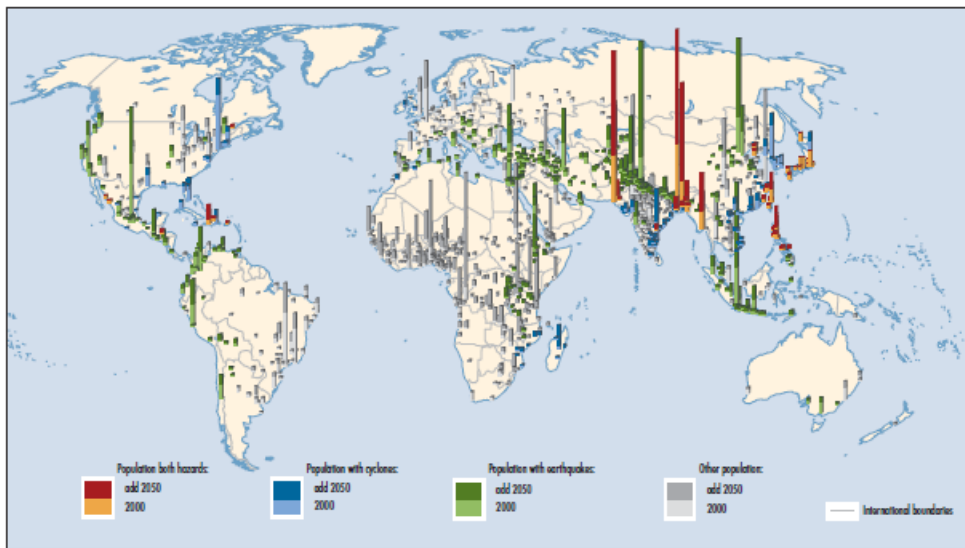


The following image (World Bank and UN, 2010) demonstrates that, factoring in population increases, these worsening damages are global in scale.



DevTreks –social budgeting that improves lives and livelihoods

**Map 3 Exposure to cyclones and earthquakes in large cities may rise from 680 million people in 2000 to 1.5 billion people by 2050**

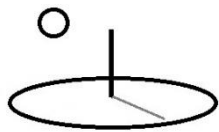


Source: Brecht and others 2010.

Putting numeric estimates on ways to prevent the damages may help citizens, organizations, firms, and governments, to understand the corresponding investments they must make to mitigate and adapt to the changes. A primary conclusion by experts in this area (World Bank and UN 2010, Moench et al 2008, V. Meyer et al 2013, European Commission 2014) is the importance of making disaster prevention information transparent. This reference uses concrete examples showing how to use CTA-Preventions (CTAPs) to quantify the probable costs and benefits of prevention interventions that prevent or correct damages caused by climate change. The overall framework and information technology used to conduct the prevention assessments is introduced in the associated *Conservation Technology Assessment* (CTA) reference. That reference should be read prior to this reference.

## **B. Damage Assessment and Disaster Risk Reduction**

The World Bank and UN (2010) reference provides recent science, with contributions from dozens of analysts, explaining the economics of natural resource disaster prevention. The reference shows that several Nobel Prize laureates endorse that science (especially the important



DevTreks –social budgeting that improves lives and livelihoods

nuances they discovered). Mechler (2005) uses the following image to summarize a standard approach, also endorsed in the World Bank and UN reference, for assessing damages from disasters.

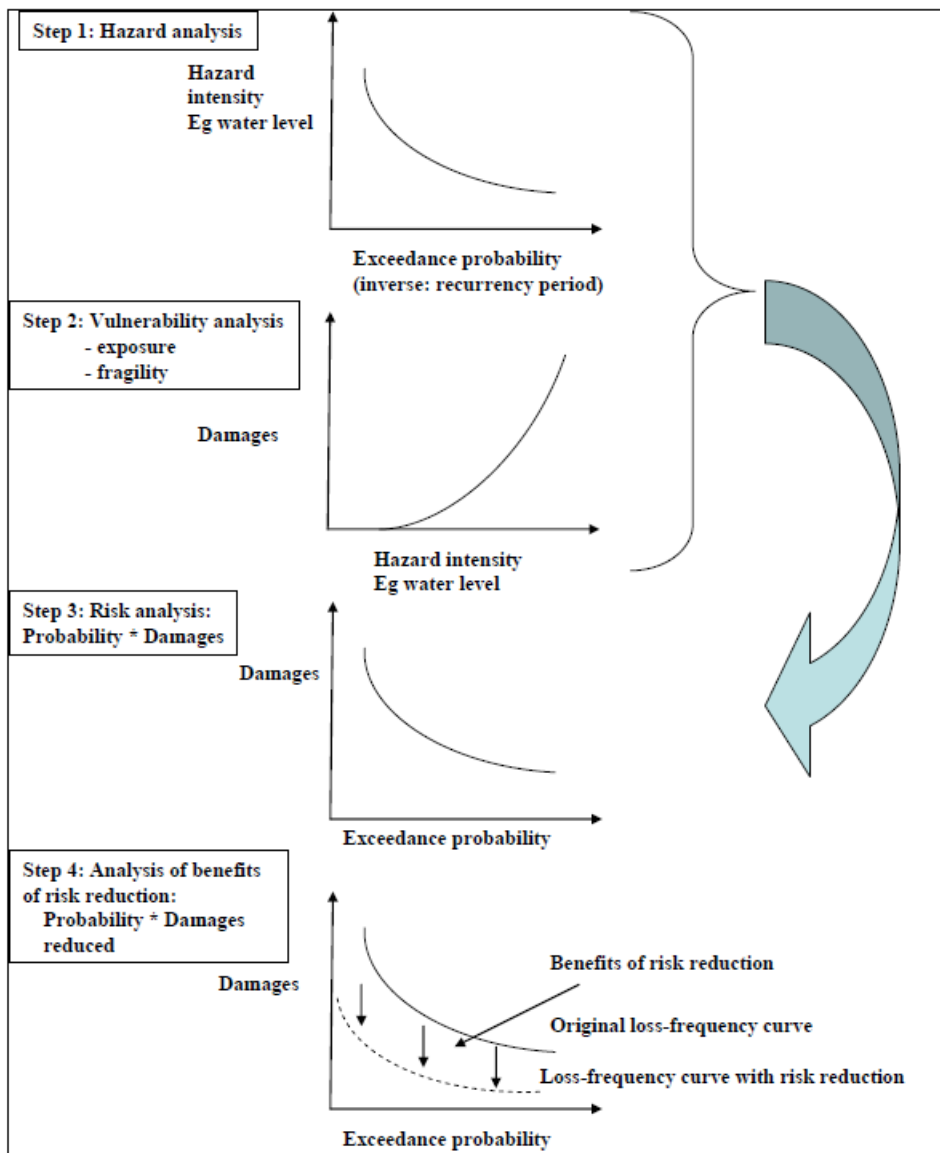
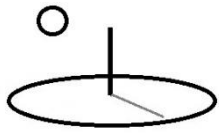


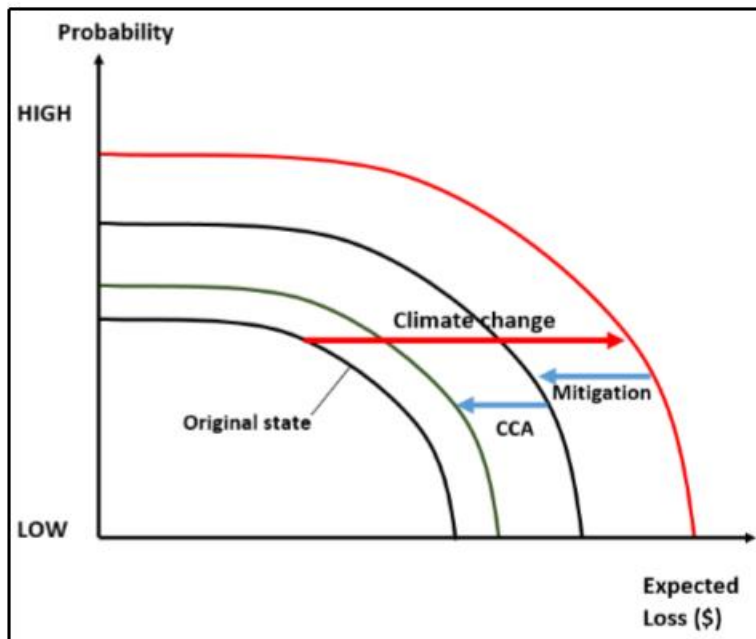
Fig. 11: Quantitative forward-looking framework for estimating disaster risk  
Illustration modified based on World Bank 1996.

The following image (UN, 2015, Annex 3) demonstrates that climate change is causing the bottom curve, Step 4, to shift upwards –damages are getting worse (the image is the inverse of Step 4's curve).



DevTreks –social budgeting that improves lives and livelihoods

**Figure 20: Climate change impact**



Source: Author

The following table defines key terms (UN, 2015) used to carry out these types of assessments.



### Box 1: Risk terminology

**Risk:** The combination of the probability of an event and its negative consequences.

**Disaster Risk:** A function of hazard, exposure and vulnerability that provides an estimate of potential disaster losses in physical, social, or environmental assets, etc.

**Hazard:** GAR15 uses the term physical hazard to refer to hazardous phenomena such as floods, storms, droughts and earthquakes with adverse effects on people and properties. Processes such as urbanization, environmental degradation and climate change shape and configure hazards; therefore its becoming increasingly difficult to disentangle their natural and human attributes. Hazards differ in severity, size and frequency and are often classified by cause (i.e. geological, hydrological, meteorological, and climatological).

**Exposure:** Assets such as people, houses, factories, offices, agricultural land, etc located in hazard-prone areas and thereby subject to potential losses.

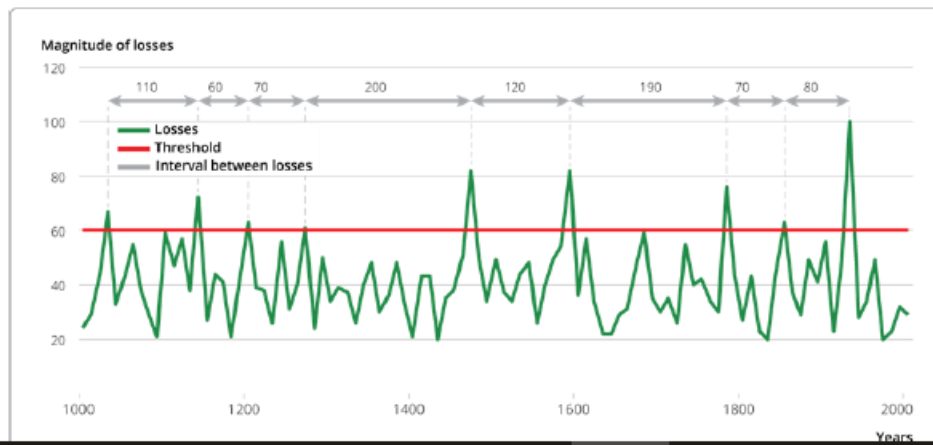
**Vulnerability:** The conditions of economic, political, physical, social and environmental infrastructure of a community, system or asset that determines the probability that a certain hazard intensity will cause a certain degree of damage. GAR global risk assessment only incorporates physical vulnerability in assessing the damage and loss.

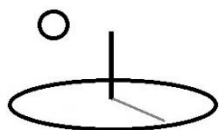
**Probability:** likelihood of an event occurring compared to all the possible events that might occur. The exceedance probability is the likelihood of one event of a given magnitude occurring or being exceeded within a defined time span.

**Frequency:** expected number of times that a particular event occurs in a defined time span. In theory, the frequency should equal the inverse of the probability of occurrence for any certain time frame.

**Return period:** average frequency with which a particular event is expected to occur. It is usually expressed in years, such as 1 in X number of years. This does not mean that an event will occur once every X numbers of years, but is another way of expressing the exceedance probability: a 1 in 200 years event has 0.5% of chances to occur or be exceeded every year.

**Figure 1: Return periods**





DevTreks –social budgeting that improves lives and livelihoods

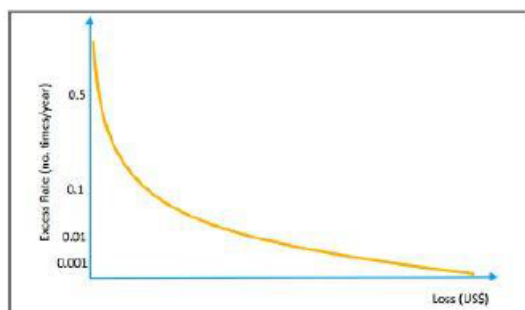
**Probabilistic Risk Assessment:** Uses a combination of probabilistic hazard scenarios, exposure and vulnerability, which is produced through modeling. Unlike historical estimates, probabilistic risk assessment takes into account all the disasters that could occur in the future, including very

4

intensive losses over long return periods, and thus overcomes the limitations associated with estimates derived from historical disaster loss data.

**Loss Exceedance Probability (EP) Curve:** Is a graphical representation of probability that a certain level of loss will be exceeded over a future time period.

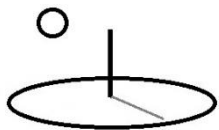
**Figure 2: Loss Exceedance Curve**



Source: UNISDR

**Annual Average Loss (AAL):** The long-term expected loss per year, averaged over many years. While there may actually be little or no losses, over a short period of time, the AAL accounts much larger losses that may occur more infrequently. In other words, it is the weighted average of expected loss from every event conditioned on the annual probability of each loss's occurrence.





**Probable Maximum Loss (PML), or loss expected at a certain annual probability or return period:** is the value of the largest loss that could result from a disaster in a defined return period such as 1 in 100 years. The term PML is always accompanied by the return period associated with the loss.

The PML for different return periods can therefore be expressed as the probability of a given loss amount being exceeded over different periods of time. Thus, even in the case of a thousand-year return period, there is still a 5 per cent probability of a PML being exceeded over a 50-year time frame.

**Table 1: Probabilities for different return periods**

Return Period PML	Probability of loss exceedance per year	Probability of loss exceedance in 20 years time frame	Probability of loss exceedance in 50 years time frame
25	4%	56%	87%
50	2%	33%	64%
100	1%	18%	39%
250	0.40%	8%	18%
500	0.20%	4%	10%
1000	0.10%	2%	5%

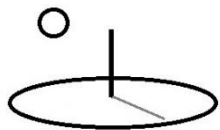
Additional damage, and disaster risk reduction, assessment models and frameworks are detailed in the Surminski et al (2015) reference and include Integrated Assessment Models, IIASA CATSIM model, Disaster Loss Assessment Guide, and about a dozen more. The UN ECLAC (2014) reference provides a comprehensive manual for assessing a broad range of losses from natural resource disasters. The European Commission references (2013, 2014) assess additional models and frameworks (i.e. DesInventar, EMDAT) and use the following image to provide practical context for the importance of disaster loss data. Some of the recommendations found in these approaches will make their way into this reference in the future.



**Table 1. Application areas of disaster damage and loss data**

Use	Compensation	Accounting	Forensics	Risk modelling
<b>Driver</b>	Fair and efficient solidarity mechanism and/or insurance market	Avoiding sovereign insolvency  Balance prevention budget and loss compensation	Evaluate prevention measures (disaster management procedures, training, technology, etc.) and protection  Improve prevention policy	Accurate risk assessment based on locally relevant loss exceedance curves  Develop economic models to estimate indirect losses
<b>Relevant legislation and agreements</b>	National legislation on compensation of victims and government aid  Insurance policy  EU solidarity fund  State Aid	National legislation on disaster prevention and risk assessment  EU Council Conclusions on a Community framework on disaster prevention within the EU  HFA-2  EU White Paper on Climate Change Adaptation	EU Council Conclusions on a Community framework on disaster prevention within the EU  EU Council conclusions on risk management capability  Union Civil Protection Mechanism	EU Flood directive  HFA-2  EU Council Conclusions on a Community framework on disaster prevention within the EU
<b>Loss period</b>	Now (event based)	Cover future losses Monitor trends in losses	Now (event-based)	Use archive to estimate future losses
<b>Interested stakeholders</b>	Member States with public compensation scheme  Insurance industry	Member States with high annual average losses and/or high maximum probable loss  European Union  Financial system  United Nations  Civil society	Member States Emergency Management authority  Regional and local emergency management authorities (for improved prevention and response protocols)	Member States potentially affected by climate change  Scientific community (early warning, disaster risk, crisis management, climate change)  Insurance Industry  EU Member States and Institutions
<b>Scale required for loss recording</b>	Asset-based	National / regional aggregates	Event-based	Asset-based (sampling)

In practical terms, these assessments are used to determine which dam size (if any) controls floods best, which coastal barrier reduces storm surges most effectively, and which building standard reduces earthquake damages most efficiently. The general approach is not only used to quantify damages from disasters, but can also be used to evaluate which health technology does the most good and least harm, which conservation collaborative processes improve habitat



DevTreks –social budgeting that improves lives and livelihoods

preservation best, which wind technology can ease energy grid deficiencies best, and what steps need to be taken to increase the resiliency of cities to withstand catastrophes.

### **C. CTA-Prevention Portfolios**

The following tables (IPCC WG2, 2014; Bierbaum et al., 2014) define key terms needed to understand how to prevent climate change from damaging the planet.



### Background Box SPM.2 | Terms Central for Understanding the Summary<sup>9</sup>

**Climate change:** Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

**Hazard:** The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term *hazard* usually refers to climate-related physical events or trends or their physical impacts.

**Exposure:** The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

**Vulnerability:** The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

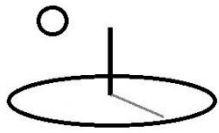
**Impacts:** Effects on natural and human systems. In this report, the term *impacts* is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as *consequences* and *outcomes*. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

**Risk:** The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard (see Figure SPM.1). In this report, the term *risk* is used primarily to refer to the risks of climate-change impacts.

**Adaptation:** The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

**Transformation:** A change in the fundamental attributes of natural and human systems. Within this summary, transformation could reflect strengthened, altered, or aligned paradigms, goals, or values towards promoting adaptation for sustainable development, including poverty reduction.

**Resilience:** The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.



## ADAPTATION KEY TERMS DEFINITIONS\*

**Adapt, Adaptation:** Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects.

**Adaptive Capacity:** The potential of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, take advantage of opportunities, and cope with the consequences.

**Mitigation:** Technological change and substitutions that reduce resource inputs and emissions per unit of output. Although several social, economic, and technological actions would reduce emissions, with respect to climate change, mitigation means implementing actions to reduce greenhouse gas emissions or increase the amount of carbon dioxide absorbed and stored by natural and man-made carbon sinks (see Ch. 27: Mitigation).

**Multiple Stressors:** Stress that originates from different sources that affect natural, managed, and socioeconomic systems and can cause impacts that are compounded and sometimes unexpected. An example would be when economic or market stress combines with drought to negatively impact farmers.

**Resilience:** A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.

**Risk:** A combination of the magnitude of the potential consequence(s) of climate change impact(s) and the likelihood that the consequence(s) will occur.

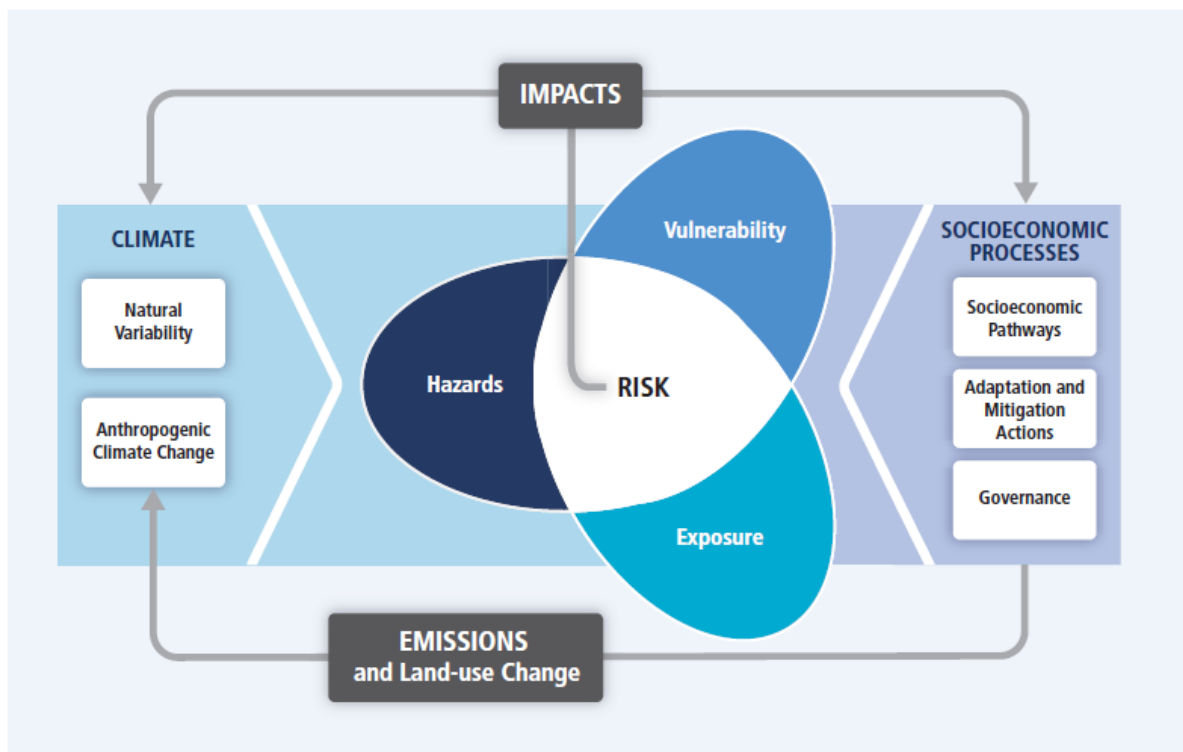
**Vulnerability:** The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

\*Definitions adapted from (IPCC 2007; <sup>16</sup> NRC 2007, <sup>17</sup> 2010<sup>11</sup>).

These terms, as further illustrated in the following images (IPCC WG 2 2014, Surminski et al, 2015), show that prevention will ultimately involve taking mitigation action, adopting adaptation measures, increasing resilience, enhancing adaptive capacity, and reducing vulnerabilities. The goal of this reference is to help decision makers determine the probability that prevention interventions with these characteristics are cost effective.



DevTreks –social budgeting that improves lives and livelihoods



**Figure SPM.1** | Illustration of the core concepts of the WGII AR5. Risk of climate-related impacts results from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability and exposure of human and natural systems. Changes in both the climate system (left) and socioeconomic processes including adaptation and mitigation (right) are drivers of hazards, exposure, and vulnerability. [19.2, Figure 19-1]

<sup>1</sup> A key finding of the WGI AR5 is, "It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century." [WGI AR5 SPM Section D.3, 2.2, 6.3, 10.3-6, 10.9]

<sup>2</sup> 1.1, Figure 1-1



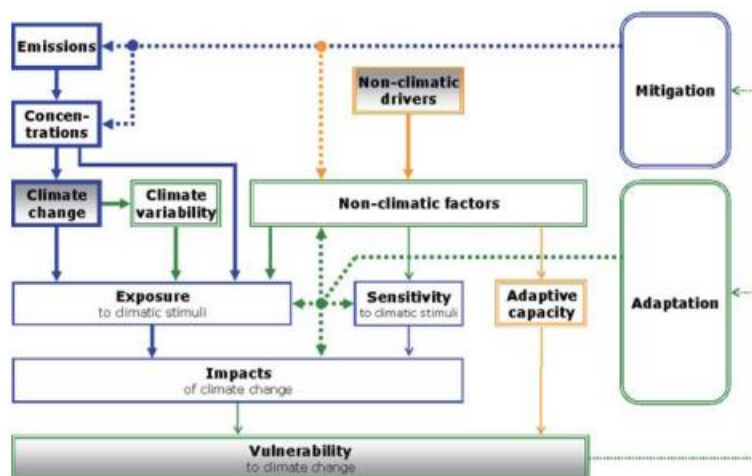
DevTreks –social budgeting that improves lives and livelihoods

## Annex II

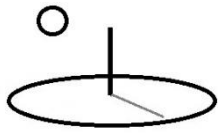
### Overview diagrams of frameworks for assessing risk and vulnerability

Figure 8

Conceptual framework for a second-generation vulnerability assessment (Füssel and Klein, 2006); this understanding corresponds largely with the vulnerability definition used in the IPCC AR4.

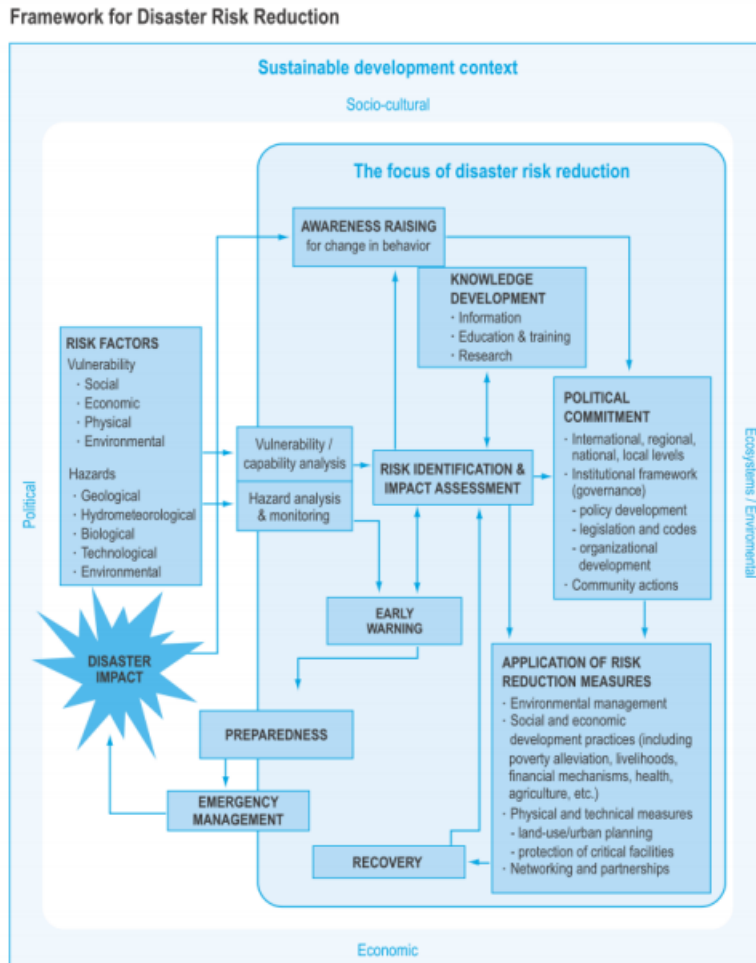


Experts cited throughout this reference consistently point out that no single policy, technology, or intervention, will work to prevent damages from climate change. Most agree that a portfolio of prevention, or mitigation and adaptation, interventions are needed. The following images show some of the ingredients needed in natural resource disaster prevention portfolios (Surminski et al 2015, IPCC WG2 2014).

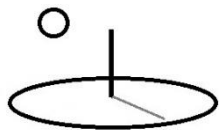


DevTreks –social budgeting that improves lives and livelihoods

Figure 9  
Framework for Disaster Risk Reduction presented by UN/ISDR (2004)







DevTreks –social budgeting that improves lives and livelihoods

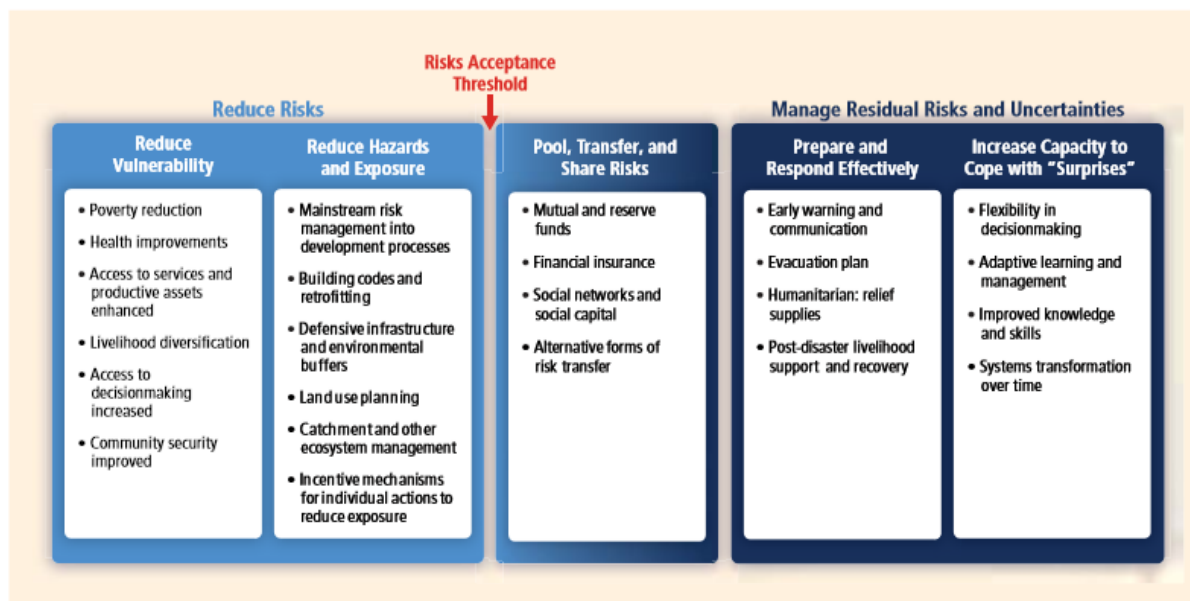


Figure 6-3 | Complementary response measures for observed and projected disaster risks supported by respective institutional and individual capacity for making informed decisions.

361

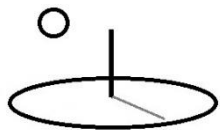
The *Resource Stock Analysis* and *Monitoring and Evaluation* (M&E) tutorials demonstrate important techniques for ensuring that prevention interventions have a better chance of achieving their planned outcomes and impacts. Appendix B contains examples demonstrating how to use the joint M&E, CTAP, and Resource Stock (i.e. Earned Value Management, or EVM), tools.

#### D. CTA-Prevention

This reference updates the traditional terms, Damage Assessment (2\*), or Disaster Risk Reduction, with the new term, CTA-Prevention. The new term is defined as follows:

**CTA-Prevention (CTAP)** is the numeric assessment of the costs and benefits of a portfolio of mitigation and adaptation interventions that prevent or correct resource stock damages. Assessments use relevant Conservation Technology Assessment (CTA) algorithms to quantify the risk and uncertainty associated with resource stock measurement and valuation.

The new term and definition have several advantages:



DevTreks –social budgeting that improves lives and livelihoods

1. They reinforce natural resource experts' emphasis on preventing disasters from occurring in the first place. They make it easier to use the newer concepts and terms devised by the experts for preventing undue losses from climate change. For example, if some level of damages from disasters is inevitable, selected populations and ecosystems can be protected better by reducing their *vulnerability*, increasing their *resilience*, and teaching people how to *adapt* (see the tables in the previous section that define these terms).
2. They are consistent with the health care sector's emerging emphasis on prevention rather than treatment. They also help analysts who complete the assessments communicate prevention strategies, rather than post-mortem actions taken after the "patient" has already suffered excessive damages. The "patients" include natural resource stocks.
3. They clearly emphasize the need to use the modern information technology techniques, embodied in CTAs, for managing data, carrying out the assessments, making the evidence transparent, and helping decision makers understand the results. They reinforce the CTA emphasis on using modern algorithms to determine likelihoods and probabilities, make forecasts, provide recommendations, and to analyze data in new ways.
4. They expand the number of assessment techniques that can be used to evaluate disaster prevention risk and savings. New algorithms, such as the Disaster Risk Index algorithm that measures indirect damages, use new ways to support decisions involving uncertain resource stock metrics.
5. They recognize that prevention won't be effective unless accompanied by changes to institutions, social norms, and personal behavior. Using the term, *resource stocks*, in the definition, rather than *natural resource stocks*, ensures that human capital stocks, social capital stocks, institutional capital stocks, and cultural capital stocks, can be fully addressed in assessments. In fact, the definition can be used as-is for assessing how well health care interventions improve human capital stocks.
6. Using the term, *costs and benefits*, in the definition emphasizes the very real and very large amounts of money that disasters impose on communities. The UNISDR GAR (2015) describes these costs as "[Probable disasters impose] contingent liabilities [that are] another category of toxic assets. If a country ignores disaster risk, ... it is in effect



DevTreks –social budgeting that improves lives and livelihoods

undermining its own future potential for social and economic development”. They further state “the costs and benefits of disaster risk management need to become fully encoded into public and private investment at all levels, into the financial system and into the design of risk-sharing and social protection mechanisms”.

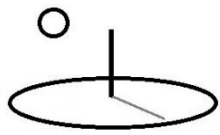
7. They help the public make the needed cultural shift from complacency to urgency. In fact, harbingers of cultural change (i.e. celebrities such as Neil Young during DesertTrip) have been holding concerts with songs that highlight this issue. Recently (September, 2016), the author has spotted people in Portland, Oregon, USA, wearing tee shirts with only the term “Adapt” printed on them. Movie industry professionals (i.e. Leonardo DiCaprio and Jenny Beavon) have used Oscar acceptance speeches to raise general public awareness of the urgency of this issue. Cultural shifts without good understanding of concomitant costs and benefits can lead to wasted resources and opportunities, so this reference is a technical manual, rather than a public relations document (3\*).

Estimating numeric savings from prevention is fraught with frailties –one farmer’s lost harvest is another farmer’s improved crop price, some people value lost lives much higher than analysts, many citizens want to prevent environmental damages regardless of discount rates, most city residents may experience minor discomforts while their city’s finances take a major beating, and the cost for one million minor actions taken to prevent a disaster can be significantly more expensive than the full recovery costs from allowing the disaster to occur.

Although damages from disasters are often related to high profile, single, catastrophic weather events, many of the damages from climate change, such as rising sea levels, will be chronic and persistent. Their full magnitude may not be realized until an unrecognized threshold is crossed and it is too late to prevent the worst outcomes (i.e. shifts in ocean currents that moderate weather).

### **E. CTA-Prevention Communication**

A primary conclusion by climate change and natural resource disaster experts is the importance of making disaster information transparent. The examples in this reference demonstrate how to make CTAPs transparent at scale (i.e. the Internet) and scope (i.e. multiple resource stocks



DevTreks –social budgeting that improves lives and livelihoods

assessed in multiple economic sectors by multiple clubs in multiple networks). The UNISDR (2009) and European Commission (2014) references provide guidance about developing and using general disaster risk reduction networks.

Several references (Appendix 2 UN GAR 2015, IPCC 2012) provide guidance for “[taking the data from] bottom-up [data loss systems], derived from microeconomics [i.e. DevTreks], [and scaling up] data from sectors at the regional or local level to aggregate an assessment of disaster costs and impacts [at national and international scales]”. The following image (IPCC 2012) demonstrates the importance of linking this local knowledge and action with global actors and their public goods responsibilities (i.e. to prevent climate change from wrecking our world).

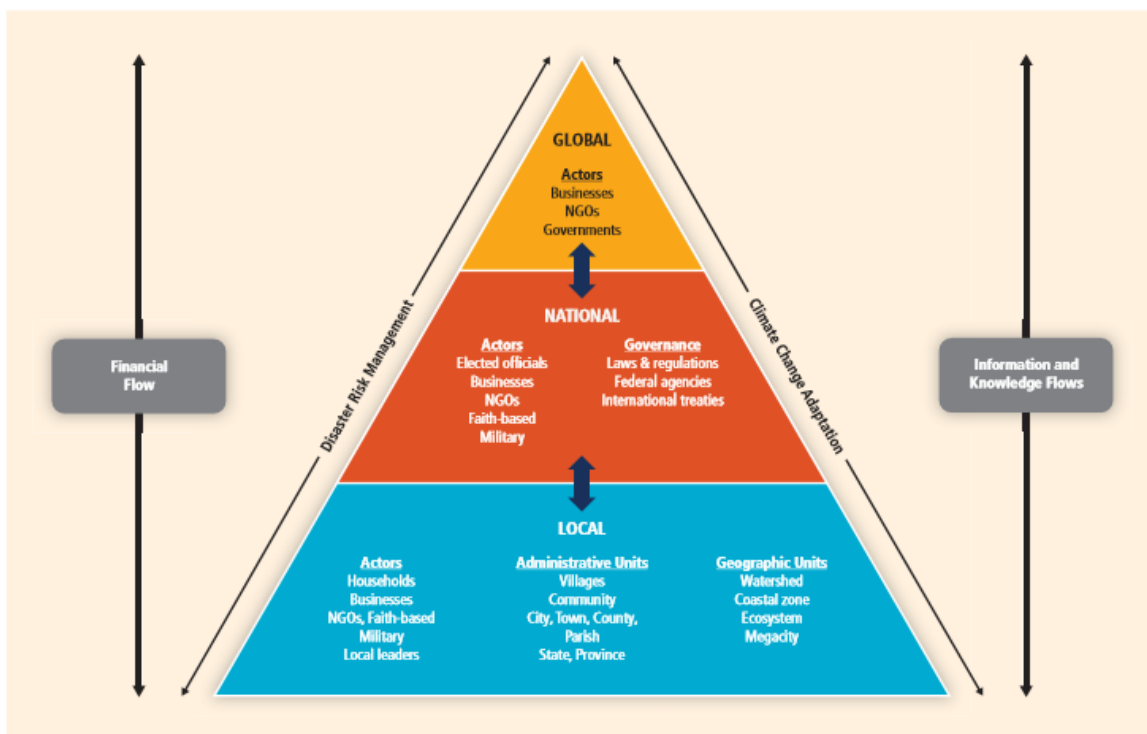
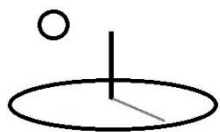
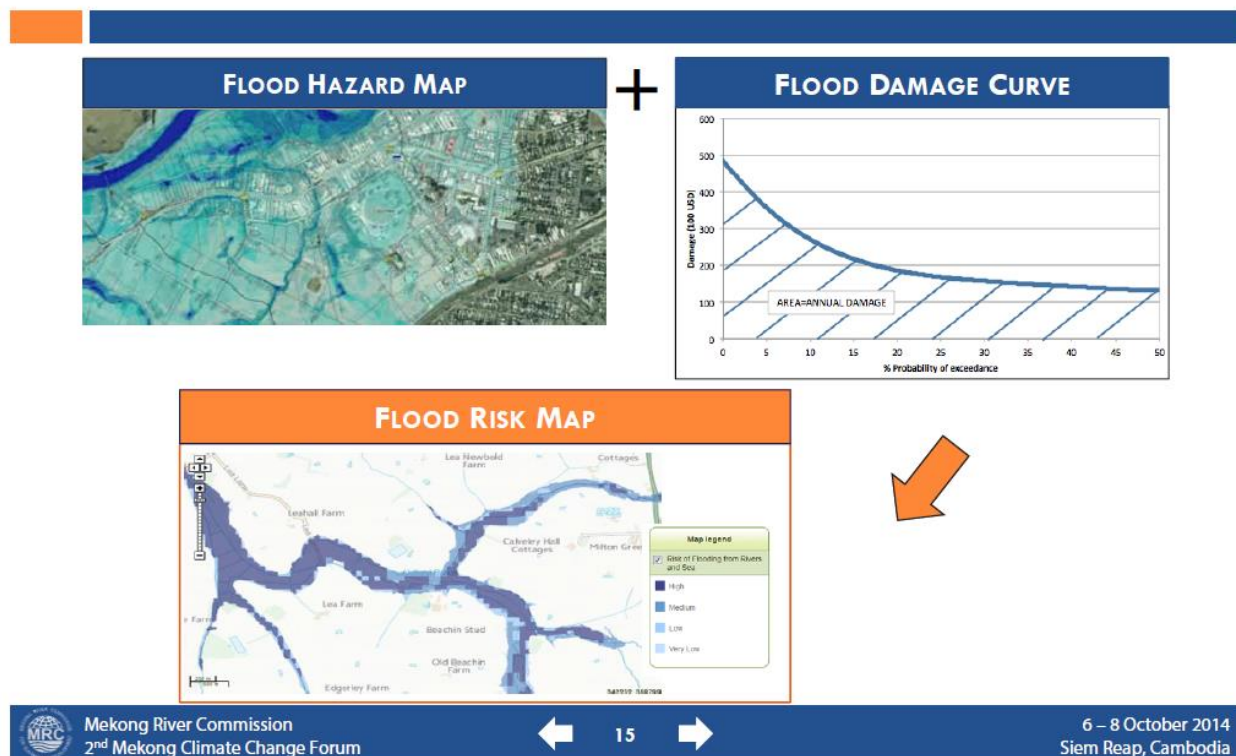


Figure 5-1 | Linking local to global actors and responsibilities.

Most of the climate change references demonstrate the value of GIS techniques in analyzing and communicating information about climate change to lay persons. The following image (Khantisidhi, 2014) demonstrates how numeric damage assessments are incorporated into commonly-used risk maps.

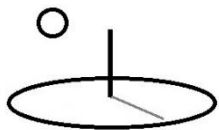


## Flood Risk Assessment



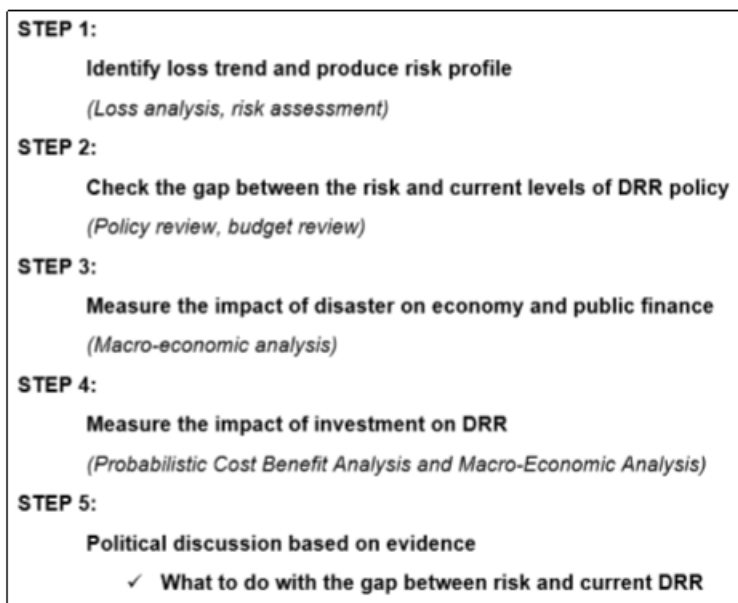
The previous images imply that CTAP data must be easily accessible to machines because the machines are getting smarter and more communicative. In information technology terms, CTAPs are best completed and communicated using an overall software library (4\*).

The following image (UN 2015) demonstrates how numeric Disaster Risk Reduction (DRR) assessments fit into more comprehensive decision support frameworks.



DevTreks –social budgeting that improves lives and livelihoods

**Figure 16: Overall design to support evidence based decision making**



Source: Author

These communication and decision support pathways will continue to be addressed in future releases.

## **F. Knowledge Banks**

Most DevTreks references discuss the importance of data standards, such as using “best practice” recommendations for calculating costs and benefits, employing Work Breakdown Schedules to classify “high quality” data, and using automated software object models to generate uniform calculations. At the most basic level, this allows cost estimate A and Benefit Cost Ratio Y, to be meaningfully compared to cost estimate B and Benefit Cost Ratio Z. At the most relevant level, it overcomes the problem of not having data to support extremely expensive decisions, such as what to do about preventing disasters (see V. Meyer et al, 2013). At the most practical level, the following image (European Commission, 2014) demonstrates how the use of best practice cost and benefit estimates, and high quality data standards, support the sharing and aggregation of data across countries.



Table 32 summarizes the proposal for a framework for damage/economic loss indicators that can be implemented at municipality, regional and national. For data sharing among Member States and international organisations, summary data (not disaggregated by loss owner and sector) will be more appropriate. The aggregated data can be reported in the final row of Table 32 (highlighted in grey). The terminology, presented at the beginning of this report (page 10), provides the definitions of the terms used in the damage/economic losses framework.

**Table 32. Aggregation of loss data: example of reporting sheet (all in monetary value). Such sheets can be created at municipality, regional and national levels.**

Direct loss to affected elements (€)							Total loss (€)						
Sector	affected elements	Loss owner					sectors	Loss owner					
		insurer	individual	business	NGO	government		insurer	individual	business	NGO	government	
housing	building						housing						Total Housing
	content/equipment												
	vehicles												
	landscape												
education research	building						education research						Total education research
	content/equipment												
	vehicles												
	landscape												
culture recreation	building						culture recreation						Total culture recreation
	content/equipment												
	vehicles												
	landscape												
-	building												Total

Appendix 2 in the UN GAR (2015) reference discusses national and international knowledge banks of disaster loss data. These systems (i.e. DesInventar, EMDAT) are similar to the tabular accounting systems demonstrated in the previous image. Their purpose is to summarize critical dimensions of disaster losses. Evidence of their importance is clear because most countries have adopted, or are adopting, these data loss systems.

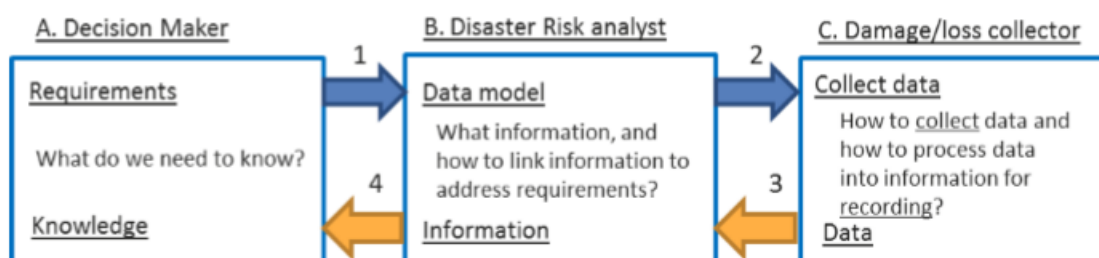
These data systems shouldn't be confused with CTAPs. CTAPs assess concrete mitigation and adaptation technologies, similar to the techniques explained in the USACOE and USFEMA references. In effect, these existing national data loss systems can be considered metadata that describes, or summarizes, the more comprehensive results generated from actual disasters or



DevTreks –social budgeting that improves lives and livelihoods

from “bottom-up” CTAP damage assessments. The UN GAR reference clearly demonstrate the difference, stating “economic data collected and reported in disaster loss databases is very scare and inconsistent”. They have to extrapolate the economic losses from the disaster loss systems. In contrast, the primary characteristic of CTAPs are their emphasis on carrying out and reporting technology assessments that include uniform cost and benefit, and cost effectiveness, damage reduction estimates. The two systems complement one another, but point to the need to develop an automated way for machines to transfer and aggregate CTAP data to summary regional, national, and global data loss systems (see Appendix D).

The following image (European Commission 2014) demonstrates how formal data loss collection systems, or knowledge banks, are used to answer practical, important, questions about disasters.



**Figure 4. Requirements determine the data model that in turns determines the data to be collected**

Typical questions expected to be answered using disaster loss data are:

- What perils are generating losses?
- What assets are being damaged?
- What is the degree of the damage?
- Where are losses occurring geographically?
- What are the trends of disaster damage in the agricultural sector?
- Which country has the highest exposure of the transport sector to natural disasters?
- Which region in the EU is most resilient to a 10-year flood event? And why (type of housing, protection of the river, elevation of built-up)?
- Which disaster type affects economic losses most?

The best practice estimation techniques coupled with the use of high quality data standards allow knowledge banks of high quality disaster-related data to be passed down to future generations.





DevTreks –social budgeting that improves lives and livelihoods

Those future generations are facing imminent demise unless 195 nations carry out their climate change pledges affordably and transparently. Countries have a moral responsibility to transfer the lessons they have learned about mitigating and adapting to climate change (i.e. passing down knowledge banks) to future decision makers. Reporting disaster losses, or GHG reductions, or Sendai Framework accomplishments, alone won't suffice –the quantified “how and why”, or, in CTAP parlance, the digital Conservation Technology Assessments, behind that metadata must be passed along too.

### **G. CTA-Prevention Unresolved Concerns**

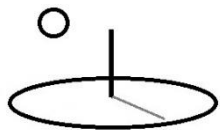
Besides the difficulties already mentioned about measuring and valuing changes in resource stocks, major concerns remain unresolved in many aspects of the stock changes (World Bank and UN, 2010; AAAS and RFF, 2014, IPCC WG2 2014, UN GAR 2015, Moench et al 2008):

**Intangibles:** Planning officials have a tendency to be engineer-oriented and pay more attention to physical infrastructure damages (i.e. bridges, highways, buildings) than savings associated with managerial adjustments (i.e. fertilizer that replaces nutrients washed away), institutional disruptions (i.e. children that leave school), and ecosystem service losses (i.e. marshlands that reduce floods).

**Indirects:** Savings from many resource stock changes don't directly involve preventing bridges from washing away, people being killed, or crops destroyed. They are associated with the indirect consequences of these changes: the time residents spend commuting because of transportation disruptions, the stunted children who develop impaired intellects, and the yield losses from soils that lose topsoil and nutrients.

**Fat Tails and Extreme Events:** The references cited, and some of the images displayed, show that the historical mean and standard deviation are no longer fully reliable predictors of future resource stock conditions. More extreme events will occur than the historical average, and many will occur with greater intensity (i.e. hurricanes in the US).

**Catastrophic and Irreversible Events:** Climate change experts use terms such as thresholds, tipping points, and surprises, to explain the great deal of uncertainty about



DevTreks –social budgeting that improves lives and livelihoods

how future levels of GHG emissions could result in irreversible damages to specific ecosystems and populations (i.e. if the Greenland ice sheet melts, sea levels rise 7 meters).

**Value of a Life:** Putting a dollar value on a life will always be controversial. Using some of the techniques employed by health care analysts, such as using Quality Adjusted Life Years, may assist putting a dollar value on saving human lives.

**Equity and Distribution of Gains:** Equity has become a general area of concern for the poor and middle class residents of many countries. Their wages have stagnated while the rich have prospered. Per capita carbon emissions are several orders of magnitude higher in developed versus developing countries. Similarly, institutional imperfections exist with how prevention and recovery funds are spent, recovery contracts awarded, disaster legislation captured by special interests, and future generations treated fairly. Without institutional improvements that address equity, many of the resource-poor will remain damaged, while the resource-rich will quickly recover.

**Unique and Threatened Systems:** Several unique and threatened ecosystems and populations are already being impacted by climate change and this trend is expected to get worse. Governments throughout the world have established precedence in putting priority on protecting these assets through actions such as land transfers to native populations, threatened and endangered species laws, and wildlife reserves.

**Tradeoffs:** Money spent on natural resource damage prevention can be spent elsewhere – on education, physical infrastructure, imprisonment, war, and foreign aid. Choices have to be made. The World Bank (2014) points to the need to understand the tradeoff between “preparing for risk with that of coping with its consequences”. The UN (2015) emphasizes that “benefit cost analysis needs to be expanded to highlight the trade-offs implicit in each [investment] decision, including the downstream benefits and avoided costs in terms of reduced poverty and inequality, environmental sustainability, economic development and social progress as well as a clear identification of who retains the risks,



DevTreks –social budgeting that improves lives and livelihoods

who bears the costs and who reaps the benefits”. Better numbers might help to make the tradeoffs, and winners and losers, clearer.

**Discount Rate:** The social discount rate used to discount future benefits and costs remains controversial. High rates lessen the value of the longer term gains from prevention actions.

**Risk Management Portfolios:** Managing risk is complex –all of the major references point to the need for a portfolio of actions. However, fewer of the references document the need to factor in social systems, financial systems, macroeconomic conditions, and public sector leadership, into the portfolios (see the WDR 2014). Even well-endowed governments have trouble understanding all of the ingredients needed in effective risk management portfolios.

Neither this reference, nor any other reference, can alleviate all of these concerns with one grand publication, or software app, –it’s not possible. This reference will evolve as the information technology, that is, the apps, used by the reference get better. Future releases will continue to address these concerns.

## **H. CTA-Prevention Examples (5\*)**

**Appendix A** has examples of CTAPs completed using Disaster Risk Reduction (DRR) algorithms. **Appendix B** has examples of CTAPs completed using Risk Management Indicator (RM) algorithms. **Appendix C** has examples of CTAPs completed using Decision Support System (DSS) algorithms. **Appendix D** has examples of CTAPs completed using national data loss systems. Many algorithms complement one another and can be used jointly. For example, the Carreno (2012) and Marulanda (2013) references demonstrate carrying out “holistic” damage assessments by using algorithms from Appendix A to incorporate physical risk indicators to estimate direct damages, and algorithms from Appendix B to incorporate social fragility and lack of resiliency indicators to estimate indirect damages.

## **Summary**



DevTreks –social budgeting that improves lives and livelihoods

This reference demonstrates how to complete CTAPs. CTAPs may help US West Coast residents take effective preventive measures for their probable earthquakes, Bangladeshi delta residents mitigate their likely floods, Central Mexican school officials keep their students enrolled during more frequent droughts, North African health care administrators reduce child stunting from disrupted food systems, Pacific Islanders reduce damages from rising typhoon intensity, and people to improve their lives and livelihoods.

## Footnotes

1. While working as an agricultural economist for the USDA, Natural Resources Conservation Service, the author provided technical assistance and coordinated training in flood damage assessments –usually for water resource management projects, such as dams, in smaller watersheds in the US. Read Footnote 6 for caveats about the author’s current expertise (i.e. software development). He initiated this project while working in that agency’s Social Sciences Institute as an agricultural economist/scientist/software developer.
2. Practitioners who deal with the aftermaths of natural resource disasters commonly complete Damage Assessments –but using simpler, summary, and field-oriented, single page forms. This reference does not recommend any changes with the Damage Assessments already being used for field work. The CTAPs endorsed in this reference are appropriate when formal economic evaluations are needed (i.e. when resources are scarce and money needs to be saved) and knowledge banks must be used to provide easy access to this evidence (i.e. when Internet technology is needed to carry out the assessments and make the evidence transparent to people *and machines*).
3. Nevertheless, public relations may be a good idea for a non-profit that writes code, rather than raises funds, so the author’s non-profit may start selling baseball caps and tee-shirts with CTAP terms printed on them.
4. DevTreks has not been explicitly built as a software dictionary, or API, that other software developers can use to develop technology assessment or cost and benefit applications. Nevertheless, the underlying database uses a fairly straightforward



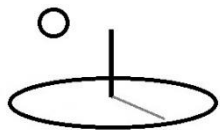
hierarchical table structure. Experiments have been conducted in the past (i.e. using OData and Web APIs) to see how much difficulty machines would have in accessing all of that data. The conclusion at that time was that machines, and the people who program the machines, would not have that much trouble accessing most of the data –hierarchical database data is not that hard to make machine-friendly (provided that high quality data standards are followed). The Source Code tutorial shows that Version 2.0.2 included a WebApi app that starts to address the need identified in this footnote. The Containers reference in that tutorial will be updated in a future release to further address this issue.

5. Although the examples in the Appendices focus on natural resource-related disasters, the author believes that several of the algorithms, with careful construction, can also be used for other stocks. For example, in Appendix A, Example 1, substitute health care damages for natural resource damages, probable health care events (i.e. DRG severity levels such as mild stroke, moderate stroke, severe stroke, and Markov transition states such as extremely ill, 50% recovery, 90% recovery), for probable natural resources events, targeted health care populations for physical asset types, QALYs for dollar damages, and health care interventions for project alternatives, and see what you come up with (i.e. basic ICERs of alternative health care interventions? see WHO, 2003).
6. The author is not a current “expert” in many of the assessment techniques demonstrated in these examples, such as flood damage assessments. One of the primary purposes of this reference is to demonstrate how to use the generic properties of Indicators and Scores to conduct basic versions of these assessments. The generic properties can handle many, if not all, of the mathematical and statistical techniques used in more advanced, or “expert”, assessments. As many of the examples will demonstrate, if the existing algorithms can’t handle the advanced calculations, it’s very likely that a new algorithm needs to be developed and added to the libraries.
7. A technical assistance visit paid years ago by the author to a fire-prone area in the Northern California foothills, concluded that the majority of homeowners would not undertake fire-safe actions around their houses until homeowner insurance companies credited their fire insurance premiums for the improvements. The homeowners themselves indirectly proposed this “solution”. This is similar to the World Bank and UN



(2010) point that individuals respond to price signals. In this case, no transparent price signals rewarded prevention actions (i.e. carbon prices are another good example). It's also similar to behavioral economists' conclusions that individuals overestimate low probable events while underestimating high probable events. In this case, experts believed that a serious fire was inevitable in a short time horizon and informed local residents about their conclusions.

8. In some cases, traditional approaches may be exactly what *are* needed. The author recently read a journal article in a literary US magazine (New Yorker) that made a convincing case that an earthquake will soon damage his Northwest US city neighborhood. He immediately wanted traditional, detailed, damage assessment information, complete with confidence intervals, for his neighborhood and building (as might most other Northwest US residents reading the article). While literary magazines may not be proper forums for this detailed information, this reference demonstrates that CTAPs completed and stored on the cloud have the potential to be a very good forum.
9. The fact that these types of algorithms are difficult to find may reflect on past, misplaced, science (i.e. science that didn't, and still doesn't, understand modern IT). Research peers appear to have reinforced this misguided science –publishing a paper that doesn't advance modern IT in some way is another squandered opportunity; publishing social science equations and numeric results that can't be easily translated into computer algorithms is at best, short-sightedness, and at worst, academic preening (often excused by sticking the word “policy” in there somewhere); contracting for economic assessments that can't be completed and stored using modern on-line technology reinforces outdated, inefficient, and wasteful, applications of science. As concrete reinforcement to this footnote, DevTreks has started adding its source code to each release.
10. Mention should be made of bugs discovered during more comprehensive testing of these Stock Progress and M&E tools. At least 5 bugs or flaws surfaced (in the 88 tools). How do these bugs slip through? Because DevTreks is a small shop and some features simply can't be tested by the author as much as others. Serious national, international, or virtual, shops must plan on having larger IT staffs. As a precursor, such shops first need to find administrators capable of caring, thinking, and acting, at appropriate scales and scopes.



DevTreks –social budgeting that improves lives and livelihoods

11. The time commitment needed to complete these types of analyses correctly should be weighed against the usefulness of the results. These tools, like most DevTreks tools, have a level of complexity, or more accurately, detail, which may make them more useful to serious specialists, rather than casual analysts. These types of specialists should be the customers obtaining funding to build additional features and tools (i.e. whether through this shop or their own shop).
12. The fact that smaller countries, such as Ireland, are missing from this European Union publication, suggests the types of countries, including developing countries, which may benefit, in particular, from this type of IT product. The author has direct knowledge of persons who are studying IT in these countries (i.e. cousins) who may gladly help with the technical requirements.
13. If disaster loss data is simply not available in most parts of the world, then how can algorithms such as these, that require data distributions, help? Use your imagination. Instead of claiming that a probability density function is known, use similar techniques to those shown in this reference (rules of thumb for distributions: normal or triangular distribution, mean = approximate average point estimate, standard deviation = approximate 30% mean, confidence intervals = approximate high and low bounds on an approximate average estimate). State that the goal is to use the “introductory data” to develop “real data” in future releases. The criteria is whether or not imperfect data can support imperfect, but better, decision making. You may have a window of time to prevent the worst outcomes.
14. A review of the UNEP web site for their MCA initiative, MCA4climate, does not confirm much advance since 2011. More recent UN references, such as UN CAPNET 2015, introduce alternative DSS systems, such as DPSIR and SWOT, rather than MCA. It’s important to keep any DSS system, or for that matter, any algorithm, in perspective. These are all tools that have the potential to assist decision making. Assess which ones make sense for local contexts, experiment with them, adapt, but ultimately figure out how to make affordable and transparent decisions for dealing with climate change.
15. Some experts, or at least critics, in this field like to qualify this statement by using the term “credible organizations”. Until those critics can provide URLs and examples as



DevTreks –social budgeting that improves lives and livelihoods

demonstrated here, along with the source code proving their web and cloud data services, *their* credibility is hard to judge. Oh, and in this type of digital world, credibility doesn't necessarily derive from attending lots of meetings, producing more paper work, being good at rent seeking, or having a big budget to spend.

## References

American Association for the Advancement of Science (AAAS) and Resources for the Future (RFF). The Economic and Financial Risks of a Changing Planet. Insights from Leading Experts. Workshop Report. November, 2014.

Bierbaum, Lee, Smith, Blair, Carter, Chapin, Fleming, Ruffo, McNeeley, Stults, Verduzco, and Seylier, 2014: Ch. 28: Adaptation. Climate Change Impacts in the United States: The Third National Climate Assessment, Melillo, Richmond, and Yohe, Eds., U.S. Global Climate Change Research Program, 670-706.

Carreño, Martha, Cardona, Omar D., Ordaz, Mario G., Barbat, Alex H. Seismic risk evaluation for an urban centre. 250th Anniversary of the 1755 Lisbon Earthquake. 2005

Carreño M.L., Cardona O.D. and Barbat, A.H.. Urban Seismic Risk Evaluation: A Holistic Approach, Natural Hazards. 40(1):137-172. 2007

Carreño, Martha, Cardona, Omar D., Barbat, Alex H. Holistic Evaluation of the Seismic Risk in Barcelona by Using Indicators. 15 WCEE, Lisbon, Portugal. 2012

European Commission, JRC Scientific and Policy Reports, Recording Disaster Losses. 2013.

European Commission, JRC Scientific and Policy Reports, Current status and Best Practices for Disaster Loss Data recording in EU Member States. 2014. (12\*)

Hochrainer, Stefan, Howard Kunreuther, Joanne Linnerooth-Bayer, Reinhard Mechler, Erwann Michel-Kerjan, Robert Muir-Wood, Nicola Ranger, Pantea Vaziri, Michael Young. The Costs and Benefits of Reducing Risk from Natural Hazards to Residential Structures in Developing





DevTreks –social budgeting that improves lives and livelihoods

Countries. Working Paper # 2011-01, Risk Management and Decision Processes Center, The Wharton School, University of Pennsylvania, 2011

Hochrainer, Stefan; Patnaik, Unmesh; Kull, Daniel, Singh, Praveen; Wajih, Shiraz. Disaster Financing and Poverty Traps for Poor Households: Realities in Northern India. *International Journal of Mass Emergencies and Disasters* March 2011, Vol. 29, No. 1, pp. 57–82.

Inter-American Development Bank. From disaster response to prevention: companion paper to the Disaster Risk Management Policy. Sustainable Development Department sector strategy and policy paper series. 2007

IPCC. Climate Change 2014, Impacts, Adaptation, and Vulnerability, Part A Global and Sectoral Aspects. Working Group 2 Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Field, Barnes, Barros, Dockken, Mach, Mastrandrea, Bilir, Chatterjee, Ebi, Estrada, Genova, Girma, Kissel, Levy, MacCracken, Mastrandrea, and White (EDS)]. SUBJECT TO FINAL EDIT

IPCC, 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Group I and II of the Intergovernmental Panel on Climate Change. [Field, C.B., V. Barros, T. F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds). Cambridge University Press, Cambridge U.K., 582p

Khantisidhi, Banthitha. Assessment of Climate Change Impacts on Flood Behavior. 2nd Mekong Climate Change Forum. 2014

Khazai, Bijan; Bendimerad, Fouad; Cardona, Omar Dario; Carreno, Martha-Lilliana; Barbat, Alex H.; Burton, Christopher G. A Guide to Measuring Urban Risk Resilience. Principle, Tools and Practice of Urban Indicators (Prerelease Draft). Earthquakes and Megacities Initiative - EMI. 2015



DevTreks –social budgeting that improves lives and livelihoods

Marulanda, Mabel C, Carreño, Martha, Cardona, Omar D., Ordaz, Mario G., Barbat, Alex H. Probabilistic earthquake risk assessment using CAPRA: application to the city of Barcelona, Spain. *Nat Hazards*, 69:59-84. 2013

Mechler, Reinhard. *Cost-benefit Analysis of Natural Disaster Risk Management in Developing Countries*. Manual. 2005

Mechler, R. and The Risk to Resilience Study Team, (2008): *The Cost-Benefit Analysis Methodology, From Risk to Resilience Working Paper No. 1*, eds. Moench, M., Caspari, E. & A. Pokhrel, ISET, ISET-Nepal and ProVention, Kathmandu, Nepal, 32 pp

Mechler, R., Hochrainer, S., Kull, D., Chopde, S., Singh, P., S. Wajih and The Risk to Resilience Study Team, (2008): *Uttar Pradesh Drought Cost-Benefit Analysis, From Risk to Resilience Working Paper No. 5.*, eds. Moench, M., Caspari, E. & A. Pokhrel ISET, ISET-Nepal and ProVention, Kathmandu, Nepal, 32 pp.

Miller, Kathleen A. and Valerie Belton, 2014. *Water resource management and climate change adaptation: a holistic and multiple criteria perspective*, *Mitigation and Adaptation Strategies for Global Change*, 19(3): 289-308. DOI 10.1007/s11027-013-9537-0

Mishra, A.K., Singh, V.P. *Drought modeling – A review*. *J. Hydrol.* (2011), doi:10.1016/j.jhydrol.2011.03.049. The full article was retrieved directly from Singh's website in January 2016, where it is described as an Article in Press.

Moench, M. and The Risk to Resilience Study Team, (2008): *Understanding the Costs and Benefits of Disaster Risk Reduction under Changing Climatic Conditions, From Risk to Resilience Working Paper No. 9*, eds. Moench, M., Caspari, E. & A. Pokhrel, ISET, ISET-Nepal and ProVention, Kathmandu, Nepal, 38 pp.

Mustafa, D., Ahmed, S., E. Saroch and The Risk to Resilience Study Team, (2008): *Pinning Down Vulnerability: From Narratives to Numbers, From Risk to Resilience Working Paper No.*



DevTreks –social budgeting that improves lives and livelihoods

2, eds. Moench, M., Caspari, E. & A. Pokhrel, ISET, ISET-Nepal and ProVention, Kathmandu, Nepal, 28 pp. (This is the second of a 9 part series on disaster risk reduction.)

Samuel Rufat, Eric Tate, Christopher G. Burton, Abu Sayeed Maroof. Social vulnerability to floods: Review of case studies and implications for measurement. *International Journal of Disaster Risk Reduction* 14 (2015) 470–486

Shreve, C.M., Kelman, I. Does mitigation save? Reviewing cost-benefit analyses of disaster risk reduction. *International Journal of Disaster Risk Reduction*. 10 (2014) 213-235

Swenja Surminski, Ana Lopez, Joern Birkmann, Torsten Welle. Current knowledge on relevant methodologies and data requirements as well as lessons learned and gaps identified at different levels, in assessing the risk of loss and damage associated with the adverse effects of climate change (Mandate of the Conference of the Parties) last accessed on the web on July 29, 2015 [https://unfccc.int/files/adaptation/cancun\\_adaptation\\_framework/loss\\_and\\_damage/application/pdf/background\\_paper\\_full.pdf](https://unfccc.int/files/adaptation/cancun_adaptation_framework/loss_and_damage/application/pdf/background_paper_full.pdf)

UK DCLG (Department of Communities and Local Government) (2009), *Multi-Criteria Analysis: A Manual*, UK DCLG, London.

United Nations. CAPNET. Drought risk reduction in integrated water resources management training manual. 2015

United Nations. ECLAC. Handbook for Disaster Assessment. 2014

United Nations Environment Programme (UNEP). *A Practical Framework for Planning Pro-Development Climate Policy*. 2011

UNISDR, 2009. *Drought Risk Reduction Framework and Practices: Contributing to the Implementation of the Hyogo Framework for Action*. United Nations secretariat of the International Strategy for Disaster Reduction (UNISDR), Geneva, Switzerland, 213 pp



DevTreks –social budgeting that improves lives and livelihoods

United Nations. Integrated Drought Management Programme (IDMP). National Drought Management Policy Guidelines, a Template for Action. 2014

United Nations. UNISDR. GAR. Global Assessment Report on Disaster Risk Reduction. 2015

United Nations. UNISDR. DRAFT Post-2015 Framework for Disaster Risk Reduction: a proposal for monitoring progress. 2014

United Nations. UNISDR and partners. Proposal on Disaster-Related Indicators to Sustainable Development Goals. 2015

UNDP. Mainstreaming Drought Risk Management. A Primer. 2011

U.S. Army Corps of Engineers, Hydrologic Engineering Center. HEC-FDA Flood Damage Reduction Analysis. User's Manual. Version 1.2.4, 2008

U.S. Federal Emergency Management Agency. HAZUS-MH. Technical Manuals (more manuals are available than listed here, including an earthquake manual):

HAZUS-MH Flood Technical Manual: [https://www.fema.gov/media-library-data/20130726-1820-25045-8292/hzmf2\\_1\\_fm\\_tm.pdf](https://www.fema.gov/media-library-data/20130726-1820-25045-8292/hzmf2_1_fm_tm.pdf)

HAZUS-MH Hurricane Technical Manual: [https://www.fema.gov/media-library-data/20130726-1820-25045-9850/hzmf2\\_1\\_hr\\_tm.pdf](https://www.fema.gov/media-library-data/20130726-1820-25045-9850/hzmf2_1_hr_tm.pdf)

V. Meyer, N. Becker, V. Markantonis, R. Schwarze, J. C. J. M. van den Bergh, L. M. Bouwer, P. Bubeck, P. Ciavola, E. Genovese, C. Green, S. Hallegatte, H. Kreibich, Q. Lequeux, I. Logar, E. Papyrakis, C. Pfurtscheller, J. Poussin, V. Przyluski, A. H. Thieken, and C. Viavattene. Review article: Assessing the costs of natural hazards – state of the art and knowledge gaps. Nat. Hazards Earth Syst. Sci., 13, 1351–1373, 2013

Walsh, Wuebbels, Hayhoe, Kossen, Kunkel, Stephens, Thorne, Voss, Wehner, Willis, Anderson, Doney, Feely, Hennon, Kharin, Knutsen, Landerer, Lenton, Kennedy, and Somerville, 2014: Ch.



DevTreks –social budgeting that improves lives and livelihoods

2: Our Changing Climate. Climate Change Impacts in the United States: The Third National Climate Assessment, Melillo, Richmond, and Yohe, Eds., U.S. Global Climate Change Research Program, 19-67.

Westen, Alkema, Damen, Kerle, and Kingma. Multi-hazard risk assessment, Distance Education Course, Guide Book. United Nations University. ITC School on Disaster Geoinformation Management. 2011

World Bank. World Development Report 2014: Risk and Opportunity - Managing Risk for Development. Washington, DC 2014

World Bank. Risk Analysis Course Manual. Global Facility for Disaster Reduction and Recovery. 2011

World Bank and United Nations. Natural hazards, unnatural disasters: the economics of effective prevention. 2010

World Health Organization. WHO Guide to Cost-Effectiveness Analysis. T. Tan-Torresedejer, R. Baltussen, T. Adam, R. Hutubessy, A. Acharya, D.B. Evans and C.J.L. Murray (eds). 2003

## **References Note**

We try to use references that are open access or that do not charge fees. Many recent publications have been found that demonstrate analytic techniques that would be useful in this reference, but many are not open access (i.e. Zekai Sen, 2015) and are therefore of limited usefulness in this context. It's not entirely clear why authors who work in publicly funded institutions support inaccessible publications (peer pressure?).

## **Improvements, Errors, and New Features**

Please notify DevTreks (devtrekkers@gmail.com) if you find errors in these references. Also please let us know about suggested improvements or recommended new features. This is another



DevTreks –social budgeting that improves lives and livelihoods

reference that has the potential for hundreds of pages of algorithm examples. Future releases will have to deal with the matter.

**A video tutorial explaining this reference can be found at:**

<https://www.devtreks.org/commontreks/preview/commons/resourcepack/Technology>  
Assessment 2/1544/none

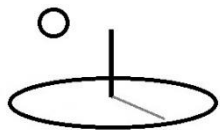


DevTreks –social budgeting that improves lives and livelihoods

## CTAP Examples Introduction (6\*)

These appendices contains examples of algorithms that are used to carry out CTAPs. The following guiding principles are used with all examples:

1. **CTAs:** All of these examples use the generic mathematical and statistical software techniques, involving numeric algorithms and structured software object models, introduced in the *CTA* reference. These techniques offer the flexibility needed to consistently quantify the uncertainty of a broad “portfolio” of prevention interventions and to make the evidence transparent to people *and machines*.
2. **CTA-Prevention Portfolios (7\*):** A portfolio of prevention, or mitigation and adaptation, interventions must be assessed for decision makers. As mentioned in the associated *Resource Stock Analysis* tutorial, the most effective interventions, such as putting a price on carbon, must be in the portfolio. Successful interventions must include changes to human capital, institutional capital, social capital, and cultural capital, resource stocks.
3. **Plausible Scenarios and Alternatives:** The probabilistic risk and statistical algorithms used in CTAs can’t accommodate all of the uncertainties associated with climate change. Many changes simply can’t be known yet. The World Bank and UN (2010) reference recommends dealing with this uncertainty by presenting ranges of plausible interventions where benefits clearly exceed costs. The IPCC references demonstrate the use of plausible assumptions, or scenarios, that show how climate change will probably change natural resource stocks.
4. **Experiment and Gain Experience:** In some cases, the new CTAP approaches may be exactly what are *not* needed to undertake effective preventive actions (8\*). People need to be experimenting and increasing their expertise in this area if prevention is to be globally affordable. That’s especially true for software developers building “apps”. Unless financed by investors, developers and data analysts should be paid for their work (i.e. including this work, so don’t be surprised if developers and analysts have to charge fees, or in the case of nonprofits, donations, for these data services).



DevTreks –social budgeting that improves lives and livelihoods

## **Appendix A. Disaster Risk Reduction (DRR) Algorithms**

### **A. Disaster Risk Reduction Introduction**

Mechler (2005) demonstrates using the following 4 steps to conduct cost-benefit analyses of natural resource disasters in developing countries. Definitions for these terms can be found in the main reference.



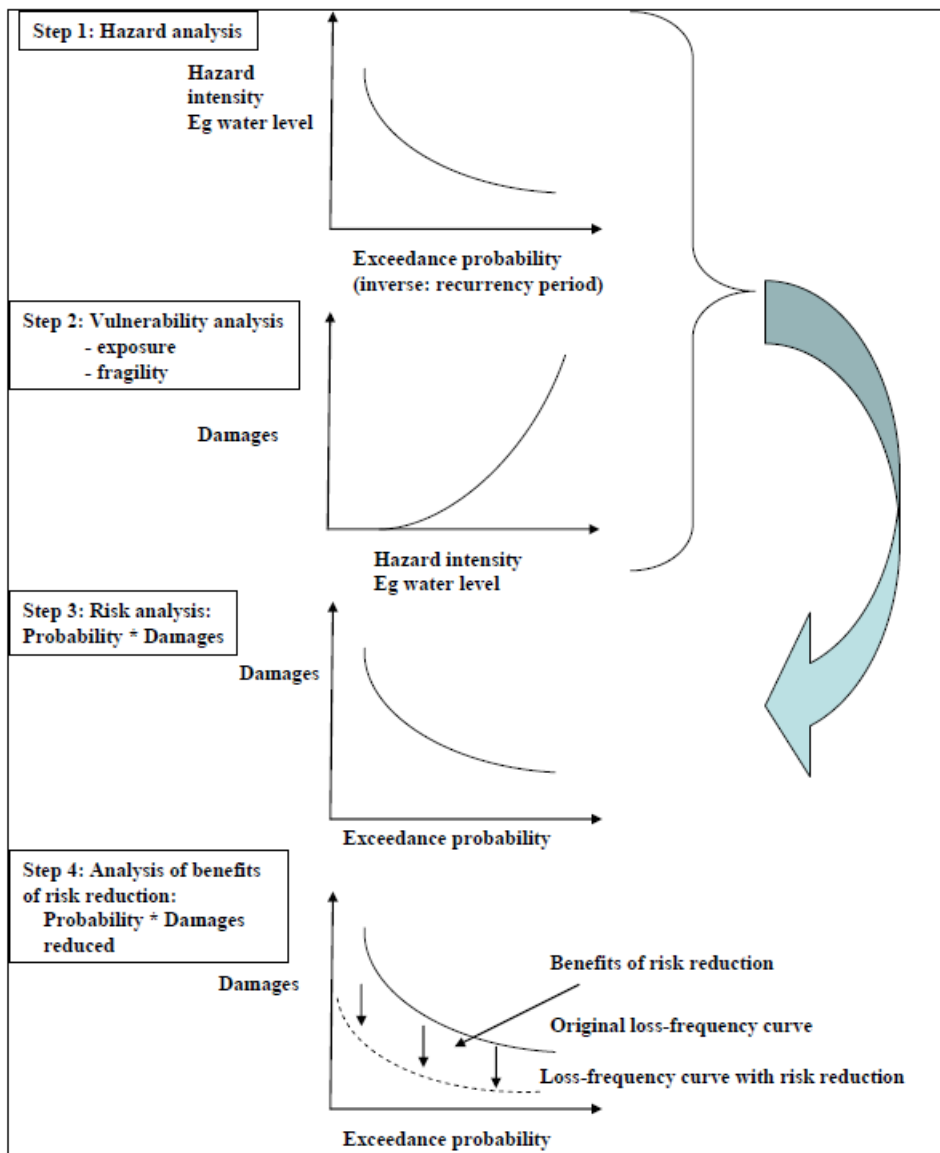
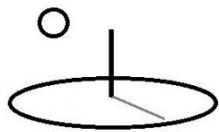


Fig. 11: Quantitative forward-looking framework for estimating disaster risk  
Illustration modified based on World Bank 1996.

Hochrainer et al (2011) explain that Step 3. Exceedance Probability (EP), is derived from data in the first 2 steps.



DevTreks –social budgeting that improves lives and livelihoods

probability  $p$  that *at least* \$X is lost in a given year. An EP curve is one output of a catastrophe model, involving four main modules depicted in Figure 1.

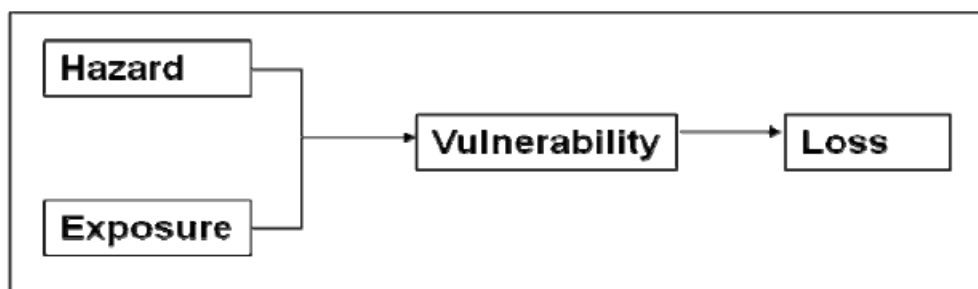
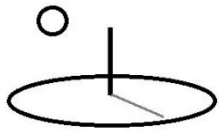


FIGURE 1: EP estimation methodology. Source: Grossi and Kunreuther (2005)

- A *hazard module* characterizes the hazard in a probabilistic manner. Often, the full suite of events which can impact the exposure at risk is described – by magnitude and associated annual probability, among other characteristics.
- An *exposure module* describes a single structure or collection of structures that may be damaged.
- A *vulnerability module* estimates the damage to the exposure at risk given the magnitude of the hazard. Vulnerability is typically characterized as a mean estimate of damage (e.g. percentage of house destroyed) and associated uncertainty given a hazard level.
- A financial *loss module* estimates losses to the various stakeholders that must manage the risk (e.g., homeowner, insurer, reinsurer).

Based on these modules a typical EP curve can be constructed as depicted in Figure 2, where the likelihood that losses will exceed  $L_i$  is given by  $p_i$ , i.e. the x-axis shows the magnitude of the loss in US dollars and the y-axis depicts the annual probability that losses will exceed this level (see for example Grossi and Kunreuther (2005) and Hochrainer (2006) for details on constructing EP curves in the context of catastrophe models). The area under the EP curve is the average annual loss (AAL). Structural DRR measures typically decrease the vulnerability of the building and therefore reduce the expected loss. Graphically, DRR shifts the EP curve to the left and therefore reduces the AAL value (Figure 2).

CTAPs must be completed using the generic Indicators and Scores in the Resource Stock or Monitoring and Evaluation calculators. In order to do so, the typical steps, or modules, used in traditional damage assessments have to be translated into Indicators and Scores as demonstrated in the list that follows. All of the images derive from the Mechler (2005) and Hochrainer et al (2011) case studies that are used in Examples 1 and 2. Note that most of the “curves” shown in



DevTreks –social budgeting that improves lives and livelihoods

these images are similar to the cumulative density distributions more thoroughly explained in the CTA reference.

- **Step 1. Indicator 1. Hazard Exceedance Probability Distribution.** The following image shows that the uncertainty of flood depths and exceedance probabilities must be translated into Indicator 1.

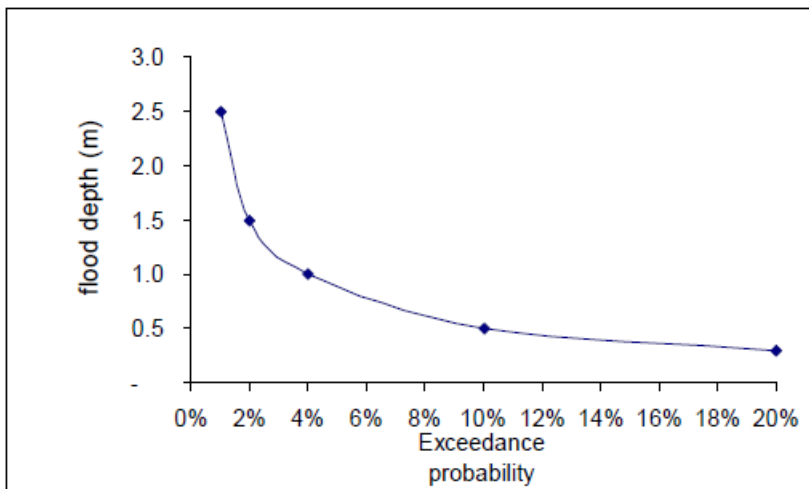


Fig. 24: Water levels due to flooding at one site along the Garang river  
Source: JICA 2000

- **Step 2. Indicator 2. Exposure Distribution.** The following image shows that the uncertainty of the number of assets being damaged and their value must be translated into Indicator 2.



DevTreks –social budgeting that improves lives and livelihoods

For estimating exposure to hazards in Semarang, use was made of JICA data on typical unit values and number of exposed assets as well as BGR/GTZ work on ground subsidence. JICA estimated typical unit values per m<sup>2</sup> at risk in the two areas outlined above (table 35).

Table 35: Unit values for important elements at risk

Category	Unit value (Rupiah 2005/m2)
<b>Buildings</b>	
Residential	147,268
Industrial	280,510
Business	280,510
<b>Indoor movable</b>	
Residential	88,361
Industrial	232,824
Business	385,702

Note: No unit value for public facilities was estimated, damages will be estimated as 46.8% of total asset damages. Data source: JICA 2000.

Combining those values with the number of exposed assets allows to calculate total values exposed. Furthermore, when looking into the future, it is necessary to account for increased exposure in a city with strong economic and population dynamics. For the matters of this study, exposure increases were assumed to be in line with forecasted increases in population. Based on a prediction of the Urban Masterplan Document of 2000 of a 1.2% annual population increase, a 90% increase of population from 2005 until 2059 was calculated. The assumption taken here is that economic exposure will increase proportional to this increase in population (table 36).

Table 36: Estimated values exposed to flooding 2005-2059  
(values in billion constant 2005 Rupiah)

Year	Value of assets	Indoor Movables	Sum	Predicted increase compared to 2005
2005	461	500	961	
2015	520	563	1,083	13%
2025	585	634	1,220	27%
2035	660	715	1,374	43%
2045	743	805	1,548	61%
2055	837	907	1,744	82%
2059	878	951	1,830	90%

- **Step 2. Indicator 3. Vulnerability Distribution.** The following image shows that the uncertainty of the percent of assets damaged at varying flood depths, wind speeds, earthquake intensity, or other damaging events, must be translated into Indicator 3. These simple percentages reflect damages to the actual physical stocks. The calculations can



DevTreks –social budgeting that improves lives and livelihoods

also use losses to the physical stock *flow*, such as rental income. Care needs to be taken not to double count both losses –measure either the loss to the physical stock or physical stock flow, but not both.

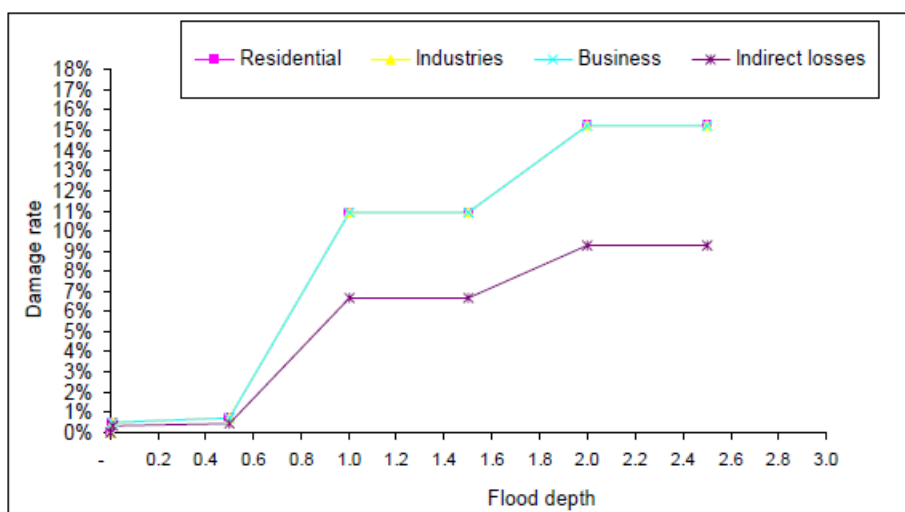


Fig. 26: Fragility functions for direct and indirect flood damages to assets

Compared to other functions, such as damage curves of flooding used for example in Australia, the estimates seem to be reasonable. However, one shortcoming is that these curves do not consider the duration of inundation, which is generally acknowledged to be a critical variable as well. Also, no curves were established for public facilities. Total damages were estimated as a fixed fraction of asset damages (46.8%).

- **Step 3. Indicator 4. Loss Exceedance Probability Distribution.** The following image shows that the uncertainty of the monetary damages and exceedance probabilities must be translated into Indicator 4. The algorithm that generates this Exceedance Probability (EP) distribution is explained in the next section.



DevTreks –social budgeting that improves lives and livelihoods

Aggregating such site-specific loss estimates for all locations according to recurrency, leads to overall losses along the Garang river basin. The following chart and table shows the flood risk as of 2005 amounting to ca. 1,100 billion Rupiah for a 100 year event.

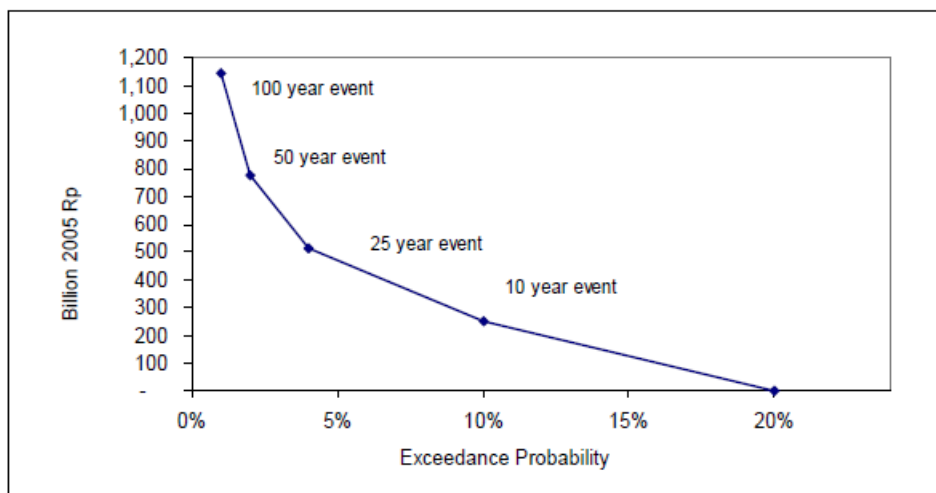


Fig. 27: Loss-frequency curve for sum of direct and indirect impacts due to flooding for whole exposed area in Semarang

EP distributions are used to measure Average Annual Losses (AAL), Return Period Losses (RPL), and Tail Value at Risk (TVAR) losses. AAL losses reflect the full area under the EP curve, RPL losses reflect the average annual losses for a specific occurrence event (i.e. one point on the curve) in one year, while TVAR losses reflect cumulative losses up to a specific event, including the tail. The following example uses the 25 year event in the previous image to demonstrate how to interpret the differences between the 3 losses:

**AAL:** In 2005, average annual losses are 72 billion rupiahs (i.e. the entire area under the curve).

**RPL or PML:** The 500 billion loss represents the 96 percentile of the annual loss distribution. The probability of exceeding \$500 billion in one year is 4%. The UNISDR GAR (2015) and Marulanda (2013) references use the term, Probable Maximum Loss (PML), for this term.



DevTreks –social budgeting that improves lives and livelihoods

**TVAR:** Given that at least a \$500B loss occurs, the average severity will be \$800 billion (using only the 10 year and 25 year events in the cumulative calculation). Note the significant difference between average annual losses and total losses.

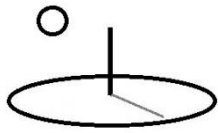
- **Step 4. Benefits Analysis. Indicator 5. Costs of Alternatives.** The following image shows that the uncertainty of the costs for each alternative must be translated into Indicator 5.

Table 42: Options under discussion

Project alternative	Characteristics	Costs (2005 values)
Dam protecting harbour Dutch development cooperation	Dam would protect city from seaside inundation, but not riverine flooding	150 billion Rupiah
Installation of more drainage pumps World Bank.	Pumps (to some extent installed) help with flooding and inundation, but do not stop subsidence problem	87 billion Rupiah
Integrated management of flooding and water supply JICA	A: West floodway/Garang River Improvement B: Jatibarang Multipurpose Dam C: Urban drainage system improvement	Total: 437 billion Rupiah • Construction: 337 billion Rupiah • Operation and maintenance: 99 billion Rupiah

The following image (V. Meyer et al, 2013) demonstrates the importance of defining and categorizing damages and using economic estimation techniques that are appropriate for specific cost and damage categories. The authors provide a comprehensive review of techniques that are appropriate for estimating disaster-related costs and damage reduction benefits. The national and international data standards proposed by the European Commission references (2013, 2014) for disaster loss accounting include similar categories.





DevTreks –social budgeting that improves lives and livelihoods

		Tangible costs	Intangible (non-market) costs
Damage costs	Direct	<ul style="list-style-type: none"> <li>Physical damage to assets: <ul style="list-style-type: none"> <li>buildings</li> <li>contents</li> <li>infrastructure</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>Loss of life</li> <li>Health effects</li> <li>Loss of environmental goods</li> </ul>
	Business interruption	<ul style="list-style-type: none"> <li>Production interruption because of destroyed machinery</li> </ul>	<ul style="list-style-type: none"> <li>Ecosystem services interrupted</li> </ul>
	Indirect	<ul style="list-style-type: none"> <li>Induced production losses of suppliers and customers of companies directly affected by the hazard</li> </ul>	<ul style="list-style-type: none"> <li>Inconvenience of post-flood recovery</li> <li>Increased vulnerability of survivors</li> </ul>
Risk mitigation costs	Direct	<ul style="list-style-type: none"> <li>Set-up of infrastructure</li> <li>Operation &amp; maintenance costs</li> </ul>	<ul style="list-style-type: none"> <li>Environmental damage <ul style="list-style-type: none"> <li>due to the development of mitigative infrastructure</li> <li>or due to a change in agricultural practices</li> </ul> </li> </ul>
	Indirect	<ul style="list-style-type: none"> <li>Induced costs in other sectors</li> </ul>	

Cost categories applied in this article:

Direct costs

Business interruption costs

Indirect costs

Intangible (non-market) costs

Risk mitigation costs

- Indicators 2 to 5. Alternatives.** The existing Indicators are used to hold data for each project alternative (i.e. mitigation and adaptation intervention). The Indicator.URL TEXT files include additional rows of data specifying how each project alternative changes the data. Each alternative uses the same number of rows as the baseline data but a simple label convention must be used so that each alternative can be properly identified. An additional letter suffix, such as A, B, and C is added to the existing label column of data (i.e. Indicator 4, Label 4A, Alternative B = Label 4A\_B).
- Step 4. Indicator 6. Benefit Cost Analysis.** The following image shows that the uncertainty of benefits of each project alternative, along with Indicator 5's Costs, must be





DevTreks –social budgeting that improves lives and livelihoods

translated into Indicator 6. This Indicator displays the final analysis of benefit cost ratios for each project alternative.

The benefits due to risk management measures are the avoided and reduced losses; graphically, this is here represented in shifting the loss-frequency curve downwards. In the example shown in figure 15, losses up to the 100 year event would be avoided.

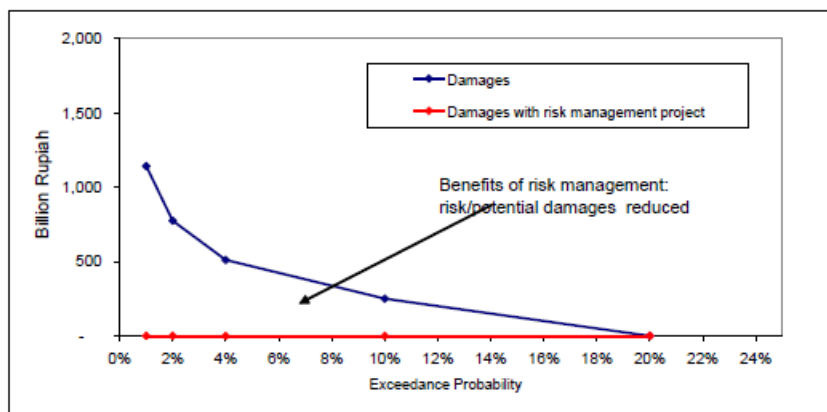


Fig. 15: Benefits due to reducing risk and potential damages

The area between the two curves represents the expected annual damages reduced or expected annual benefits due to risk management.

- Indicator 7. Cost Effectiveness Analysis (CEA).** This Indicator is calculated in a similar manner to Indicator 6, but instead of calculating reductions in direct monetary damages as benefits, it calculates reductions in indirect non-monetary damages as benefits. Typical examples of non-monetary damages are the Indirect and Intangible concerns discussed in the main reference, such as transportation disruptions, job losses, and QALYs. Changes in alternative project costs are divided by changes in the alternative benefits to develop Cost Effectiveness Ratios. The following image (WHO, 2003) demonstrates a CEA for human capital stock interventions. Note that the WHO reference stresses the importance of defining the baseline using the null practice, because current practice may be less effective than all other alternatives. [This latter statement was corrected in version 2.1.0 because new algorithms released included upgraded CEA techniques].



DevTreks –social budgeting that improves lives and livelihoods

**Table 1.1** Incremental CERs for 11 interventions

Intervention	Costs	Health benefits	Incremental CER compared to the null
a1	120	1.0	120
a2	140	5.5	25.45
a3	170	3.0	56.67
a4	190	7.0	27.14
b1	100	12.0	8.33
b2	120	17.0	7.06
b3	150	20.0	7.50
c1	50	22.0	2.27
c2	70	24.5	2.86
c3	120	29.0	4.14
c4	170	31.0	5.48

When Appendix B, subalgorithm 10, is used to generate the Indicator7.URL TEXT file, Indicator 7 measures the cost effectiveness of alternative interventions in reducing the *indirect* damages from disasters. A nice complement to Indicator 6's measurement of *direct* damages.

- **Optional Trend, Scenario, and/or Sensitivity Analysis. Optional second datasets.** The following images show that the uncertainty of time-related trends such as changes in population, alternative scenarios such as changes in natural resource stocks due to climate change, and/or additional assumptions about changes in key indicators such as discount rates



DevTreks –social budgeting that improves lives and livelihoods

or asset life, can be translated into additional tables and datasets.

Table 41: Losses due to floods and inundation over time  
(billion Rupiah 2005)

Year	Annual average losses due to flooding	Annual losses due to inundation	Total losses
2005	72	32	<b>105</b>
2015	82	42	<b>124</b>
2025	92	55	<b>147</b>
2035	104	72	<b>176</b>
2045	117	94	<b>211</b>
2055	132	123	<b>255</b>
2059	146	137	<b>283</b>

Table 46: Results for Semarang case study

	Best estimate	No exposure increase	No subsidence increase	No exposure and subsidence increase
NPV (billion Rupiah)	414	296	330	257
B/C ratio	2.5	2.0	2.2	1.9
IRR	23%	19%	21%	18%

In all scenarios, the project remained efficient. Thus, in total, given the available data and assumptions used, the analysed integrated JICA project would be efficient in terms of avoidance of damages due to flooding and inundation in Semarang.

TABLE 2: SUMMARY OF SELECTED B/C RATIOS (NUMBERS ABOVE 1 IN BOLD)

DRR measure	Time horizon (years)	Masonry				Wood Frame			
		Canaries (Max Hazard)		Patience (Min Hazard)		Canaries (Max Hazard)		Patience (Min Hazard)	
		Discount rate		Discount rate		Discount rate		Discount rate	
		5%	12%	5%	12%	5%	12%	5%	12%
1. Roof upgrade	10	0.75	0.55	0.16	0.11	0.95	0.69	0.22	0.16
	25	<b>1.37</b>	0.76	0.29	0.16	<b>1.73</b>	0.96	0.41	0.23
2. Opening protection	10	0.62	0.46	0.09	0.07	<b>1.48</b>	<b>1.08</b>	0.25	0.18
	25	<b>1.14</b>	0.63	0.17	0.09	<b>2.70</b>	<b>1.51</b>	0.46	0.26
3. Combined	10	0.59	0.44	0.11	0.08	0.99	0.72	0.20	0.14
	25	<b>1.09</b>	0.60	0.20	0.11	<b>1.80</b>	1.00	0.36	0.20

- **Scores. Decision Support Systems.** Appendix C has examples of wider frameworks that can also be employed for decision support. For example, V. Meyer et al (2013) state “[Benefit Cost Analysis] could be usefully embedded in a wider Multi-Criteria Analysis



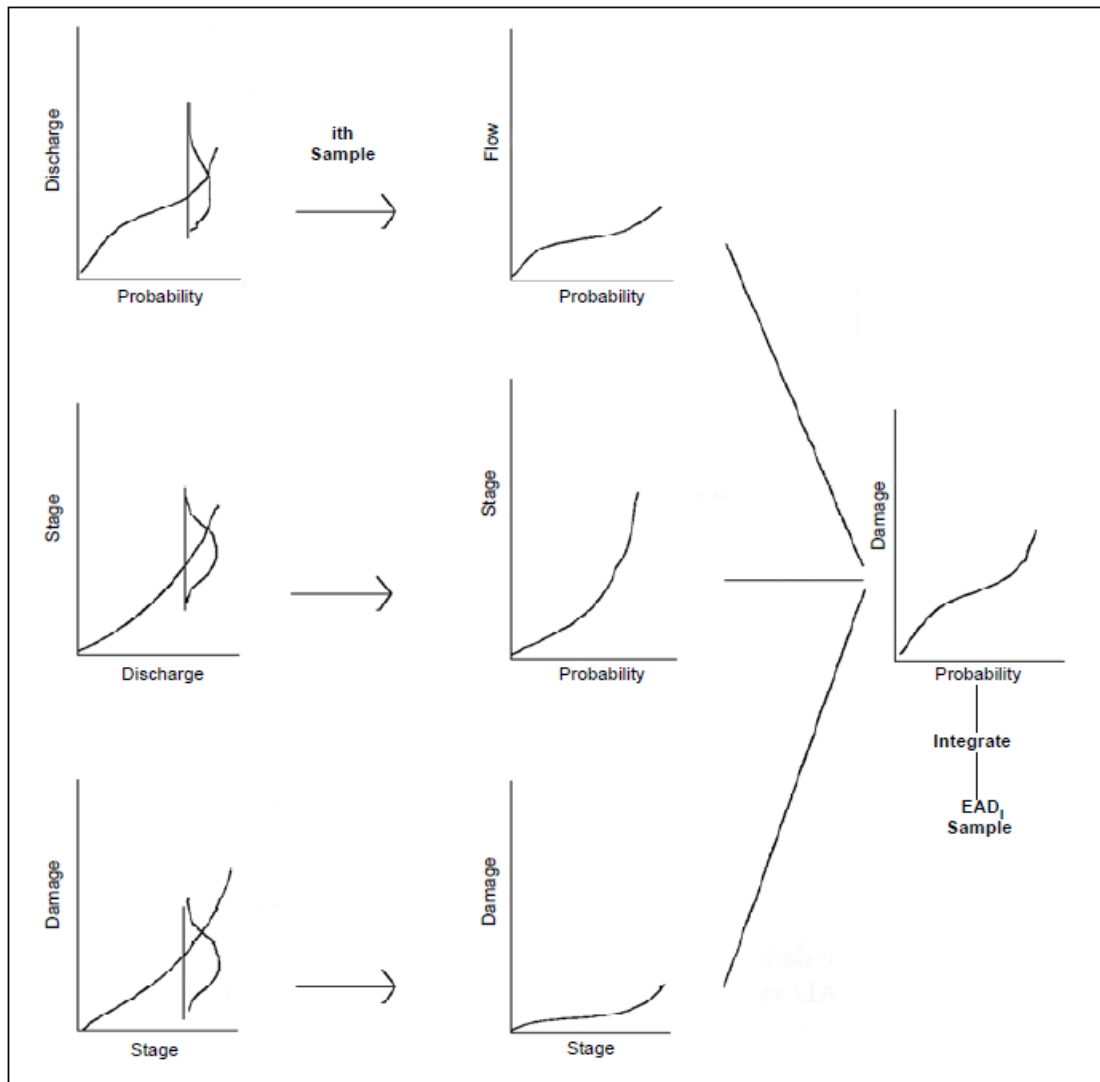
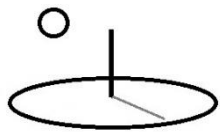
DevTreks –social budgeting that improves lives and livelihoods

framework. This allows stakeholders and decision makers to decide on the relative importance of the different decision criteria and their related uncertainties”.

Appendix A in Mechler’s, 2005 reference, Moench et al’s 2008 reference, as well as Annex 3 in the UN 2015 GAR reference, demonstrate how these steps fit into a more comprehensive Cost Benefit Analysis (CBA) framework. CBA frameworks are important when resources are scarce (i.e. money needs to be saved) and formal evaluations are needed that provide formal evidence of resource savings (i.e. Internet technology must be used to complete the evaluations and display the evidence).

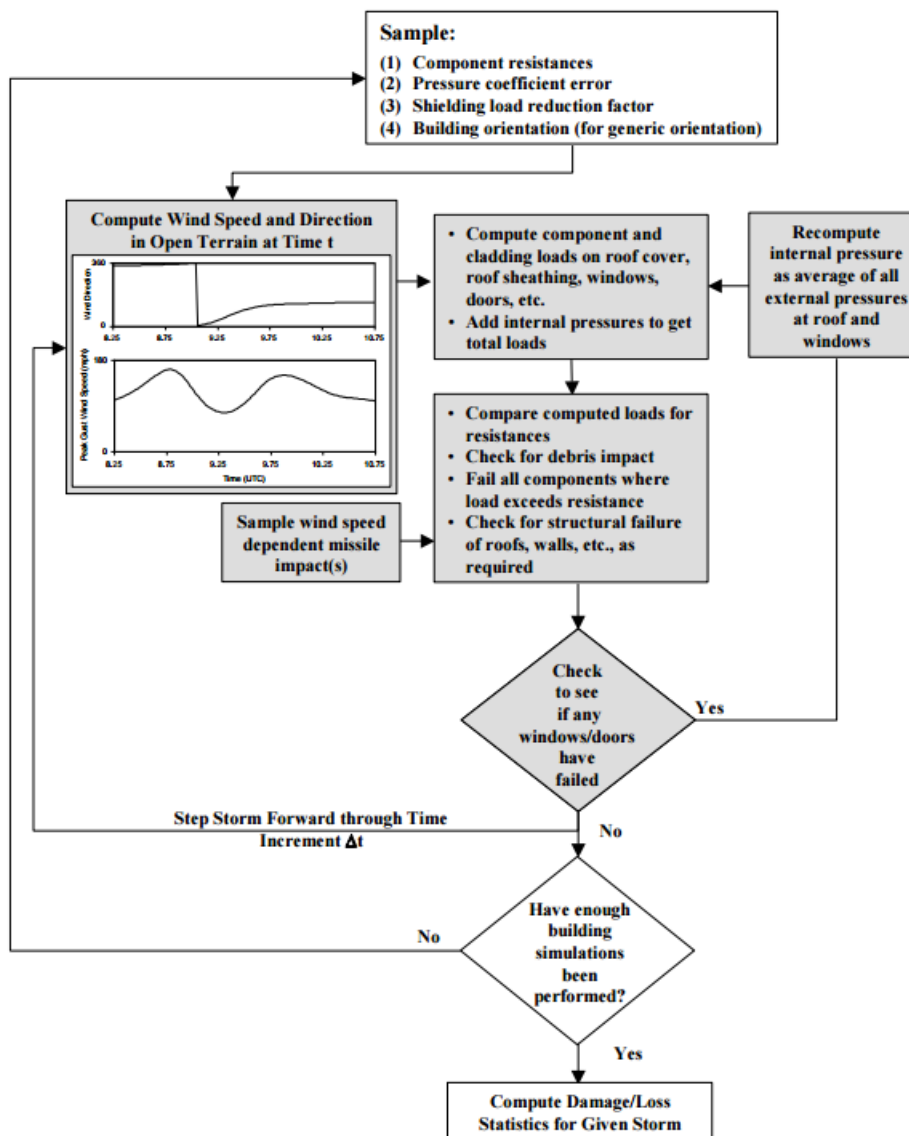
## **B. Disaster Risk Reduction (DRR) Algorithms**

The USACOE (2008) reference is a User Manual for desktop software that carries out comprehensive flood damage assessments. Appendix H in that reference explains the algorithms and Monte Carlo simulation techniques employed by that software to carry out the assessments. The following image from that reference demonstrates that comprehensive damage assessments use more advanced techniques than the simple 2 step process depicted in the previous section. In this image, relationships between several “damage assessment steps” are aggregated by an algorithm into the final Exceedance Probability distribution.



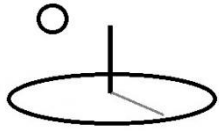
**Figure H.3** Monte Carlo Simulation Algorithm for Estimating EAD

The following image introduces how the U.S. Federal Emergency Management Agency uses actual observed damage losses to develop loss calculations in their HAZUS-MH software.



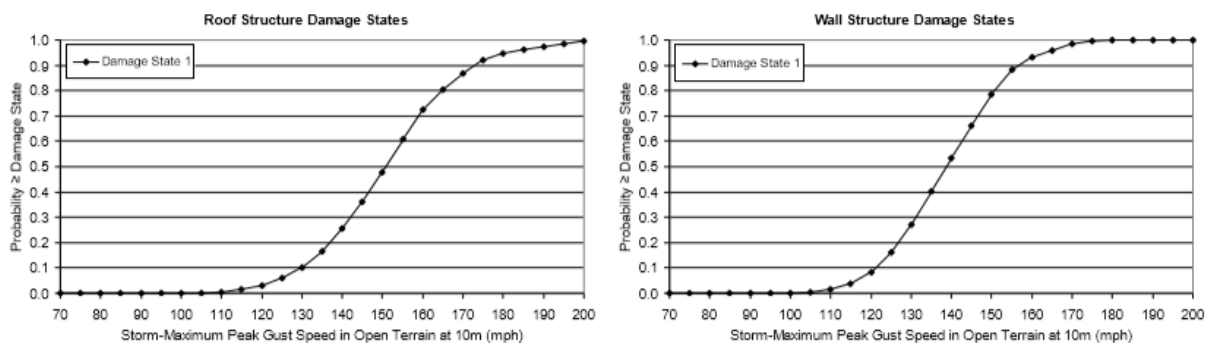
**Figure 6-1. Approach Used to Simulate Damage to Buildings.**

With the exception of the HAZUS-MH reference manuals, most of the references cited in this Appendix do not present actual numerical examples of DRR algorithms. Without numerical examples, algorithms can't be proofed for accuracy. The HAZUS-MH manuals are exceptions. These manuals include comprehensive numerical formulas, but some of their software development techniques appear to be very "domain-specific", rather than "generic-indicator-

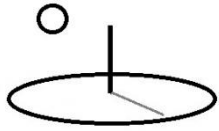


nonspecific”. For example, many of the algorithms introduced in this reference use probability density functions (pdf) to characterize damages. These functions can be defined using four properties (Distribution, QT, QTD1, and QTD2) that include standard pdf shape and scale parameters, such as mean and standard deviation.

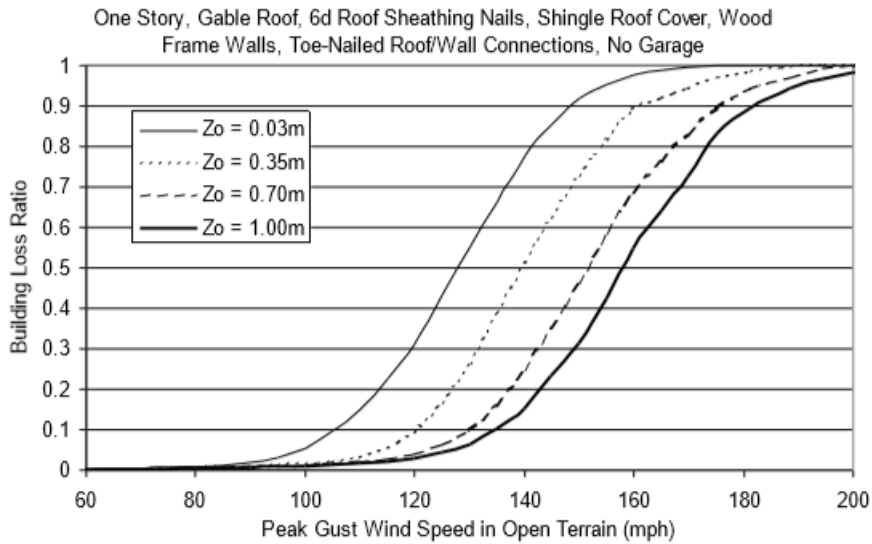
In contrast, “domain-specific” algorithms require custom distributions that often need to be expressed using mathematical formulas, or, to use HAZUS terms, “multivariate damage state functions”. Although Chapter 1 in the HAZUS Hurricane technical reference mentions that their software may translate multivariate damage state functions into simpler probability density functions (i.e. by fitting “curves” to the data), the Appendixes in their technical manual, show hundreds of examples of the following damage state, and content loss ratio, multivariate functions. If these types of multivariate functions can’t be reasonably defined using standard pdf properties, the case will be made for using more advanced algorithms (i.e. that inherit from regression, bayesian, and machine learning subalgorithms, rather than Monte Carlo subalgorithms).



**Figure C.26. Damage States vs. Maximum Peak Gust Wind Speed – Four-Story, 8d Roof Deck Nails, Strapped Roof Trusses, Wood Frame Walls, Gable Roof with Shingles,  $z_0=0.35$  m.**



H-8



**Figure H.1. Building Loss Function for Single Family Residential Building (One Story, 6d Roof Sheathing Nails, Gable Roof, No Garage, Toe-Nailed Roof Wall Connections, Wood Frame).**

For example, when modeling drought losses, Mishra et al (2011) summarize the use of multivariate damage algorithms that use techniques such as regression (ARIMA), probabilistic risk (Markov chains), copula (Normal), artificial intelligence (Neural Network), and data mining. The references in the Technology Assessment, Performance Analysis, and Social Performance Analysis, tutorials have examples of introductory subalgorithms that demonstrate many of these techniques. The mathematical and statistical packages used to carry out CTAs also contain numerous examples of multivariate data analysis.

### C. Additional Tools

Additional natural resource damage assessment tools are available (i.e. Central America CAPRA, USFEMA HAZUS, UNISDR's Global Risk Assessment, commercial catastrophe software, several tools reviewed by the European Commission references) and should be closely evaluated prior to using this example's techniques. In addition, most serious natural disaster





DevTreks –social budgeting that improves lives and livelihoods

damage assessments are done in the context of overall watershed planning –the assessment is one ingredient in an overall natural resources conservation, or ecosystem, planning approach (see the *Resource Stock Analysis* reference for an example of such an approach).

In effect, this example demonstrates simple algorithms for quickly implementing the World Bank and UN (2010) recommendation to present ranges of plausible interventions where benefits clearly exceed costs. The results from the more advanced algorithms can also be summarized using these simpler tools. Future releases will include examples and algorithms that demonstrate some of the more advanced assessment techniques, such as the use of multivariate loss functions (i.e. see the Social Performance references).

#### **D. DRR Algorithm Examples**

The following algorithms demonstrate how to use Disaster Risk Reduction (DRR) Distributions to calculate reductions in natural resource disaster damages. Most algorithms use probability distributions, defined by QT, QTD1, and QTD2 properties stored in URL.Indicator TEXT files, as the initial data used in each damage assessment step. The distributions are used to generate final mean and confidence interval calculations expressed using an Indicator's QTM, QTL, and QTU properties. This reference believes that modern information technology will make these distributions more transparent and available for replication in related assessments. That is, they'll be easier to find and use.

- **Algorithm 1. Disaster Risk Reduction: algorithm1, subalgorithm9:** This is a custom DevTreks algorithm that adds basic uncertainty analysis to traditional natural resource damage assessments. The algorithm uses Monte Carlo simulation to estimate the uncertainty of damages of disaster risk reduction interventions (subalgorithm1). In effect, this algorithm generates upper and lower confidence intervals for each point in each step of traditional Disaster Risk Reduction distributions. The algorithm is designed to be used jointly with some of Appendix B's Risk Management Indicators algorithms (subalgorithm10).

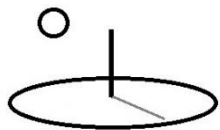


DevTreks –social budgeting that improves lives and livelihoods

At this stage of development, the following algorithms are still a wish list, but to the author's knowledge, climate change isn't going away anytime soon. Although this list suggests that these will be custom algorithms (i.e. algorithm1), the statistical packages used by other algorithms will also be used (i.e. because they already contain packages that carry out these multivariate data analysis techniques). The sibling Social Performance Analysis references confirm that Version 2.1.4 began supporting these types of algorithms.

- **Algorithm 1. Disaster Risk Reduction: algorithmx, subalgorithmx:** The algorithm uses Copula simulations to estimate the uncertainty of damages of disaster risk reduction interventions. For example, when correlated damage variables have different distributions (i.e. drought severity and duration), Copula-based algorithms can account for the correlations correctly.
- **Algorithm 1. Disaster Risk Reduction: algorithmx, subalgorithmx:** The algorithm uses Markov Chain Monte Carlo (MCMC) simulation to estimate the uncertainty of damages of disaster risk reduction interventions. [Cross reference with HTAs –DRG severity levels and health transition states.]
- **Algorithm 1. Disaster Risk Reduction: algorithmx, subalgorithmx:** The algorithm uses Machine Learning (AI) simulation to estimate the uncertainty of damages of disaster risk reduction interventions.
- **Algorithm 1. Disaster Risk Reduction: algorithmx, subalgorithmx:** The algorithm uses regression analysis (logistic, ARIMA) to estimate the uncertainty of damages of disaster risk reduction interventions.
- **Algorithm 1. Disaster Risk Reduction: algorithmx, subalgorithmx:** The algorithm uses randomized control trial analysis (ANOVA) to estimate the uncertainty of damages of disaster risk reduction interventions. [Cross reference with HTAs.]
- **Additional Algorithms. Disaster Risk Reduction (under planning):** Customers with an immediate need for additional algorithms can contact DevTreks directly.

The goal of the following examples are not to carry out exact replications of the case studies' damage assessments. Instead, the examples emphasize developing and using CTA algorithms to



DevTreks –social budgeting that improves lives and livelihoods

assess the probability of the costs and benefits associated with resource stock loss prevention interventions. As such, although care has been taken to match the studies' overall methodology, less importance was placed on matching the exact numbers used in the studies. For example, all of the probability distributions used in the examples are fictitious (i.e. standard deviations are all 10% of means). The author acknowledges that this could lead to flawed analyses (i.e. that will need to be improved in future releases).



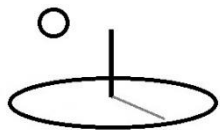
DevTreks –social budgeting that improves lives and livelihoods

### **Algorithm1. Subalgorithm9. Disaster Risk Reduction**

This algorithm will be explained using two case studies of traditional natural resource damage assessments that have been completed in developing countries. Example 1 will cover Hochrainer et al's (2011) damage assessments for hurricanes in St. Lucia, Caribbean. Example 2 will be Mechler's (2005) case study of a flood damage assessment carried out in Semarang, Indonesia.

The algorithm uses the simple 2 step process introduced in the previous section, along with a subset of the ACOE and HAZUS techniques, to generate uncertain DRR distributions. The algorithm carries out the CTAP as follows:

1. Hydrologists, or physical science experts, prepare Indicator 1. Hazard Probability Distribution. The distributions are used to calculate means and confidence intervals showing the probability that a given exceedance probability will produce an uncertain quantity of damage-causing wind, water, fire, seismic activity, or other event. The locations specified in this Indicator are also used with most other algorithms. These integer locations can be linked to separate GIS data structures. In this example, a 2<sup>nd</sup> location is calculated as a 10% increase in the 1<sup>st</sup> location exceedance probabilities (and subsequent damages). All Monte Carlo simulations are based on the QT, QTD1, and QTD2 parameters with the distribution specified in the “distribtype” column and use subalgorithm1 to generate means, or QTMs, and confidence intervals, or QTLs and QTUs.
2. Up to 7 exceedance probability events can be defined for any Indicator that specifies events. The exceedance period can be any integer value. A required data convention is to concatenate the integer value with the suffix “year” and use the concatenated string as a column header in the Indicator datasets. The word “year” is actually parsed from the column header to obtain the integer exceedance period. The examples below show the correct conventions to follow (i.e. 10year, 100year, 1572year). The current release does not focus on internationalization of the algorithms in this reference. Example 2 demonstrates some of the results from using 7 events.



3. Analysts use Indicator 1 to prepare Indicator 2. Exposure, and Indicator 3. Vulnerability. Data TEXT files holding probability distributions for the 2 indicators are referenced in the Indicator.URL property. Calculations generate confidence intervals for each Indicator's distribution which are stored in the Indicator.MathResult. Subalgorithms 9, 10, and 11 share 95% of their source code and employ consistent data formats for all Indicators. The use of 3 aggregation levels increases the size of the data that must be stored, displayed, and analyzed. That tradeoff was made over simplicity because that technique is recommended by the experts cited in Appendix B's references, the data format stays consistent among all algorithms, and because these analyses have grave consequences.
4. Indicator 2's asset values can be expressed either on a unit value (i.e. m2 of area), or unit asset (i.e. single residential property), basis. Multiplying these asset prices by the number of assets, or quantity, results in the total value of exposed assets. Example 1 demonstrates unit asset value (i.e. single residential property). Example 2 demonstrates unit values (m2 of area). Example 1 further demonstrates that Indicator 5's Costs, have also been calculated on a *unit cost* basis (i.e. repair cost per residential structure) by setting the "isprojectcost" column to "no". That tells Indicator 6 and 7 to calculate costs by multiplying Indicator 5's unit costs by Indicator 4's asset quantities. In contrast, Example 2 demonstrates that the costs associated with unit value assets are calculated as *project costs* by setting the "isprojectcost" column to "yes". Indicators 6 and 7 will calculate costs using Indicator 5's project costs alone. Those costs are not multiplied by Indicator 4's asset quantities.
5. The confidence intervals for Indicators 2 and 3 are multiplied by one another (damage for each stage = asset market value \* percent damage) to generate confidence intervals for average annual damages (the EP curve). The EP confidence intervals are stored in Indicator 4's Math Result.
6. Example 1 in Appendix C demonstrates incorporating projected trends in exposed asset value by adding an optional TEXT file to Indicator 4. When this file is found, the value of exposed assets used to calculate Indicator 4's damage losses is multiplied by the trend variables. This technique allows changes in population, output



DevTreks –social budgeting that improves lives and livelihoods

production, natural resource conditions, or other asset trend characteristics, to be included in the projected asset losses (i.e. by simple multiplication).

7. Indicator 5 is used to define uncertain cost distributions for current practice and each project alternative. Costs must be specified in the same manner as Indicator 2's asset values. That is, they must be listed as either project costs or unit costs. The annual operating cost amount is calculated as a uniform present value cost over the project life span. The installation cost is calculated as a discounted installation cost at the end of 1 year. When installation costs occur over more than 1 year, make appropriate adjustments in the initial installation cost listed in the TEXT file. The generated confidence intervals for the resultant present value costs are stored in Indicator5.MathResult. Indicator 6 must use comparable present value benefits in the Benefit Cost Ratios. In order to so, the average annual damage reduction calculated in Indicator 6 uses a uniform present value discounting formula with the discount rates and life spans in the sensitivity analysis. Indicator 7 assumes benefits are nonmonetary and does not discount benefits. The CTA reference has examples that demonstrate these types of discounting formulas.
8. Indicator 4's Math Results are used to calculate changes in EP discounted monetary damages, or Benefits, for each project alternative. Indicator 5's Math Results are used to calculate changes in discounted costs for each project alternative. The change in Benefits, are divided by the change in Costs to obtain an uncertain Benefit Cost Ratio (BCR). The uncertain BCR is defined by a mean with upper and lower confidence intervals and added to the Indicator6.Math Result. The discount rates and project life spans stored in Indicator 5 are used to conduct a sensitivity analysis of the ratios.
9. Indicator 7 is calculated in a similar manner to Indicator 6, but instead of calculating changes in monetary damages as benefits, it calculates changes in non-monetary indicators, or effects. The changes in Costs are divided by the changes in non-monetary Benefits to calculate Cost Effectiveness Ratios, such as incremental change in cost per incremental change in Greenhouse Gas Emissions, or QALYs. Unlike Indicator 6, the current release recommends that the confidence intervals for the non-monetary damages be calculated elsewhere, such as using the Indicator4.MathResult



DevTreks –social budgeting that improves lives and livelihoods

produced using Appendix B subalgorithm 10, and then referenced using the Indicator.URL property. If no TEXT file is found in the Indicator.URL, it will use the same data as Indicator 6 –the MathResults from Indicator 4.

10. Indicator 6 and 7's meta (i.e. QTM, QTL, and QTU) will display a summation of the total costs and benefits for either the project alternative with the highest Benefit Cost Ratio or the lowest Cost Effectiveness Ratio. These values are derived by aggregating the Total Risk Rows across all locations. This reference recommends using the various Math Results to develop multimedia that decision makers will quickly understand when they load a typical URL to preview the calculations. The case studies show examples of appropriate media that include Loss EP Distributions, BCR tables, color-coded maps, and damage reduction graphs.

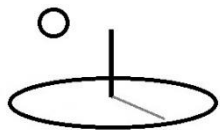
Besides generating uncertain EP distributions, BCR ratios, and CERs, this type of algorithm can be used to carry out supplemental analyses that complement the basic benefit cost analysis result. Examples of supplemental analyses include:

**Scenario analysis:** Appendix C addresses scenario analysis. The data can always be imported into other programs for more advanced scenario analysis.

**Trend analysis:** Appendix C includes examples of simple trend analysis. The health care sector's Health Technology Assessments often use separate population algorithms to simulate how demographic trends affect benefits and costs. The WHO 2003 reference includes an example. Examples 5 and 6 in the sibling Social Performance Analysis 3 reference provide examples of using population algorithms to determine social impacts associated with disaster risk reduction activities.

**Sensitivity analysis:** Indicator 5 must include a 2nd URL TEXT file holding discount rates and project life spans that are used to conduct sensitivity analysis of Benefit Cost Ratios and Cost Effectiveness Ratios.

The algorithm relies heavily on parsing TEXT datasets and then using specific indexing techniques to produce Math Results that are formatted correctly. These techniques require that



DevTreks –social budgeting that improves lives and livelihoods

Indicator.Labels and Indicator.URL TEXT files closely follow the conventions shown in the Examples, or the parsing and indexing will fail. If an example shows a Label with 3 characters, then that Label has to have exactly 3 characters. Certain Labels must have specific characters, such as “TR” for Total Risk, or “RF” for Physical Risk. If a column of data has an underscore (“\_”) then that dataset must use the exact same convention. The algorithm supports additional rows and columns in the TEXT datasets, but only if they follow the logic used by the Indicator. For example, up to 7 exceedance events can be defined. The number of locations, assets, and project alternatives, can be lower or higher than the numbers used in the examples.

The algorithm requires that Indicators have the exact indexes demonstrated in the examples. The next section demonstrates the Indicator and Score properties that need to be filled out to complete the uncertain EP distribution, BCA, and CEA analyses. All Indicators must use only MathType = algorithm1 and MathSubType = subalgorithm9.





DevTreks –social budgeting that improves lives and livelihoods

## **Example 1. Hurricanes, St. Lucia, Caribbean**

### **URLs**

<https://www.devtreks.org/greentreks/preview/carbon/output/CTAP Ex- 1 - Hurricane DRR/2141223461/none>

<https://www.devtreks.org/greentreks/preview/carbon/resourcepack/DRRs, DRIs, and RMIs/1539/none>

<https://www.devtreks.org/greentreks/preview/carbon/resourcepack/SubAlgo 09 DRR 1A/1537/none>

<http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 1 - Hurricane DRR/2141223467/none>

Hochrainer et al. (2011) use four case studies demonstrating how to use Disaster Risk Reduction distributions to communicate the costs and benefits of reasonable disaster prevention interventions to decision makers. The case studies reinforce the World Bank and UN (2010) recommendation to present a range of alternatives to decision makers that clearly demonstrate where benefits exceed costs.

This example uses the St. Lucia in the Caribbean case study which demonstrates how to use this technique with home improvements that reduce damages from hurricanes. The authors provide caveats about the techniques they employed. They note that only one case study, Istanbul in Turkey, accounted for damages from lives lost, and that indirect losses due to disruptions from lost jobs, damaged roads, and personal lives, were left out of the analyses. Even so, many of their benefit-cost ratios are greater than one.

The following Score and Indicators show the properties for the completed analysis of hurricane damage prevention alternatives. Although all of these Indicators use normal distributions, any distribution supported by the calculator can be used. The references demonstrate that most Indicators are not normally distributed. For simplicity, data for the second location, 2, has been calculated as 10% greater than the first location, 1.



DevTreks –social budgeting that improves lives and livelihoods

The following Scores and Indicators can be placed in either base Input or Output elements, but can't be split up into both. As with all Resource Stock Calculators, Operating and Capital Budgets can be used to combine Input and Output calculations (see the Resource Stock Analysis tutorial). The logic for using Output base elements is that Outputs are aggregated into Outcomes and those elements are usually associated, with “disaster loss and damage metrics”, such as Indicators 4, 6, and 7 (see UNISDR, 2014). The logic for using Input base elements is when the assessments are primarily being used to measure “contingent liabilities”, or costs.

Very large Math Results may be too large to store in both the stylesheet and the database table field. Large datasets should use the Math Result to reference a Resource base element URL that will be used to store a TEXT csv file holding the Math Results.

### **Score. Starting Properties**

The following initial Score properties are used in this example:

**Confidence Interval:** 90

**Random Seed:** 7

**Iterations:** 10,000

**Description:** This example demonstrates ....

### **Indicator 1. Hazard Distribution**

The current version generates confidence intervals for this Indicator, but does not use the results in subsequent calculations. More advanced DRR algorithms will use these results in subsequent calculations.

Selected properties include:

**Distribution Type:** none (the URL TEXT holds distribution)

**Math Type and Math Sub Type:** algorithm1, subalgorithm9



DevTreks –social budgeting that improves lives and livelihoods

**QTMUnit, QTUnit, QTD1Unit, QTD2Unit:** manually enter (most units that are entered manually will not be overwritten)

The following Math Expression is only used to identify the columns of TEXT data to include in the calculation.

**Math Expression =**

I1.Q1.distribtype + I1.Q2.100year + I1.Q3. 50year + I1.Q4.25year + I1.Q5.10year + I1.Q6.5year

**Indicator.URL TEXT:** Although the case study incorporates location directly in the type of asset being damaged, the following convention allows more general use of locational data, which will prove useful when this data is used by GIS applications. Location data stored in all TEXT datasets must be integers. Although, for appearances sake, distributype columns throughout this algorithm include the distribution (i.e. normal) in the QTD1 and QTD2 properties, only the QT distribution is actually used.

Indicator 1. Hazard Exceedance Probability Distribution (matrix numbers are miles per hour)									
Description: Each reach is described by a probability distribution (QTs) defined by the event probability (1, 2, 4, 10, 20 percent) and the wind speed (the matrix numbers).									
label	location	distribution	total	distribtype	100year	50year	25year	10year	5year
1A	1	QT	0.000	normal	100.000	75.000	50.000	35.000	25.000
1A	1	QTD1	0.000	normal	100.000	75.000	50.000	35.000	25.000
1A	1	QTD2	0.000	normal	10.000	7.500	5.000	3.500	2.500
1A	2	QT	0.000	normal	110.000	82.500	55.000	38.500	27.500
1A	2	QTD1	0.000	normal	110.000	82.500	55.000	38.500	27.500
1A	2	QTD2	0.000	normal	11.000	8.250	5.500	3.850	2.750

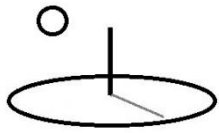
The Monte Carlo algorithm is run using these properties and the distribution data stored in the TEXT file. The results of the simulations are then used to fill in the rest of the following properties.

**Q1 to Q5** = filled in automatically with the mean and unit for each location

**QT** = the average of each location's mean wind speed

**QTD1 and QTD2** = average of distributions in the TEXT files

**QTM** = average of the mean wind speeds calculated for each location



DevTreks –social budgeting that improves lives and livelihoods

**QTL and QTU** = x lower and upper x% ci

The following images show the resultant calculations.

Indicator 1

Hazard Distribution

Indicator 1 Description

Each reach is described by a probability distribution (QTs) defined by the event probability (1, 2, 4, 10, 20 percent) and the associate quantity of the hazard (the matrix numbers).

Indicator 1 URL

[http://localhost/resources/network\\_carbon/resourcepack\\_527/resource\\_1801/Ind1-Hazard.csv](http://localhost/resources/network_carbon/resourcepack_527/resource_1801/Ind1-Hazard.csv)

Label 1

1A

Rel Label 1

Date 1

01/01/2005

Dist Type 1

none

Q1 1

104.8302

Q1 Unit 1

100year

Q2 1

78.6227

Q2 Unit 1

50year

Q3 1

52.4151

Q3 Unit 1

25year

Q4 1

36.6906

Q4 Unit 1

10year

Q5 1

26.2076

Q5 Unit 1

5year

Math Operator 1

equalto

BaseIO 1

none

QT 1

49.8750

QT Unit 1

mean wind speed mph

68



DevTreks –social budgeting that improves lives and livelihoods

QT 1	QT Unit 1
49.8750	mean wind speed mph
Math Type 1	Math Sub Type 1
algorithm1	subalgorithm9
QT D1 1	QT D1 Unit 1
49.8750	mean
QT D2 1	QT D2 Unit 1
4.9875	sd
QT Most 1	QT Most Unit 1
49.7943	mean wind speed mph
QT Low 1	QT Low Unit 1
49.5297	lower 90% ci
QT High 1	QT High Unit 1
50.0590	upper 90% ci
Math Expression 1	
I1.Q1.distribtype + I1.Q2.100year + I1.Q3. 50year + I1.Q4.25year + I1.Q5.10year + I1.Q6	
Math Result 1	
drr results label,location,loc_confid,total,distribtype,100year,50year,25year,10year,5year 1A,1.000,QTM,47.4232,normal,99.8383,74.8787,49.9191,34.9434,24.9596 1A,1.000,QTL,47.1711,normal,99.3077,74.4807,49.6538,34.7577,24.8269 1A,1.000,QTU,47.6752,normal,100.3689,75.2767,50.1844,35.1291,25.0923 1A,2.000,QTM,52.1655,normal,109.8221,82.3666,54.911,38.4377,27.4555 1A,2.000,QTL,51.8882,normal,109.2384,81.9288,54.6191,38.2334,27.3096 1A,2.000,QTU,52.4428,normal,110.4058,82.8044,55.2029,38.642,27.6014	

+
Indicator 2

## Indicator 2. Exposure Distribution



DevTreks –social budgeting that improves lives and livelihoods

This Indicator uses asset value distributions to calculate confidence intervals for asset values that might be damaged from the hazards documented in Indicator 1. The asset distributions are organized by Categorical Indexes, such as ResidentialType1, CommercialType2, and Public, which are then added to parent Locational Index, such as All Residential, which in turn are added to a final Total Risk Index. Although these aggregators are not real “Indexes”, that term is used in order to stay consistent with the subalgorithms introduced in Appendix B.

Selected properties include:

**Distribution Type:** none (the Indicator.URL dataset holds the distribution types).

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Units:** automatically filled in (but most units that are entered manually will not be overwritten)

The following Math Expression is only used to identify the columns of TEXT data to include in the calculation.

**Math Expression =**

$$I2.Q1.distribtype + I2.Q2.QT + I2.Q3.QTUnit + I2.Q4.QTD1 + I2.Q5.QTD1Unit + I2.Q6.QTD2 + I2.Q7.QTD2Unit + I2.Q8.normalization + I2.Q9.weight + I2.Q10.quantity$$

**Indicator.URL TEXT:** The “RF” labeling convention will be used to distinguish physical assets from other types of assets (i.e. SF for social fragility and SR for social resiliency). The “RF” row is a location aggregation, or Locational Index. The “RF1” row is an asset category, or Categorical Index. The “TR” row is the final Total Risk for all aggregated Indicators for each separate location. The SubIndicator asset rows, have 1 additional letter suffix, such as “RF1A”. The “TR” and “RF” Labels are required, but the remaining Labels, can be changed but the number of characters used in these Labels cannot be changed. The algorithm uses the number of characters in the Label to determine which row of data is a Locational Index (2), a Categorical Index (3), and a SubIndicator, or asset type (4). Assets commonly have values that vary by location. The column named location must be integers. The column named distribution specifies the probability density distribution to use in the Monte Carlo simulation for this Indicator.



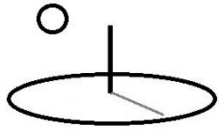
DevTreks –social budgeting that improves lives and livelihoods

The normalization and weight columns are used for consistency with Appendix B, subalgorithm 10’s use of non-monetary Indicators to calculate *unit-less* values. We recommend using this algorithm to calculate monetary damages, and subalgorithm10 to calculate indirect, non-monetary, indicators. For this algorithm, the normalization value has been set to “none” and the weight to 1.

The quantity column is used to identify the number of assets, or SubIndicators. The total value of exposed assets will be calculated by multiplying the price of the asset (QTM, QTL, and QTU) by the quantity of the asset. To demonstrate the resultant calculations, the WoodPMin and MasonPMax asset quantities have been set to 10.

In the case study, both benefits and costs are being defined based on 1 single house. This algorithm will aggregate the children SubIndicator asset values into each parent category, location, and total risk rows. That means that subsequent benefit calculations will already be based on correctly aggregated damages. However, Indicator 5 shows that initial costs have been defined on a per unit asset, or house, basis by setting the “isprojectcost” column to “no”. Indicator 6 and 7’s costs are calculated by multiplying Indicator 5’s unit costs by Indicator 4’s asset quantity. Example 2 demonstrates that an alternative way to aggregate costs is to define costs on a per project basis. In the latter case, Indicator 6 and 7’s costs are calculated by using Indicator 5’s costs directly –no multiplication occurs.

Indicator 2. Exposure Distribution (totals are US\$, price and quantity are actual).												
Description: The total value of each asset type is described by a probability distribution (QTs) calculated from the price (p1) and quantity (q1) of the a												
label	location	assettype	total	distribtype	QT	QTUnit	QTD1	QTD1Unit	QTD2	QTD2Unit	norm weight	quantity
RF1	1	Residential1	0.000	none	0.000	none	0.000	none	0.000	none	none	1.000
RF1A	1	WoodCMax	0.000	normal	100000.000	house value:	100000.000	mean	10000.000	sd	none	1.000
RF1B	1	MasonCMax	0.000	normal	100000.000	house value:	100000.000	mean	10000.000	sd	none	1.000
RF2	1	Residential2	0.000	none	0.000	none	0.000	none	0.000	none	none	1.000
RF2A	1	WoodPMin	0.000	normal	100000.000	house value:	100000.000	mean	10000.000	sd	none	10.000
RF2B	1	MasonPMax	0.000	normal	100000.000	house value:	100000.000	mean	10000.000	sd	none	10.000
RF	1	All	0.000	none	0.000	none	0.000	none	0.000	none	none	1.000
TR	1	TotalRisk	0.000	none	0.000	none	0.000	none	0.000	none	none	1.000
RF1	2	Residential1	0.000	none	0.000	none	0.000	none	0.000	none	none	1.000
RF1A	2	WoodCMax	0.000	normal	110000.000	house value:	110000.000	mean	11000.000	sd	none	1.000
RF1B	2	MasonCMax	0.000	normal	125000.000	house value:	125000.000	mean	12500.000	sd	none	1.000
RF2	2	Residential2	0.000	none	0.000	none	0.000	none	0.000	none	none	1.000
RF2A	2	WoodPMin	0.000	normal	90000.000	house value:	90000.000	mean	9000.000	sd	none	10.000
RF2B	2	MasonPMax	0.000	normal	95000.000	house value:	95000.000	mean	9500.000	sd	none	10.000
RF	2	All	0.000	none	0.000	none	0.000	none	0.000	none	none	1.000
TR	2	TotalRisk	0.000	none	0.000	none	0.000	none	0.000	none	none	1.000



DevTreks –social budgeting that improves lives and livelihoods

The Monte Carlo algorithm, subalgorithm1, is run using these properties and the distribution data stored in the TEXT file. The results of the simulations are then used to fill in the rest of the following properties. The Math Expression is only used to identify the columns of TEXT data to include in the calculation.

**Q1 to Q5** = filled in automatically with the total asset value for the first five locations

**QT** = the average of the first five locations

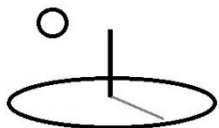
**QTD1 and QTD2** = none, the TEXT file defines the distributions

**QTM** = total value of all indicators

**QTL and QTU** = x lower and upper x% ci

The following images show the resultant calculations. The reason for the million+ results is that the \$100,000 house values are being multiplied by the quantity column, 10.





Indicator 2

Exposure Distribution

Indicator 2 Description

The total value of each asset type is described by a probability distribution (QTs) calculated from the price (p1) and quantity (q1) of the asset.

Indicator 2 URL

[http://localhost/resources/network\\_carbon/resourcepack\\_527/resource\\_1803/Ind2-Exposure.csv](http://localhost/resources/network_carbon/resourcepack_527/resource_1803/Ind2-Exposure.csv)

Label 2

2A

Rel Label 2

Date 2

01/01/2005

Dist Type 2

none

Q1 2

2,196,441.8938

Q1 Unit 2

location1 total value

Q2 2

2,081,627.8856

Q2 Unit 2

location2 total value

Q3 2

0.0000

Q3 Unit 2

none

Q4 2

0.0000

Q4 Unit 2

none

Q5 2

0.0000

Q5 Unit 2

none

Math Operator 2

equalto

BaseIO 2

none

QT 2

4,278,069.7794

QT Unit 2

location1, 2 totals



DevTreks –social budgeting that improves lives and livelihoods

QT 2	QT Unit 2
4,278,069.7794	location1, 2 totals
Math Type 2	Math Sub Type 2
algorithm1	subalgorithm9
QT D1 2	QT D1 Unit 2
0.0000	none
QT D2 2	QT D2 Unit 2
0.0000	none
QT Most 2	QT Most Unit 2
4,278,069.7794	total value
QT Low 2	QT Low Unit 2
4,255,331.5981	lower 90% ci
QT High 2	QT High Unit 2
4,300,807.9607	upper 90% ci
Math Expression 2	
I2.Q1.distribtype + I2.Q2.QT + I2.Q3.QTUnit + I2.Q4.QTD1+ I2.Q5.QTD1Unit + I2.Q6.QTD1Unit	
Math Result 2	
drr results label,location,assettype,total,distribtype,QTM,QTMUnit,QL,QLUnit,QTU,QTUUnit,quantity RF1,1,Residential1,0,none,199676.5358,category mean,198615.2438,category low ci,200737.8278,category high ci,1.0000 RF1A,1,WoodCMax,0,normal,99838.2679,total value,99307.6219,lower 90% ci,100368.9139,upper 90% ci,1.0000 RF1B,1,MasonCMax,0,normal,99838.2679,total value,99307.6219,lower 90% ci,100368.9139,upper 90% ci,1.0000 RF2,1,Residential2,0,none,199676.5358,category mean,198615.2438,category low ci,200737.8278,category high ci,1.0000 RF2A,1,WoodPMin,0,normal,99838.2679,total value,99307.6219,lower 90% ci,100368.9139,upper 90% ci,1.0000 RF2B,1,MasonPMax,0,normal,99838.2679,total value,99307.6219,lower 90% ci,100368.9139,upper 90% ci,1.0000 RF 1 All 0 none 2196441 8938 sum categories 2184767 6818 category low	

### Indicator 3. Vulnerability Distribution



DevTreks –social budgeting that improves lives and livelihoods

This Indicator uses a normal distribution of asset percent damage for physical assets to calculate uncertain damage loss percentages for each asset in each location and in each project alternative. The asset being damaged can be any resource stock, including human capital stocks. As mentioned in Section C. DRR Algorithms, custom distributions, such as those used to model seismic damages to buildings, are not supported by this algorithm (but some of the existing distributions, such as gamma, are fairly flexible).

Selected properties include:

**Distribution Type:** none (URL dataset is used)

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Units:** automatically filled in (but most units that are entered manually will not be overwritten)

The following Math Expression is only used to identify the columns of TEXT data to include in the calculation.

**Math Expression:**

I3.Q1.distribtype + I3.Q2.5year + I3.Q3.10year + I3.Q4.25year + I3.Q5.50year +  
I3.Q6.100year

**Indicator.URL TEXT:** The Labels in the following dataset use the same convention as Indicator 2, but the Categorical Indexes (RF1, RF2), Locational Indexes (RF), and Total Risk Index (TR), are placeholders that are used to display the final calculated results. The Categorical Indexes are calculated as summations of their children Sub Indicators. The Locational Indexes are calculated as summations of the Categorical Indexes. The Total Risk Index is a summation of the Locational Indexes. In addition, letter suffixes are used to identify the project alternatives listed in Indicator 5. The distributions have integer prefixes identifying the location.

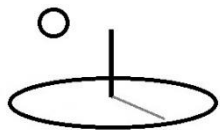


DevTreks –social budgeting that improves lives and livelihoods

<b>Indicator 3. Vulnerability Distribution. (matrix numbers are percent)</b>									
<b>Description: The damage percent for each asset type is described by a probability distribution (QTs) defined by the hazard exceedance probability (5 to 100 year) and the percent of damage.</b>									
label	assettype	loc_distrib	total	distribtype	5year	10year	25year	50year	100year
RF1	Residential1	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF1	Residential1	1_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF1	Residential1	1_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF1A	WoodCMax	1_QT	0.000	normal	2.500	10.000	35.000	50.000	59.000
RF1A	WoodCMax	1_QTD1	0.000	normal	2.500	10.000	35.000	50.000	59.000
RF1A	WoodCMax	1_QTD2	0.000	normal	0.250	1.000	3.500	5.000	5.900
RF1B	MasonCMax	1_QT	0.000	normal	0.000	7.500	22.000	30.000	36.000
RF1B	MasonCMax	1_QTD1	0.000	normal	0.000	7.500	22.000	30.000	36.000
RF1B	MasonCMax	1_QTD2	0.000	normal	0.000	0.750	2.200	3.000	3.600
RF2	Residential2	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF2	Residential2	1_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF2	Residential2	1_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF2A	WoodPMin	1_QT	0.000	normal	0.000	0.500	4.000	12.000	22.500
RF2A	WoodPMin	1_QTD1	0.000	normal	0.000	0.500	4.000	12.000	22.500
RF2A	WoodPMin	1_QTD2	0.000	normal	0.000	0.050	0.400	1.200	2.250
RF2B	MasonPMax	1_QT	0.000	normal	0.000	0.500	3.750	5.000	13.000
RF2B	MasonPMax	1_QTD1	0.000	normal	0.000	0.500	3.750	5.000	13.000
RF2B	MasonPMax	1_QTD2	0.000	normal	0.000	0.050	0.375	0.500	1.300
RF	All	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF	All	1_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF	All	1_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
TR	TotalRisk	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
TR	TotalRisk	1_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
TR	TotalRisk	1_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF1_A	Residential1	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000

...

...



DevTreks –social budgeting that improves lives and livelihoods

RF1A_C	WoodCMax	2_QTD2	0.000	normal	0.150	0.601	2.103	3.004	3.545
RF1B_C	MasonCMax	2_QT	0.000	normal	0.000	4.319	12.670	17.278	20.733
RF1B_C	MasonCMax	2_QTD1	0.000	normal	0.000	4.319	12.670	17.278	20.733
RF1B_C	MasonCMax	2_QTD2	0.000	normal	0.000	0.432	1.267	1.728	2.073
RF2_C	Residential2	2_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF2_C	Residential2	2_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF2_C	Residential2	2_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF2A_C	WoodPMin	2_QT	0.000	normal	0.000	0.218	1.743	5.230	9.807
RF2A_C	WoodPMin	2_QTD1	0.000	normal	0.000	0.218	1.743	5.230	9.807
RF2A_C	WoodPMin	2_QTD2	0.000	normal	0.000	0.022	0.174	0.523	0.981
RF2B_C	MasonPMax	2_QT	0.000	normal	0.000	0.260	1.953	2.604	6.770
RF2B_C	MasonPMax	2_QTD1	0.000	normal	0.000	0.260	1.953	2.604	6.770
RF2B_C	MasonPMax	2_QTD2	0.000	normal	0.000	0.026	0.195	0.260	0.677
RF_C	All	2_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF_C	All	2_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF_C	All	2_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
TR_C	TotalRisk	2_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
TR_C	TotalRisk	2_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
TR_C	TotalRisk	2_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000

The Monte Carlo algorithm is run using these properties and the distribution data stored in the TEXT file. The results of the simulations are then used to fill in the rest of the following properties.

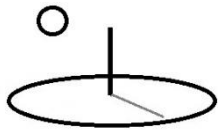
**Q1 to Q5** = filled in automatically with total percent damages and units for each event summed for all baseline TR rows across all locations

**QT, QTD1, and QTD2** = none

**QTM** = total percent damages summed for all baseline TR rows across all locations

**QTL and QTU** = x lower and upper x% ci

The following images show the resultant calculations. The Math Result table displays confidence intervals for damage loss percentages.



Indicator 3

Vulnerability Distribution

Description 3

The damage percent for each asset type is described by a probability distribution (QTs) defined by the flood depth (0.5, 1.0, 1.5, 2.0, 2.5) and the percent of asset damage (the matrix numbers).

Indicator 3 URL

[http://localhost/resources/network\\_carbon/resourcepack\\_527/resource\\_1805/Ind3-Vulnerability.csv](http://localhost/resources/network_carbon/resourcepack_527/resource_1805/Ind3-Vulnerability.csv)

Label 3

3A

Rel Label 3

Date 3

01/01/2005

Dist Type 3

none

Q1 3

5.2416

Q1 Unit 3

5year

Q2 3

38.7872

Q2 Unit 3

10year

Q3 3

135.7550

Q3 Unit 3

25year

Q4 3

203.3705

Q4 Unit 3

50year

Q5 3

273.6069

Q5 Unit 3

100year

Math Operator 3

equalto

BaselO 3

none

QT 3

0.0000

QT Unit 3

none



DevTreks –social budgeting that improves lives and livelihoods

<b>QT Most 3</b> <input type="text" value="17.1607"/>	<b>QT Most Unit 3</b> <input type="text" value="total percent damage"/>
<b>QT Low 3</b> <input type="text" value="17.0695"/>	<b>QT Low Unit 3</b> <input type="text" value="lower 90% ci"/>
<b>QT High 3</b> <input type="text" value="17.2519"/>	<b>QT High Unit 3</b> <input type="text" value="upper 90% ci"/>
<b>Math Expression 3</b> <input type="text" value="I3.Q1.distribtype + I3.Q2.5year + I3.Q3.10year + I3.Q4.25year + I3.Q5.50year + I3.Q6."/>	
<b>Math Result 3</b> <div> drr results  label,asstype,loc_confid,total,distribtype,5year,10year,25year,50year,100year  RF1,Residential1,1_QTM,7.0686,normal,2.4960,17.4717,56.9078,79.8706,94.8464  RF1,Residential1,1_QTL,7.0310,normal,2.4827,17.3788,56.6054,79.4461,94.3423  RF1,Residential1,1_QTU,7.1061,normal,2.5093,17.5646,57.2102,80.2951,95.3505  RF1A,WoodCMax,1_QTM,4.4827,normal,2.50,9.98,34.94,49.92,58.90  RF1A,WoodCMax,1_QTL,4.4589,normal,2.48,9.93,34.76,49.65,58.59  RF1A,WoodCMax,1_QTU,4.5066,normal,2.51,10.04,35.13,50.18,59.22  RF1B,MasonCMax,1_QTM,2.5858,normal,0.00,7.49,21.96,29.95,35.94  RF1B,MasonCMax,1_QTL,2.5721,normal,0.00,7.45,21.85,29.79,35.75  RF1B,MasonCMax,1_QTU,2.5996,normal,0.00,7.53,22.08,30.11,36.13  RF2,Residential2,1_QTM,1.1032,normal,0.0000,0.9984,7.7374,16.9725,35.4426  RF2,Residential2,1_QTL,1.0973,normal,0.0000,0.9930,7.6963,16.8823,35.2542  RF2,Residential2,1_QTU,1.1091,normal,0.0000,1.0038,7.7785,17.0627,35.6310  RF2A,WoodPMin,1_QTM,0.6739,normal,0.00,0.50,3.99,11.98,22.46  RF2A,WoodPMin,1_QTL,0.6703,normal,0.00,0.50,3.97,11.92,22.34  RF2A,WoodPMin,1_QTU,0.6775,normal,0.00,0.50,4.01,12.04,22.58  RF2B,MasonPMax,1_QTM,0.4293,normal,0.00,0.50,3.74,4.99,12.98  RF2B,MasonPMax,1_QTL,0.4270,normal,0.00,0.50,3.72,4.97,12.91  RF2B,MasonPMax,1_QTU,0.4316,normal,0.00,0.50,3.76,5.02,13.05  RF,All,1_QTM,8.1718,normal,2.4960,18.4701,64.6452,96.8431,130.2890  RF,All,1_QTL,8.1283,normal,2.4827,18.3718,64.3017,96.3284,129.5965  RF,All,1_QTU,8.2152,normal,2.5093,18.5684,64.9887,97.3578,130.9815  TR,TotalRisk,1_QTM,8.1718,normal,2.4960,18.4701,64.6452,96.8431,130.2890  TR,TotalRisk,1_QTL,8.1283,normal,2.4827,18.3718,64.3017,96.3284,129.5965  TR,TotalRisk,1_QTU,8.2152,normal,2.5093,18.5684,64.9887,97.3578,130.9815 </div>	

#### Indicator 4. Loss Exceedance Probability (EP) Distribution

This Indicator uses the Math Results from Indicators 2 and 3 to generate confidence intervals for average annual damages and total damages by exceedance probability. The calculation uses the



DevTreks –social budgeting that improves lives and livelihoods

same Categorical Indexes and Locational Indexes as Indicator 3 for aggregating damages. Appendix C demonstrates how to use this Indicator to carry out simple trend analysis.

Selected properties include:

**Distribution Type:** none (URL datasets are used)

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Units:** automatically filled in (but most units that are entered manually will not be overwritten)

The following Math Expression is only used to identify the columns of TEXT data to include in the calculation.

**Math Expression =**

I4.Q1.distribtype + I4.Q2.5year + I4.Q3.10year + I4.Q4.25year + I4.Q5.50year +  
I4.Q6.100year

**Optional Indicator.URL TEXT:** Appendix C, Example 1, demonstrates how to use this property to conduct trend analysis.

**Q1 to Q5** = filled in automatically with total damages and units for each event summed for all baseline TR rows across all locations

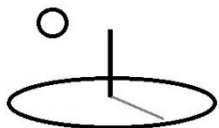
**QT, QTD1, and QTD2** = with this distribution, mean and sd

**QTM** = average annual damages summed for all baseline TR rows across all locations

**QTL and QTU** = x lower and upper x% ci

The following images show the resultant calculations. The Math Result totals column displays confidence intervals for average annual damages. The Math Result exceedance probability columns display confidence intervals for total damages. Example 2 demonstrates using up to 7 exceedance probabilities. The last column of data, quantity, can be used to verify that the naming conventions used in Indicators 2 and 3 are identical. A zero quantity indicates differences in either labels, locations, or asset names.





Indicator 4	
Loss EP Distribution	
Description 4	
The damages for each asset type is described by a probability distribution (QTs) defined by the event probability (20, 10, 4, 2, 1) and the total damages (the matrix numbers).	
Indicator 4 URL	
none	
Label 4	Rel Label 4
4A	
Date 4	Dist Type 4
01/01/2005	none
Q1 4	Q1 Unit 4
5,516.0643	5year
Q2 4	Q2 Unit 4
59,925.9235	10year
Q3 4	Q3 Unit 4
284,872.5233	25year
Q4 4	Q4 Unit 4
521,089.3660	50year
Q5 4	Q5 Unit 4
926,494.1342	100year
Math Operator 4	BaseIO 4
equalto	none
QT 4	QT Unit 4
0.0000	none



DevTreks –social budgeting that improves lives and livelihoods

QT Most 4	QT Most Unit 4
38,177.4348	total avg ann damages
QT Low 4	QT Low Unit 4
37,783.9036	lower 90% ci
QT High 4	QT High Unit 4
38,573.1035	upper 90% ci

Math Expression 4

I4.Q1.distribtype + I4.Q2.5year + I4.Q3.10year + I4.Q4.25year + I4.Q5.50year + I4.Q6.

Math Result 4

drr results

label	assettype	loc_confid	total	distribtype	5year	10year	25year	50year	100year	quantit	y
RF1,Residential1,1_QTM	7057.3675	none	2495.9567	17441.7454	56807.9744	79740.8246	94686.6133	1.0000			
RF1,Residential1,1_QTL	6981.9217	none	2462.8290	17259.6647	56218.0448	78889.9748	93686.8105	1.0000			
RF1,Residential1,1_QTU	7132.9176	none	2519.2597	17634.8182	57421.0556	80586.2010	95701.7594	1.0000			
RF1A,WoodCMax,1_QTM	4475.7495	normal	2495.96	9963.86	34883.49	49839.26	58804.74	1.0000			
RF1A,WoodCMax,1_QTL	4427.4317	normal	2462.83	9861.25	34519.33	49306.23	58184.34	1.0000			
RF1A,WoodCMax,1_QTU	4523.6269	normal	2519.26	10077.04	35259.60	50365.12	59438.47	1.0000			
RF1B,MasonCMax,1_QTM	2581.6179	normal	0.00	7477.89	21924.48	29901.56	35881.87	1.0000			
RF1B,MasonCMax,1_QTL	2554.4900	normal	0.00	7398.42	21698.72	29583.74	35502.47	1.0000			
RF1B,MasonCMax,1_QTU	2609.2907	normal	0.00	7557.78	22161.46	30221.08	36263.29	1.0000			
RF2,Residential2,1_QTM	11012.1609	none	0.0000	9983.8268	77174.9811	169425.54	06,353826.8214	1.0000			
RF2,Residential2,1_QTL	10902.9838	none	0.0000	9930.7622	76367.5612	167730.57	34,350059.3672	1.0000			
RF2,Residential2,1_QTU	11123.8867	none	0.0000	10036.8914	77986.6461	171229.3	671,357614.4402	1.0000			
RF2A,WoodPMin,1_QTM	6727.1025	normal	0.00	4991.91	39835.47	119606.24	224236.75	10.0000			

## Indicator 5. Costs of Alternatives Distribution



DevTreks –social budgeting that improves lives and livelihoods

This Indicator uses baseline and project alternative cost distributions to calculate confidence intervals for discounted costs. The full cost estimates for each project alternative cost should be completed and stored using standard tools in DevTreks (see the *CTA*, *LCA* or *NPV* tutorials).

Selected properties include:

**Distribution Type:** none, the TEXT file specifies the distributions

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Units:** automatically filled in (but most units that are entered manually will not be overwritten)

The following Math Expression is only used to identify the columns of TEXT data to include in the calculation.

**Math Expression =**

$$I5.Q1.installcost + I5.Q2.installdistrib + I5.Q3.omcost + I5.Q4.omdistrib + I5.Q5.isprojectcost$$

**Indicator.URL TEXT:** The following TEXT datasets displays the data conventions used by this algorithm. The baseline, or Current Practice, does not include suffixes, such as “\_A”, identifying the project alternative. Labels contain between 4 and 6 characters. Units concatenate the location with the distribution property. Both installation and operating/maintenance costs must be defined using a probability distribution. The “isprojectcost” column must specify whether the costs are project costs (yes) or unit costs (no). The latter costs will be calculated in Indicators 6 and 7 by multiplying them by Indicator 4’s asset quantity column.



DevTreks –social budgeting that improves lives and livelihoods

Indicator 5. Costs of Alternatives (US\$)								
Description: The cost for each project alternative equals discounted installation cost and a stream of operating and maintenance costs.								
label	alternat	loc_distrib	total	installcost	installdistrib	omcost	omdistrib	isprojectcost
AC1A	Current	1_QT	0.000	100.000	normal	1.500	normal	no
AC1A	Current	1_QTD1	0.000	100.000	normal	1.500	normal	no
AC1A	Current	1_QTD2	0.000	10.000	normal	0.150	normal	no
AC1A_A	RoofUp	1_QT	0.000	9200.000	normal	2.500	normal	no
AC1A_A	RoofUp	1_QTD1	0.000	9200.000	normal	2.500	normal	no
AC1A_A	RoofUp	1_QTD2	0.000	920.000	normal	0.250	normal	no
AC1A_B	Openin	1_QT	0.000	6720.000	normal	2.500	normal	no
AC1A_B	Openin	1_QTD1	0.000	6720.000	normal	2.500	normal	no
AC1A_B	Openin	1_QTD2	0.000	672.000	normal	0.250	normal	no
AC1A_C	BothRc	1_QT	0.000	15920.000	normal	2.500	normal	no
AC1A_C	BothRc	1_QTD1	0.000	15920.000	normal	2.500	normal	no
AC1A_C	BothRc	1_QTD2	0.000	1592.000	normal	0.250	normal	no
AC1A	Current	2_QT	0.000	100.000	normal	1.500	normal	no
AC1A	Current	2_QTD1	0.000	100.000	normal	1.500	normal	no
AC1A	Current	2_QTD2	0.000	10.000	normal	0.150	normal	no
AC1A_A	RoofUp	2_QT	0.000	9200.000	normal	2.500	normal	no
AC1A_A	RoofUp	2_QTD1	0.000	9200.000	normal	2.500	normal	no
AC1A_A	RoofUp	2_QTD2	0.000	920.000	normal	0.250	normal	no
AC1A_B	Openin	2_QT	0.000	6720.000	normal	2.500	normal	no
AC1A_B	Openin	2_QTD1	0.000	6720.000	normal	2.500	normal	no
AC1A_B	Openin	2_QTD2	0.000	672.000	normal	0.250	normal	no
AC1A_C	BothRc	2_QT	0.000	15920.000	normal	2.500	normal	no
AC1A_C	BothRc	2_QTD1	0.000	15920.000	normal	2.500	normal	no
AC1A_C	BothRc	2_QTD2	0.000	1592.000	normal	0.250	normal	no

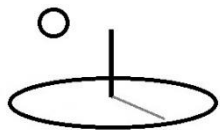
### Sensitivity Analysis Data TEXT (stored as csv text data):

The following dataset has been referenced as the second URL in the Indicator.URL property.

The discount rates must be decimals while the life must be doubles. The Math Result property displays the sensitivity analysis completed from this data. At least 1 rate and 1 life must be included in this TEXT file.

Indicator 5. Sensitivity Analysis				
Description: This table holds variables used to conduct a sensitivity analysis of the costs for each project alternative.				
label	type	variable	value1	value2
5A	sensitivity	rate	0.050	0.120
5A	sensitivity	life	10.000	25.000

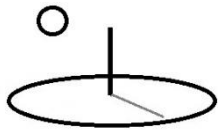
The Monte Carlo algorithm is run using these properties and the distribution data stored in the TEXT file. The results of the simulations are then used to fill in the rest of the following properties.



DevTreks –social budgeting that improves lives and livelihoods

**Qs** – the Indicator properties are relatively meaningless –the MathResult has the important data.

The following images show the resultant calculations. The MathResult table displays QTM as the average annual cost and QTL and QTU as the lower and upper confidence intervals. The results include a sensitivity analysis conducted using the 2nd URL's discount rates and life spans.

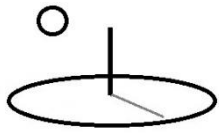


DevTreks –social budgeting that improves lives and livelihoods

<b>Math Type 5</b>	<b>Math Sub Type 5</b>
algorithm1	subalgorithm9
<b>QT D1 5</b>	<b>QT D1 Unit 5</b>
0.0000	low
<b>QT D2 5</b>	<b>QT D2 Unit 5</b>
0.0000	high
<b>QT Most 5</b>	<b>QT Most Unit 5</b>
3,023.6790	annual cost
<b>QT Low 5</b>	<b>QT Low Unit 5</b>
3,007.6079	lower 90% ci
<b>QT High 5</b>	<b>QT High Unit 5</b>
3,039.7501	upper 90% ci
<b>Math Expression 5</b>	
I5.Q1.installcost + I5.Q2.installdistrib + I5.Q3.omcost+ I5.Q4.omdistrib + I5.Q5.isprojectcost	
<b>Math Result 5</b>	
<pre> drr results label,alternative,loc_confid,total,life_10,life_25,isprojectcost AC1A,CurrentPractice,1_QTM_0.05,106.6482,106.6482,116.1912,no AC1A,CurrentPractice,1_QTL_0.05,106.0811,106.0811,115.5731,no AC1A,CurrentPractice,1_QTU_0.05,107.2153,107.2153,116.8093,no AC1A,CurrentPractice,1_QTM_0.12,97.6031,97.6031,100.8872,no AC1A,CurrentPractice,1_QTL_0.12,97.0842,97.0842,100.3507,no AC1A,CurrentPractice,1_QTU_0.12,98.1221,98.1221,101.4237,no AC1A_A,RoofUpgrade,1_QTM_0.05,8767.0074,8767.0074,8782.9124,no AC1A_A,RoofUpgrade,1_QTL_0.05,8720.4100,8720.4100,8736.2303,no AC1A_A,RoofUpgrade,1_QTU_0.05,8813.6047,8813.6047,8829.5945,no AC1A_A,RoofUpgrade,1_QTM_0.12,8215.1035,8215.1035,8220.5770,no AC1A_A,RoofUpgrade,1_QTL_0.12,8171.4396,8171.4396,8176.8839,no AC1A_A,RoofUpgrade,1_QTU_0.12,8258.7674,8258.7674,8264.2701,no AC1A_B,OpeningProtection,1_QTM_0.05,6408.9226,6408.9226,6424.8276,no AC1A_B,OpeningProtection,1_QTL_0.05,6374.8586,6374.8586,6390.6788,no </pre>	

## Indicator 6. Benefit Cost Analysis

This Indicator uses the Math Results from Indicator 4 to define discounted benefits and the Math Results from Indicator 5 to define discounted costs. Benefits are defined as the changes in damages for each project alternative in comparison to the baseline. Costs are defined as the



DevTreks –social budgeting that improves lives and livelihoods

changes in costs for each project alternative in comparison to the baseline. Calculations generate confidence intervals for benefit cost ratios for each project alternative in each location.

Each baseline finds related alternatives using the label, assettype, and loc\_confid, columns of data in the URL TEXT or Indicator4.MathResults. The only difference allowed between both sets of strings are the alternatives' use of suffixes, such as “\_A”, to distinguish each alternative. This is the first error to check when calculations have missing rows of data. The “assettype” should use simple strings, without spaces or unusual characters, because data errors are easier to spot.

Selected properties include:

**Distribution Type:** none

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Units:** automatically filled in (but most units that are entered manually will not be overwritten)

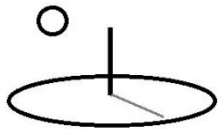
**Math Expression =**

I6.Q1.distribtype + I6.Q2.100year + I6.Q3.50year + I6.Q4.25year + I6.Q5.10year +  
I6.Q6.5year

**Indicator.URL TEXT:** This optional URL can be used to reference a URL containing a custom distribution. This TEXT file must have the exact same format as the Indicator4.MathResult. This release has only tested small datasets: 2 locations with a small number of Indicators, Categorical Indexes, and Locational Indexes.

**Qs =** All of the Qs automatically document the project alternative with the highest benefit cost ratio. The Unit properties can be used to find the corresponding rows of full calculations in the Math Results.

The following results list the benefit cost analysis for each project alternative in the columns and the confidence intervals for each asset/rate/life sensitivity analysis in the rows. The csv file can be imported into other software for further analysis or to develop multimedia support. The reason that the QTM, QTL, and QTU ratios are equal is explained using the second image.



Indicator 6

Benefit Cost Analysis

Description 6

The Math Results from Indicator 4 define average annual benefits and the Math Results from Indicator 5 defines average annual costs. Benefits are defined as the reduction in damages of each project alternative in comparison to the baseline.

Indicator 6 URL

none

Label 6

6A

Rel Label 6

Date 6

01/01/2005

Dist Type 6

none

Q1 6

537,200.4234

Q1 Unit 6

base damage

Q2 6

232.3824

Q2 Unit 6

base cost

Q3 6

385,493.7847

Q3 Unit 6

AC1A\_B damage

Q4 6

12,849.6552

Q4 Unit 6

AC1A\_B cost

Q5 6

0.0000

Q5 Unit 6

none

Math Operator 6

equalto

BaseIO 6

none

QT 6

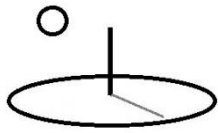
139,089.3658

QT Unit 6

net benefits

The following image from localhost shows equal QTM, QTL, and QTU ratios. Although, the cloud shows unequal ratios, the explanation offered in the next paragraph still holds.





DevTreks –social budgeting that improves lives and livelihoods

localhost

☆

...

100,000.1000

not benefits

Math Type 6

Math Sub Type 6

algorithm1

subalgorithm9

QT D1 6

QT D1 Unit 6

0.0000

none

QT D2 6

QT D2 Unit 6

0.0000

none

QT Most 6

QT Most Unit 6

12.0432

2\_QTM\_0.05\_25, bcr

QT Low 6

QT Low Unit 6

11.9977

lower 90 % ci

QT High 6

QT High Unit 6

12.1065

upper 90 % ci

Math Expression 6

I6.Q1.distribtype + I6.Q2.100year + I6.Q3.50year

Math Result 6

dr results

label,assettype,loc\_confid,total,RF1\_damage,RF1\_cost,RF1\_A\_damage,RF1\_A\_cost,RF1\_A\_bcr,RF1\_B\_damage,RF1\_B\_cost,RF1\_B\_bcr,RF1\_C\_damage,RF1\_C\_cost,RF1\_C\_bcr

RF1\_A,Residential1,1\_QTM\_0.05\_10,0,54495.1211328437,106.6482,38859.9985857052,8767.0074,1.8054,40335.5480020171,6408.9226,2.2467,29305.1585321391,15156.6565,1.6738

RF1\_A,Residential1,1\_QTM\_0.05\_25,0,99466.1463272059,116.1912,70928.4469003816,8782.9124,3.2928,73621.6644050849,6424.8276,4.0967,53488.6633171084,15172.5615,3.0537

RF1\_A,Residential1,1\_QTM\_0.12\_10,0,39875.7003684584,97.6031,28435.0163410938,8215.1035,1.4094,29514.7197196821,6004.399,1.7541,21443.4557917419,14205.3996,1.3065

RF1\_A,Residential1,1\_QTM\_0.12\_25,0,55351.91



DevTreks –social budgeting that improves lives and livelihoods

The following localhost image, derived using Version 2.0.2, demonstrates that the calculations for the highest BCR derives from the summation of the damages and costs for each location (not from a simple summation of each location's BCR). The information conveyed to decision makers must include the actual costs and benefits used in the ratios.

207	label	assettype	loc_confid	total	RF1_dama	RF1_cost	RF1_A_dam	RF1_A_co	RF1_A_bcr	RF1_B_dam	RF1_B_co	RF1_B_bcr	RF1_C_dam	RF1_C_co	RF1_C_bcr
208	TR_A	TotalRisk	1_QTM_0.05_25	0	254670.9	116.1912	161715.5	8782.912	10.7256	182293.2	6424.828	11.4728	119721.6	15172.56	8.9629
209	TR_A	TotalRisk	2_QTM_0.05_25	0	283399.7	116.1912	181481.7	8782.912	11.7597	203825.1	6424.828	12.6136	134987.1	15172.56	9.8571
210	QTM Sum	Locations			538070.6	232.3824	343197.3	17565.82	<b>11.24263</b>	386118.3	12849.66	<b>12.0432</b>	254708.6	30345.12	<b>9.410037</b>
211															
212	TR_A	TotalRisk	1_QTL_0.05_25	0	252068.9	115.5731	160059.6	8736.23	10.6731	180249.3	6390.679	11.4452	118470.8	15091.92	8.9206
213	TR_A	TotalRisk	2_QTL_0.05_25	0	280455.4	115.5731	179537.4	8736.23	11.7065	201701.5	6390.679	12.5502	133589.7	15091.92	9.8065
214	QTM Sum	Locations			532524.2	231.1462	339597	17472.46	<b>11.18982</b>	381950.8	12781.36	<b>11.99768</b>	252060.5	30183.84	<b>9.363557</b>
215															
216	TR_A	TotalRisk	1_QTU_0.05_25	0	257310.4	116.8093	163428	8829.595	10.7752	184166	6458.976	11.533	120993	15253.21	9.0059
217	TR_A	TotalRisk	2_QTU_0.05_25	0	286336.8	116.8093	183412.2	8829.595	11.8131	205918.1	6458.976	12.68	136391.7	15253.21	9.9063
218	QTM Sum	Locations			543647.2	233.6186	346840.2	17659.19	<b>11.29415</b>	390084	12917.95	<b>12.10652</b>	257384.7	30506.41	<b>9.456097</b>

The following image derived from an earlier release. It demonstrates that although the ratios for QTM, QTL, and QTU, may be equal or close, the actual costs and benefits used in the ratios differ appropriately.

label	assettype	loc_confid	total	RF1_damage	RF1_cost	RF1_A_dam	RF1_A_cost	RF1_A_bcr	RF1_B_dama	RF1_B_cost	RF1_B_bcr
TR_A	TotalRisk	1_QTM_0.05_25	0.000	254259.049	116.191	161453.968	8782.912	10.708	181998.325	6424.828	11.4543
TR_A	TotalRisk	2_QTM_0.05_25	0.000	282941.375	116.191	181188.215	8782.912	11.741	203495.459	6424.828	12.5932
QTM Sum	Locations			537200.423	232.382	342642.184	17565.825	11.224	385493.785	12849.655	<b>12.0237</b>
TR_A	TotalRisk	1_QTL_0.05_25	0.000	252907.647	115.573	160595.832	8736.230	10.708	181030.994	6390.679	11.4543
TR_A	TotalRisk	2_QTL_0.05_25	0.000	281437.524	115.573	180225.190	8736.230	11.741	202413.869	6390.679	12.5932
QTL Sum	Locations			534345.171	231.146	340821.022	17472.461	11.224	383444.863	12781.358	<b>12.0237</b>
TR_A	TotalRisk	1_QTU_0.05_25	0.000	255610.449	116.809	162312.105	8829.595	10.708	182965.657	6458.976	11.4543
TR_A	TotalRisk	2_QTU_0.05_25	0.000	284445.224	116.809	182151.242	8829.595	11.741	204577.049	6458.976	12.5932
QTU Sum	Locations			540055.673	233.619	344463.347	17659.189	11.224	387542.706	12917.953	<b>12.0237</b>

## Indicator 7. Cost Effectiveness Analysis.

This Indicator is calculated in a similar manner to Indicator 6, but instead of calculating changes in direct monetary damages as benefits, it calculates changes in indirect non-monetary indicators as benefits. The changes in costs are divided by the changes in non-monetary benefits to develop Cost Effectiveness Ratios.



DevTreks –social budgeting that improves lives and livelihoods

Unlike Indicator 6, this reference recommends obtaining the confidence intervals for these damage reductions elsewhere and then referencing them using the Indicator.URL property. If no TEXT file is found in the Indicator.URL, it will use the same data as Indicator 6 –the MathResults from Indicator 4. When the Math Results from Indicator 4, Appendix B, subalgorithm 10, are used as the TEXT file, Indicator 7 measures the cost effectiveness of alternative interventions in reducing the *indirect* damages from disasters. A complement to Indicator 6’s measurement of *direct* damages. The case studies used in Appendix B document that, for some types of disasters, the magnitude of the indirect damages can be as high as the direct damages.

Avoid using damages with numbers that are too small to evaluate meaningfully. For example, human mortality amounts, expressed as percent of population, can result in percentages such as 0.002 –an amount too small to evaluate given the 3 digit precision shown in this example. Instead use the actual number of deaths (.002 of 1,000,000 = 2000 deaths per 1 million). The normalization techniques used in Appendix B also reinforce the need for careful data management. Avoid using Sub Indicator values that use significantly different scales or the 4 digit precision of the normalized values don’t pick up full differences in confidence intervals.

Selected properties include:

**Distribution Type:** none

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Units:** automatically filled in (but most units that are entered manually will not be overwritten)

**Math Expression =**

I7.Q1.distribtype + I7.Q2.100year + I7.Q3.50year + I7.Q4.25year + I7.Q5.10year +  
I7.Q6.5year

**Indicator.URL TEXT:** This optional URL can be used to reference a URL containing a custom distribution. This TEXT file must have the exact same format as the Indicator4.MathResult. This optional URL measures indirect and intangible indicators. This TEXT file must have the exact same format as the Indicator4.MathResult, except instead of comparing direct damages for



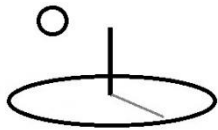
DevTreks –social budgeting that improves lives and livelihoods

multiple “assettypes”, it compares indirect damages for multiple nonmonetary damage indicators. The Math Results for Indicator 4, Appendix B, subalgorithm 10, can be used for this file or it can be manually built. If this file is not found, Indicator4.MathResults will be used to conduct the analysis.

**Qs** = All of the Qs automatically document the project alternative with the lowest cost effectiveness ratio. The Unit properties can be used to find the corresponding rows of full calculations in the Math Results.

The following images show that, because this Indicator assumes benefits are nonmonetary and does not discount them, a different project alternative is selected than Indicator 6. These results list the cost effectiveness analysis for each project alternative in the columns and the confidence intervals for each indicator/rate/life sensitivity analysis in the rows. Unlike a BCA, where a higher benefit cost ratio is better, in a CEA, a lower cost effectiveness ratio is better. The use of normalized damage data with regular monetary costs in CEA results in unusual, but accurate, ratios. Analysts may want to scale the ratios (min = 0, max = 100) when communicating the results to decision makers. The csv file can be imported into other software for further analysis or to develop multimedia support.

As explained for Indicator 6, although the QTM, QTL, and QTU ratios can be equal or have very small differences, the underlying cost and benefit information has correct confidence intervals that should be communicated to decision makers.



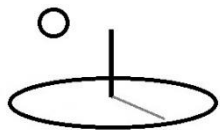
Indicator 7	
Cost Effectiveness Analysis	
Description 7	
The URL dataset define average annual benefits from non monetary disaster loss reductions and the Math Results from Indicator 5 defines average annual costs. Benefits are defined as the reduction in damages of each project alternative in comparison to the	
Indicator 7 URL	
none	
Label 7	Rel Label 7
7A	
Date 7	Dist Type 7
01/01/2005	none
Q1 7	Q1 Unit 7
38,115.6901	base damage
Q2 7	Q2 Unit 7
195.2062	base cost
Q3 7	Q3 Unit 7
27,351.7313	AC1A_B damage
Q4 7	Q4 Unit 7
12,008.7980	AC1A_B cost
Q5 7	Q5 Unit 7
0.0000	none
Math Operator 7	BaseIO 7
equalto	none
QT 7	QT Unit 7
1.0975	net benefits



DevTreks –social budgeting that improves lives and livelihoods

Math Type 7		Math Sub Type 7	
<input type="text" value="algorithm1"/>		<input type="text" value="subalgorithm9"/>	
QT D1 7		QT D1 Unit 7	
<input type="text" value="0.0000"/>		<input type="text" value="none"/>	
QT D2 7		QT D2 Unit 7	
<input type="text" value="0.0000"/>		<input type="text" value="none"/>	
QT Most 7		QT Most Unit 7	
<input type="text" value="1.0957"/>		<input type="text" value="2_QTM_0.12_10, cer"/>	
QT Low 7		QT Low Unit 7	
<input type="text" value="1.0999"/>		<input type="text" value="lower 90 % ci"/>	
QT High 7		QT High Unit 7	
<input type="text" value="1.0900"/>		<input type="text" value="upper 90 % ci"/>	
Math Expression 7			
<input type="text" value="I7.Q1.distribtype + I7.Q2.100year + I7.Q3.50year + I7.Q4"/>			
Math Result 7			
<pre> drr results label,assettype,loc_confid,total,RF1_damage,RF1_cost,RF 1_A_damage,RF1_A_cost,RF1_A_cer,RF1_B_damage,R F1_B_cost,RF1_B_cer,RF1_C_damage,RF1_C_cost,RF1 _C_cer RF1_A,Residential1,1_QTM_0.05_10,0,7057.3675,106.64 82,5032.5476,8767.0074,4.2771,5223.638,6408.9226,3.43 69,3795.1521,15156.6565,4.6134 RF1_A,Residential1,1_QTM_0.05_25,0,7057.3675,116.19 12,5032.5476,8782.9124,4.2802,5223.638,6424.8276,3.44 03,3795.1521,15172.5615,4.6154 RF1_A,Residential1,1_QTM_0.12_10,0,7057.3675,97.603 1,5032.5476,8215.1035,4.009,5223.638,6004.399,3.2212, 3795.1521,14205.3996,4.3246 RF1_A,Residential1,1_QTM_0.12_25,0,7057.3675,100.88 72,5032.5476,8220.577,4.0101,5223.638,6009.8725,3.222 4,3795.1521,14210.8731,4.3253 RF1_A,Residential1,1_QTL_0.05_10,0,6981.9217,106.081 1 4980 0786 8720 41 4 3032 5168 2666 6374 8586 3 4564 </pre>			

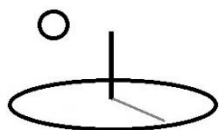
## Scores and Indicators 8 to 15. Decision Support Systems



DevTreks –social budgeting that improves lives and livelihoods

Appendix C introduces subalgorithms that demonstrate using Scores and Indicators 8 to 15 to produce wider decision support.

The following image from Version 2.0.6 demonstrates that M&E calculators treat the Score as the 0 index in collections of M&E Indicators. M&E Scores include a Name, Label, and Date while Stock Scores do not have these properties.



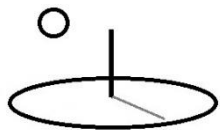
DevTreks –social budgeting that improves lives and livelihoods

## Output Group: CTAP Output Examples

### Output : CTAP Example 1 - Hurricane DRR

Indicators Details	
<b>Indic 0 Name:</b> Disaster Score	Label: S0
Date: 01/01/2005	Rel Label: 200b
Math Type: algorithm1	Dist Type: normal
Math Sub Type: subalgorithm1	Base IO: quantity
Math Express: I6.QTM	Math Operator: equalto
QT Amount: 12.0657	QT Unit: highest bcr
QT D1 Amount: 12.0237	QT D1 Unit: mean
QT D2 Amount: 3.0000	QT D2 Unit: sd
QT Most Amount: 12.0209	QT Most Unit: 3.0000
QT Low Amount: 11.8631	QT Low Unit: lower 90 % ci
QT High Amount: 12.1787	QT High Unit: upper 90 % ci
Score Math Result: sampled descriptive statistics	
N,Total,Mean,Median,StdDev,Var,Min,Max 1000, 12020.8763, 12.0209, 11.9374, 3.0240, 9.1446, 1.6435, 20.6134, sampled cumulative density function 0.00,0.10,0.20,0.30,0.40,0.50,0.60,0.70,0.80,0.90,1.00	
1.6435,8.2644,9.4902,10.3632,11.2701,11.9424,12.7758,13.6160,14.5839,	
<b>Indic 1 Name:</b> Hazard Distribution	Label: 1A
Date: 01/01/2005	Rel Label: none
Math Type: algorithm1	Dist Type: none
Math Sub Type: subalgorithm9	Base IO: none
Q1 Amount: 104.9901	Q1 Unit: 100year
Q2 Amount: 78.7426	Q2 Unit: 50year
Q3 Amount: 52.4951	Q3 Unit: 25year
Q4 Amount: 36.7466	Q4 Unit: 10year
Q5 Amount: 26.2475	Q5 Unit: 5year
Math Express: I1.Q1.distribtype + I1.Q2.100year + I1.Q3. 50year + I1.Q4.25year + I1.Q5.10year + I1.Q6.5year	Math Operator: equalto
QT Amount: 49.8750	QT Unit:
QT D1 Amount: 49.8750	QT D1 Unit: none
QT D2 Amount: 4.9875	QT D2 Unit: none
QT Most Amount: 49.8703	QT Most Unit:
QT Low Amount: 49.6080	QT Low Unit: lower 90 % ci
QT High Amount: 50.1326	QT High Unit: upper 90 % ci
Indic 1 Description: Each reach is described by a probability distribution (QTs) defined by the event probability (1, 2, 4, 10, 20 percent) and the associate quantity of the hazard (the matrix numbers).	
<b>Indic 2 Name:</b> Exposure Distribution	Label: 2A
Date: 01/01/2005	Rel Label: none





DevTreks –social budgeting that improves lives and livelihoods

## **Example 2. Floods, Semarang, Indonesia**

### **URLs**

<https://www.devtreks.org/greentreks/preview/carbon/resourcepack/SubAlgo 09 DRR 2/1542/none>

<https://www.devtreks.org/greentreks/preview/carbon/output/CTAP Example 5 - Floods DRR/2141223469/none>

<http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 6 - Floods DRR/2141223476/none>

This case study uses Mechler's (2005) case study of a benefit cost analysis completed for floods in the subject central Java city. The flood damages arise from flooding caused by the neighboring Garang River combined with tidal inundation caused by the proximity of the ocean. This example only analyzes the flood damages.

This Example mainly focuses on differences from Example 1. As with Example 1, a lot of the data used in this analysis had to be extrapolated from summary tables presented in the case study. That makes the absolute numbers in the analysis less important than the techniques employed to generate the numbers. All of the initial data uses monetary units of million Rupiah.

### **Indicator 1. Hazard Distribution**

The following image shows the initial data used with this Indicator. The values are flood depths for the respective event periods. Other than using flood events, this Indicator has not been changed from Example 1 and requires no additional documentation.



DevTreks –social budgeting that improves lives and livelihoods

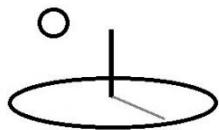
label	location	distributio	total	distribtype	100year	50year	25year	10year	5year
1A	1	QT	0	normal	2.5	1.5	1	0.5	0.25
1A	1	QTD1	0	normal	2.5	1.5	1	0.5	0.25
1A	1	QTD2	0	normal	0.25	0.15	0.1	0.05	0.025
1A	2	QT	0	normal	3	1.8	1.2	0.6	0.3
1A	2	QTD1	0	normal	3	1.8	1.2	0.6	0.3
1A	2	QTD2	0	normal	0.3	0.18	0.12	0.06	0.03

For testing purposes, the following image displays the MathResults using 7 exceedance probability events.

label	location	loc_confid	total	distribtype	750year	250year	100year	50year	25year	10year	5year
1A	1	QTM	1.6571	normal	4.3772	3.1266	2.5013	1.5008	1.0005	0.5003	0.2501
1A	1	QTL	1.6544	normal	4.3701	3.1215	2.4972	1.4984	0.9989	0.4995	0.2497
1A	1	QTU	1.6598	normal	4.3843	3.1317	2.5054	1.5032	1.0021	0.5011	0.2505
1A	2	QTM	1.9885	normal	5.2526	3.7519	3.0015	1.8009	1.2006	0.6003	0.3002
1A	2	QTL	1.9853	normal	5.244	3.7458	2.9966	1.798	1.1986	0.5993	0.2997
1A	2	QTU	1.9918	normal	5.2612	3.758	3.0064	1.8038	1.2026	0.6013	0.3007

## Indicator 2. Exposure Distribution

The following image shows the initial data used with this Indicator. The asset unit value, in million Rupiah, come from Table 35 in Mechler’s case study. The quantity is extrapolated from Table 40. For example, the asset, Business-Structure, must have a 95 billion Rupiah total asset value when the asset prices and quantities for both locations are multiplied and summed (i.e. 47.5 billion per location). As Indicator 6 will demonstrate, this example had to stray a good deal from the case study.



## DevTreks –social budgeting that improves lives and livelihoods

label	location	assettype	total	distribtype	QT	QTUnit	QTD1	QTD1Unit	QT1D2	QTD2Unit	normalizat	weight	quantity
RF1	1	Residentia	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF1A	1	Residentia	0.0000	normal	0.1473	unit value	0.1473	mean	0.0147	sd	none	1.0000	322541.2174
RF2	1	Industrial1	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF2A	1	Industrial1	0.0000	normal	0.2805	unit value	0.2805	mean	0.0281	sd	none	1.0000	183594.1678
RF2B	1	Business-S	0.0000	normal	0.2805	unit value	0.2805	mean	0.0281	sd	none	1.0000	160422.0883
RF2C	1	Public Busi	0.0000	normal	200000.0000	unit value	200000.0000	mean	20000.0000	sd	none	1.0000	1.0000
RF3	1	Residentia	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF3A	1	Residentia	0.0000	normal	0.0884	unit value	0.0884	mean	0.0088	sd	none	1.0000	1120403.7981
RF4	1	Industrial1	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF4A	1	Industrial1	0.0000	normal	0.2328	unit value	0.2328	mean	0.0233	sd	none	1.0000	450984.4346
RF4B	1	Business-M	0.0000	normal	0.3857	unit value	0.3857	mean	0.0386	sd	none	1.0000	343529.4606
RF	1	All Physica	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
TR	1	Total Risk	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF1	2	Residentia	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF1A	2	Residentia	0.0000	normal	0.1473	unit value	0.1473	mean	0.0147	sd	none	1.0000	1290164.8695
RF2	2	Industrial1	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF2A	2	Industrial1	0.0000	normal	0.2805	unit value	0.2805	mean	0.0281	sd	none	1.0000	734376.6711
RF2B	2	Business-S	0.0000	normal	0.2805	unit value	0.2805	mean	0.0281	sd	none	1.0000	641688.3534
RF2C	2	Public Busi	0.0000	normal	200000.0000	unit value	200000.0000	mean	20000.0000	sd	none	1.0000	1.0000
RF3	2	Residentia	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF3A	2	Residentia	0.0000	normal	0.0884	unit value	0.0884	mean	0.0088	sd	none	1.0000	4481615.1922
RF4	2	Industrial1	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF4A	2	Industrial1	0.0000	normal	0.2328	unit value	0.2328	mean	0.0233	sd	none	1.0000	1803937.7384
RF4B	2	Business-M	0.0000	normal	0.3857	unit value	0.3857	mean	0.0386	sd	none	1.0000	1374117.8423
RF	2	All Physica	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
TR	2	Total Risk	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000

Asset values are defined for the same assets as the case study, including Structures (-S) and Indoor Movables (-M). In addition, Table 40 shows that the case study uses Indicator 4 to quantify additional losses for Public Infrastructure and Business Suspension. In contrast, this algorithm treats these losses just like any other loss and defines them using Indicators 2 and 3.

Unlike Example 1, where costs have been defined on a *per unit asset* basis, this Example defines costs on a *per unit project* basis. Although Indicator 2's total exposed asset value will be calculated by multiplying asset value by asset quantity, the final costs used in Indicators 6 and 7 will not be multiplied by the asset quantity.

The following image displays the Math Results for this Indicator. Notice that each Indicator.QTM, QTL, and QTU, have been calculated as total asset values by multiplying their initial PRA-calculated prices by their quantities. Note that the RF1A row's, 47.5 billion asset value for location 1, corresponds to 50% of the corresponding 95 billion asset value displayed in Table 40 in the case study.



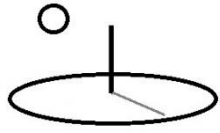
DevTreks –social budgeting that improves lives and livelihoods

label	location	assettype	total	distribtype	QTM	QTMUnit	QTL	QTLUnit	QTU	QTUUnit	quantity
RF1	1	Residential1	0	none	47542.5754	category mea	47478.0672	category l	47607.0837	category h	1
RF1A	1	Residential-S	0	normal	47542.5754	total value	47478.0672	lower 90%	47607.0837	upper 90%	322541.217
RF2	1	Industrial1	0	none	296631.6899	category mea	296133.9602	category l	297129.4195	category h	1
RF2A	1	Industrial-S	0	normal	51516.5235	total value	51424.7264	lower 90%	51608.3206	upper 90%	183594.168
RF2B	1	Business-S	0	normal	45014.438	total value	44934.2269	lower 90%	45094.649	upper 90%	160422.088
RF2C	1	Public Busin Los	0	normal	200100.7284	total value	199775.0069	lower 90%	200426.4499	upper 90%	1
RF3	1	Residential1	0	none	99043.6958	category mea	98931.6554	category l	99155.7361	category h	1
RF3A	1	Residential-M	0	normal	99043.6958	total value	98931.6554	lower 90%	99155.7361	upper 90%	1120403.8
RF4	1	Industrial1	0	none	237602.2937	category mea	237215.7822	category l	237988.8051	category h	1
RF4A	1	Industrial-M	0	normal	105034.2748	total value	104853.881	lower 90%	105214.6686	upper 90%	450984.435
RF4B	1	Business-M	0	normal	132568.0188	total value	132361.9012	lower 90%	132774.1365	upper 90%	343529.461
RF	1	All Physical	0	none	680820.2547	sum categori	679759.465	category l	681881.0444	category h	1
TR	1	Total Risk	0	none	680820.2547	sum categori	679759.465	category l	681881.0444	category h	1
RF1	2	Residential1	0	none	190170.30	category mea	189912.27	category l	190428.33	category h	1.00
RF1A	2	Residential-S	0	normal	190170.30	total value	189912.27	lower 90%	190428.33	upper 90%	1290164.87
RF2	2	Industrial1	0	none	586224.57	category mea	585210.82	category l	587238.33	category h	1.00
RF2A	2	Industrial-S	0	normal	206066.09	total value	205698.91	lower 90%	206433.28	upper 90%	734376.67
RF2B	2	Business-S	0	normal	180057.75	total value	179736.91	lower 90%	180378.60	upper 90%	641688.35
RF2C	2	Public Busin Los	0	normal	200100.73	total value	199775.01	lower 90%	200426.45	upper 90%	1.00
RF3	2	Residential1	0	none	396174.78	category mea	395726.62	category l	396622.94	category h	1.00
RF3A	2	Residential-M	0	normal	396174.78	total value	395726.62	lower 90%	396622.94	upper 90%	4481615.19
RF4	2	Industrial1	0	none	950409.17	category mea	948863.13	category l	951955.22	category h	1.00
RF4A	2	Industrial-M	0	normal	420137.10	total value	419415.52	lower 90%	420858.67	upper 90%	1803937.74
RF4B	2	Business-M	0	normal	530272.08	total value	529447.60	lower 90%	531096.55	upper 90%	1374117.84
RF	2	All Physical	0	none	2122978.83	sum categori	2119712.84	category l	2126244.83	category h	1.00
TR	2	Total Risk	0	none	2122978.83	sum categori	2119712.84	category l	2126244.83	category h	1.00

### Indicator 3. Vulnerability Distribution

The following image shows the initial data used with this Indicator. The damage loss percent is extrapolated from Table 40 in the case study. For example, the economic loss for the Residential asset with the 10 year event is 6 billion Rupiah. That can be derived by multiplying the \$95 billion total loss by the 6.32% damage loss percent in this table. The latter value is calculated by dividing the final 6 billion loss by the 95 billion total loss. The Public and Business asset row is included to demonstrate the difference between how this subalgorithm treats “indirect damages” and the case study’s approach.

This example also differs from the case study by treating Mechler’s 3 “options” for reducing flood damages as mutually exclusive project alternatives. Only the project alternative with the highest BCR will be chosen. Mechler only gives damage reduction estimates, at 100%, for the selected project. For illustrative purposes, Alternative A will reduce damages by 50%, Alternative B by 75%, and Alternative C by 100%.



DevTreks –social budgeting that improves lives and livelihoods

label	assettype	loc_distrib	total	distribtype	5year	10year	25year	50year	100year
RF1	Residential1	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF1	Residential1	1_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF1	Residential1	1_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF1A	Residential-S	1_QT	0.000	normal	0.000	6.316	16.842	25.263	45.263
RF1A	Residential-S	1_QTD1	0.000	normal	0.000	6.316	16.842	25.263	45.263
RF1A	Residential-S	1_QTD2	0.000	normal	0.000	0.632	1.684	2.526	4.526
RF2	Industrial1	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF2	Industrial1	1_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF2	Industrial1	1_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF2A	Industrial-S	1_QT	0.000	normal	1.000	4.854	10.680	20.388	30.097
RF2A	Industrial-S	1_QTD1	0.000	normal	1.000	4.854	10.680	20.388	30.097
RF2A	Industrial-S	1_QTD2	0.000	normal	0.100	0.485	1.068	2.039	3.010
RF2B	Business-S	1_QT	0.000	normal	0.000	14.444	23.333	33.333	40.000
RF2B	Business-S	1_QTD1	0.000	normal	0.000	14.444	23.333	33.333	40.000
RF2B	Business-S	1_QTD2	0.000	normal	0.000	1.444	2.333	3.333	4.000
RF2C	Public Busin Loss	1_QT	0.000	normal	0.000	21.750	44.250	66.750	98.750
RF2C	Public Busin Loss	1_QTD1	0.000	normal	0.000	21.750	44.250	66.750	98.750
RF2C	Public Busin Loss	1_QTD2	0.000	normal	0.000	2.175	4.425	6.675	9.875
RF3	Residential1	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF3	Residential1	1_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF3	Residential1	1_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF3A	Residential-M	1_QT	0.000	normal	0.000	13.131	36.869	54.545	94.949
RF3A	Residential-M	1_QTD1	0.000	normal	0.000	13.131	36.869	54.545	94.949
RF3A	Residential-M	1_QTD2	0.000	normal	0.000	1.313	3.687	5.455	9.495
RF4	Industrial1	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF4	Industrial1	1_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF4	Industrial1	1_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF4A	Industrial-M	1_QT	0.000	normal	1.000	12.800	34.762	62.857	95.238
RF4A	Industrial-M	1_QTD1	0.000	normal	1.000	12.800	34.762	62.857	95.238
RF4A	Industrial-M	1_QTD2	0.000	normal	0.100	1.280	3.476	6.286	9.524
RF4B	Business-M	1_QT	0.000	normal	0.000	32.453	52.453	72.830	93.962
RF4B	Business-M	1_QTD1	0.000	normal	0.000	32.453	52.453	72.830	93.962
RF4B	Business-M	1_QTD2	0.000	normal	0.000	3.245	5.245	7.283	9.396
RF	All Physical	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF	All Physical	1_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF	All Physical	1_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
TR	Total Risk	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
TR	Total Risk	1_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
TR	Total Risk	1_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF1_A	Residential1	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000

The following image displays the first few Math Result rows for this Indicator.



DevTreks –social budgeting that improves lives and livelihoods

label	assetty	loc_confid	total	distribtype	5year	10year	25year	50year	100year
RF1	Resider	1_QTM	2.264	normal	0.000	6.319	16.851	25.276	45.286
RF1	Resider	1_QTL	2.261	normal	0.000	6.309	16.823	25.235	45.212
RF1	Resider	1_QTU	2.268	normal	0.000	6.330	16.878	25.317	45.360
RF1A	Resider	1_QTM	2.264	normal	0.000	6.320	16.850	25.280	45.290
RF1A	Resider	1_QTL	2.261	normal	0.000	6.310	16.820	25.230	45.210
RF1A	Resider	1_QTU	2.268	normal	0.000	6.330	16.880	25.320	45.360
RF2	Industri	1_QTM	11.539	normal	1.001	41.069	78.302	120.532	168.932
RF2	Industri	1_QTL	11.520	normal	0.999	41.002	78.175	120.336	168.657
RF2	Industri	1_QTU	11.558	normal	1.002	41.136	78.430	120.728	169.207
RF2A	Industri	1_QTM	1.822	normal	1.000	4.860	10.690	20.400	30.110
RF2A	Industri	1_QTL	1.819	normal	1.000	4.850	10.670	20.370	30.060
RF2A	Industri	1_QTU	1.825	normal	1.000	4.860	10.700	20.430	30.160
RF2B	Busines	1_QTM	3.446	normal	0.000	14.450	23.340	33.350	40.020
RF2B	Busines	1_QTL	3.441	normal	0.000	14.430	23.310	33.300	39.960
RF2B	Busines	1_QTU	3.452	normal	0.000	14.470	23.380	33.400	40.090
RF2C	Public E	1_QTM	6.271	normal	0.000	21.760	44.270	66.780	98.800
RF2C	Public E	1_QTL	6.261	normal	0.000	21.730	44.200	66.670	98.640
RF2C	Public E	1_QTU	6.281	normal	0.000	21.800	44.340	66.890	98.960
RF3	Resider	1_QTM	4.831	normal	0.000	13.138	36.888	54.573	94.997
RF3	Resider	1_QTL	4.823	normal	0.000	13.116	36.828	54.484	94.842
RF3	Resider	1_QTU	4.839	normal	0.000	13.159	36.948	54.661	95.151
RF3A	Resider	1_QTM	4.831	normal	0.000	13.140	36.890	54.570	95.000
RF3A	Resider	1_QTL	4.823	normal	0.000	13.120	36.830	54.480	94.840
RF3A	Resider	1_QTU	4.839	normal	0.000	13.160	36.950	54.660	95.150
RF4	Industri	1_QTM	12.826	normal	1.001	45.276	87.259	135.755	189.295
RF4	Industri	1_QTL	12.805	normal	0.999	45.202	87.117	135.534	188.987
RF4	Industri	1_QTU	12.847	normal	1.002	45.349	87.401	135.976	189.603
RF4A	Industri	1_QTM	5.083	normal	1.000	12.810	34.780	62.890	95.290
RF4A	Industri	1_QTL	5.074	normal	1.000	12.790	34.720	62.790	95.130
RF4A	Industri	1_QTU	5.091	normal	1.000	12.830	34.840	62.990	95.440
RF4B	Busines	1_QTM	7.744	normal	0.000	32.470	52.480	72.870	94.010
RF4B	Busines	1_QTL	7.731	normal	0.000	32.420	52.390	72.750	93.860
RF4B	Busines	1_QTU	7.756	normal	0.000	32.520	52.560	72.990	94.160
RF	All Phys	1_QTM	31.460	normal	2.001	105.801	219.299	336.135	498.510
RF	All Phys	1_QTL	31.409	normal	1.998	105.629	218.943	335.588	497.699
RF	All Phys	1_QTU	31.511	normal	2.004	105.973	219.656	336.682	499.321
TR	Total Ri	1_QTM	31.460	normal	2.001	105.801	219.299	336.135	498.510
TR	Total Ri	1_QTL	31.409	normal	1.998	105.629	218.943	335.588	497.699
TR	Total Ri	1_QTU	31.511	normal	2.004	105.973	219.656	336.682	499.321
RF1_A	Resider	1_QTM	1.132	normal	0.000	3.160	8.425	12.638	22.643

For testing purposes, the following image displays some of the MathResults using 7 exceedance probability events.

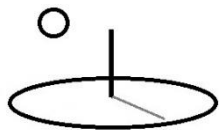


DevTreks –social budgeting that improves lives and livelihoods

label	assettype	loc_confid	total	distribtype	5year	10year	25year	50year	100year	250year	750year
RF1	Residentia	1_QTM	2.5964	normal	0	6.3192	16.8505	25.2757	45.2858	56.6075	79.2509
RF1	Residentia	1_QTL	2.5922	normal	0	6.3089	16.8231	25.2346	45.2121	56.5154	79.1219
RF1	Residentia	1_QTU	2.6006	normal	0	6.3295	16.8779	25.3168	45.3595	56.6996	79.3799
RF1A	Residentia	1_QTM	2.5964	normal	0	6.32	16.85	25.28	45.29	56.61	79.25
RF1A	Residentia	1_QTL	2.5922	normal	0	6.31	16.82	25.23	45.21	56.52	79.12
RF1A	Residentia	1_QTU	2.6006	normal	0	6.33	16.88	25.32	45.36	56.7	79.38
RF2	Industrial	1_QTM	12.7779	normal	1.0005	41.0687	78.3024	120.5317	168.932	211.1653	295.6318
RF2	Industrial	1_QTL	12.7571	normal	0.9989	41.0019	78.1749	120.3355	168.6571	210.8216	295.1506
RF2	Industrial	1_QTU	12.7986	normal	1.0021	41.1355	78.4299	120.7279	169.2069	211.509	296.113
RF2A	Industrial	1_QTM	2.0431	normal	1	4.86	10.69	20.4	30.11	37.64	52.7
RF2A	Industrial	1_QTL	2.0397	normal	1	4.85	10.67	20.37	30.06	37.58	52.61
RF2A	Industrial	1_QTU	2.0464	normal	1	4.86	10.7	20.43	30.16	37.7	52.78
RF2B	Business-S	1_QTM	3.7396	normal	0	14.45	23.34	33.35	40.02	50.03	70.04
RF2B	Business-S	1_QTL	3.7335	normal	0	14.43	23.31	33.3	39.96	49.94	69.92
RF2B	Business-S	1_QTU	3.7457	normal	0	14.47	23.38	33.4	40.09	50.11	70.15
RF2C	Public Busi	1_QTM	6.9952	normal	0	21.76	44.27	66.78	98.8	123.5	172.9
RF2C	Public Busi	1_QTL	6.9838	normal	0	21.73	44.2	66.67	98.64	123.3	172.62
RF2C	Public Busi	1_QTU	7.0066	normal	0	21.8	44.34	66.89	98.96	123.7	173.18

#### Indicator 4. Loss EP Distribution

The following image displays some of the Math Results for this Indicator.



## DevTreks –social budgeting that improves lives and livelihoods

label	assettype	loc_confid	total	distribtype	5year	10year	25year	50year	100year	quantity
RF1	Residential1	1_QTM	1076.602	none	0.000	3004.691	8010.924	12018.763	21532.032	1
RF1	Residential1	1_QTL	1073.242	none	0.000	2995.866	7985.811	11978.716	21464.834	1
RF1	Residential1	1_QTU	1079.824	none	0.000	3013.528	8036.076	12054.114	21594.573	1
RF1A	Residential-S	1_QTM	1076.602	normal	0.000	3004.690	8010.920	12018.760	21532.030	322541.2
RF1A	Residential-S	1_QTL	1073.242	normal	0.000	2995.870	7985.810	11978.720	21464.830	322541.2
RF1A	Residential-S	1_QTU	1079.824	normal	0.000	3013.530	8036.080	12054.110	21594.570	322541.2
RF2	Industrial1	1_QTM	15037.215	none	515.165	52550.208	104598.079	159148.952	231225.923	1
RF2	Industrial1	1_QTL	14989.528	none	514.247	52389.217	104261.740	158628.311	230472.057	1
RF2	Industrial1	1_QTU	15086.486	none	516.083	52726.326	104934.307	159670.445	231985.529	1
RF2A	Industrial-S	1_QTM	938.992	normal	515.170	2503.700	5507.120	10509.370	15511.630	183594.2
RF2A	Industrial-S	1_QTL	935.827	normal	514.250	2494.100	5487.020	10475.220	15458.270	183594.2
RF2A	Industrial-S	1_QTU	941.439	normal	516.080	2508.160	5522.090	10543.580	15565.070	183594.2
RF2B	Business-S	1_QTM	1551.108	normal	0.000	6504.590	10506.370	15012.320	18014.780	160422.1
RF2B	Business-S	1_QTL	1546.187	normal	0.000	6484.010	10474.170	14963.100	17955.720	160422.1
RF2B	Business-S	1_QTU	1556.261	normal	0.000	6525.200	10543.130	15061.610	18078.440	160422.1
RF2C	Public Busin Lc	1_QTM	12547.116	normal	0.000	43541.920	88584.590	133627.270	197699.520	1
RF2C	Public Busin Lc	1_QTL	12507.514	normal	0.000	43411.110	88300.550	133190.000	197058.070	1
RF2C	Public Busin Lc	1_QTU	12588.785	normal	0.000	43692.970	88869.090	134065.250	198342.010	1
RF3	Residential1	1_QTM	4784.801	none	0.000	13014.342	36537.219	54048.145	94091.511	1
RF3	Residential1	1_QTL	4771.672	none	0.000	12979.833	36436.529	53897.966	93826.782	1
RF3	Residential1	1_QTU	4797.849	none	0.000	13048.895	36638.045	54198.525	94346.683	1
RF3A	Residential-M	1_QTM	4784.801	normal	0.000	13014.340	36537.220	54048.140	94091.510	1120404
RF3A	Residential-M	1_QTL	4771.672	normal	0.000	12979.830	36436.530	53897.970	93826.780	1120404
RF3A	Residential-M	1_QTU	4797.849	normal	0.000	13048.890	36638.040	54198.530	94346.680	1120404
RF4	Industrial1	1_QTM	15604.457	none	1050.343	56499.726	106102.617	162658.371	224714.355	1
RF4	Industrial1	1_QTL	15554.393	none	1048.539	56322.540	105749.668	162131.035	223982.378	1
RF4	Industrial1	1_QTU	15653.965	none	1052.147	56677.191	106442.877	163186.562	225437.007	1
RF4A	Industrial-M	1_QTM	5338.787	normal	1050.340	13454.890	36530.920	66056.060	100087.160	450984.4
RF4A	Industrial-M	1_QTL	5321.230	normal	1048.540	13410.810	36405.270	65837.750	99747.500	450984.4
RF4A	Industrial-M	1_QTU	5356.268	normal	1052.150	13499.040	36656.790	66274.720	100416.880	450984.4
RF4B	Business-M	1_QTM	10265.670	normal	0.000	43044.840	69571.700	96602.320	124627.190	343529.5
RF4B	Business-M	1_QTL	10233.163	normal	0.000	42911.730	69344.400	96293.280	124234.880	343529.5
RF4B	Business-M	1_QTU	10297.697	normal	0.000	43178.150	69786.090	96911.840	125020.130	343529.5
RF	All Physical	1_QTM	36503.075	none	1565.508	125068.967	255248.839	387874.231	571563.821	1
RF	All Physical	1_QTL	36388.834	none	1562.786	124687.456	254433.747	386636.029	569746.050	1
RF	All Physical	1_QTU	36618.123	none	1568.230	125465.941	256051.304	389109.646	573363.792	1
TR	Total Risk	1_QTM	36503.075	none	1565.508	125068.967	255248.839	387874.231	571563.821	1
TR	Total Risk	1_QTL	36388.834	none	1562.786	124687.456	254433.747	386636.029	569746.050	1
TR	Total Risk	1_QTU	36618.123	none	1568.230	125465.941	256051.304	389109.646	573363.792	1
RF1_A	Residential1	1_QTM	538.372	none	0.000	1502.345	4007.839	6009.382	10763.639	1

For testing purposes, the following image displays some of the MathResults using 7 exceedance probability events.





DevTreks –social budgeting that improves lives and livelihoods

label	assettype	loc_confid	total	distribtype	5year	10year	25year	50year	100year	250year	750year	quantity
RF1	Residentia	1_QTM	1234.494	none	0	3004.691	8010.924	12018.76	21532.03	26913.85	37677.49	1
RF1	Residentia	1_QTL	1230.666	none	0	2995.866	7985.811	11978.72	21464.83	26834.6	37564.65	1
RF1	Residentia	1_QTU	1238.184	none	0	3013.528	8036.076	12054.11	21594.57	26993.22	37790.5	1
RF1A	Residentia	1_QTM	1234.494	normal	0	3004.69	8010.92	12018.76	21532.03	26913.85	37677.49	322541.2
RF1A	Residentia	1_QTL	1230.666	normal	0	2995.87	7985.81	11978.72	21464.83	26834.6	37564.65	322541.2
RF1A	Residentia	1_QTU	1238.184	normal	0	3013.53	8036.08	12054.11	21594.57	26993.22	37790.5	322541.2
RF2	Industrial1	1_QTM	16732.89	none	515.1652	52550.21	104598.1	159149	231225.9	289035.9	404651.5	1
RF2	Industrial1	1_QTL	16679.65	none	514.2473	52389.22	104261.7	158628.3	230472.1	288088.1	403324.2	1
RF2	Industrial1	1_QTU	16787.7	none	516.0832	52726.33	104934.3	159670.4	231985.5	289980.8	405971.3	1
RF2A	Industrial1	1_QTM	1052.754	normal	515.17	2503.7	5507.12	10509.37	15511.63	19390.82	27149.21	183594.2
RF2A	Industrial1	1_QTL	1049.202	normal	514.25	2494.1	5487.02	10475.22	15458.27	19325.41	27054.55	183594.2
RF2A	Industrial1	1_QTU	1055.583	normal	516.08	2508.16	5522.09	10543.58	15565.07	19456.34	27238.87	183594.2
RF2B	Business-S	1_QTM	1683.228	normal	0	6504.59	10506.37	15012.32	18014.78	22520.72	31528.11	160422.1
RF2B	Business-S	1_QTL	1677.838	normal	0	6484.01	10474.17	14963.1	17955.72	22440.15	31418.01	160422.1
RF2B	Business-S	1_QTU	1688.828	normal	0	6525.2	10543.13	15061.61	18078.44	22596.93	31633.9	160422.1
RF2C	Public Busi	1_QTM	13996.91	normal	0	43541.92	88584.59	133627.3	197699.5	247124.4	345974.2	1
RF2C	Public Busi	1_QTL	13952.61	normal	0	43411.11	88300.55	133190	197058.1	246322.6	344851.6	1
RF2C	Public Busi	1_QTU	14043.29	normal	0	43692.97	88869.09	134065.3	198342	247927.5	347098.5	1
RF3	Residentia	1_QTM	5474.805	none	0	13014.34	36537.22	54048.14	94091.51	117614.4	164660.1	1
RF3	Residentia	1_QTL	5459.748	none	0	12979.83	36436.53	53897.97	93826.78	117283.5	164206.8	1
RF3	Residentia	1_QTU	5489.744	none	0	13048.89	36638.04	54198.53	94346.68	117935.8	165114.1	1

## Indicator 5. Cost Distribution

Alternative C's project costs were estimated at \$320 billion installation and \$2 billion O&M.

They were divided by 2 to account for the 2 locations being studied. Alternatives A and B were given arbitrary 75% and 50% reductions in respective costs.

The following image shows the initial costs. The final column of data confirms that all costs are project, rather than unit, costs. That means that the costs calculated in Indicator 6 and 7 will not be multiplied by the Indicator4.MathResult's quantity of asset column.



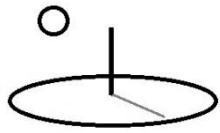
DevTreks –social budgeting that improves lives and livelihoods

label	alternative	loc_distrib	total	installcost	installdis	omcost	omdistrib	isprojectcost
AC1A	CurrentPractice	1_QT	0.000	100.000	normal	0.100	normal	yes
AC1A	CurrentPractice	1_QTD1	0.000	100.000	normal	0.100	normal	yes
AC1A	CurrentPractice	1_QTD2	0.000	10.000	normal	0.010	normal	yes
AC1A_A	Dams	1_QT	0.000	80000.000	normal	500.000	normal	yes
AC1A_A	Dams	1_QTD1	0.000	80000.000	normal	500.000	normal	yes
AC1A_A	Dams	1_QTD2	0.000	8000.000	normal	50.000	normal	yes
AC1A_B	Pumps	1_QT	0.000	120000.000	normal	750.000	normal	yes
AC1A_B	Pumps	1_QTD1	0.000	120000.000	normal	750.000	normal	yes
AC1A_B	Pumps	1_QTD2	0.000	12000.000	normal	75.000	normal	yes
AC1A_C	IWM	1_QT	0.000	160000.000	normal	1000.000	normal	yes
AC1A_C	IWM	1_QTD1	0.000	160000.000	normal	1000.000	normal	yes
AC1A_C	IWM	1_QTD2	0.000	16000.000	normal	100.000	normal	yes
AC1A	CurrentPractice	2_QT	0.000	100.000	normal	0.100	normal	yes
AC1A	CurrentPractice	2_QTD1	0.000	100.000	normal	0.100	normal	yes
AC1A	CurrentPractice	2_QTD2	0.000	10.000	normal	0.010	normal	yes
AC1A_A	Dams	2_QT	0.000	80000.000	normal	500.000	normal	yes
AC1A_A	Dams	2_QTD1	0.000	80000.000	normal	500.000	normal	yes
AC1A_A	Dams	2_QTD2	0.000	8000.000	normal	50.000	normal	yes
AC1A_B	Pumps	2_QT	0.000	120000.000	normal	750.000	normal	yes
AC1A_B	Pumps	2_QTD1	0.000	120000.000	normal	750.000	normal	yes
AC1A_B	Pumps	2_QTD2	0.000	12000.000	normal	75.000	normal	yes
AC1A_C	IWM	2_QT	0.000	160000.000	normal	1000.000	normal	yes
AC1A_C	IWM	2_QTD1	0.000	160000.000	normal	1000.000	normal	yes
AC1A_C	IWM	2_QTD2	0.000	16000.000	normal	100.000	normal	yes

The following image shows the initial data used with this Indicator's sensitivity analysis. As Example 1 shows, project life and discount rate are often used to conduct sensitivity analysis. The case study's use of subsidence-related scenarios in their sensitivity analysis can still be done by custom manipulation of Indicator 6's results.

Indicator 5a Sensitivity				
label	type	variable	value1	value2
5A	sensitivity	rate	0.050	0.120
5A	sensitivity	life	50.000	75.000

The following image displays the Math Results, confirming that the IWM alternative's discounted initial installation and O&M costs for a .05 rate and 50 year life are in the 170,000 million R range for 1 location. This subalgorithm discounts Installation Costs by 1 year. O&M



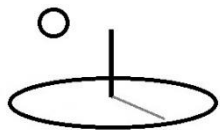
DevTreks –social budgeting that improves lives and livelihoods

Costs are calculated as a discounted uniform present value cost. The final 170,000 million is the summation of both discounted costs. Note that Indicator 6's Benefit calculations are calculated as a discounted uniform present value of the average annual loss for each SubIndicator.



## DevTreks –social budgeting that improves lives and livelihoods

Indicator 5. Costs (million R)									
label	alternative	loc_confid	total	life_50	life_75	isprojectcost			
AC1A	CurrentPractic	1_QTM_0.05	97.1135	97.1135	97.2365	yes			
AC1A	CurrentPractic	1_QTL_0.05	96.9547	96.9547	97.0775	yes			
AC1A	CurrentPractic	1_QTU_0.05	97.2723	97.2723	97.3956	yes			
AC1A	CurrentPractic	1_QTM_0.12	90.162	90.162	90.1647	yes			
AC1A	CurrentPractic	1_QTL_0.12	90.0149	90.0149	90.0176	yes			
AC1A	CurrentPractic	1_QTU_0.12	90.3091	90.3091	90.3118	yes			
AC1A_A	Dams	1_QTM_0.05	85361.4085	85361.4085	85976.2402	yes			
AC1A_A	Dams	1_QTL_0.05	85222.4583	85222.4583	85836.2893	yes			
AC1A_A	Dams	1_QTU_0.05	85500.3587	85500.3587	86116.1912	yes			
AC1A_A	Dams	1_QTM_0.12	75618.8862	75618.8862	75632.4624	yes			
AC1A_A	Dams	1_QTL_0.12	75495.7947	75495.7947	75509.3488	yes			
AC1A_A	Dams	1_QTU_0.12	75741.9777	75741.9777	75755.5759	yes			
AC1A_B	Pumps	1_QTM_0.05	128042.1127	128042.1127	128964.3603	yes			
AC1A_B	Pumps	1_QTL_0.05	127833.6865	127833.6865	128754.4328	yes			
AC1A_B	Pumps	1_QTU_0.05	128250.5389	128250.5389	129174.2877	yes			
AC1A_B	Pumps	1_QTM_0.12	113428.3292	113428.3292	113448.6935	yes			
AC1A_B	Pumps	1_QTL_0.12	113243.6916	113243.6916	113264.0227	yes			
AC1A_B	Pumps	1_QTU_0.12	113612.9668	113612.9668	113633.3642	yes			
AC1A_C	IWM	1_QTM_0.05	170722.817	170722.817	171952.4804	yes			
AC1A_C	IWM	1_QTL_0.05	170444.9166	170444.9166	171672.5784	yes			
AC1A_C	IWM	1_QTU_0.05	171000.7173	171000.7173	172232.3824	yes			
AC1A_C	IWM	1_QTM_0.12	151237.7723	151237.7723	151264.9247	yes			
AC1A_C	IWM	1_QTL_0.12	150991.5894	150991.5894	151018.6976	yes			
AC1A_C	IWM	1_QTU_0.12	151483.9553	151483.9553	151511.1518	yes			
AC1A	CurrentPractic	2_QTM_0.05	97.1135	97.1135	97.2365	yes			
AC1A	CurrentPractic	2_QTL_0.05	96.9547	96.9547	97.0775	yes			
AC1A	CurrentPractic	2_QTU_0.05	97.2723	97.2723	97.3956	yes			
AC1A	CurrentPractic	2_QTM_0.12	90.162	90.162	90.1647	yes			
AC1A	CurrentPractic	2_QTL_0.12	90.0149	90.0149	90.0176	yes			
AC1A	CurrentPractic	2_QTU_0.12	90.3091	90.3091	90.3118	yes			
AC1A_A	Dams	2_QTM_0.05	85361.4085	85361.4085	85976.2402	yes			
AC1A_A	Dams	2_QTL_0.05	85222.4583	85222.4583	85836.2893	yes			
AC1A_A	Dams	2_QTU_0.05	85500.3587	85500.3587	86116.1912	yes			
AC1A_A	Dams	2_QTM_0.12	75618.8862	75618.8862	75632.4624	yes			
AC1A_A	Dams	2_QTL_0.12	75495.7947	75495.7947	75509.3488	yes			
AC1A_A	Dams	2_QTU_0.12	75741.9777	75741.9777	75755.5759	yes			
AC1A_B	Pumps	2_QTM_0.05	128042.1127	128042.1127	128964.3603	yes			
AC1A_B	Pumps	2_QTL_0.05	127833.6865	127833.6865	128754.4328	yes			
AC1A_B	Pumps	2_QTU_0.05	128250.5389	128250.5389	129174.2877	yes			
AC1A_B	Pumps	2_QTM_0.12	113428.3292	113428.3292	113448.6935	yes			
AC1A_B	Pumps	2_QTL_0.12	113243.6916	113243.6916	113264.0227	yes			
AC1A_B	Pumps	2_QTU_0.12	113612.9668	113612.9668	113633.3642	yes			
AC1A_C	IWM	2_QTM_0.05	170722.817	170722.817	171952.4804	yes			
AC1A_C	IWM	2_QTL_0.05	170444.9166	170444.9166	171672.5784	yes			
AC1A_C	IWM	2_QTU_0.05	171000.7173	171000.7173	172232.3824	yes			
AC1A_C	IWM	2_QTM_0.12	151237.7723	151237.7723	151264.9247	yes			
AC1A_C	IWM	2_QTL_0.12	150991.5894	150991.5894	151018.6976	yes			
AC1A_C	IWM	2_QTU_0.12	151483.9553	151483.9553	151511.1518	yes			



DevTreks –social budgeting that improves lives and livelihoods

### **Indicator 6. Benefit Cost Analysis**

The following images show that the results for the project alternative with the highest BCR, aggregated across all locations, has been used to fill in the Indicator's properties. Decision makers should be given the underlying cost and benefit data used in the ratios.

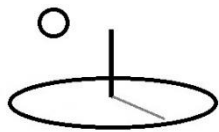


DevTreks –social budgeting that improves lives and livelihoods

DevTreks -social budg ×

DevTreks [US] <https://www.devtreks.org/greentreks/search/wa>

Q1 6	Q1 Unit 6
2,822,866.0243	base damage
Q2 6	Q2 Unit 6
194.4730	base cost
Q3 6	Q3 Unit 6
353,033.1945	AC1A_B damage
Q4 6	Q4 Unit 6
257,928.7206	AC1A_B cost
Q5 6	Q5 Unit 6
0.0000	none
Math Operator 6	BaselO 6
equalto	none
QT 6	QT Unit 6
2,212,098.5822	net benefits
Math Type 6	Math Sub Type 6
algorithm1	subalgorithm9
QT D1 6	QT D1 Unit 6
0.0000	none
QT D2 6	QT D2 Unit 6
0.0000	none
QT Most 6	QT Most Unit 6
9.5829	2_QTM_0.05_75, bcr
QT Low 6	QT Low Unit 6
9.5699	lower 90% ci
QT High 6	QT High Unit 6
9.5975	upper 90% ci

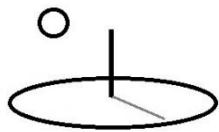


DevTreks –social budgeting that improves lives and livelihoods

The following image displays some of the initial rows from Math Results for the first location in this Indicator. The last several rows demonstrate positive BCRs even for some individual asset categories.

label	assettype	loc_confid	total	RF1_dama	RF1_cost	RF1_A_dai	RF1_A_co	RF1_A_bcr	RF1_B_dai	RF1_B_co	RF1_B_bcr	RF1_C_dai	RF1_C_co	RF1_C_bcr
RF1_A	Residentia	1_QTM_0.05_50	0	19654.36	97.1135	9828.481	85361.41	0.1152	2457.989	128042.1	0.1344	0	170722.8	0.1152
RF1_A	Residentia	1_QTM_0.05_75	0	20977.55	97.2365	10490.16	85976.24	0.1221	2623.468	128964.4	0.1424	0	171952.5	0.1221
RF1_A	Residentia	1_QTM_0.12_50	0	8940.636	90.162	4470.91	75618.89	0.0592	1118.123	113428.3	0.069	0	151237.8	0.0592
RF1_A	Residentia	1_QTM_0.12_75	0	8969.854	90.1647	4485.521	75632.46	0.0594	1121.777	113448.7	0.0692	0	151264.9	0.0593
RF1_A	Residentia	1_QTL_0.05_50	0	19593.02	96.9547	9793.477	85222.46	0.1151	2448.585	127833.7	0.1342	0	170444.9	0.115
RF1_A	Residentia	1_QTL_0.05_75	0	20912.08	97.0775	10452.8	85836.29	0.122	2613.431	128754.4	0.1422	0	171672.6	0.1219
RF1_A	Residentia	1_QTL_0.12_50	0	8912.734	90.0149	4454.987	75495.79	0.0591	1113.845	113243.7	0.0689	0	150991.6	0.0591
RF1_A	Residentia	1_QTL_0.12_75	0	8941.86	90.0176	4469.546	75509.35	0.0593	1117.485	113264	0.0691	0	151018.7	0.0592
RF1_A	Residentia	1_QTU_0.05_50	0	19713.18	97.2723	9852.246	85500.36	0.1155	2462.193	128250.5	0.1346	0	171000.7	0.1153
RF1_A	Residentia	1_QTU_0.05_75	0	21040.34	97.3956	10515.53	86116.19	0.1224	2627.955	129174.3	0.1426	0	172232.4	0.1222
RF1_A	Residentia	1_QTU_0.12_50	0	8967.396	90.3091	4481.721	75741.98	0.0593	1120.035	113613	0.0691	0	151484	0.0592
RF1_A	Residentia	1_QTU_0.12_75	0	8996.701	90.3118	4496.367	75755.58	0.0595	1123.695	113633.4	0.0693	0	151511.2	0.0594
RF1A_A	Residentia	1_QTM_0.05_50	0	19654.36	97.1135	9828.481	85361.41	0.1152	2457.989	128042.1	0.1344	0	170722.8	0.1152
RF1A_A	Residentia	1_QTM_0.05_75	0	20977.55	97.2365	10490.16	85976.24	0.1221	2623.468	128964.4	0.1424	0	171952.5	0.1221
RF1A_A	Residentia	1_QTM_0.12_50	0	8940.636	90.162	4470.91	75618.89	0.0592	1118.123	113428.3	0.069	0	151237.8	0.0592
RF1A_A	Residentia	1_QTM_0.12_75	0	8969.854	90.1647	4485.521	75632.46	0.0594	1121.777	113448.7	0.0692	0	151264.9	0.0593
RF1A_A	Residentia	1_QTL_0.05_50	0	19593.02	96.9547	9793.477	85222.46	0.1151	2448.585	127833.7	0.1342	0	170444.9	0.115
RF1A_A	Residentia	1_QTL_0.05_75	0	20912.08	97.0775	10452.8	85836.29	0.122	2613.431	128754.4	0.1422	0	171672.6	0.1219
RF1A_A	Residentia	1_QTL_0.12_50	0	8912.734	90.0149	4454.987	75495.79	0.0591	1113.845	113243.7	0.0689	0	150991.6	0.0591
RF1A_A	Residentia	1_QTL_0.12_75	0	8941.86	90.0176	4469.546	75509.35	0.0593	1117.485	113264	0.0691	0	151018.7	0.0592
RF1A_A	Residentia	1_QTU_0.05_50	0	19713.18	97.2723	9852.246	85500.36	0.1155	2462.193	128250.5	0.1346	0	171000.7	0.1153
RF1A_A	Residentia	1_QTU_0.05_75	0	21040.34	97.3956	10515.53	86116.19	0.1224	2627.955	129174.3	0.1426	0	172232.4	0.1222
RF1A_A	Residentia	1_QTU_0.12_50	0	8967.396	90.3091	4481.721	75741.98	0.0593	1120.035	113613	0.0691	0	151484	0.0592
RF1A_A	Residentia	1_QTU_0.12_75	0	8996.701	90.3118	4496.367	75755.58	0.0595	1123.695	113633.4	0.0693	0	151511.2	0.0594
RF2_A	Industrial1	1_QTM_0.05_50	0	274518.3	97.1135	137270	85361.41	1.6097	34327.85	128042.1	1.8773	0	170722.8	1.6089
RF2_A	Industrial1	1_QTM_0.05_75	0	292999.7	97.2365	146511.4	85976.24	1.7058	36638.9	128964.4	1.9893	0	171952.5	1.7049
RF2_A	Industrial1	1_QTM_0.12_50	0	124876.5	90.162	62443.19	75618.89	0.8266	15615.51	113428.3	0.964	0	151237.8	0.8262
RF2_A	Industrial1	1_QTM_0.12_75	0	125284.6	90.1647	62647.25	75632.46	0.8292	15666.54	113448.7	0.967	0	151264.9	0.8287

For testing purposes, the following image displays some of the MathResults using 7 exceedance probability events.



## DevTreks –social budgeting that improves lives and livelihoods

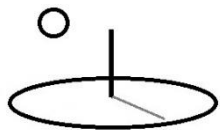
label	assettype	loc_confid	total	RF1_dama	RF1_cost	RF1_A_da	RF1_A_co	RF1_A_bcr	RF1_B_da	RF1_B_co	RF1_B_bcr	RF1_C_da	RF1_C_co	RF1_C_bcr
RF1_A	Residentia	1_QTM_0.	0	22536.82	97.1135	11269.48	85361.41	0.1321	2818.47	128042.1	0.1541	0	170722.8	0.1321
RF1_A	Residentia	1_QTM_0.	0	24054.07	97.2365	12028.18	85976.24	0.14	3008.218	128964.4	0.1633	0	171952.5	0.14
RF1_A	Residentia	1_QTM_0.	0	10251.85	90.162	5126.413	75618.89	0.0679	1282.103	113428.3	0.0791	0	151237.8	0.0678
RF1_A	Residentia	1_QTM_0.	0	10285.35	90.1647	5143.165	75632.46	0.0681	1286.293	113448.7	0.0794	0	151264.9	0.068
RF1_A	Residentia	1_QTL_0.0	0	22466.95	96.9547	11230.44	85222.46	0.132	2807.654	127833.7	0.1539	0	170444.9	0.1319
RF1_A	Residentia	1_QTL_0.0	0	23979.5	97.0775	11986.51	85836.29	0.1399	2996.673	128754.4	0.1631	0	171672.6	0.1398
RF1_A	Residentia	1_QTL_0.1	0	10220.07	90.0149	5108.653	75495.79	0.0678	1277.183	113243.7	0.079	0	150991.6	0.0677
RF1_A	Residentia	1_QTL_0.1	0	10253.47	90.0176	5125.348	75509.35	0.068	1281.357	113264	0.0793	0	151018.7	0.0679
RF1_A	Residentia	1_QTU_0.0	0	22604.2	97.2723	11297.75	85500.36	0.1324	2823.628	128250.5	0.1544	0	171000.7	0.1323
RF1_A	Residentia	1_QTU_0.0	0	24125.98	97.3956	12058.35	86116.19	0.1403	3013.723	129174.3	0.1636	0	172232.4	0.1402
RF1_A	Residentia	1_QTU_0.0	0	10282.5	90.3091	5139.272	75741.98	0.068	1284.449	113613	0.0793	0	151484	0.0679
RF1_A	Residentia	1_QTU_0.0	0	10316.1	90.3118	5156.067	75755.58	0.0682	1288.647	113633.4	0.0795	0	151511.2	0.0681
RF1A_A	Residentia	1_QTM_0.	0	22536.82	97.1135	11269.48	85361.41	0.1321	2818.47	128042.1	0.1541	0	170722.8	0.1321
RF1A_A	Residentia	1_QTM_0.	0	24054.07	97.2365	12028.18	85976.24	0.14	3008.218	128964.4	0.1633	0	171952.5	0.14
RF1A_A	Residentia	1_QTM_0.	0	10251.85	90.162	5126.413	75618.89	0.0679	1282.103	113428.3	0.0791	0	151237.8	0.0678
RF1A_A	Residentia	1_QTM_0.	0	10285.35	90.1647	5143.165	75632.46	0.0681	1286.293	113448.7	0.0794	0	151264.9	0.068
RF1A_A	Residentia	1_QTL_0.0	0	22466.95	96.9547	11230.44	85222.46	0.132	2807.654	127833.7	0.1539	0	170444.9	0.1319
RF1A_A	Residentia	1_QTL_0.0	0	23979.5	97.0775	11986.51	85836.29	0.1399	2996.673	128754.4	0.1631	0	171672.6	0.1398
RF1A_A	Residentia	1_QTL_0.1	0	10220.07	90.0149	5108.653	75495.79	0.0678	1277.183	113243.7	0.079	0	150991.6	0.0677
RF1A_A	Residentia	1_QTL_0.1	0	10253.47	90.0176	5125.348	75509.35	0.068	1281.357	113264	0.0793	0	151018.7	0.0679
RF1A_A	Residentia	1_QTU_0.0	0	22604.2	97.2723	11297.75	85500.36	0.1324	2823.628	128250.5	0.1544	0	171000.7	0.1323
RF1A_A	Residentia	1_QTU_0.0	0	24125.98	97.3956	12058.35	86116.19	0.1403	3013.723	129174.3	0.1636	0	172232.4	0.1402
RF1A_A	Residentia	1_QTU_0.0	0	10282.5	90.3091	5139.272	75741.98	0.068	1284.449	113613	0.0793	0	151484	0.0679
RF1A_A	Residentia	1_QTU_0.0	0	10316.1	90.3118	5156.067	75755.58	0.0682	1288.647	113633.4	0.0795	0	151511.2	0.0681
RF2_A	Industrial1	1_QTM_0.	0	305474.5	97.1135	152747.9	85361.41	1.7912	38197.66	128042.1	2.089	0	170722.8	1.7903
RF2_A	Industrial1	1_QTM_0.	0	326039.9	97.2365	163031.4	85976.24	1.8981	40769.24	128964.4	2.2137	0	171952.5	1.8972
RF2_A	Industrial1	1_QTM_0.	0	138958.3	90.162	69484	75618.89	0.9198	17375.86	113428.3	1.0727	0	151237.8	0.9194
RF2_A	Industrial1	1_QTM_0.	0	139412.4	90.1647	69711.07	75632.46	0.9227	17432.64	113448.7	1.0761	0	151264.9	0.9222

The following image displays some of the final rows from Math Results for the second location in this Indicator.

04	TR_A	Total Risk	2_QTM_0.05_75	0	2353538	97.2365	1176667	85976.24	13.7038	294334.3	128964.4	15.9793	0	171952.5	13.6949
05	TR_A	Total Risk	2_QTM_0.12_50	0	1003078	90.162	501495.6	75618.89	6.641	125445.3	113428.3	7.7435	0	151237.8	6.6364
06	TR_A	Total Risk	2_QTM_0.12_75	0	1006356	90.1647	503134.4	75632.46	6.6615	125855.3	113448.7	7.7674	0	151264.9	6.6569
07	TR_A	Total Risk	2_QTL_0.05_50	0	2198196	96.9547	1098974	85222.46	12.913	274628.3	127833.7	15.0588	0	170444.9	12.9041
08	TR_A	Total Risk	2_QTL_0.05_75	0	2346185	97.0775	1172960	85836.29	13.6836	293117.1	128754.4	15.9576	0	171672.6	13.6744
09	TR_A	Total Risk	2_QTL_0.12_50	0	999944.4	90.0149	499915.8	75495.79	6.6312	124926.6	113243.7	7.733	0	150991.6	6.6265
10	TR_A	Total Risk	2_QTL_0.12_75	0	1003212	90.0176	501549.5	75509.35	6.6516	125334.8	113264	7.7569	0	151018.7	6.6469
11	TR_A	Total Risk	2_QTU_0.05_50	0	2211912	97.2723	1105909	85500.36	12.9504	276537.6	128250.5	15.102	0	171000.7	12.9425
12	TR_A	Total Risk	2_QTU_0.05_75	0	2360825	97.3956	1180362	86116.19	13.7233	295155	129174.3	16.0034	0	172232.4	13.715
13	TR_A	Total Risk	2_QTU_0.12_50	0	1006184	90.3091	503070.5	75741.98	6.6504	125795.1	113613	7.7552	0	151484	6.6461
14	TR_A	Total Risk	2_QTU_0.12_75	0	1009472	90.3118	504714.5	75755.58	6.6709	126206.2	113633.4	7.7791	0	151511.2	6.6667

The following image demonstrates that the calculation for the highest QTM BCR, 9.5829 on the 3<sup>rd</sup> line, is not a summation of each location's BCR, but rather derives from the summation of the damages and costs for each location. Although the BCRs don't use the case study's Net Present Value techniques shown in Table 45, the use of discounted present values and uniform present values in the calculations result in equivalent ratios. The case study's final BCR value of 2.5





DevTreks –social budgeting that improves lives and livelihoods

reflects different assumptions about project alternatives, costs, and the additional inundation data included in their study.

label	assettype	loc_confid	total	RF1_dama	RF1_cost	RF1_A_dai	RF1_A_co	RF1_A_bcr	RF1_B_dai	RF1_B_co	RF1_B_bcr	RF1_C_dai	RF1_C_co	RF1_C_bcr
TR_A	Total Risk	1_QTU_0.12_75	0	340120.8	90.3118	170056.2	75755.58	2.2476	42512.73	113633.4	2.6211	0	151511.2	2.2462
TR_A	Total Risk	2_QTU_0.12_75	0	1009472	90.3118	504714.5	75755.58	6.6709	126206.2	113633.4	7.7791	0	151511.2	6.6667
QTM Sum	Locations			1349593	180.6236	674770.8	151511.2	<b>4.45926</b>	168718.9	227266.7	<b>5.200116</b>	0	303022.3	<b>4.456431</b>

## Indicator 7. Cost Effectiveness Analysis

The following images show that, because this Indicator assumes benefits are nonmonetary and does not discount them, a different project alternative is selected than Indicator 6. The case study does not present any non-monetary data that can be used to calculate indirect damages, so these results don't supply additional decision support.



DevTreks –social budgeting that improves lives and livelihoods

Indicator 7

Cost Effectiveness Analysis

Description 7

This Indicator is used in a CTAP tutorial demonstrating disaster risk reduction for floods in Semarang, Indonesia.

Indicator 7 URL

none

Label 7

7A

Rel Label 7

none

Date 7

01/01/2005

Dist Type 7

none

Q1 7

161,481.8904

Q1 Unit 7

base damage

Q2 7

180.3240

Q2 Unit 7

base cost

Q3 7

20,194.2066

Q3 Unit 7

AC1A\_B damage

Q4 7

226,856.6584

Q4 Unit 7

AC1A\_B cost

Q5 7

0.0000

Q5 Unit 7

none

Math Operator 7

equalto

BaseIO 7

none

QT 7

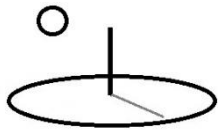
1.6044

QT Unit 7

net benefits

Math Type 7

Math Sub Type 7



DevTreks –social budgeting that improves lives and livelihoods

Math Type 7		Math Sub Type 7	
<input type="text" value="algorithm1"/>		<input type="text" value="subalgorithm9"/>	
QT D1 7		QT D1 Unit 7	
<input type="text" value="0.0000"/>		<input type="text" value="none"/>	
QT D2 7		QT D2 Unit 7	
<input type="text" value="0.0000"/>		<input type="text" value="none"/>	
QT Most 7		QT Most Unit 7	
<input type="text" value="1.6044"/>		<input type="text" value="2_QTM_0.12_50, cer"/>	
QT Low 7		QT Low Unit 7	
<input type="text" value="1.6066"/>		<input type="text" value="lower 90 % ci"/>	
QT High 7		QT High Unit 7	
<input type="text" value="1.6019"/>		<input type="text" value="upper 90 % ci"/>	
Math Expression 7			
<input type="text" value="I7.Q1.distribtype + I7.Q2.100year + I7.Q3.50year + I7.Q4."/>			
Math Result 7			
<input type="text" value="http://localhost:50032/resources/network_carbon/resourcepack_532/resource_1836/Ind7-CER.csv"/>			

+
Indicator 8

## Scores. Decision Support Systems

Wider decision support is completed at the discretion of the analyst.

The following image from Version 2.0.6 show how M&E calculators treat the Scores.



DevTreks –social budgeting that improves lives and livelihoods

GreenTreks	Search	Preview	Select
Edit	Pack	Views	Club

← Select

PackIt →

↻ Edit Linked Views

Make base ⚙

M and E Output 2 Calculat ▼

Get

Media

✓ Mobile

Desktop

Intro	1	2	3	Help
Step 3 of 3. Save				
<b>Method 1.</b> Do you wish to save step 2's calculations? These calculations are viewed by opening this particular calculator addin.				
<div>Save Calcs +</div>				

Output Group: CTAP Output Examples

Output : CTAP Example 6 - Floods DRR

#### — Indicators Details

**Indic 0 Name:** Disaster Score      Label: S0  
 Date: 11/21/2016      Rel Label: none  
 Math Type: algorithm1      Dist Type: normal  
 Math Sub Type: subalgorithm1      Base IO: none  
 Math Express: I6.QTM      Math Operator: equalto  
 QT Amount: 10.6767      QT Unit: highest bcr  
 QT D1 Amount: 10.6815      QT D1 Unit: mean  
 QT D2 Amount: 3.5000      QT D2 Unit: sd  
 QT Most Amount: 10.6782      QT Most Unit: highest bcr  
 QT Low Amount: 10.4941      QT Low Unit: lower 90 % ci  
 QT High Amount: 10.8623      QT High Unit: upper 90 % ci  
 Score Math Result: sampled descriptive statistics  
 N,Total,Mean,Median,StdDev,Var,Min,Max 1000, 10678.2057, 10.6782,  
 10.5808, 3.5280, 12.4468, -1.4288, 20.7029, sampled cumulative



DevTreks –social budgeting that improves lives and livelihoods

## Appendix B. Risk Management Indicator (RM) Algorithms

### A. Introduction

This appendix demonstrates how to complete CTAPs using comprehensive sets of disaster-related indicators that are designed to reduce the risk of excess damages occurring from disasters.

### B. Risk Management Indicator Systems Introduction

Khazai et al (2015) demonstrate the use of indicator systems and performance target systems to assess urban risk from natural resource disasters. The authors demonstrate using indicator systems to generate the 3 specific Indexes displayed in the following image.

## CHAPTER

### 01 General notions of urban risk and resilience

### 02 Urban Disaster Risk Index (UDRI)

A risk communication tool which provides a holistic view of disaster risk by capturing through indices both the direct physical damages of buildings and infrastructure, as well as considering social vulnerability or lack of resilience that can aggravate the physical effects.

### 03 Risk Management Index (RMI)

A risk management tool which brings together a group of indicators that measure a city's risk management performance, reflecting organizational, development, capacity and institutional actions taken to reduce risk, to prepare for crisis and to recover efficiently from disasters.

### 04 Disaster Resilience Index (DRI)

A monitoring and evaluation tool for benchmarking and measuring progress (or lack of progress) along a city's key development policies and processes for mainstreaming of risk reduction and increasing resilience.



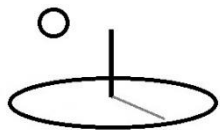
DevTreks –social budgeting that improves lives and livelihoods

Additional examples of disaster risk reduction indicator systems can be found in the IDB (2007), World Bank (2011), European Commission (2014), United Nations UNISDR (2014, 2015), and United Nations CAPNET (2015) references. Although the latter indicator systems are designed for use at national and international scale, the references discuss the importance of developing similar indicator systems for use at local scales. Section E, CTA-Prevention Communication, discusses the importance of linking local evidence gathered using these indicator systems to global actors tasked with reducing the planet’s risks from climate change.

Mustafa et al (2008) use the term “shared learning dialogues” (SLDs) for these types of indicator systems and point out that the collaborative process needed to complete these systems is often more important than final economic estimates of losses. The European Commission (2014) points out that indicator systems are particularly important when disaster loss data is simply not available for making reliable economic estimates of losses (13\*).

Some social scientists frown upon the use of indicator systems for scientific applications because the indicators selected can appear to be somewhat arbitrary, rather than derived from a scientific theory or historical scientific evidence. For example, Rufat et al (2015) find that the temporal context for the indicators may not be well known (i.e. at what damage stage are people most vulnerable?), the most influential drivers of final indexes may not be well understood (i.e. what proof exists that a particular set of indicators measure vulnerability best?), and the interactions among indicators may never have been adequately tested (i.e. what is the basis for weighting indicators in a particular way?). Most of the references used in this Appendix demonstrate that, if selected properly and used carefully, indicators can aid important decision-making for important problems, such as climate change-induced disasters.

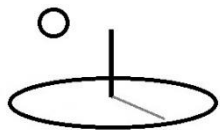
UN CAPNET (2015) provides the following guidance about the use of indicator systems: “Due to their limitations, it is important that decision-making is not limited to following the direct outcome of indicator assessments but that a sensible holistic view is taken. Selecting indicators should be done in such a way that they represent the root causes of a particular issue. Otherwise there is a danger of “treating the symptoms rather than the sickness””. Appendixes C and D introduce algorithms and examples that offer potential ways to take this “sensible holistic view”.



### C. Risk Management Indicator (RM) Algorithms

A representative RM, the Urban Disaster Risk Index, is derived using the following general steps. The case studies presented in the Khazai et al (2015) reference, along with examples presented in the Carreno (2005, 2007, and 2012) and Marulanda (2013) references, demonstrate these steps.

1. Stakeholders choose indicators from several categories, such as Physical Risk, Social Fragility, and Lack of Resiliency. Values for the Physical Risk indicators can be taken directly from the Disaster Risk Reduction algorithms demonstrated in Appendix A and are equivalent to the direct damages from disasters. The Social Fragility and Lack of Resilience Indicators are selected so that they can be used to calculate “aggravating coefficient” factors, or the indirect damages from disasters. The case studies demonstrate that additional custom indicators and categories, such as Coping Capacity, can also be used. The studies also demonstrate subdividing each indicator into Sub Indicators. Although the references focus on urban areas, indicators can be developed and used for any area, including rural areas.
2. Indicator values are collected for each location within the project boundaries. Although not always explicit, the more recent references demonstrate that the DRR framework introduced in Appendix A is also used with the DRI. Some cities consider these assessments to be important enough to warrant supplementing existing population surveys, or designing new surveys, to collect data for the Indicator values. The case studies also demonstrate using experts, along with historical data, to develop minimum and maximum values, along with normalization functions, to develop the Indicator values.
3. The indicator values are first normalized. Data can be normalized using data transformation functions that include the formulas in Appendix A, Example 1 in the *Resource Stock Calculation* reference (i.e. z-scores, min-max, logistic, logit, pnorm, and tanh). The case studies demonstrate using more advanced transformation functions (i.e. fuzzy logic using membership functions with bell and sigmoidal distributions).



DevTreks –social budgeting that improves lives and livelihoods

4. The normalized values are then weighted using numeric multipliers. The case studies derive the weights using a combination of expert opinion and an Analytic Hierarchy Process.
5. The normalized, weighted indicators are aggregated into Categorical Indexes (CIs). The CIs are weighted and aggregated into a final Total Risk Index for each location. The CIs help to define the most important “drivers” of damages. The DRI uses specific mathematical formulas in the aggregation. The case studies use the Moncho equation,  $R_t = R_f * (1 + F)$ , in the aggregation. The  $R_t$  term is the total risk calculated from the Physical Indicators, the  $R_f$  term, and the Social Fragility and Lack of Resilience Indicators, the  $1 + F$  term. The logic is that the indirect effects of disasters can be highly significant. For example, the case studies document that indirect damages from earthquakes can be 75% or more ( $1.75 = 1 + 0.75$ ), of the direct damages. At this stage, each location has Total Risk Indexes ( $R_t$ ), Physical Factor Indexes ( $R_f$ ), and Aggravating Coefficients ( $F$ ). The three Total Risk Indexes for each location, along with their driving Categorical Indexes, are unit-less and can be meaningfully compared among all locations.

#### **D. Additional Tools**

Additional RM assessment tools are available (i.e. EMI’s Integrated Risk Toolkit, Central America CAPRA, UNISDR’s Global Risk Assessment) and should be closely evaluated prior to using this example’s techniques. In addition, most serious disaster risk assessments are done in the context of overall civil disaster planning or integrated natural resource management planning –the assessment is one ingredient in an overall disaster preparation and prevention approach. For example, UNCAPNET points out that drought disaster planning is best carried out in the context of an Integrated Water Resources Management approach. They mention that these types of integrated natural resources management approaches focus on achieving “economic viability, social equity, and environmental sustainability”. In addition, many of the references demonstrate that GIS makes an appropriate platform for communicating the assessment results to decision makers.

#### **E. RM Algorithm Examples**





DevTreks –social budgeting that improves lives and livelihoods

The following algorithms demonstrate how to use indicator distributions to calculate risk management indexes. Most algorithms use probability distributions, defined by QT, QTD1, and QTD2 properties stored in Indicator.URL TEXT files, as the initial data for each category of Sub Indicators used in the final indexes. The distributions are used with the Monte Carlo algorithm, subalgorithm1, to generate final mean and confidence interval calculations expressed using a Sub Indicator's QTM, QTL, and QTU properties. Keep in mind that the source code shows that any other subalgorithm (i.e. copula, neural network, regression) can just as easily be used.

- **Existing Algorithms.** The Indexes demonstrated in the case studies use indicators that are aggregated by using typical weighting and normalization functions. Appendix A, Example 1, in the *Resource Stock Calculation* reference demonstrates how Life Cycle Assessments use similar mathematical techniques. Those techniques can also be used to produce simplified versions of the Indexes. Use regular Indicators as the Indicator categories and an Indicator's Q1 to Q10 properties as the Sub Indicators in the algorithms. Use the Score to produce the final Indexes.
- **Algorithm 1. Disaster Risk Index: algorithm1, subalgorithm10:** The algorithm produces Benefit Cost Ratios and Cost Effectiveness Ratios for Disaster Risk Indexes (DRI). This algorithm quantifies both the direct and indirect effects of disasters for specific disaster prevention interventions. The algorithm is designed to be used jointly with Appendix A's DRR algorithms (subalgorithm9).
- **Algorithm 2. Risk Management Index: algorithm1, subalgorithm11:** The algorithm uses Risk Management Indexes (RMI) to calculate confidence intervals for Cost Effectiveness Ratios. These Indexes measure a community's ability to manage disasters. Subalgorithm11 calculates Total Risk Indexes (TR rows) using weighted averages, subalgorithm12 does not use weighted averages.
- **Algorithm 2. Resiliency Index: algorithm1, subalgorithm12:** The algorithm uses Resiliency Indexes (RI) to calculate confidence intervals for Cost Effectiveness Ratios. These Indexes are used to monitor and evaluate a community's disaster prevention goals. **Appendix E, Resource Stock and Monitoring and Evaluation Analyzers**, demonstrate



DevTreks –social budgeting that improves lives and livelihoods

the use of additional tools that can be to provide further support for all Stock and M&E algorithms. These examples further demonstrate that any system of Indicators that can be analyzed using these techniques (i.e. normalization, weighting, aggregation by Indexes, EVM, and M&E) can employ this algorithm.

- **Additional algorithms:** Algorithms based on any other algorithm (i.e. the regression and machine learning subalgorithms introduced in the CTA reference), the fuzzy logic techniques used by the main references, or Bayesian statistics and Machine Learning techniques (see Examples 7 and 8 in the sibling Social Performance Analysis reference), make logical additional algorithms. The references suggest that source code for some of these techniques might be available, potentially making these algorithms straightforward to build. The author's preference is to start with Bayesian and Machine Learning techniques because statistical libraries may be more readily available (i.e. R, Python, and AML). Customers with an immediate need for additional algorithms can contact DevTreks directly.

In effect, these algorithms reinforce the UN GAR (2015) recommendation to expand cost benefit analysis to highlight the tradeoffs implicit in investment decisions. An important aspect of those tradeoffs involve comparison of the indirect effects of disasters and the institutions charged with managing disasters. The winners and losers from those decisions can be partially addressed by careful attention to the selection of locations and appropriate Indicators for the locations (i.e. see Example 1's Slums and Squatters Sub Indicator). Equity, externalities, and tradeoffs, can be addressed further by using Scores with the wider assessment techniques demonstrated in Appendix C.

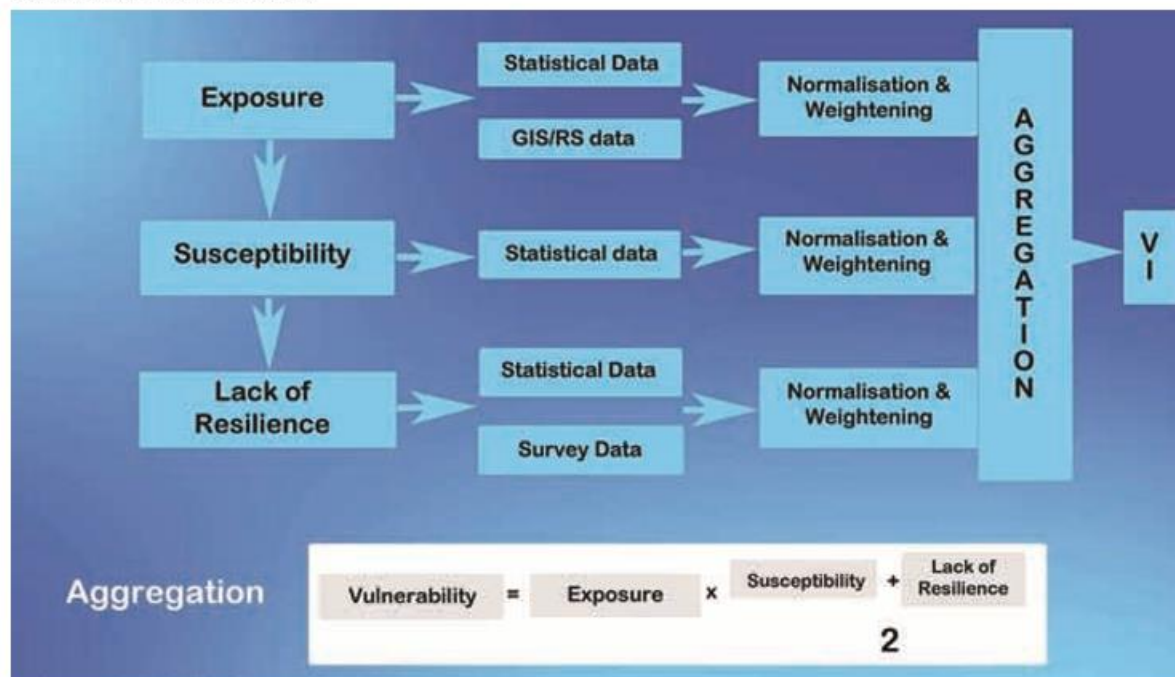
The following image (UNCAPNET, 2015) demonstrates that the general approach used by this algorithm (i.e. indicator, normalization, weighting, aggregation) can be used to build Indexes for many indicator systems. That's why the algorithms in this Appendix support additional types of Indexes, such as the Drought Vulnerability Index and Multi-Criteria Analysis, demonstrated in Appendix C.



## 2.5.1 METHODS OF COMPUTATION OF INDICES

**FIGURE 2.7** | Computing indices

Source: European Commission, 2011.



Although the case studies use the final Indexes in urban areas, these algorithms can be used for any area, including rural areas. The case studies demonstrate developing custom indicators, such as Coping Capacity Indicators, that are appropriate for specific locations. Mustafa et al (2008) demonstrate the use of a similar Community level Vulnerabilities and Capacities Index that has been developed for rural areas. Make sure to use Internet technology that allows the Indicators to be shared throughout the world with anyone who has access to a web browser and an Internet connection.

As with the examples in Appendix A, the goal of these examples are not to carry out exact replications of the referenced case studies. Instead, the examples emphasize developing and using CTA algorithms to support decisions associated with uncertain natural resource damage



DevTreks –social budgeting that improves lives and livelihoods

prevention interventions. The author acknowledges that this could lead to flawed analyses (i.e. that will need to be improved in future releases).



DevTreks –social budgeting that improves lives and livelihoods

### **Algorithm 1. Subalgorithm 10. Disaster Risk Index**

This algorithm will be explained using case studies that demonstrate developing Disaster Risk Indexes (DRI). Example 1 uses data from the Carreno 2005 reference for Bogota, Columbia with the methodology used in the Marulanda 2013 reference for Barcelona, Spain. The Carreno case study does not explicitly address the Hazard, Exposure, Vulnerability, and Loss Exceedance steps of assessments, while the Marulanda case study does. Although this case study analyzes earthquake damages, the same techniques apply to damages associated with climate change.

The algorithm is designed to be fully compatible with the algorithms in Appendix A so that they can be used jointly. In fact, the two algorithms share more than 95% of their source code. The case studies clearly demonstrate that measurement of the indirect effects of disasters is as important as the direct effects. All CTAP algorithms assess technologies, or specific disaster interventions, rather than the whole cities demonstrated in the underlying references.

Assessments for cities, or any area, can still be carried out by organizing data appropriately (i.e. alternative A = Time Period 2, alternative 3 = Time Period 3...).

The algorithm uses the exact same steps as Appendix A, algorithm 9, but adds non-monetary Social Fragility and Lack of Resilience Indicators to the physical asset monetary damages and normalizes, weights, and aggregates, Indicators into unit-less metrics, or Total Risk Indexes.

The algorithm uses the Index generation process introduced in the previous section, to generate an uncertain DRI distributions. The algorithm carries out the CTAPs as follows:

1. Physical Risk, Social Fragility, and Lack of Resilience Categorical Indexes and Sub-Indicators are derived the same way as the case studies. That is, they can be chosen from studies carried out using Appendix A's algorithms, expert opinions, surveys, historical data, or related studies. The Text files organize each Sub Indicator by a parent Categorical Index. The TEXT files contain data for multiple locations (i.e. locations, zip



codes, neighborhoods) and each location is processed using the following steps to produce Total Risk Indexes properties for the location. Because the Sub Indicator data for each location will be normalized, usually in a range of 0 to 1, the original scale of each Indicator should be comparable, otherwise the normalized data, with 4 digits of precision, does not pick up the full differences in confidence intervals.

2. The `Score.Iterations`, `Score.RandomSeed`, and `Score.ConfidenceLevel` properties will be used with each row of data's distribution parameters and a Monte Carlo algorithm (`subalgorithm1`) to generate randomized variables. Descriptive statistics are generated from the vector and the mean and standard deviation from the statistics are used to generate confidence intervals. The 3 parameters used in the confidence interval, QTM, QTL, and QTU, are normalized and weighted. The next 3 steps explain the normalization and weighting. Subalgorithms 9, 10, and 11 share 95% of their source code and employ consistent data formats for all Indicators.
3. The fuzzy logic used by the references is considered too advanced for introductory algorithms. Instead, the Sub Indicator data is described by probability density functions, easily discoverable using this Internet technology, and the following, simpler, normalization functions are used to calculate the desired unit-less, aggregated, non-linear, index values.

zscore, minmax, logistic, logit, or tanh

The normalization function is applied to the final vector of combined QTMs, QTLs, and QTUs generated from running the Monte Carlo simulation algorithm (`subalgorithm1`) for each separate Sub Indicator for each location. The references refer to these numbers as “gross values”. The row/column format of the TEXT data means that each row has a separate normalization value. In practice, only the first legitimate normalization value is used to normalize all vector values. For consistency and appearance sake, all of the TEXT normalization values should be filled in as demonstrated in the examples.

4. The normalized Sub Indicator vector is weighted using numeric multipliers. Those weights can be derived using the case studies' expert opinions and an Analytic Hierarchy Process, but this algorithm does not automatically calculate the weights. The weights must be specified in Indicator 2's TEXT files. The resultant QTM, QTL, and QTL



DevTreks –social budgeting that improves lives and livelihoods

properties are added to a corresponding Sub Indicator csv row which is stored in the Indicator.MathResult.

5. The SubIndicator confidence intervals are multiplied by a parent Categorical Index weight. Each SubIndicator's QTM properties are added to their parent Categorical Index. A csv row for each Categorical Index confidence interval is stored in the Indicator.MathResult. The Categorical Indexes are further weighted by their parent Locational Index and aggregated into the parent Locational Index. The references don't weight Locational Indexes, so the examples set the weights to 1.
6. This step is the only difference from Appendix A, subalgorithm9. When all of the Locational Indexes for a location have been completed, the Moncho equation,  $R_t = R_f * (1 + F)$ , is applied to the Locational Indexes. All of the  $R_f$  categories are summed into 1 set of QTM, QTL, and QTUs, as are the remaining social categories. The  $R_f$ , or physical, categories are distinguished from the  $F$ , or social categories, through the use of a required "RF" label. The  $F$  term is a simple summation of the social Locational Indexes. Although not tested with actual data, the source code supports more than the 2 social Locational Indexes per location demonstrated in the references. The equation is then applied to the aggregated sums and the resultant confidence interval is added to a parent Total Risk Index. The Total Risk Indexes for each location are added to csv rows in the Indicator.MathResult.
7. The Indicator metadata properties (i.e. Indicator6.QTM = .001, QTL = .001, QTU = .001) suggest flaws with this algorithm's current normalization techniques. As usual, DevTreks recommends that developers get their hands dirty and develop better algorithms.

Scores and Decision Support Systems are completed at the discretion of the analyst. Fuller incremental economic analysis can be carried out using this data with the techniques explained in the WHO, 2003 reference. The algorithm requires that Indicators have the exact indexes demonstrated in the examples, although the actual number of Indicators and Indexes can vary.



DevTreks –social budgeting that improves lives and livelihoods

### **Example 3. Earthquakes, Bogota, Columbia**

#### **URLs:**

<https://www.devtreks.org/greentreks/preview/carbon/output/CTAP Ex- 2 - Earthquake DRI/2141223462/none>

<https://www.devtreks.org/greentreks/preview/carbon/resourcepack/DRRs, DRIs, and RMIs/1539/none>

<https://www.devtreks.org/greentreks/preview/carbon/resourcepack/SubAlgo 10 DRI 1A/1538/none>

<http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 2 - Earthquake DRI/2141223468/none>

This example uses data from the Carreno 2005 reference to complete the DRI. The case study presents summary results for full Indicators, but the Khazai et al (2015) reference demonstrates that current best practice is to use Sub Indicators as well. The following example employs a simple technique for using the required Sub Indicators –it simply takes the full Indicator, splits it into 2 Sub Indicators using A and B suffixes, and divides the Indicator value by 2 to obtain the Sub Indicator values. Their weight value is simply  $1 / 2 = 0.5$ . The exceedance probabilities are used the same way as algorithm 9 and are fictitious.

The full Indicator is still included in Indicator.URL TEXT datasets, but it becomes the Categorical Index, or “driving factor”, used to aggregate its children Sub Indicators (the Sub Indicators are actually referred to as Indicators in other examples in this reference). As such, it does not have Distribution values (currently), but it does have the same weight value as shown in the reference. For illustrative purposes, only 3 Categorical Indexes are used for each type of Indicator (Physical, Social, and Resilience).

The case study Indicator values are all point estimates calculated using fuzzy logic mathematics. The following datasets turn the point estimate into probability distributions defined by shape, or QTD1, and scale, or QTD2, parameters. In this example, the shape parameter is a mean and the





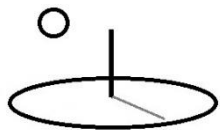
DevTreks –social budgeting that improves lives and livelihoods

scale parameter is a standard deviation calculated as 10% of the mean. Although only normal distributions are used in these datasets, any distribution supported by the calculator can be used. As mentioned, beneficiaries take these assessments seriously and often will collect this data thereby allowing realistic distributions to be used.

Because the primary difference between this algorithm and Appendix A, subalgorithm9 is step 6 in the previous section, the following images highlight the main differences. Although this algorithm can incorporate monetary damage physical Indicators, its primary advantage is the assessment of the social Indicators.

## **Indicator 2. Exposure Distribution**

**URL:** The following image shows the initial TEXT data. The “TR” label is a requirement and is a placeholder for a Total Risk Index for each location. The exact number of characters in the remaining labels are required. The “RF”, “FS”, and “SR”, rows are placeholders for Locational Indexes and are required. The characters “RF” in the label is a requirement. The “RF1, RF2, RF3”, “FS1, FS2, FS3”, and “SR1, SR2, SR3”, rows are placeholders for Categorical Indexes. The remaining rows are Sub Indicators. Locations must be integers. The “indicator” column is better to format without spaces and any unusual characters (and terms such as “dead people”, although used in the case study, can be worded more tactfully). One Total Risk Index row must be included for each separate location.



## DevTreks –social budgeting that improves lives and livelihoods

### Indicator 2. Exposure Distribution.

Description: The total quantity of each indicator is categorized and described by a probability distribution (QTs).

The last 2 columns normalize and weight the Indicator values.

label	locatio	indicator	total	distribtype	QT	QTUnit	QTD1	QTD1Unit	QTD2	QTD2Unit	normalize	weight	quantity
RF1	1	Physical Damages	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	0.3100	1
RF1A	1	Damaged area A	0.0000	normal	7.5590	each	7.5590	mean	0.7590	sd	tanh	0.5000	1
RF1B	1	Damaged area B	0.0000	normal	7.5590	each	7.5590	mean	0.7590	sd	tanh	0.5000	1
RF2	1	Fatalities	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	0.1000	1
RF2A	1	Dead people A	0.0000	normal	2.0000	each	2.0000	mean	0.2000	sd	tanh	0.5000	1
RF2B	1	Dead people B	0.0000	normal	2.0000	each	2.0000	mean	0.2000	sd	tanh	0.5000	1
RF3	1	Injuries	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	0.1000	1
RF3A	1	Injured people A	0.0000	normal	13.5000	each	13.5000	mean	0.1350	sd	tanh	0.5000	1
RF3B	1	Injured people B	0.0000	normal	13.5000	each	13.5000	mean	0.1350	sd	tanh	0.5000	1
RF	1	All Physical	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1
FS1	1	Slums-squatter neighbourhoods	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	0.1800	1
FS1A	1	Slums-squatter neighbourhoods A	0.0000	normal	0.1550	each	0.1550	mean	0.0160	sd	tanh	0.5000	1
FS1B	1	Slums-squatter neighbourhoods B	0.0000	normal	0.1550	each	0.1550	mean	0.0160	sd	tanh	0.5000	1
FS2	1	Mortality rate	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	0.0400	1
FS2A	1	Mortality rate A	0.0000	normal	630.0000	each	630.0000	mean	63.0000	sd	tanh	0.5000	1
FS2B	1	Mortality rate B	0.0000	normal	630.0000	each	630.0000	mean	63.0000	sd	tanh	0.5000	1
FS3	1	Delinquency rate	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	0.0400	1
FS3A	1	Delinquency rate A	0.0000	normal	216.5000	each	216.5000	mean	21.6500	sd	tanh	0.5000	1
FS3B	1	Delinquency rate B	0.0000	normal	216.5000	each	216.5000	mean	21.6500	sd	tanh	0.5000	1
FS	1	All Social Fragility	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1
SR1	1	Hospital beds	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	0.0600	1
SR1A	1	Hospital beds A	0.0000	normal	0.0900	each	0.0900	mean	0.0090	sd	tanh	0.5000	1
SR1B	1	Hospital beds B	0.0000	normal	0.0900	each	0.0900	mean	0.0090	sd	tanh	0.5000	1
SR2	1	Health care resources	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	0.0600	1
SR2A	1	Health human resources A	0.0000	normal	14.0000	each	14.0000	mean	1.4000	sd	tanh	0.5000	1
SR2B	1	Health human resources B	0.0000	normal	14.0000	each	14.0000	mean	1.4000	sd	tanh	0.5000	1
SR3	1	Public space	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	0.0400	1
SR3A	1	Public space A	0.0000	normal	0.0250	each	0.0250	mean	0.0020	sd	tanh	0.5000	1
SR3B	1	Public space B	0.0000	normal	0.0250	each	0.0250	mean	0.0020	sd	tanh	0.5000	1
SR	1	All Resiliency	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1
TR	1	TotalRisk	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1
RF1	2	Physical Damages	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	0.3100	1

The normalization column demonstrates that only the SubIndicator final QTM, QTL, and QTU properties will be normalized. Those results will be weighted and aggregated into parent Categorical, Locational, and Total Risk Indexes. Default values for the quantity column are set to 1 because this subalgorithm only uses the quantity column in order to stay consistent with subalgorithm 9.

The following partial Math Results demonstrate that the normalization of the Sub Indicator confidence intervals result in significantly condensed distributions. Data must be managed carefully with this algorithm, possibly by transforming it prior to adding the data to the URL. Additional normalization, or data transformation, techniques, beyond the existing standard normalization functions, will be explored in future releases.



DevTreks –social budgeting that improves lives and livelihoods

label	location	indicator	total	distribtype	QTM	QTMUnit	QTL	QTLUnit	QTU	QTUUnit	quantity
RF1	1	Physical Damage	0.0000	none	0.3100	category n	0.3100	category lc	0.3100	category h	1.0000
RF1A	1	Damaged a	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
RF1B	1	Damaged a	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
RF2	1	Fatalities	0.0000	none	0.0965	category n	0.0964	category lc	0.0965	category h	1.0000
RF2A	1	Dead peop	0.0000	normal	0.4824	total value	0.4821	lower 90%	0.4828	upper 90%	1.0000
RF2B	1	Dead peop	0.0000	normal	0.4822	total value	0.4819	lower 90%	0.4826	upper 90%	1.0000
RF3	1	Injuries	0.0000	none	0.1000	category n	0.1000	category lc	0.1000	category h	1.0000
RF3A	1	Injured peo	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
RF3B	1	Injured peo	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
RF	1	All Physical	0.0000	none	0.5065	sum categ	0.5064	category lc	0.5065	category h	1.0000
FS1	1	Slums-squa	0.0000	none	0.0278	category n	0.0277	category lc	0.0280	category h	1.0000
FS1A	1	Slums-squa	0.0000	normal	0.0769	total value	0.0765	lower 90%	0.0773	upper 90%	1.0000
FS1B	1	Slums-squa	0.0000	normal	0.0777	total value	0.0773	lower 90%	0.0781	upper 90%	1.0000
FS2	1	Mortality r	0.0000	none	0.0400	category n	0.0400	category lc	0.0400	category h	1.0000
FS2A	1	Mortality r	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
FS2B	1	Mortality r	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
FS3	1	Delinquenc	0.0000	none	0.0400	category n	0.0400	category lc	0.0400	category h	1.0000
FS3A	1	Delinquenc	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
FS3B	1	Delinquenc	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
FS	1	All Social F	0.0000	none	0.1078	sum categ	0.1077	category lc	0.1080	category h	1.0000
SR1	1	Hospital be	0.0000	none	0.0054	category n	0.0054	category lc	0.0054	category h	1.0000
SR1A	1	Hospital be	0.0000	normal	0.0448	total value	0.0446	lower 90%	0.0451	upper 90%	1.0000
SR1B	1	Hospital be	0.0000	normal	0.0451	total value	0.0448	lower 90%	0.0453	upper 90%	1.0000
SR2	1	Health car	0.0000	none	0.0600	category n	0.0600	category lc	0.0600	category h	1.0000
SR2A	1	Health hur	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
SR2B	1	Health hur	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
SR3	1	Public spa	0.0000	none	0.0010	category n	0.0010	category lc	0.0010	category h	1.0000
SR3A	1	Public spa	0.0000	normal	0.0125	total value	0.0125	lower 90%	0.0126	upper 90%	1.0000
SR3B	1	Public spa	0.0000	normal	0.0126	total value	0.0125	lower 90%	0.0126	upper 90%	1.0000
SR	1	All Resilien	0.0000	none	0.0664	sum categ	0.0664	category lc	0.0664	category h	1.0000
TR	1	TotalRisk	0.0000	none	0.5947	sum categ	0.5945	category lc	0.5949	category h	1.0000
RF1	2	Physical Damage	0.0000	none	0.3100	category n	0.3100	category lc	0.3100	category h	1.0000
RF1A	2	Damaged a	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
RF1B	2	Damaged a	0.0000	normal	0.5000	total value	0.5000	lower 90%	0.5000	upper 90%	1.0000
RF2	2	Fatalities	0.0000	none	0.1000	category n	0.1000	category lc	0.1000	category h	1.0000

### Indicator 3. Vulnerability Distribution

**URL:** Indicator 3's TEXT rows must use the exact same naming conventions as Indicator 2 – labels, indicator names, and locations must be exact matches. The URL demonstrates that the 3 aggregating Indexes result in large datasets which, in turn, generate large Math Results. The aggregating Indexes were deemed a requirement so that all subalgorithms that use these techniques can share the exact same source code. That allows the source code to be debugged



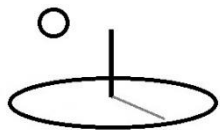
DevTreks –social budgeting that improves lives and livelihoods

and optimized better. When Math Results are too large for storage, display, or performance, store them as csv TEXT files by referencing a URL in the Math Result, as demonstrated for Indicator 7. The following image displays some of the initial data.

Indicator 3. Vulnerability Distribution. (matrix numbers are percent)									
Description: The damage percent for each asset type is described by a probability distribution (QTs)									
label	assettype	loc_distrib	total	distribtype	5year	10year	25year	50year	100year
RF1	Physical Damages	1_QT	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF1	Physical Damages	1_QTD1	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF1	Physical Damages	1_QTD2	0.000	normal	0.000	0.000	0.000	0.000	0.000
RF1A	Damaged area A	1_QT	0.0000	normal	2.5000	10.0000	35.0000	50.0000	59.0000
RF1A	Damaged area A	1_QTD1	0.0000	normal	2.5000	10.0000	35.0000	50.0000	59.0000
RF1A	Damaged area A	1_QTD2	0.0000	normal	0.2500	1.0000	3.5000	5.0000	5.9000
RF1B	Damaged area B	1_QT	0.0000	normal	0.0000	7.5000	22.0000	30.0000	36.0000
RF1B	Damaged area B	1_QTD1	0.0000	normal	0.0000	7.5000	22.0000	30.0000	36.0000
RF1B	Damaged area B	1_QTD2	0.0000	normal	0.0000	0.7500	2.2000	3.0000	3.6000
RF2	Fatalities	1_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000
RF2	Fatalities	1_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000
RF2	Fatalities	1_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000
RF2A	Dead people A	1_QT	0.0000	normal	0.0000	0.5000	4.0000	12.0000	22.5000
RF2A	Dead people A	1_QTD1	0.0000	normal	0.0000	0.5000	4.0000	12.0000	22.5000
RF2A	Dead people A	1_QTD2	0.0000	normal	0.0000	0.0500	0.4000	1.2000	2.2500
RF2B	Dead people B	1_QT	0.0000	normal	0.0000	0.5000	3.7500	5.0000	13.0000
RF2B	Dead people B	1_QTD1	0.0000	normal	0.0000	0.5000	3.7500	5.0000	13.0000
RF2B	Dead people B	1_QTD2	0.0000	normal	0.0000	0.0500	0.3750	0.5000	1.3000
RF3	Injuries	1_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000
RF3	Injuries	1_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000
RF3	Injuries	1_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000
RF3A	Injured people A	1_QT	0.0000	normal	1.8688	7.4753	26.1634	37.3763	44.1041
RF3A	Injured people A	1_QTD1	0.0000	normal	1.8688	7.4753	26.1634	37.3763	44.1041
RF3A	Injured people A	1_QTD2	0.0000	normal	0.1869	0.7475	2.6163	3.7376	4.4104
RF3B	Injured people B	1_QT	0.0000	normal	0.0000	4.9005	14.3747	19.6018	23.5222
RF3B	Injured people B	1_QTD1	0.0000	normal	0.0000	4.9005	14.3747	19.6018	23.5222
RF3B	Injured people B	1_QTD2	0.0000	normal	0.0000	0.4900	1.4375	1.9602	2.3522
RF	All Physical	1_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000
RF	All Physical	1_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000
RF	All Physical	1_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000
FS1	Slums-squatter nei	1_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000

...

...



DevTreks –social budgeting that improves lives and livelihoods

SR2B_A	Health human reso	2_QTD2	0.0000	normal	0.0000	0.0091	0.0684	0.0911	0.2370	
FS3_A	Public Space	2_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	
FS3_A	Public Space	2_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	
FS3_A	Public Space	2_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	
SR3A_A	Public space A	2_QT	0.0000	normal	1.0588	4.2350	14.8225	21.1750	24.9865	
SR3A_A	Public space A	2_QTD1	0.0000	normal	1.0588	4.2350	14.8225	21.1750	24.9865	
SR3A_A	Public space A	2_QTD2	0.0000	normal	0.1059	0.4235	1.4823	2.1175	2.4987	
SR3B_A	Public space B	2_QT	0.0000	normal	0.0000	3.1763	9.3170	12.7050	15.2460	
SR3B_A	Public space B	2_QTD1	0.0000	normal	0.0000	3.1763	9.3170	12.7050	15.2460	
SR3B_A	Public space B	2_QTD2	0.0000	normal	0.0000	0.3176	0.9317	1.2705	1.5246	
SR_A	All Resiliency	2_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	
SR_A	All Resiliency	2_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	
SR_A	All Resiliency	2_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	
TR_A	TotalRisk	2_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	
TR_A	TotalRisk	2_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	
TR_A	TotalRisk	2_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	

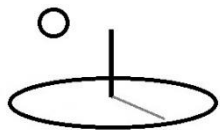
**MathResults:** The following image shows typical Math Results being stored directly in that property.



DevTreks –social budgeting that improves lives and livelihoods

QT Most 3	QT Most Unit 3
67.0898	total percent damage
QT Low 3	QT Low Unit 3
66.7405	lower 90% ci
QT High 3	QT High Unit 3
67.4391	upper 90% ci
Math Expression 3	
I3.Q1.distribtype + I3.Q2.5year + I3.Q3.10year + I3.Q4.25year + I3.Q5.50year + I3.Q6.100year	
Math Result 3	
<p>dri results</p> <p>label,assettype,loc_confid,total,distribtype,5year,10year,25year,50year,100year</p> <p>RF1,Physical Damages,1_QTM,7.0658,normal,2.4952,17.4620,56.9474,79.7815,94.7020</p> <p>RF1,Physical Damages,1_QTL,7.0289,normal,2.4821,17.3716,56.6501,79.3634,94.2011</p> <p>RF1,Physical Damages,1_QTU,7.1027,normal,2.5083,17.5524,57.2447,80.1996,95.2029</p> <p>RF1A,Damaged area A,1_QTM,4.4816,normal,2.50,9.98,34.99,49.88,58.77</p> <p>RF1A,Damaged area A,1_QTL,4.4579,normal,2.48,9.92,34.81,49.61,58.46</p> <p>RF1A,Damaged area A,1_QTU,4.5052,normal,2.51,10.03,35.18,50.14,59.08</p> <p>RF1B,Damaged area B,1_QTM,2.5842,normal,0.00,7.49,21.95,29.90,35.93</p> <p>RF1B,Damaged area B,1_QTL,2.5710,normal,0.00,7.45,21.84,29.75,35.74</p> <p>RF1B,Damaged area B,1_QTU,2.5975,normal,0.00,7.53,22.06,30.06,36.12</p> <p>RF2,Fatalities,1_QTM,1.1053,normal,0.0000,1.0031,7.7422,16.9661,35.5971</p> <p>RF2,Fatalities,1_QTL,1.0995,normal,0.0000,0.9979,7.7001,16.8801,35.4091</p> <p>RF2,Fatalities,1_QTU,1.1111,normal,0.0000,1.0083,7.7843,17.0521,35.7851</p> <p>RF2A,Dead people A,1_QTM,0.6758,normal,0.00,0.50,3.99,12.03,22.53</p> <p>RF2A,Dead people A,1_QTL,0.6722,normal,0.00,0.50,3.97,11.96,22.42</p> <p>RF2A,Dead people A,1_QTU,0.6793,normal,0.00,0.50,4.02,12.09,22.65</p> <p>RF2B,Dead people B,1_QTM,0.4295,normal,0.00,0.50,3.75,4.94,13.06</p> <p>RF2B,Dead people B,1_QTL,0.4273,normal,0.00,0.50,3.73,4.92,12.99</p> <p>RF2B,Dead people B,1_QTU,0.4318,normal,0.00,0.50,3.77,4.97,13.13</p> <p>RF3,Injuries,1_QTM,5.0449,normal,1.8789,12.3610,40.4620,56.9658,67.5264</p> <p>RF3,Injuries,1_QTL,5.0189,normal,1.8693,12.2982,40.2532,56.6635,67.1844</p> <p>RF3,Injuries,1_QTU,5.0710,normal,1.8885,12.4238,40.6708,57.2681,67.8684</p> <p>RF3A,Injured people A,1_QTM,3.3569,normal,1.88,7.48,26.13,37.35,44.07</p> <p>RF3A,Injured people A,1_QTL,3.3396,normal,1.87,7.44,26.00,37.15,43.85</p> <p>RF3A,Injured people A,1_QTU,3.3742,normal,1.89,7.52,26.27,37.55,44.30</p> <p>RF3B,Injured people B,1_QTM,1.6880,normal,0.00,4.88,14.33,19.61,23.46</p>	

The following image shows the final rows of the Indicator3.MathResults.



DevTreks –social budgeting that improves lives and livelihoods

SR2_A	Health care resources	2_QTU	0.1822	normal	0.0000	0.1681	1.2979	2.7625	5.8268
SR2A_A	Health human resourc	2_QTM	0.1031	normal	0.0000	0.0800	0.6100	1.8400	3.4400
SR2A_A	Health human resourc	2_QTL	0.1025	normal	0.0000	0.0800	0.6100	1.8300	3.4200
SR2A_A	Health human resourc	2_QTU	0.1036	normal	0.0000	0.0800	0.6100	1.8500	3.4500
SR2B_A	Health human resourc	2_QTM	0.0782	normal	0.0000	0.0900	0.6800	0.9100	2.3600
SR2B_A	Health human resourc	2_QTL	0.0778	normal	0.0000	0.0900	0.6800	0.9100	2.3500
SR2B_A	Health human resourc	2_QTU	0.0786	normal	0.0000	0.0900	0.6900	0.9200	2.3700
SR3_A	Public Space	2_QTM	2.9953	normal	1.0544	7.3896	24.1404	33.8929	40.2029
SR3_A	Public Space	2_QTL	2.9797	normal	1.0490	7.3509	24.0143	33.7156	39.9912
SR3_A	Public Space	2_QTU	3.0110	normal	1.0598	7.4283	24.2665	34.0702	40.4146
SR3A_A	Public space A	2_QTM	1.8996	normal	1.0500	4.2200	14.8600	21.1800	24.9200
SR3A_A	Public space A	2_QTL	1.8897	normal	1.0500	4.2000	14.7800	21.0600	24.7900
SR3A_A	Public space A	2_QTU	1.9096	normal	1.0600	4.2400	14.9300	21.2900	25.0500
SR3B_A	Public space B	2_QTM	1.0957	normal	0.0000	3.1700	9.2800	12.7200	15.2800
SR3B_A	Public space B	2_QTL	1.0900	normal	0.0000	3.1600	9.2400	12.6500	15.2000
SR3B_A	Public space B	2_QTU	1.1014	normal	0.0000	3.1900	9.3300	12.7800	15.3600
SR_A	All Resiliency	2_QTM	4.6419	normal	1.5820	11.1793	37.1809	53.1670	65.6996
SR_A	All Resiliency	2_QTL	4.6176	normal	1.5738	11.1211	36.9855	52.8902	65.3540
SR_A	All Resiliency	2_QTU	4.6662	normal	1.5902	11.2375	37.3763	53.4438	66.0452
TR_A	TotalRisk	2_QTM	12.3080	normal	3.9454	28.6193	97.9165	143.6912	186.6467
TR_A	TotalRisk	2_QTL	12.2437	normal	3.9250	28.4704	97.4028	142.9432	185.6672
TR_A	TotalRisk	2_QTU	12.3722	normal	3.9658	28.7682	98.4302	144.4392	187.6262

#### Indicator 4. Loss Exceedance Probability (EP) Distribution

The following images display representative rows of the Indicator4.MathResults. As with the results for Indicator 2, the use of normalized confidence intervals increases the need for careful data management.



## DevTreks –social budgeting that improves lives and livelihoods

label	assettype	loc_conf	total	distribtype	5year	10year	25year	50year	100year	quantity
RF1	Physical Damages	1_QTM	0.0354	none	0.0125	0.0876	0.2848	0.4006	0.4751	1.0000
RF1	Physical Damages	1_QTL	0.0352	none	0.0125	0.0871	0.2833	0.3985	0.4727	1.0000
RF1	Physical Damages	1_QTU	0.0356	none	0.0126	0.0881	0.2863	0.4027	0.4776	1.0000
RF1A	Damaged area A	1_QTM	0.0224	normal	0.0100	0.0500	0.1700	0.2500	0.3000	1.0000
RF1A	Damaged area A	1_QTL	0.0223	normal	0.0100	0.0500	0.1700	0.2500	0.2900	1.0000
RF1A	Damaged area A	1_QTU	0.0226	normal	0.0100	0.0500	0.1800	0.2500	0.3000	1.0000
RF1B	Damaged area B	1_QTM	0.0130	normal	0.0000	0.0400	0.1100	0.1500	0.1800	1.0000
RF1B	Damaged area B	1_QTL	0.0129	normal	0.0000	0.0400	0.1100	0.1500	0.1800	1.0000
RF1B	Damaged area B	1_QTU	0.0130	normal	0.0000	0.0400	0.1100	0.1500	0.1800	1.0000
RF2	Fatalities	1_QTM	0.0053	none	0.0000	0.0048	0.0373	0.0818	0.1708	1.0000
RF2	Fatalities	1_QTL	0.0053	none	0.0000	0.0048	0.0371	0.0813	0.1698	1.0000
RF2	Fatalities	1_QTU	0.0053	none	0.0000	0.0048	0.0376	0.0823	0.1718	1.0000
RF2A	Dead people A	1_QTM	0.0032	normal	0.0000	0.0000	0.0200	0.0600	0.1100	1.0000
RF2A	Dead people A	1_QTL	0.0032	normal	0.0000	0.0000	0.0200	0.0600	0.1100	1.0000
RF2A	Dead people A	1_QTU	0.0033	normal	0.0000	0.0000	0.0200	0.0600	0.1100	1.0000
RF2B	Dead people B	1_QTM	0.0021	normal	0.0000	0.0000	0.0200	0.0200	0.0600	1.0000
RF2B	Dead people B	1_QTL	0.0021	normal	0.0000	0.0000	0.0200	0.0200	0.0600	1.0000
RF2B	Dead people B	1_QTU	0.0021	normal	0.0000	0.0000	0.0200	0.0200	0.0600	1.0000
RF3	Injuries	1_QTM	0.0253	none	0.0094	0.0619	0.2034	0.2858	0.3388	1.0000
RF3	Injuries	1_QTL	0.0252	none	0.0093	0.0616	0.2023	0.2843	0.3370	1.0000
RF3	Injuries	1_QTU	0.0254	none	0.0094	0.0623	0.2044	0.2873	0.3405	1.0000
RF3A	Injured people A	1_QTM	0.0168	normal	0.0100	0.0400	0.1300	0.1900	0.2200	1.0000
RF3A	Injured people A	1_QTL	0.0167	normal	0.0100	0.0400	0.1300	0.1900	0.2200	1.0000
RF3A	Injured people A	1_QTU	0.0169	normal	0.0100	0.0400	0.1300	0.1900	0.2200	1.0000
RF3B	Injured people B	1_QTM	0.0085	normal	0.0000	0.0200	0.0700	0.1000	0.1200	1.0000
RF3B	Injured people B	1_QTL	0.0084	normal	0.0000	0.0200	0.0700	0.1000	0.1200	1.0000
RF3B	Injured people B	1_QTU	0.0085	normal	0.0000	0.0200	0.0700	0.1000	0.1200	1.0000
RF	All Physical	1_QTM	0.0660	none	0.0219	0.1543	0.5254	0.7681	0.9846	1.0000

...

SR2B_A	Health human reso	2_QTU	0.0004	normal	0.0000	0.0000	0.0000	0.0000	0.0100	1.0000
SR3_A	Public Space	2_QTM	0.0004	none	0.0001	0.0010	0.0033	0.0046	0.0054	1.0000
SR3_A	Public Space	2_QTL	0.0004	none	0.0001	0.0010	0.0032	0.0045	0.0054	1.0000
SR3_A	Public Space	2_QTU	0.0004	none	0.0001	0.0010	0.0033	0.0046	0.0055	1.0000
SR3A_A	Public space A	2_QTM	0.0003	normal	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
SR3A_A	Public space A	2_QTL	0.0003	normal	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
SR3A_A	Public space A	2_QTU	0.0003	normal	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
SR3B_A	Public space B	2_QTM	0.0001	normal	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
SR3B_A	Public space B	2_QTL	0.0001	normal	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
SR3B_A	Public space B	2_QTU	0.0001	normal	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
SR_A	All Resiliency	2_QTM	0.0020	none	0.0004	0.0036	0.0155	0.0265	0.0441	1.0000
SR_A	All Resiliency	2_QTL	0.0020	none	0.0004	0.0036	0.0154	0.0263	0.0438	1.0000
SR_A	All Resiliency	2_QTU	0.0021	none	0.0004	0.0037	0.0157	0.0267	0.0444	1.0000
TR_A	TotalRisk	2_QTM	0.0285	none	0.0084	0.0614	0.2251	0.3463	0.4713	2.0000
TR_A	TotalRisk	2_QTL	0.0283	none	0.0084	0.0610	0.2238	0.3443	0.4682	2.0000
TR_A	TotalRisk	2_QTU	0.0286	none	0.0085	0.0617	0.2264	0.3485	0.4741	2.0000





DevTreks –social budgeting that improves lives and livelihoods

The reason that the final 3 rows have quantities of 2 is that the Total Risk Indexes are calculated from two Indicator aggregations –the Physical and Social categories. The quantity column is not used by subalgorithms 10 and 11.

## Indicator 5. Costs Distribution

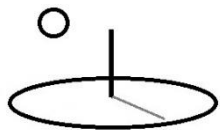
No cost data was available, so the following fictitious data is used in this study. The “isprojectcost” column confirms that this subalgorithm uses project costs only. In this example, Indicators 6 and 7 will analyze one “project alternative” (\_A), or time period progress, in reference to the “Current Practice”. Subalgorithms 10 and 11 must use only project costs.

Indicator 5. Costs								
label	alternative	loc_distrib	total	installcost	installdistr	omcost	omdistrib	isprojectcost
AC1A	CurrentPracti	1_QT	0.0000	100.0000	normal	1.5000	normal	yes
AC1A	CurrentPracti	1_QTD1	0.0000	100.0000	normal	1.5000	normal	yes
AC1A	CurrentPracti	1_QTD2	0.0000	10.0000	normal	0.1500	normal	yes
AC1A_A	AlternativeA	1_QT	0.0000	10000.0000	normal	2.5000	normal	yes
AC1A_A	AlternativeA	1_QTD1	0.0000	10000.0000	normal	2.5000	normal	yes
AC1A_A	AlternativeA	1_QTD2	0.0000	1000.0000	normal	0.2500	normal	yes
AC1A	CurrentPracti	2_QT	0.0000	100.0000	normal	1.5000	normal	yes
AC1A	CurrentPracti	2_QTD1	0.0000	100.0000	normal	1.5000	normal	yes
AC1A	CurrentPracti	2_QTD2	0.0000	10.0000	normal	0.1500	normal	yes
AC1A_A	AlternativeA	2_QT	0.0000	12500.0000	normal	2.5000	normal	yes
AC1A_A	AlternativeA	2_QTD1	0.0000	12500.0000	normal	2.5000	normal	yes
AC1A_A	AlternativeA	2_QTD2	0.0000	1250.0000	normal	0.2500	normal	yes

## Indicator 7. Cost Effectiveness Analysis

Cost Effectiveness Ratios are generated in the same manner as subalgorithm9 in Appendix A. The Indicator itself displays the lowest CER for the Total Risk rows, summed across Locations. The following images demonstrate that the use of normalized damage data in the CER divisor, results in unusual, but accurate, ratios.

**MathResults:** [http://localhost/resources/network\\_carbon/resourcepack\\_529/resource\\_1818/Ind7-Math-Result.csv](http://localhost/resources/network_carbon/resourcepack_529/resource_1818/Ind7-Math-Result.csv) or



DevTreks –social budgeting that improves lives and livelihoods

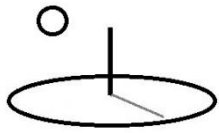
[https://devtreks1.blob.core.windows.net/resources/network\\_carbon/resourcepack\\_1538/resource\\_8017/Ind7-Math-Result.csv](https://devtreks1.blob.core.windows.net/resources/network_carbon/resourcepack_1538/resource_8017/Ind7-Math-Result.csv)

The image also demonstrates the use of URLs to store Math Results. In this Indicator, a csv file was built using 1 single string (i.e. math), uploaded to the Resource element, and the URL was copied from the Download URI button displayed on the Preview panel into this property. Once the calculations are run the file content is replaced with the full Math Results. Algorithms 9 and 10 subtract alternative damages from base damages, while Algorithm 11 subtracts base performance indicators from alternative performance indicators.



Indicator 7	
Cost Effectiveness Analysis	
<b>Description 7</b> The URL dataset define average annual benefits from non monetary disaster loss reductions and the Math Results from Indicator 5 defines average annual costs. Benefits are defined as the reduction in damages of each project alternative in comparison to the	
Indicator 7 URL	
none	
Label 7	Rel Label 7
7A	
Date 7	Dist Type 7
01/01/2005	none
Q1 7	Q1 Unit 7
0.1826	base damage
Q2 7	Q2 Unit 7
194.9264	base cost
Q3 7	Q3 Unit 7
0.0539	AC1A_A damage
Q4 7	Q4 Unit 7
20,146.8322	AC1A_A cost
Q5 7	Q5 Unit 7
0.0000	none
Math Operator 7	BaseIO 7
none	none
QT 7	QT Unit 7
155,026.4631	net benefits

The cost effective ratios in the following images result from using regular monetary costs in the numerator with normalized indicator values in the denominator. The reason that QTU is smaller



DevTreks –social budgeting that improves lives and livelihoods

than QTL is that smaller CERs are better than higher CERs. As with Example 1, decision makers should be given the full cost and benefit data used to calculate the ratios.

<b>Math Type 7</b>		<b>Math Sub Type 7</b>	
<input type="text" value="algorithm1"/>		<input type="text" value="subalgorithm10"/>	
<b>QT D1 7</b>		<b>QT D1 Unit 7</b>	
<input type="text" value="0.0000"/>		<input type="text" value="none"/>	
<b>QT D2 7</b>		<b>QT D2 Unit 7</b>	
<input type="text" value="0.0000"/>		<input type="text" value="none"/>	
<b>QT Most 7</b>		<b>QT Most Unit 7</b>	
<input type="text" value="155,026.4631"/>		<input type="text" value="2_QTM_0.12_10, cer"/>	
<b>QT Low 7</b>		<b>QT Low Unit 7</b>	
<input type="text" value="155,407.1378"/>		<input type="text" value="lower 90% ci"/>	
<b>QT High 7</b>		<b>QT High Unit 7</b>	
<input type="text" value="154,890.5027"/>		<input type="text" value="upper 90% ci"/>	
<b>Math Expression 7</b>			
<input type="text" value="I7.Q1.distribtype + I7.Q2.100year + I7.Q3.50year + I7.Q4.25year + I7.Q5.10year + I7.Q6.5year +"/>			
<b>Math Result 7</b>			
<input type="text" value="http://localhost/resources/network_carbon/resourcepack_529/resource_1818/Ind7-Math-Result.csv"/>			

**+ Indicator 8**

The following image shows partial results taken from the Math Result TEXT csv file. Calculations that return large Math Results should always use this technique. In addition, overall Indicator performance can be increased using this technique. Make sure that children Input or Output Series use unique URLs. The csv file can always be imported into other software and manipulated in a manner that produces multimedia that decision makers will understand.



DevTreks –social budgeting that improves lives and livelihoods

label	assettype	loc_confid	total	RF1_damage	RF1_cost	RF1_A_dar	RF1_A_cost	RF1_A_cer
RF1_A	Physical Damages	1_QTM_0.05	0.0000	0.0355	106.5390	0.0124	9537.8357	408281.2424
RF1_A	Physical Damages	1_QTM_0.05	0.0000	0.0355	116.1285	0.0124	9553.7834	408556.4892
RF1_A	Physical Damages	1_QTM_0.12	0.0000	0.0355	97.4892	0.0124	8937.7444	382695.0303
RF1_A	Physical Damages	1_QTM_0.12	0.0000	0.0355	100.7893	0.0124	8943.2326	382789.7532
RF1_A	Physical Damages	1_QTL_0.05	0.0000	0.0353	105.9739	0.0123	9488.1211	407919.4435
RF1_A	Physical Damages	1_QTL_0.05	0.0000	0.0353	115.5156	0.0123	9503.9873	408194.4217
RF1_A	Physical Damages	1_QTL_0.12	0.0000	0.0353	96.9713	0.0123	8891.1573	382355.9130
RF1_A	Physical Damages	1_QTL_0.12	0.0000	0.0353	100.2549	0.0123	8896.6175	382450.5478
RF1_A	Physical Damages	1_QTU_0.05	0.0000	0.0356	107.1042	0.0125	9587.5502	410408.9177
RF1_A	Physical Damages	1_QTU_0.05	0.0000	0.0356	116.7415	0.0125	9603.5795	410685.6277
RF1_A	Physical Damages	1_QTU_0.12	0.0000	0.0356	98.0071	0.0125	8984.3314	384689.3636
RF1_A	Physical Damages	1_QTU_0.12	0.0000	0.0356	101.3237	0.0125	8989.8477	384784.5887
RF1A_A	Damaged area A	1_QTM_0.05	0.0000	0.0225	106.5390	0.0079	9537.8357	645979.2260
RF1A_A	Damaged area A	1_QTM_0.05	0.0000	0.0225	116.1285	0.0079	9553.7834	646414.7192
RF1A_A	Damaged area A	1_QTM_0.12	0.0000	0.0225	97.4892	0.0079	8937.7444	605496.9315
RF1A_A	Damaged area A	1_QTM_0.12	0.0000	0.0225	100.7893	0.0079	8943.2326	605646.8014
RF1A_A	Damaged area A	1_QTL_0.05	0.0000	0.0224	105.9739	0.0078	9488.1211	642612.8219
RF1A_A	Damaged area A	1_QTL_0.05	0.0000	0.0224	115.5156	0.0078	9503.9873	643046.0068
RF1A_A	Damaged area A	1_QTL_0.12	0.0000	0.0224	96.9713	0.0078	8891.1573	602341.5068
RF1A_A	Damaged area A	1_QTL_0.12	0.0000	0.0224	100.2549	0.0078	8896.6175	602490.5890
RF1A_A	Damaged area A	1_QTU_0.05	0.0000	0.0226	107.1042	0.0079	9587.5502	644928.2993
RF1A_A	Damaged area A	1_QTU_0.05	0.0000	0.0226	116.7415	0.0079	9603.5795	645363.1293
RF1A_A	Damaged area A	1_QTU_0.12	0.0000	0.0226	98.0071	0.0079	8984.3314	604511.8571
RF1A_A	Damaged area A	1_QTU_0.12	0.0000	0.0226	101.3237	0.0079	8989.8477	604661.4966
RF1B_A	Damaged area B	1_QTM_0.05	0.0000	0.0130	106.5390	0.0045	9537.8357	1109564.3176



DevTreks –social budgeting that improves lives and livelihoods

### **Algorithm 1. SubAlgorithm 11. Risk Management Index (RMI)**

The RMI uses a simplified version of the Indicator measurement and aggregation techniques used in subalgorithms 9 and 10. Khazai et al (2015) explain that “the RMI is defined as the average of the following four composite indicators [for a specific location]”. The authors also refer to these Indexes as being “public policies”.

1. Risk Identification Index: measures the individual perceptions of risk
2. Risk Reduction Index: measures the existence of prevention and mitigation measures
3. Disaster Management Index: measures response, recovery and governance
4. Financial Protection Index: measures the degree of institutionalization and risk transfer

Each of the composite indexes is composed of the 6 Indicators shown in the following image (Khazai et al, 2015). The authors describe these Indicators using the phrase “topics [within the public policy Indexes] to be evaluated”.



DevTreks –social budgeting that improves lives and livelihoods

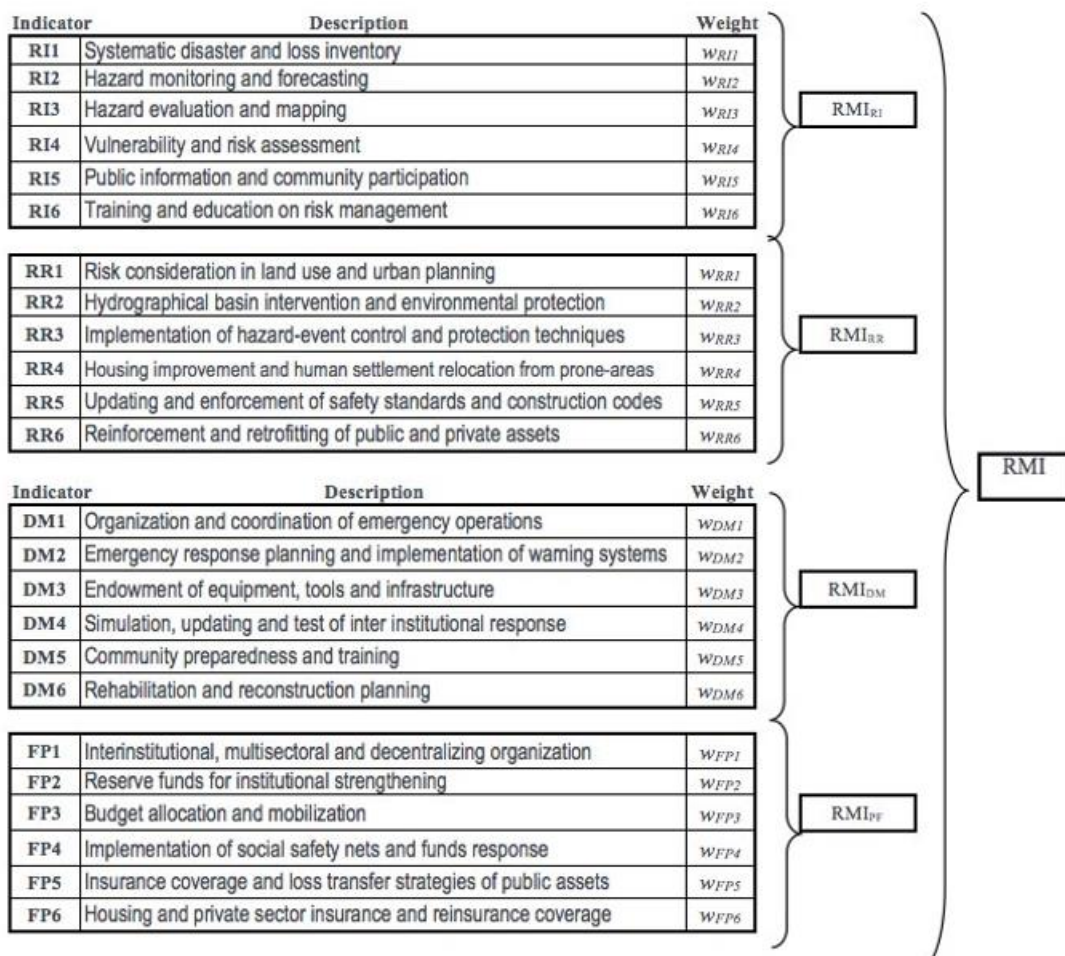
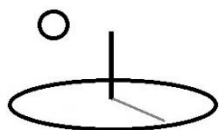


Figure 3.1 Component indicators for RMI (Cardona et al., 2005; Carreño et al., 2007b)

The authors do not recommend using additional Indicators or subdividing these Indicators into Sub Indicators. The use of standard Indicators allows performance and effectiveness to be compared over time and location. The 4 composite indexes are equivalent to the Categorical Indexes used by subalgorithms 9 and 10. The weighted average of the CIs are added to 1 Locational Index and that Index is then added to the final Total Risk Index, or RMI. Multiple locations can be included in the analysis.

Indicator values are based on 5 performance levels: 1 (low), 2 (incipient), 3 (significant), 4 (outstanding), and 5 (optimal). Each Indicator's performance levels are qualitatively defined in



DevTreks –social budgeting that improves lives and livelihoods

separate reference tables. The following image (Khazai et al, 2015) displays an example of performance levels for 2 Indicators.

## ANNEX 2: CITY'S RMI PERFORMANCE LEVELS

### RISK IDENTIFICATION INDICATORS (RII)

#### INDICATOR AND PERFORMANCE LEVELS

##### RII. Systematic disaster and loss inventory

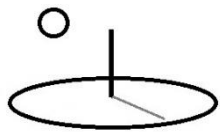
1. Some basic and superficial data on the history of events that have affected the city
2. Continual registering of current events, incomplete catalogues of the occurrence of some phenomena and limited information on losses and effects.
3. Some complete catalogues at the national and regional levels, systematization of actual events and their economic, social and environmental effects.
4. Complete inventory and multiple catalogues of events; registry and detailed systematization of effects and losses at the local level.
5. Detailed inventory of events and effects for all types of existing hazards and data bases at the sub-national and local levels.

##### RI2. Hazard monitoring and forecasting

1. Minimum and deficient instrumentation of some important phenomena.
2. Basic instrumentation networks with problems of updated technology and continuous maintenance.
3. Some networks with advanced technology at the national level or in particular areas; improved prognostics and information protocols established for principal hazards.
4. Good and progressive instrumentation cover at the national level, advanced research in the matter on the majority of hazards, and some automatic warning systems working.
5. Wide coverage of station and sensor networks for all types of hazard in all the city; permanent and opportune analysis of information and automatic early warning systems working continuously at the local, regional and national levels.

This algorithm uses the same probabilistic risk and normalization techniques introduced in subalgorithm9 and subalgorithm10: each Sub Indicator is defined by a probability distribution





DevTreks –social budgeting that improves lives and livelihoods

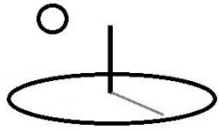
(QT, QTD1, and QTD2). The probability distributions can be defined using the same methods as the other subalgorithms: survey data, observational data, historical data, or expert opinion. This Internet technology makes the distributions transparent and reusable. The 0 to 5 performance scale is retained, except the values are doubles, with non-integers being acceptable. The current version does not scale the values to the 0 to 100 Index bounds demonstrated by the references.

Monte Carlo simulation is used with those distributions to generate Sub Indicator descriptive statistics and cumulative density data. The statistics are used to generate confidence intervals (QTM, QTL, and QTU) for each Sub Indicator. The confidence intervals for a vector of Sub Indicator QTM, QTL, and QTU properties for each location are normalized and multiplied by a weight and then aggregated into the ancestor Categorical, Locational, and Risk Management Indexes.

The baseline, or benchmark, RMIs for each location can be compared to each “project alternative” in the same manner as subalgorithm9 and subalgorithm10. The alternatives can be for different time periods, as demonstrated in the case studies for assessing progress, or for actual alternative policy interventions for assessing effectiveness and efficiency. Although the references don’t use economic analysis with the Indexes, the nature of CTAPs means that Cost Effectiveness Analysis (CEA) is carried out for the alternatives. Benefit Cost Analysis is not carried out because the Indicators are not monetary.

The CEA’s logic is that each alternative improvement in “public policies” requires investments (i.e. costs) and is subject to tradeoffs. Cost effectiveness ratios allow the uniform comparison among the alternative investments.

Example 1 uses the Indicators displayed in the previous image with fictitious values and weights to generate the final RMI CEA analysis. The algorithm requires that Indicators have the exact indexes demonstrated in the examples, although the actual number of Indicators and Indexes can vary.



DevTreks –social budgeting that improves lives and livelihoods

#### **Example 4. Risk Management Index**

##### **URLs:**

[https://www.devtreks.org/greentreks/preview/carbon/output/CTAP Ex 3 - Generic RMI/2141223463/none](https://www.devtreks.org/greentreks/preview/carbon/output/CTAP%20Ex%203%20-%20Generic%20RMI/2141223463/none)

[https://www.devtreks.org/greentreks/preview/carbon/resourcepack/SubAlgo 11 RMI 1A/1540/none](https://www.devtreks.org/greentreks/preview/carbon/resourcepack/SubAlgo%2011%20RMI%201A/1540/none)

[https://www.devtreks.org/greentreks/preview/carbon/resourcepack/DRRs, DRIs, and RMIs/1539/none](https://www.devtreks.org/greentreks/preview/carbon/resourcepack/DRRs,%20DRIs,%20and%20RMIs/1539/none)

[http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 3 - Generic RMI/2141223469/none](http://localhost:5000/greentreks/preview/carbon/output/CTAP%20Example%203%20-%20Generic%20RMI/2141223469/none)

##### **Score. Starting Properties**

The following initial Score properties are used in this example:

**Confidence Interval:** 90

**Random Seed:** 7

**Iterations:** 10,000

**Description:** This example demonstrates ....

##### **Indicator 1. Risk Management Indicator Distribution**

This Indicator defines probability distributions, normalization functions, and weights, for each of the RMI Indicators. The values are fictitious and selected to facilitate debugging the calculations.

Selected properties include:

**Distribution Type:** none (URL datasets are used)

**Math Type and Math Sub Type:** algorithm1, subalgorithm11



DevTreks –social budgeting that improves lives and livelihoods

**Units:** automatically filled in (but most units that are entered manually will not be overwritten)

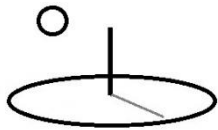
The following Math Expression is only used to identify the columns of TEXT data to include in the calculation.

**Qs** = Q1 to Q5 automatically document the RMIs for the first five “Locational Indexes”. The QTs document a summation of the Locational Indexes. The QTM documents the weighted average of the Location Indexes.

**Math Expression** =

I1.Q1.distribtype + I1.Q2.QT + I1.Q3.QTUnit + I1.Q4.QTD1 + I1.Q5.QTD1Unit + I1.Q6.QTD2 + I1.Q7.QTD2Unit + I1.Q8.normalization + I1.Q9.weight + I1.Q10.quantity

The following images demonstrate the IndicatorQs properties are filled in with the RMIs for different locations. The QTM is the sum of all RMIs for all locations.



DevTreks –social budgeting that improves lives and livelihoods

Indicator 1

Risk Management Indicators Distribution

Indicator 1 Description

This indicator is used in a CTAP tutorial.

Indicator 1 URL

[http://localhost:50032/resources/network\\_carbon/resourcepack\\_530/resource\\_1815/Ind1-RMI.csv](http://localhost:50032/resources/network_carbon/resourcepack_530/resource_1815/Ind1-RMI.csv)

Label 1

1A

Rel Label 1

Date 1

10/15/2015

Dist Type 1

none

Q1 1

0.8710

Q1 Unit 1

location1 rmi

Q2 1

0.8859

Q2 Unit 1

location2 rmi

Q3 1

0.8852

Q3 Unit 1

location3 rmi

Q4 1

0.9008

Q4 Unit 1

location4 rmi

Q5 1

0.8985

Q5 Unit 1

location5 rmi

Math Operator 1

equalto

BaseIO 1

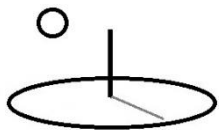
none

QT 1

1.7569

QT Unit 1

base MCA score



DevTreks –social budgeting that improves lives and livelihoods

CTAP Ex 3 - Generic

<https://www.devtreks.org/greentreks/preview/carbon/ou>

QT 1	QT Unit 1
1.7586	base MCA score
Math Type 1	Math Sub Type 1
algorithm1	subalgorithm11
QT D1 1	QT D1 Unit 1
1.7575	category low ci
QT D2 1	QT D2 Unit 1
1.7596	category high ci
QT Most 1	QT Most Unit 1
1.8147	ri all locations for B
QT Low 1	QT Low Unit 1
1.8138	lower90% ci
QT High 1	QT High Unit 1
1.8156	upper90% ci
Math Expression 1	
I1.Q1.distribtype + I1.Q2.QT + I1.Q3.QTUnit + I1.Q4.QTD1+ I1.Q5.QTD'	
Math Result 1	
<pre>rmi results label,location,indicator,total,distribtype,QTM,QTMUnit,QTL,QTLUnit,QTU, QTUUnit,normalization,weight,quantity RI1,1.0000,RiskIdentification,0,none,0.8867,category mean,0.8862,category low ci,0.8872,category high ci,none,1.0000,1.0000 RI1A,1.0000,DisasterInventory,0,normal,0.1472,ri all locations for</pre>	

**Indicator.URL TEXT:** The following labeling conventions are slight variations of the conventions used by the references. The algorithm uses the number of characters in the Label to determine which row of data is a Risk Management Index (2), a Categorical Index (3), and which row is an Indicator (4). With the exception of the “TR” Risk Management Index, the characters



DevTreks –social budgeting that improves lives and livelihoods

themselves can be changed, but the strings used in the baseline must be able to find their corresponding alternatives (which use the same “\_A, \_B suffix extensions as the other algorithms). The RMI and CI rows are placeholders and do not have probability distributions – they are used to hold the aggregated Indicator confidence intervals. The column named location must be integers. The column named distribution specifies the probability density distribution to use in the Monte Carlo simulation for this Indicator.

Version 1.9.8 started requiring uniform 4 level hierarchies in these datasets. Previous datasets must be modified as shown in this example.

The normalization column must use the same exact options used in other algorithms (i.e. zscore, minmax, logistic, logit, or tanh). The weight column is a double that is used as a multiplier. The quantity column is only used to stay consistent with the data formats employed in other subalgorithms and uses default values set to 1.

For simplicity, Alternative A increases the baseline values by 10% and Alternative B adds another 10% to Alternative A’s values.



## DevTreks –social budgeting that improves lives and livelihoods

label	location	indicator	total	distribtype	QT	QTUnit	QTD1	QTD1Unit	QTD2	QTD2Unit	normaliza	weight	quantity
RI1		1 RiskIdentification	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI1A		1 DisasterInventory	0.0000	normal	2.0000	mean	2.0000	mean	0.4000	sd	logistic	0.1670	1.0000
RI1B		1 HazardMonitoring	0.0000	normal	1.0000	mean	1.0000	mean	0.2000	sd	logistic	0.1670	1.0000
RI1C		1 HazardEvaluation	0.0000	normal	3.2500	mean	3.2500	mean	0.6500	sd	logistic	0.1670	1.0000
RI1D		1 VulnerabilityAssess	0.0000	normal	2.5000	mean	2.5000	mean	0.5000	sd	logistic	0.1670	1.0000
RI1E		1 PublicInformation	0.0000	normal	4.7500	mean	4.7500	mean	0.9500	sd	logistic	0.1670	1.0000
RI1F		1 TrainingEducation	0.0000	normal	1.5000	mean	1.5000	mean	0.3000	sd	logistic	0.1670	1.0000
RI		1 AllRiskIdentification	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RR2		1 RiskReduction	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RR2A		1 LandUsePlanning	0.0000	normal	2.0000	mean	0.1000	mean	0.0200	sd	logistic	0.1670	1.0000
RR2B		1 EnvironmentalProt	0.0000	normal	1.0000	mean	1.0000	mean	0.2000	sd	logistic	0.1670	1.0000
RR2C		1 HazardControl	0.0000	normal	3.2500	mean	3.2500	mean	0.6500	sd	logistic	0.1670	1.0000
RR2D		1 HousingImprovement	0.0000	normal	2.5000	mean	2.5000	mean	0.5000	sd	logistic	0.1670	1.0000
RR2E		1 SafetyStandards	0.0000	normal	4.7500	mean	4.7500	mean	0.9500	sd	logistic	0.1670	1.0000
RR2F		1 AssetImprovement	0.0000	normal	1.5000	mean	1.5000	mean	0.3000	sd	logistic	0.1670	1.0000
RR		1 AllRiskReduction	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
DM3		1 DisasterManagement	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
DM3A		1 EmergencyOperati	0.0000	normal	2.0000	mean	2.0000	mean	0.4000	sd	logistic	0.1670	1.0000
DM3B		1 EmergencyRespon	0.0000	normal	1.0000	mean	1.0000	mean	0.2000	sd	logistic	0.1670	1.0000
DM3C		1 PhysicalCapital	0.0000	normal	3.2500	mean	3.2500	mean	0.6500	sd	logistic	0.1670	1.0000
DM3D		1 InstitutionalRespo	0.0000	normal	2.5000	mean	2.5000	mean	0.5000	sd	logistic	0.1670	1.0000
DM3E		1 CommunityPrepara	0.0000	normal	4.7500	mean	4.7500	mean	0.9500	sd	logistic	0.1670	1.0000
DM3F		1 AssetRehabilitatio	0.0000	normal	1.5000	mean	1.5000	mean	0.3000	sd	logistic	0.1670	1.0000
DM		1 AllDisasterManage	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
FP4		1 FinancialProtection	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
FP4A		1 EmergencyOrganiz	0.0000	normal	2.0000	mean	2.0000	mean	0.4000	sd	logistic	0.1670	1.0000
FP4B		1 InstitutionalStreng	0.0000	normal	1.0000	mean	1.0000	mean	0.2000	sd	logistic	0.1670	1.0000
FP4C		1 BudgetAllocation	0.0000	normal	3.2500	mean	3.2500	mean	0.6500	sd	logistic	0.1670	1.0000
FP4D		1 SafetyNets	0.0000	normal	2.5000	mean	2.5000	mean	0.5000	sd	logistic	0.1670	1.0000
FP4E		1 InsuranceCoverage	0.0000	normal	4.7500	mean	4.7500	mean	0.9500	sd	logistic	0.1670	1.0000
FP4F		1 PrivateInsurance	0.0000	normal	1.5000	mean	1.5000	mean	0.3000	sd	logistic	0.1670	1.0000
FP		1 AllFinancialProtect	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
TR		1 RiskManagementIn	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI1		2 RiskIdentification	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000

The following image show some of the resultant calculations. Normalized confidence intervals become much more condensed when normalized. Some analysis may prefer not to normalize the vector of Sub Indicator values at all, rescale the initial Indicator values, rescale the initial cost values, or carry out other types of data transformations with the initial data.



## DevTreks –social budgeting that improves lives and livelihoods

label	location	indicator	total	distribtype	QTM	QTMUnit	QTL	QTLUnit	QTU	QTUUnit	normalizat	weight	quantity
RI1	1.0000	RiskIdentif	0.0000	none	0.8859	category n	0.8841	category lc	0.8875	category h none		1.0000	1.0000
RI1A	1.0000	DisasterIn	0.0000	normal	0.1470	mean	0.1466	lower 90%	0.1473	upper 90%	logistic	0.1670	1.0000
RI1B	1.0000	HazardMo	0.0000	normal	0.1220	mean	0.1216	lower 90%	0.1223	upper 90%	logistic	0.1670	1.0000
RI1C	1.0000	HazardEva	0.0000	normal	0.1607	mean	0.1605	lower 90%	0.1609	upper 90%	logistic	0.1670	1.0000
RI1D	1.0000	Vulnerabili	0.0000	normal	0.1542	mean	0.1539	lower 90%	0.1545	upper 90%	logistic	0.1670	1.0000
RI1E	1.0000	PublicInfo	0.0000	normal	0.1655	mean	0.1655	lower 90%	0.1656	upper 90%	logistic	0.1670	1.0000
RI1F	1.0000	TrainingEd	0.0000	normal	0.1364	mean	0.1360	lower 90%	0.1368	upper 90%	logistic	0.1670	1.0000
RI	1.0000	AllRiskIder	0.0000	none	0.8859	risk mngt i	0.8841	category lc	0.8875	category h none		1.0000	1.0000
RR2	1.0000	RiskReduc	0.0000	none	0.8265	category n	0.8251	category lc	0.8279	category h none		1.0000	1.0000
RR2A	1.0000	LandUsePl	0.0000	normal	0.0877	mean	0.0876	lower 90%	0.0877	upper 90%	logistic	0.1670	1.0000
RR2B	1.0000	Environme	0.0000	normal	0.1220	mean	0.1216	lower 90%	0.1223	upper 90%	logistic	0.1670	1.0000
RR2C	1.0000	HazardCor	0.0000	normal	0.1607	mean	0.1605	lower 90%	0.1609	upper 90%	logistic	0.1670	1.0000
RR2D	1.0000	HousingIm	0.0000	normal	0.1542	mean	0.1539	lower 90%	0.1545	upper 90%	logistic	0.1670	1.0000
RR2E	1.0000	SafetyStan	0.0000	normal	0.1655	mean	0.1655	lower 90%	0.1656	upper 90%	logistic	0.1670	1.0000
RR2F	1.0000	AssetImpr	0.0000	normal	0.1364	mean	0.1360	lower 90%	0.1368	upper 90%	logistic	0.1670	1.0000
RR	1.0000	AllRiskRed	0.0000	none	0.8265	risk mngt i	0.8251	category lc	0.8279	category h none		1.0000	1.0000
DM3	1.0000	DisasterMi	0.0000	none	0.8859	category n	0.8841	category lc	0.8875	category h none		1.0000	1.0000
DM3A	1.0000	Emergency	0.0000	normal	0.1470	mean	0.1466	lower 90%	0.1473	upper 90%	logistic	0.1670	1.0000
DM3B	1.0000	Emergency	0.0000	normal	0.1220	mean	0.1216	lower 90%	0.1223	upper 90%	logistic	0.1670	1.0000
DM3C	1.0000	PhysicalCa	0.0000	normal	0.1607	mean	0.1605	lower 90%	0.1609	upper 90%	logistic	0.1670	1.0000
DM3D	1.0000	Institution	0.0000	normal	0.1542	mean	0.1539	lower 90%	0.1545	upper 90%	logistic	0.1670	1.0000
DM3E	1.0000	Communit	0.0000	normal	0.1655	mean	0.1655	lower 90%	0.1656	upper 90%	logistic	0.1670	1.0000
DM3F	1.0000	AssetReha	0.0000	normal	0.1364	mean	0.1360	lower 90%	0.1368	upper 90%	logistic	0.1670	1.0000
DM	1.0000	AllDisaster	0.0000	none	0.8859	risk mngt i	0.8841	category lc	0.8875	category h none		1.0000	1.0000
FP4	1.0000	FinancialPi	0.0000	none	0.8859	category n	0.8841	category lc	0.8875	category h none		1.0000	1.0000
FP4A	1.0000	Emergency	0.0000	normal	0.1470	mean	0.1466	lower 90%	0.1473	upper 90%	logistic	0.1670	1.0000
FP4B	1.0000	Institution	0.0000	normal	0.1220	mean	0.1216	lower 90%	0.1223	upper 90%	logistic	0.1670	1.0000
FP4C	1.0000	BudgetAllc	0.0000	normal	0.1607	mean	0.1605	lower 90%	0.1609	upper 90%	logistic	0.1670	1.0000
FP4D	1.0000	SafetyNets	0.0000	normal	0.1542	mean	0.1539	lower 90%	0.1545	upper 90%	logistic	0.1670	1.0000
FP4E	1.0000	InsuranceC	0.0000	normal	0.1655	mean	0.1655	lower 90%	0.1656	upper 90%	logistic	0.1670	1.0000
FP4F	1.0000	PrivateInsu	0.0000	normal	0.1364	mean	0.1360	lower 90%	0.1368	upper 90%	logistic	0.1670	1.0000
FP	1.0000	AllFinancia	0.0000	none	0.8859	risk mngt i	0.8841	category lc	0.8875	category h none		1.0000	1.0000
TR	1.0000	RiskManag	0.0000	none	0.8710	risk mngt i	0.8694	category lc	0.8726	category h none		1.0000	1.0000
RI1	2.0000	RiskIdentif	0.0000	none	0.8859	category n	0.8841	category lc	0.8875	category h none		1.0000	1.0000

### Indicator 2. Costs of Alternatives Distribution

The following image verifies that this Indicator use the exact same techniques as subalgorithm10, but instead of putting costs on disaster interventions alone, costs are also placed on the changes being made to increase the performance of civil disaster management. These improvements are subject to the same tradeoffs as any other government budget expenditure, and decisions must be based upon the cost effectiveness of any proposed improvement (i.e. at least in rational societies). Because the properties are the same as the other subalgorithms, including the use of sensitivity analysis, no additional documentation is needed.





DevTreks –social budgeting that improves lives and livelihoods

Indicator 5. Costs of Alternatives (million US\$)									
Description: The cost for each project alternative equals discounted installation cost and a stream of operating and maintenance costs (\$2.5 per year).									
label	altern	loc_distrib	total	installcost	installdistr	omcost	omdistrib	isprojectcost	
AC1A	Currer	1_QT	0.0000	100.0000	normal	1.5000	normal	yes	
AC1A	Currer	1_QTD1	0.0000	100.0000	normal	1.5000	normal	yes	
AC1A	Currer	1_QTD2	0.0000	10.0000	normal	0.1500	normal	yes	
AC1A_A Altern	1_QT		0.0000	10000.0000	normal	2.5000	normal	yes	
AC1A_A Altern	1_QTD1		0.0000	10000.0000	normal	2.5000	normal	yes	
AC1A_A Altern	1_QTD2		0.0000	1000.0000	normal	0.2500	normal	yes	
AC1A_B Altern	1_QT		0.0000	11000.0000	normal	5.0000	normal	yes	
AC1A_B Altern	1_QTD1		0.0000	11000.0000	normal	5.0000	normal	yes	
AC1A_B Altern	1_QTD2		0.0000	1100.0000	normal	0.5000	normal	yes	
AC1A	Currer	2_QT	0.0000	100.0000	normal	1.5000	normal	yes	
AC1A	Currer	2_QTD1	0.0000	100.0000	normal	1.5000	normal	yes	
AC1A	Currer	2_QTD2	0.0000	10.0000	normal	0.1500	normal	yes	
AC1A_A Altern	2_QT		0.0000	12500.0000	normal	2.5000	normal	yes	
AC1A_A Altern	2_QTD1		0.0000	12500.0000	normal	2.5000	normal	yes	
AC1A_A Altern	2_QTD2		0.0000	1250.0000	normal	0.2500	normal	yes	
AC1A_B Altern	2_QT		0.0000	13500.0000	normal	7.0000	normal	yes	
AC1A_B Altern	2_QTD1		0.0000	13500.0000	normal	7.0000	normal	yes	
AC1A_B Altern	2_QTD2		0.0000	1350.0000	normal	0.7500	normal	yes	

### Indicator 3. Cost Effectiveness Analysis.

This Indicator is calculated in a similar manner as the CEA Indicator in subalgorithm10. It divides the changes in Indicator 2's alternative costs by the changes in Indicator 1's alternative Indicators to calculate cost effectiveness ratios.

Selected properties include:

**Distribution Type:** none (defined in the URL TEXT file)

**Math Type and Math Sub Type:** algorithm1, subalgorithm11

**Units:** automatically filled in (but most units that are entered manually will not be overwritten)

The following Math Expression is only used to identify the columns of TEXT data to include in the calculation.

**Math Expression:**



DevTreks –social budgeting that improves lives and livelihoods

$I3.Q1.distribtype + I3.Q2.QTM + I3.Q3.QTMUnit + I3.Q4.QTL + I3.Q5.QTLUnit + I3.Q6.QTU + I3.Q7.QTUUnit + I3.Q8.QTUUnit + I3.Q9.quantity$

**Qs** = All of the Qs automatically document the project alternative with the lowest cost effectiveness ratio. The QTMUnit property can be used to find the corresponding 3 rows of full calculations in the Math Results.

**Math Results** =

[http://localhost/resources/network\\_carbon/resourcepack\\_530/resource\\_1819/Ind3-Math-Result.csv](http://localhost/resources/network_carbon/resourcepack_530/resource_1819/Ind3-Math-Result.csv)

or

[https://devtreks1.blob.core.windows.net/resources/network\\_carbon/resourcepack\\_1540/resource\\_8020/Ind3-Math-Result.csv](https://devtreks1.blob.core.windows.net/resources/network_carbon/resourcepack_1540/resource_8020/Ind3-Math-Result.csv)

Due to the size of the calculated Math Results, a URL is used to store the results. Large Math Results should always be stored using URLs. Make sure that children Input or Output Series use unique URLs. The following images display some of the results. These results list the cost effectiveness analysis for each project alternative in the columns and the confidence intervals for each indicator/rate/life sensitivity analysis in the rows. The csv file can be imported into other software for further analysis or to develop multimedia support. The ratios can be scaled in a manner that decision makers can understand.



DevTreks –social budgeting that improves lives and livelihoods

label	indicator	loc_confid	total	RI1_perfor	RI1_cost	RI1_A_per	RI1_A_cost	RI1_A_cer	RI1_B_per	RI1_B_cost	RI1_B_cer
RI1_A	RiskIdentification	1_QTM_0.05_50	0.0000	0.8859	122.4242	0.9008	9553.9733	632989.8725	0.9147	10550.3789	362081.7604
RI1_A	RiskIdentification	1_QTL_0.05_50	0.0000	0.8841	121.7728	0.8991	9503.1927	625427.9933	0.9132	10494.3036	356444.3574
RI1_A	RiskIdentification	1_QTU_0.05_50	0.0000	0.8875	123.0755	0.9024	9604.7538	636354.2483	0.9162	10606.4542	365274.5192
RI1_A	RiskIdentification	1_QTM_0.05_75	0.0000	0.8859	124.2648	0.9008	9557.0410	633072.2282	0.9147	10556.5142	362230.8819
RI1_A	RiskIdentification	1_QTL_0.05_75	0.0000	0.8841	123.6036	0.8991	9506.2441	625509.3667	0.9132	10500.4063	356591.1581
RI1_A	RiskIdentification	1_QTU_0.05_75	0.0000	0.8875	124.9260	0.9024	9607.8378	636437.0336	0.9162	10612.6220	365424.9477
RI1_A	RiskIdentification	1_QTM_0.12_50	0.0000	0.8859	101.5782	0.9008	8934.8591	592837.6443	0.9147	9846.9994	338382.6806
RI1_A	RiskIdentification	1_QTL_0.12_50	0.0000	0.8841	101.0380	0.8991	8887.3695	585755.4333	0.9132	9794.6623	333114.2371
RI1_A	RiskIdentification	1_QTU_0.12_50	0.0000	0.8875	102.1183	0.9024	8982.3487	595988.6174	0.9162	9899.3365	341366.4878
RI1_A	RiskIdentification	1_QTM_0.12_75	0.0000	0.8859	101.6188	0.9008	8934.9268	592839.4631	0.9147	9847.1349	338385.9757
RI1_A	RiskIdentification	1_QTL_0.12_75	0.0000	0.8841	101.0784	0.8991	8887.4369	585757.2333	0.9132	9794.7971	333117.4811
RI1_A	RiskIdentification	1_QTU_0.12_75	0.0000	0.8875	102.1592	0.9024	8982.4168	595990.4430	0.9162	9899.4727	341369.8084
RI1A_A	DisasterInventory	1_QTM_0.05_50	0.0000	0.1470	122.4242	0.1502	9553.9733	2947359.0937	0.1533	10550.3789	1655230.9048
RI1A_A	DisasterInventory	1_QTL_0.05_50	0.0000	0.1466	121.7728	0.1499	9503.1927	2842854.5152	0.1529	10494.3036	1646433.4603
RI1A_A	DisasterInventory	1_QTU_0.05_50	0.0000	0.1473	123.0755	0.1506	9604.7538	2873235.8485	0.1536	10606.4542	1664028.3651
RI1A_A	DisasterInventory	1_QTM_0.05_75	0.0000	0.1470	124.2648	0.1502	9557.0410	2947742.5625	0.1533	10556.5142	1655912.6032
RI1A_A	DisasterInventory	1_QTL_0.05_75	0.0000	0.1466	123.6036	0.1499	9506.2441	2843224.3939	0.1529	10500.4063	1647111.5397
RI1A_A	DisasterInventory	1_QTU_0.05_75	0.0000	0.1473	124.9260	0.1506	9607.8378	2873609.6364	0.1536	10612.6220	1664713.6508
RI1A_A	DisasterInventory	1_QTM_0.12_50	0.0000	0.1470	101.5782	0.1502	8934.8591	2760400.2812	0.1533	9846.9994	1546892.2540
RI1A_A	DisasterInventory	1_QTL_0.12_50	0.0000	0.1466	101.0380	0.1499	8887.3695	2662524.6970	0.1529	9794.6623	1538670.5238
RI1A_A	DisasterInventory	1_QTU_0.12_50	0.0000	0.1473	102.1183	0.1506	8982.3487	2690978.9091	0.1536	9899.3365	1555114.0000
RI1A_A	DisasterInventory	1_QTM_0.12_75	0.0000	0.1470	101.6188	0.1502	8934.9268	2760408.7500	0.1533	9847.1349	1546907.3175
RI1A_A	DisasterInventory	1_QTL_0.12_75	0.0000	0.1466	101.0784	0.1499	8887.4369	2662532.8788	0.1529	9794.7971	1538685.5079
RI1A_A	DisasterInventory	1_QTU_0.12_75	0.0000	0.1473	102.1592	0.1506	8982.4168	2690987.1515	0.1536	9899.4727	1555129.1270
RI1B_A	HazardMonitoring	1_QTM_0.05_50	0.0000	0.1220	122.4242	0.1252	9553.9733	2947359.0937	0.1285	10550.3789	1604300.7231

## Scores and Decision Support Systems

Wider decision support is completed at the discretion of the analyst.



DevTreks –social budgeting that improves lives and livelihoods

### **Algorithm 1. SubAlgorithm 12. Resiliency Index (RI)**

The following image (Khazai et al, 2015) displays the initial Indicators developed for a Disaster Resilience Index completed for Mumbai, India. These indexes are used to monitor and evaluate (M&E) progress in achieving disaster prevention goals. Unlike Indexes such as the Risk Management Index, the RI does not need to contain specific Indicators. Experts assist local stakeholders to select appropriate Indicators for the 5 thematic areas displayed in the image. The authors discuss the importance of allowing local stakeholders to develop, and take ownership of, local systems of indicators.

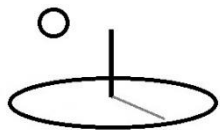


Table 4.1 Outline for the six dimensions of the DRI and the characteristics of each of these dimensions.

SECTORS	INDICATORS	CHARACTERISTICS
LEGAL AND INSTITUTIONAL	Indicator 1: Effectiveness of Legislative Framework	<ul style="list-style-type: none"> <li>• Laws, acts and regulations</li> <li>• DRR Policies</li> <li>• Compliance and Accountability</li> <li>• Resource mobilization and allocations (financial, human)</li> </ul>
	Indicator 2: Effectiveness of Institutional Arrangements	<ul style="list-style-type: none"> <li>• Organizational structures that define roles and responsibilities</li> <li>• Review, update, enforcement, monitoring and reporting process</li> <li>• Partnerships with civil society and communities</li> </ul>
AWARENESS AND CAPACITY BUILDING	Indicator 3: Training and Capacity Building	<ul style="list-style-type: none"> <li>• Institutional commitment to training and capacity building with dedicated resources and evaluations</li> <li>• Knowledge Management, Research and Development</li> </ul>
	Indicator 4: Advocacy, Communication, Education and Public Awareness	<ul style="list-style-type: none"> <li>• Commitment to advocacy and public awareness and education programs that engage all relevant audiences and stakeholders including civil society and community organizations</li> <li>• Commitment to participatory processes and community involvement</li> <li>• Research facilitation, Use of Information, Information Technology and Communication (ITC) to disseminate information</li> <li>• Pro-active and constructive Media relations</li> </ul>



SECTORS	INDICATORS	CHARACTERISTICS
CRITICAL SERVICES, INFRASTRUCTURE RESILIENCY	Indicator 5: Resiliency of Critical Services	<ul style="list-style-type: none"> <li>• Inclusive, participatory and transparent slum rehabilitation policies and programs</li> <li>• Protection of living (i.e. shelter) and livelihood conditions (i.e. access to and availability critical services including opportunities for livelihood) against disasters</li> <li>• Resiliency of health services to deliver services during a disaster</li> </ul>
	Indicator 6: Resiliency of Infrastructure	<ul style="list-style-type: none"> <li>• Resiliency of water, sewer and storm drain systems</li> <li>• Resiliency of transportation systems</li> <li>• Contingency for delivery of essential services</li> </ul>
CRITICAL SERVICES, INFRASTRUCTURE RESILIENCY	Indicator 7: Emergency Management	<ul style="list-style-type: none"> <li>• Functioning EOP with Basic Plan and ESF system</li> <li>• Year-round Response Planning and functioning SOP's</li> <li>• Drills and Simulation involving relevant stakeholders including civil society and communities</li> <li>• Preparedness programs for first responders and leaders and representatives of communities at risk</li> </ul>
	Indicator 8: Resource Management, Logistics and Contingency Planning	<ul style="list-style-type: none"> <li>• Self analysis of resource management and logistics</li> <li>• Contingency planning for key institutions for pre-defined scenario analysis and planning parameters</li> <li>• Ability to manage delivery of resources to most vulnerable populations</li> </ul>
DEVELOPMENT PLANNING, REGULATION AND RISK MITIGATION	Indicator 9: Hazard, Vulnerability and Risk Assessment	<ul style="list-style-type: none"> <li>• Awareness of hazards and vulnerabilities (natural and man-made)</li> <li>• Risk Identification and Assessment, Vulnerability and Capacity Analysis,</li> <li>• Impact Assessments (loss analysis) by relevant sectors and segments of populations at risk</li> <li>• Use of forecasting and early warning in preparedness and response planning</li> </ul>
	Indicator 10: Risk-Sensitive Urban Development	<ul style="list-style-type: none"> <li>• Risk-Sensitive Land use planning and urban re-development,</li> <li>• Enforcements of codes and standards, particularly in slum upgrading programs; quality control norms in construction</li> <li>• Reinforcing and retrofitting of critical assets and infrastructure</li> </ul>



DevTreks –social budgeting that improves lives and livelihoods

The authors use the following image to demonstrate how each indicator is tracked over time using 5 benchmark and target levels of progress: 1) little or no awareness, 2) awareness of needs, 3) engagement, and commitment, 4) policy engagement and solution development and 5) full integration. The authors also use Annex 3 to demonstrate that the five levels can be defined for local contexts, using terms such as 1) low, 2) very low, 3) neutral, 4) high, and 5) very high.

The only difference between subalgorithm12 and subalgorithm11 is the use of weighted averages in the Total Risk Index calculations. Subalgorithm12 does not use weighted averages.

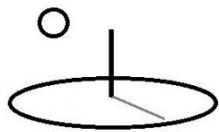


Table 4.2: Defining Target Levels of Attainment

<b>LEVEL 1</b>	'Little or no awareness' Level 1 represents little or no awareness and understanding of mainstreaming. There is no institutional policy or process for incorporating risk reduction within the functions and operations of the organization. Further, in some cases there is an adverse attitude and adverse institutional culture towards adopting measures to reduce risk. As a result, significant resistance is expected from any risk reduction initiative resulting in greater vulnerability and higher losses in the future.
<b>LEVEL 2</b>	'Awareness of needs' Level 2 refers to an early stage of awareness. The organization has a growing level of awareness, and there is support for disaster reduction among the policy makers. The institution may have activities and dedicated efforts for preparedness but these are simply limited to response. However, support is limited and does not necessarily carry through all levels of the organization; resistance to change is expected at various levels where business as usual is judged sufficient. In general, the institution has no established policy, guidelines or system for mainstreaming, and action will be needed at the highest level to establish such policies and systems. This level is expected not to result in risk reduction in the long term. Vulnerability is expected to increase.
<b>LEVEL 3</b>	"Engagement and Commitment". Level 3 refers to a high level of engagement and commitment to DRR by the institutions. However, the policies and systems have not been fully established yet. The institution may not have a deep understanding of the mainstreaming process and requirements and still has limited capacity, but overall it is willing to make the investments and has already taken some action; commitment for change, and in particular to shift from response only to mainstreaming DRR. There may be "pockets of resistance" but these are expected to be overcome with time.
<b>LEVEL 4</b>	'Policy Engagement and Solution Development' Level 4 refers to an intermediate stage in mainstreaming, where there is already an established policy for mainstreaming, an overall institutional process/system, and identifiable actions that render the system sustainable and irreversible. In general DRR is seen as an asset by policy makers who are willing to invest in it. The organization is engaged into planning and control processes to address the requirements of integrating risk reduction into its planning and development processes, and in building resiliency in the core services. Processes of coordination and regular drills and exercises have been put in place.
<b>LEVEL 5</b>	'Full integration' Level 5 refers to a situation where risk reduction is fully absorbed into planning and development processes as well as core services. The organization places high importance on reducing disaster risks in a sustainable program of action at multiple levels and within multiple sectors, and there is a comprehensive demonstration of practice. Level 5 describes a situation where disaster risk reduction is 'institutionalized'. However, this is not to suggest that an optimum level of attainment has occurred: there is still a need for further progress. The process of mainstreaming should be viewed as open-ended: while organizations should aim

The authors complete the full RI using the following 5 step process: 1) Stakeholder Participation, 2) Stakeholder Consultations. 3) Initial Indicator Development, 4) Validation of the RI in Workshops, and 5) Participatory Evaluation of the RI. They communicate the results of the RI





DevTreks –social budgeting that improves lives and livelihoods

using the concepts they explain for the following image. The UN CAPNET (2015) reference demonstrates the use of similar Drought Vulnerability Index radar graphs to communicate the results of disaster-specific indicator systems.

In the schematic below green is positive territory and red/orange is negative territory. An institution in yellow is in transition between positive and negative territory meaning there is commitment, but this may not be sustainable. The “bull’s eye” representation depicts in one glance how close to target an institution in meeting the goal of fully integrating DRR along key areas of the DRI. The above schematic is flexible, and can be used to show the evolving mainstreaming of an institution through time.

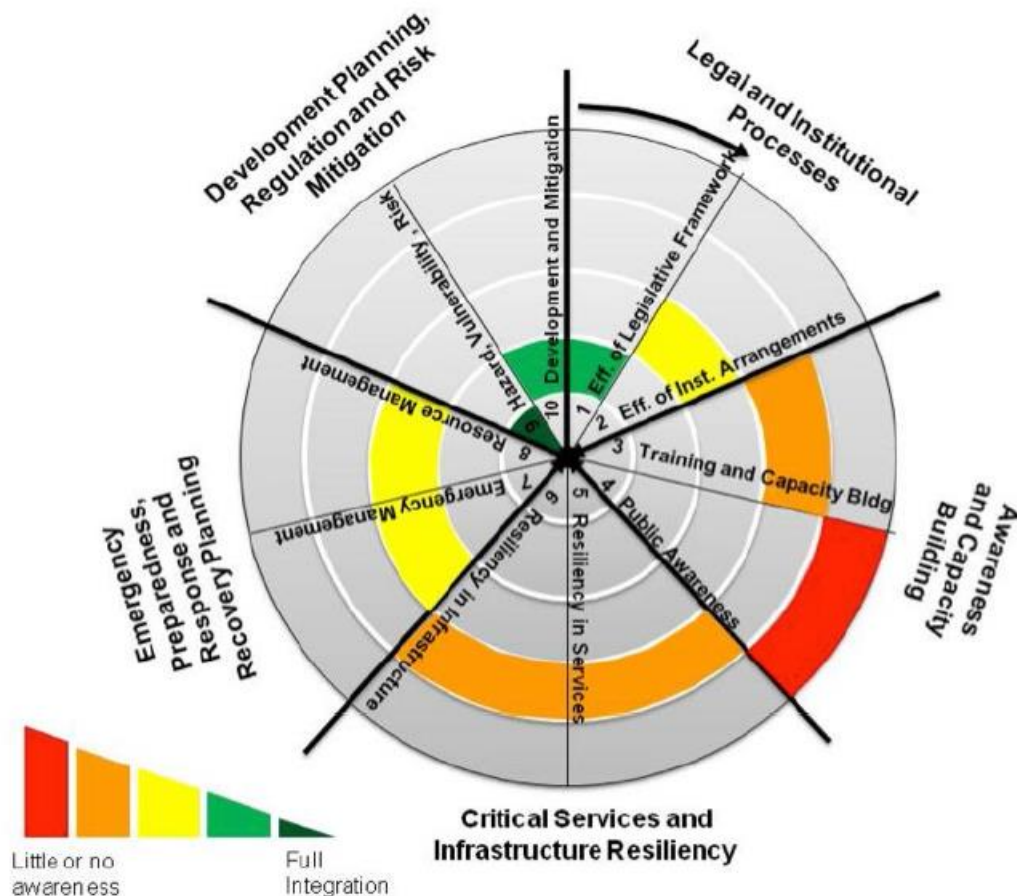
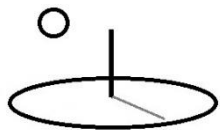


Figure 4.3 Schematic representation of the mainstreaming scale presented as an example. Goal is full integration (direction towards the “bulls-eye”, represented by dark green). The chart should be read clockwise, where each of the 10 indicators is represented by a pie.



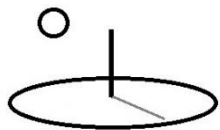
DevTreks –social budgeting that improves lives and livelihoods

Three sets of tools, demonstrated in the 3 examples that follow, can be used in DevTreks to complete these types of M&E Indexes. Example 1 demonstrates using subalgorithm12 to complete the RI. Example 2 demonstrates using Resource Stock Progress Analyzers to assess progress over time for Example 1’s aggregate Indexes. Example 3 demonstrates using M&E calculators and analyzers for completing the RI.

All of the Indicator values are fictitious and selected to facilitate debugging the calculations. Normal distributions are defined for all Indicators with the shape parameter, or QTD1, being the mean and the scale parameter, or QTD2, being a standard deviation set at 15% of the mean. For simplicity, Alternative A increases the baseline values by 10% and Alternative B adds another 10% to Alternative A’s values.

The previous Risk Management Index example demonstrated the use of Categorical Indexes (CIs) and Locational Indexes (LIs) to aggregate Indicators. In this example, the CIs correspond to the 5 thematic areas used to organize the Resiliency Indicators (i.e. Critical Services and Infrastructure Resiliency). The final Locational Indexes, are aggregated into the final Risk Management Index, is equivalent to this example’s Resiliency Index. The authors do not demonstrate normalizing, weighting, or aggregating, the Indicators as done in the RMI. So this example simply sets the normalization value to “none”, the weights to 1, but still aggregates the Indicators. If desired, the Indicators can be normalized and weighted and the final Resiliency Index can be used in a similar manner to the RMI example. Although this example uses 2 Indicators in each Categorical Index, the authors stress the importance of using as many Indicators as deemed important by local stakeholders.

The M&E Analysis 2, Earned Value Management (EVM), and Resource Stock Analysis, tutorials demonstrate the conventions, or properties, used in DevTreks for assessing performance and progress. Each calculator must set a “Target Type” property, with options such as “benchmark” or “actual”, for its associated base element. Progress is then measured using the relationship between the benchmark and actual base elements. Example 1 shows a partial



DevTreks –social budgeting that improves lives and livelihoods

exception to those rules. The benchmark, or baseline, Indicators do not have labels with “project alternative” suffixes, such as “\_A” or “\_B”. The “actual” Indicators do. That is, the project alternatives demonstrated in previous examples, are not actual alternatives in this example – instead they are used to measure progress in achieving goals, and are often related to time periods.

The algorithm requires that Indicators have the exact indexes demonstrated in the examples, although the actual number of Indicators and Indexes can vary.

Example 2 demonstrates that multiple base Input and/or Outputs can be used to analyze progress in achieving disaster prevention goals. In this example, some base elements are used to hold “benchmark” Indicators, while others are used to hold “actual” Indicators. Resource Stock Outcome and Investment Progress Analyzers then measure the progress being made between the benchmark goals and the actual accomplishments. The Resource Stock Analysis and Earned Value Management tutorials explain more about the use of Progress Analyzers.

Example 3 demonstrates that formal Monitoring and Evaluation tools can also be used to assess progress between targeted goals and actual accomplishments. Several references (UNDP 2011, UNDP CAPNET 2015) discuss how to use M&E in the context of disaster risk reduction programs. The 49 M&E tools currently available for this purpose are documented in the Monitoring and Evaluation tutorials. In this example, M&E analysis has been conducted for Inputs, Outputs, Outcomes, Components, and Investments. Version 2.0.4 upgraded the M&E tools so that the CTA algorithms can also be used to measure the risk and uncertainty associated with M&E Indicator measurement and valuation.



DevTreks –social budgeting that improves lives and livelihoods

### Example 5. Generic RI Indicators

#### URLs:

<https://www.devtreks.org/greentreks/preview/carbon/output/CTAP Ex 4 - Generic RI/2141223464/none>

<https://www.devtreks.org/greentreks/preview/carbon/resourcepack/SubAlgo 12 RI 1A/1541/none>

<https://www.devtreks.org/greentreks/preview/carbon/resourcepack/DRRs, DRIs, RMIs, and RIs/1539/none>

<http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 4 - Generic RI/2141223470/none>

#### Score. Starting Properties

The following initial Score properties are used in this example:

**Confidence Interval:** 90

**Random Seed:** 7

**Iterations:** 10,000

**Description:** This example demonstrates ....

#### Indicator 1. Resiliency Indicator Distribution

This Indicator defines probability distributions, normalization functions, and weights, for each of the RI Indicators. This Indicator is equivalent to Indicator 2, Exposure Distribution, in subalgorithms 9 and 10. The values are fictitious and selected to facilitate debugging the calculations.

Selected properties include:

**Distribution Type:** none (URL datasets are used)

**Math Type and Math Sub Type:** algorithm1, subalgorithm12



DevTreks –social budgeting that improves lives and livelihoods

**Units:** automatically filled in (but most units that are entered manually will not be overwritten)

The following Math Expression is only used to identify the columns of TEXT data to include in the calculation.

**Qs** = Q1 to Q5 automatically document the RIs for the first five “Locational Indexes”. The QTs document a summation of the Locational Indexes. The QTM documents a summation of the TR rows for all locations for the project alternative with the highest TRs.

**Math Expression =**

$$\text{I1.Q1.distribtype} + \text{I1.Q2.QT} + \text{I1.Q3.QTUnit} + \text{I1.Q4.QTD1} + \text{I1.Q5.QTD1Unit} + \\ \text{I1.Q6.QTD2} + \text{I1.Q7.QTD2Unit} + \text{I1.Q8.normalization} + \text{I1.Q9.weight} + \text{I1.Q10.quantity}$$

The following images show the initial data used in Indicator 1. The quantity column is only used to stay consistent with the data formats employed in other subalgorithms and uses default values set to 1.

Version 1.9.8 started requiring uniform 4 level hierarchies in these datasets. Previous datasets must be modified as shown in this example or as shown in the previous RMI example. The previous example used multiple Locational Indexes (i.e. RI, RR, DM, and FP). This example uses one Locational Index, RI. Subalgorithms 9, 10, 11, and 12, support arbitrary numbers of Indicators, Categorical Indexes, Locational Indexes, and locations, but their indexing must be uniform.



## DevTreks –social budgeting that improves lives and livelihoods

label	location	indicator	total	distribtype	QT	QTUnit	QTD1	QTD1Unit	QTD2	QTD2Unit	normaliz	weight	quantity
RI1	1	LegalInstitutional	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI1A	1	LegislativeFramew	0.0000	normal	2.0000	mean	2.0000	mean	0.3000	sd	none	1.0000	1.0000
RI1B	1	InstitutionalArrang	0.0000	normal	1.0000	mean	1.0000	mean	0.1500	sd	none	1.0000	1.0000
RI2	1	AwarenessCapacit	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI2A	1	AdvocacyCommun	0.0000	normal	0.1000	mean	0.1000	mean	0.0150	sd	none	1.0000	1.0000
RI2B	1	EnvironmentalProt	0.0000	normal	1.0000	mean	1.0000	mean	0.1500	sd	none	1.0000	1.0000
RI3	1	CriticalServicesInfr	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI3A	1	CriticalServices	0.0000	normal	2.0000	mean	2.0000	mean	0.3000	sd	none	1.0000	1.0000
RI3B	1	Infrastructure	0.0000	normal	1.0000	mean	1.0000	mean	0.1500	sd	none	1.0000	1.0000
RI4	1	EmergencyPrepare	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI4A	1	EmergencyManage	0.0000	normal	2.0000	mean	2.0000	mean	0.3000	sd	none	1.0000	1.0000
RI4B	1	ResourceManagen	0.0000	normal	1.0000	mean	1.0000	mean	0.1500	sd	none	1.0000	1.0000
RI5	1	DevelopmentPlanr	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI5A	1	HazardVulnerabilit	0.0000	normal	2.5000	mean	2.5000	mean	0.3750	sd	none	1.0000	1.0000
RI5B	1	RiskSensitiveDevel	0.0000	normal	4.7500	mean	4.7500	mean	0.7125	sd	none	1.0000	1.0000
RI	1	AllMonitoringandE	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
TR	1	ResiliencyIndex	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI1	2	LegalInstitutional	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000

...

RI4_B	2	EmergencyPrepare	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI4A_B	2	EmergencyManage	0.0000	normal	4.0227	mean	4.0227	mean	0.6034	sd	none	1.0000	1.0000
RI4B_B	2	ResourceManagen	0.0000	normal	2.0114	mean	2.0114	mean	0.3017	sd	none	1.0000	1.0000
RI5_B	2	DevelopmentPlanr	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI5A_B	2	HazardVulnerabilit	0.0000	normal	3.0000	mean	3.0000	mean	0.4500	sd	none	1.0000	1.0000
RI5B_B	2	RiskSensitiveDevel	0.0000	normal	3.6369	mean	3.6369	mean	0.5455	sd	none	1.0000	1.0000
RI_B	2	AllMonitoringandE	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
TR_B	2	ResiliencyIndex	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000

The following are partial results for this Indicator. These results confirm that the only difference between subalgorithm 11 and 12 is the use of weighted averages to calculate TR.

label	location	indicator	total	distribtype	QTM	QTMUnit	QTL	QTLUnit	QTU	QTUUnit	normal	weight	quantity
RI1	1.0000	LegalInstit	0.0000	none	2.9906	category r	2.9832	category low	2.9980	category h	none	1.0000	1.0000
RI1A	1.0000	Legislative	0.0000	normal	1.9937	mean	1.9888	lower 90% ci	1.9986	upper 90% none	1.0000	1.0000	1.0000
RI1B	1.0000	Institution	0.0000	normal	0.9969	mean	0.9944	lower 90% ci	0.9994	upper 90% none	1.0000	1.0000	1.0000
RI2	1.0000	Awareness	0.0000	none	1.0966	category r	1.0939	category low	1.0993	category h	none	1.0000	1.0000
RI2A	1.0000	AdvocacyC	0.0000	normal	0.0997	mean	0.0995	lower 90% ci	0.0999	upper 90% none	1.0000	1.0000	1.0000
RI2B	1.0000	Environme	0.0000	normal	0.9969	mean	0.9944	lower 90% ci	0.9994	upper 90% none	1.0000	1.0000	1.0000
RI3	1.0000	CriticalSer	0.0000	none	2.9906	category r	2.9832	category low	2.9980	category h	none	1.0000	1.0000
RI3A	1.0000	CriticalSer	0.0000	normal	1.9937	mean	1.9888	lower 90% ci	1.9986	upper 90% none	1.0000	1.0000	1.0000
RI3B	1.0000	Infrastruct	0.0000	normal	0.9969	mean	0.9944	lower 90% ci	0.9994	upper 90% none	1.0000	1.0000	1.0000
RI4	1.0000	Emergency	0.0000	none	2.9906	category r	2.9832	category low	2.9980	category h	none	1.0000	1.0000
RI4A	1.0000	Emergency	0.0000	normal	1.9937	mean	1.9888	lower 90% ci	1.9986	upper 90% none	1.0000	1.0000	1.0000
RI4B	1.0000	ResourceN	0.0000	normal	0.9969	mean	0.9944	lower 90% ci	0.9994	upper 90% none	1.0000	1.0000	1.0000
RI5	1.0000	Developm	0.0000	none	7.2271	category r	7.2092	category low	7.2450	category h	none	1.0000	1.0000
RI5A	1.0000	HazardVul	0.0000	normal	2.4921	mean	2.4859	lower 90% ci	2.4983	upper 90% none	1.0000	1.0000	1.0000
RI5B	1.0000	RiskSensiti	0.0000	normal	4.7350	mean	4.7233	lower 90% ci	4.7467	upper 90% none	1.0000	1.0000	1.0000
RI	1.0000	AllMonitor	0.0000	none	17.2955	resiliency	17.2527	category low	17.3383	category h	none	1.0000	1.0000
TR	1.0000	ResiliencyI	0.0000	none	17.2955	resiliency	17.2527	category low	17.3383	category h	none	1.0000	1.0000



DevTreks –social budgeting that improves lives and livelihoods

## Indicator 2. Costs of Alternatives Distribution

No cost data was available for this Indicator, so it uses the same data as subalgorithm 10. Actual cost data should reflect the amount of funds being spent to achieve the performance improvements being monitored and evaluated.

## Indicator 3. Cost Effectiveness Analysis.

This Indicator is calculated in the same manner as the RMI Example, but uses subalgorithm 12. The following image displays part of the Math Results. The same caveats about careful data management and data transformation apply here.

label	indicator	loc_confid	total	RI1_perfi	RI1_cost	RI1_A_	RI1_A_cost	RI1_A_cer	RI1_B_pe	RI1_B_cost	RI1_B_cer
RI1_A	LegallInstitutio	1_QTM_0.05_50	0.0000	2.9906	122.3655	3.9550	9549.3609	9774.9849	5.2305	10545.2856	4653.2971
RI1_A	LegallInstitutio	1_QTL_0.05_50	0.0000	2.9832	122.1637	3.9452	9533.6650	9783.2654	5.2176	10527.9526	4657.0842
RI1_A	LegallInstitutio	1_QTU_0.05_50	0.0000	2.9980	122.5673	3.9648	9565.0568	9766.7454	5.2434	10562.6185	4649.5285
RI1_A	LegallInstitutio	1_QTM_0.05_75	0.0000	2.9906	124.2052	3.9550	9552.4271	9776.2566	5.2305	10551.4179	4655.2135
RI1_A	LegallInstitutio	1_QTL_0.05_75	0.0000	2.9832	124.0003	3.9452	9536.7262	9784.5384	5.2176	10534.0749	4659.0022
RI1_A	LegallInstitutio	1_QTU_0.05_75	0.0000	2.9980	124.4101	3.9648	9568.1280	9768.0160	5.2434	10568.7609	4651.4433
RI1_A	LegallInstitutio	1_QTM_0.12_50	0.0000	2.9906	101.5293	3.9550	8930.5456	9154.9319	5.2305	9842.2456	4348.7282
RI1_A	LegallInstitutio	1_QTL_0.12_50	0.0000	2.9832	101.3621	3.9452	8915.8668	9162.6868	5.2176	9826.0682	4352.2673
RI1_A	LegallInstitutio	1_QTU_0.12_50	0.0000	2.9980	101.6965	3.9648	8945.2243	9147.2153	5.2434	9858.4229	4345.2064
RI1_A	LegallInstitutio	1_QTM_0.12_75	0.0000	2.9906	101.5699	3.9550	8930.6133	9154.9600	5.2305	9842.3810	4348.7705
RI1_A	LegallInstitutio	1_QTL_0.12_75	0.0000	2.9832	101.4027	3.9452	8915.9344	9162.7149	5.2176	9826.2034	4352.3097
RI1_A	LegallInstitutio	1_QTU_0.12_75	0.0000	2.9980	101.7372	3.9648	8945.2922	9147.2435	5.2434	9858.5586	4345.2487
RI1A_A	LegislativeFran	1_QTM_0.05_50	0.0000	1.9937	122.3655	2.6367	9549.3609	14660.9571	3.4870	10545.2856	6979.7898
RI1A_A	LegislativeFran	1_QTL_0.05_50	0.0000	1.9888	122.1637	2.6302	9533.6650	14673.3728	3.4784	10527.9526	6985.6263
RI1A_A	LegislativeFran	1_QTU_0.05_50	0.0000	1.9986	122.5673	2.6432	9565.0568	14648.6030	3.4956	10562.6185	6973.9821
RI1A_A	LegislativeFran	1_QTM_0.05_75	0.0000	1.9937	124.2052	2.6367	9552.4271	14662.8645	3.4870	10551.4179	6982.6644
RI1A_A	LegislativeFran	1_QTL_0.05_75	0.0000	1.9888	124.0003	2.6302	9536.7262	14675.2820	3.4784	10534.0749	6988.5034
RI1A_A	LegislativeFran	1_QTU_0.05_75	0.0000	1.9986	124.4101	2.6432	9568.1280	14650.5087	3.4956	10568.7609	6976.8542
RI1A_A	LegislativeFran	1_QTM_0.12_50	0.0000	1.9937	101.5293	2.6367	8930.5456	13730.9740	3.4870	9842.2456	6522.9467
RI1A_A	LegislativeFran	1_QTL_0.12_50	0.0000	1.9888	101.3621	2.6302	8915.8668	13742.6017	3.4784	9826.0682	6528.4010
RI1A_A	LegislativeFran	1_QTU_0.12_50	0.0000	1.9986	101.6965	2.6432	8945.2243	13719.4040	3.4956	9858.4229	6517.5193
RI1A_A	LegislativeFran	1_QTM_0.12_75	0.0000	1.9937	101.5699	2.6367	8930.6133	13731.0162	3.4870	9842.3810	6523.0102
RI1A_A	LegislativeFran	1_QTL_0.12_75	0.0000	1.9888	101.4027	2.6302	8915.9344	13742.6437	3.4784	9826.2034	6528.4645
RI1A_A	LegislativeFran	1_QTU_0.12_75	0.0000	1.9986	101.7372	2.6432	8945.2922	13719.4462	3.4956	9858.5586	6517.5828
RI1B_A	InstitutionalAr	1_QTM_0.05_50	0.0000	0.9969	122.3655	1.3183	9549.3609	29331.0373	1.7435	10545.2856	13960.5145



DevTreks –social budgeting that improves lives and livelihoods

## **Appendix C. Decision Support System Algorithms**

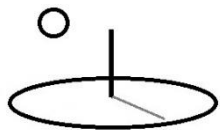
This Appendix supplements, or expands the use of, the algorithms introduced in the previous Appendixes with additional Decision Support Systems (DSS). Appendix A introduced economic analysis techniques, such as Cost Benefit Analysis, that had limited capacity to study the distribution of gains among winners and losers, externalities, and tradeoffs. Appendix B introduced indicator systems that were described as having potential limitations, such as picking indicators that address the symptoms, rather than the root causes, of disasters. These examples and algorithms demonstrate potential ways to take a “sensible holistic view” to deal with these shortfalls by using Scores to conduct analyses based on DSS systems such as (UNEP 2011, UNDP CAPNET 2015):

- a) Scenario and Trend Analysis (see Appendix A for examples)
- b) Multi-Criteria Analysis (MCA)
- c) Strengths, Limitations, Opportunities, and Threats (SWOT) strategic planning processes
- d) Driver, Pressure, Impact, Response (DPSIR) performance systems

The Loss EP Distributions, Risk Management Indexes, Benefit Cost Ratios, and Cost Effectiveness Ratios, introduced in the previous Appendixes become part of the overall decision criteria in DSS systems, rather than the sole decision criteria.

Even with these examples of expanded decision support, algorithms alone are not sufficient to tackle all of the dimensions needed to manage climate-change induced disasters, such as droughts. For example, the UNDP (2011) identified 5 basic steps needed to “mainstream” drought risk management that start with stakeholder identification and end with program monitoring and evaluation. The UN IDMP (2014) recommends a 10 step process that can be used to implement national drought mitigation policies, starting with the establishment of a drought management team and ending with the evaluation and revision of national drought mitigation policies. Strong disaster management institutions are needed that can provide the





DevTreks –social budgeting that improves lives and livelihoods

overall context, and manpower, for managing disasters. It's not clear yet how many of these institutions will end up being primarily cloud-based, rather than political jurisdiction-based. Efficiency dictates the former in the long term, convention means the latter in the short term.

The following examples will be explained using case studies of natural resource damage assessments that have been completed in developing countries. Example 1 uses the Mechler et al (2008) drought CBA conducted in Uttar Pradesh, India. Example 1 also uses the UNEP (2011) integrated water management MCA conducted for the Sana'a Water Basin, Yemen. Example 2 uses the UN CAPNET (2015) Drought Vulnerability Index as supplemental decision support for Example 1. Limited documentation is presented for algorithms that have already been explained in Appendixes A and B.

The Social Performance Analysis tutorials verify that Versions 2.1.2 and 2.1.4 introduced new algorithms that more fully address the principal concerns raised in this Appendix -equity, externalities, and tradeoffs.



DevTreks –social budgeting that improves lives and livelihoods

### **Example 8. Drought, Uttar Pradesh, India and Sana’a Water Basin, Yemen**

#### **URLs**

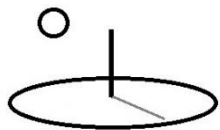
[https://www.devtreks.org/greentreks/preview/carbon/output/CTAP Example 6 - Drought DRR and DSS/2141223470/none](https://www.devtreks.org/greentreks/preview/carbon/output/CTAP%20Example%206%20-%20Drought%20DRR%20and%20DSS/2141223470/none)

[https://www.devtreks.org/greentreks/preview/carbon/resourcepack/Drought DRR and DSS/1543/none](https://www.devtreks.org/greentreks/preview/carbon/resourcepack/Drought%20DRR%20and%20DSS/1543/none)

[http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 7 - Drought DRR and DSS/2141223477/none](http://localhost:5000/greentreks/preview/carbon/output/CTAP%20Example%207%20-%20Drought%20DRR%20and%20DSS/2141223477/none)

The Rohini water basin in Uttar Pradesh, India, is the main focus of this case study. The Sana’a water basin in Yemen supplements the case study with Multi-Criteria Analysis. Climate change is particularly important because most of the Indian households are engaged in agriculture and their predominant crops are dependent upon monsoon rains. The unit of study is a representative farm household with 7 family members farming 0.8 hectares of land. This example has 3 initial objectives (i.e. the term “must attempt” has been more fully addressed in the Social Performance Analysis tutorial):

1. *CTAPs must attempt to fully address equity.* Equity and the distribution of gains from climate change mitigation technologies is especially important to understand because as Mechler et al put it “Small and marginal farmers and landless labourers, the most vulnerable groups, suffer the effects of drought the most. They not only lose the investments they made in the sowing and other operations but also lose the food grain they rely on for subsistence. The landless are also heavily affected as there is no agricultural work available locally and they lose employment opportunities.”. In addition, the second project alternative, Crop Insurance, does not directly improve the livelihoods of farmworkers. Portfolios of climate change mitigation technologies must address all vulnerable groups.
2. *CTAPs must attempt to fully address natural resource externalities.* Groundwater pumping for irrigation is one of the two project interventions being analyzed. Many good examples



DevTreks –social budgeting that improves lives and livelihoods

can be found where this irrigation technique is causing groundwater supplies to become contaminated (i.e. Pakistan) and aquifers to become permanently damaged (i.e. Central Valley of California). Although the case study mentions that groundwater depletion is not an issue in this area, the author’s experience in natural resources conservation planning suggests that externalities from agriculture are the rule rather than the exception. The possibility of externalities must, at least, be addressed.

3. *CTAPs must attempt to fully address tradeoffs.* Ground water pumping is a proven technology for alleviating drought –thereby potentially increasing the incomes of the most vulnerable groups being impacted by drought. But the potential external social costs of this technology has to be weighed against the internal private benefits accruing to needy socioeconomic groups. In addition, the Crop Insurance alternative has government subsidies which are subject to the same tradeoffs as any other government expenditure.

This example does not focus on conducting a robust, scientific, drought loss assessment. The overall drought assessment is limited to summary, “eyeball” data taken from graphs and does not use any of the typical analytic techniques that most serious drought analysts employ (i.e. Appendix A’s list of planned algorithms). With the exception of limited tabular data presented in obscure scientific articles, full drought data that could be used in a complete CTAP case study could not be found (i.e. literally anywhere, pointing to the need for this technology). This example addresses the following shortfalls found in previous examples:

1. **All Indicators:** The introduction to each Indicator points out that reality is messier than depicted in previous examples. Each Indicator tries to expand the approaches used in its measurement, so that the overall CTAP processes work in reality, rather than strictly through simplified case studies. Although the author’s resources don’t permit field tests, most of the CTAP processes explained in this example have already undergone field testing with ample proof presented in the referenced publications. One of their main limitations is that they haven’t undergone adequate automation.



DevTreks –social budgeting that improves lives and livelihoods

2. **Indicator 1 Hazard Distribution: Scenario Analysis:** This Indicator addresses the need to expand the definition of hazards to include scenario analyses of climate change impacts on drought.
3. **Indicator 2 Exposure Distribution:** This Indicator expands the definition of exposure by introducing supplemental tools that can be used to identify the assets being impacted by drought.
4. **Indicator 3 Vulnerability Distribution: Drought Vulnerability Index:** This Indicator expands the definition of vulnerability by using a second base element, explained in Example 2, to complete a Drought Vulnerability Index. The Index includes indicators that help to quantify the root causes of vulnerability, the winners and losers from drought mitigation policies, and the external costs of mitigation technologies. In addition, this Indicator stores an optional Action Identification Table that further defines project alternatives in terms of measurable performance criteria.
5. **Indicator 4 Loss EP Distribution: Trend Analysis:** This Indicator expands the definition of exposure and vulnerability by including a trend analysis demonstrating how demographic trends, technological changes, and/or natural resource stock scenarios, affect changes in damage losses over time.
6. **Score Decision Support System: Multi-Criteria Analysis:** Scores expand decision support by including a Multi-Criteria Analysis (MCA). The most important criteria addressed in this example are equity, externalities, and tradeoffs. The MCA helps analysts to develop recommendations to decision makers. The MCA can be used as the final step in a general iterative approach that identifies changes needed in Indicators 1 through 7. Once the changes are completed, a new MCA is completed until reasonable consensus emerges about final risk mitigation strategies. In many cases, the amount of losses from disasters justifies such careful deliberation.
7. **Processing Time and Progress:** This example takes more time to run the calculations than any other example in this reference. A lot of calculations must be processed. Running calculations for an Input or Output and the children Series should be used cautiously. Feedback showing the progress of the calculations is not currently supported.



DevTreks –social budgeting that improves lives and livelihoods

The Technology Assessment 1 references are beginning to address the need to process very large datasets.

8. **Appendix B Decision Support System. Multi-Criteria Analysis:** The Score MCA section in this example points out that MCA can be completed using the techniques introduced in Appendix B, with no modifications needed. The indicators used in Appendix B’s algorithms can be the same indicators used to conduct MCA. When used in this manner, it’s “advanced” MCA.

### Indicator 1. Hazard Distribution

The scientific literature documents that droughts have multiple uncertain natural resource characteristics, chiefly associated with identification of the drought onset, and quantifying the drought’s severity, duration, and frequency (Mishra et al 2011, UN CAPNET 2015). Multivariate natural resource models and indices (i.e. Standardized Precipitation Index or SPI) are commonly used to capture these multiple hazard distributions. Examples of these distributions will be made when algorithms listed in Appendix A are developed.

The following properties identify the simpler techniques employed in the case study and used this example.

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Math Expression:**

$$I1.Q1.distribtype + I1.Q2.200year + I1.Q3.100year + I1.Q4.50year + I1.Q5.25year + I1.Q6.10year + I1.Q7.5year$$

**Indicator.URL TEXT:** This example exemplifies the complexity of modeling rainfall exceedance probabilities because the case study does not present a table or graphic that could be used to summarize rainfall exceedance probabilities for a growing season. Instead, the following table displays a simplistic and fictitious hazard distribution extrapolated loosely from Figure 9 in the case study.



DevTreks –social budgeting that improves lives and livelihoods

Indicator 1 Hazard Distribution (mm growing season rainfall)										
label	location	distribution	total	distribtype	200year	100year	50year	25year	10year	5year
1A	1.0000	QT	0.0000	normal	50.0000	100.0000	200.0000	300.0000	500.0000	520.0000
1A	1.0000	QTD1	0.0000	normal	50.0000	100.0000	200.0000	300.0000	500.0000	520.0000
1A	1.0000	QTD2	0.0000	normal	15.0000	30.0000	60.0000	90.0000	150.0000	156.0000
1A	2.0000	QT	0.0000	normal	50.0000	100.0000	200.0000	300.0000	500.0000	520.0000
1A	2.0000	QTD1	0.0000	normal	50.0000	100.0000	200.0000	300.0000	500.0000	520.0000
1A	2.0000	QTD2	0.0000	normal	15.0000	30.0000	60.0000	90.0000	150.0000	156.0000

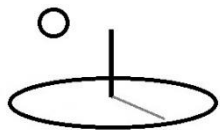
## Math Result:

label	location	loc_confid	total	distribtype	200year	100year	50year	25year	10year	5year
1A	1.0000	QTM	238.5041	normal	49.9859	99.9718	199.9435	299.9153	499.8588	519.8532
1A	1.0000	QTL	234.7398	normal	49.1970	98.3939	196.7878	295.1817	491.9695	511.6484
1A	1.0000	QTU	242.2684	normal	50.7748	101.5497	203.0992	304.6489	507.7481	528.0580
1A	2.0000	QTM	238.5041	normal	49.9859	99.9718	199.9435	299.9153	499.8588	519.8532
1A	2.0000	QTL	234.7398	normal	49.1970	98.3939	196.7878	295.1817	491.9695	511.6484
1A	2.0000	QTU	242.2684	normal	50.7748	101.5497	203.0992	304.6489	507.7481	528.0580

## Scenario Analysis

The authors cite IPCC scenarios that project future monsoon conditions to be 15% to 20% higher in South Asia by 2099. The authors downscale the IPCC projections for the Rohini basin and add actual observed data to their climate change scenarios. Figure 4 in the case study displays some of the resultant scenarios. Although the Trend Analysis introduced for Indicator 4 can be used to model simple natural resource scenarios, serious scenario analysis has to be conducted using all Indicators. The most practical way to conduct scenario analysis is to complete a full Conservation Technology Assessment for an Input or Output base element. Copy the initial assessment into children Input or Output Series. Adjust the datasets in each Series member to the scenario being modeled. Use the Resource Stock Progress Analyzers to assess the joint Series data.

Algorithms that mathematically tie Indicators 1 to 4 together may also be sound approaches for handling Scenario Analysis in future releases. For example, Indicator 3's loss ratio functions

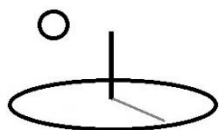


DevTreks –social budgeting that improves lives and livelihoods

look up Indicator 1’s scenarios and adjust losses appropriately (i.e. the existing data distributions, or functions, support this technique but the current algorithms do not).

## **Indicator 2. Exposure Distribution**

The following image (UNDP 2011) shows that the assets exposed to drought and used to model the benefits of drought risk reduction actions (i.e. the impacts of drought mitigation and adaptation actions) are more complex than evaluated in previous examples.



**Table 1: Economic impacts of drought**

	<i>Direct Impacts</i>	<i>Indirect Impacts</i>
<i>Costs and losses to agricultural producers</i>	<ul style="list-style-type: none"> <li>• Annual and perennial crop losses</li> <li>• Damage to crop quality</li> <li>• Reduced productivity of cropland, e.g., wind erosion</li> <li>• Insect infestations</li> <li>• Plant diseases</li> <li>• Wildlife damage to crops</li> </ul>	<ul style="list-style-type: none"> <li>• Income loss to farmers because of reduced crop yields</li> <li>• Increased irrigation costs</li> <li>• Cost of new or supplemental water resource development, e.g., wells, dams and pipelines</li> <li>• Long-term loss of organic matter</li> <li>• Loss to industries directly dependent on agricultural production, e.g., food processors</li> <li>• Increased commodity prices</li> </ul>
<i>Costs and losses to livestock producers</i>	<ul style="list-style-type: none"> <li>• Reduced productivity of range land, animal carrying capacity</li> <li>• Increased travel time for grazing</li> <li>• Decreased stock weights and reduced milk production</li> <li>• Increased livestock diseases</li> <li>• Closure/limitation of public lands to grazing</li> <li>• Range fires</li> </ul>	<ul style="list-style-type: none"> <li>• Forced reduction of foundation stock (seeds)</li> <li>• High cost/unavailability of feed or water for livestock</li> <li>• Reductions in livestock market prices</li> <li>• Increased feed transportation costs</li> <li>• Disruption of reproduction cycles (delayed breeding, more miscarriages)</li> <li>• Increased predation and pouching</li> </ul>
<i>Costs and losses to industry and urban activities</i>	<ul style="list-style-type: none"> <li>• Higher cost of water and sanitation</li> <li>• Decrease in public water supplies</li> <li>• Impacts on transportation</li> <li>• Higher cost/lower availability of hydro-electric power</li> </ul>	<ul style="list-style-type: none"> <li>• Higher cost or unavailability of water for horticulture, agri-food processing and value-added manufacturing</li> <li>• Impaired productivity of forest land and reduced timber production</li> <li>• Increased pollution, e.g., dust</li> <li>• Increased diseases</li> <li>• Reduction in tourism revenue, e.g., wildlife</li> <li>• Strain on financial institutions, e.g., greater credit risks</li> </ul>

*Source: National Drought Monitoring Center (NDMC), University of Nebraska (2006).*

**Table 2: Environmental impacts of drought**

	<i>Direct Impacts</i>	<i>Indirect impacts</i>
<i>Hydrological</i>	<ul style="list-style-type: none"> <li>• Lower water levels in reservoirs, lakes and ponds</li> <li>• Reduced stream flow</li> <li>• Loss of wetlands</li> <li>• Increased groundwater depletion and land subsidence</li> </ul>	<ul style="list-style-type: none"> <li>• Increased time and cost for water collection and transfer</li> <li>• Lower water quality, e.g., salinization and temperature increase</li> <li>• Waterborne diseases</li> <li>• Wind and water erosion on soils</li> </ul>





## DevTreks –social budgeting that improves lives and livelihoods

	ON FARM SUBSISTENCE	OFF FARM PRODUCTIVITY AND LIVELIHOODS
<i>Biological</i>	<ul style="list-style-type: none"> <li>• Loss of trees and vegetation</li> <li>• Loss of animal species diversity</li> </ul>	<ul style="list-style-type: none"> <li>• Fragmentation and destruction of wildlife habitats</li> <li>• Migration, concentration and increased predation</li> <li>• Loss of biodiversity</li> </ul>

Source: NDMC, University of Nebraska (2006).

**Table 3: Social impacts of drought**

	<i>Direct Impacts</i>	<i>Indirect impacts</i>
<i>Reduced quality of life</i>	<ul style="list-style-type: none"> <li>• Increased workload for women in collecting fuel-wood and water</li> <li>• Reduced levels and variety of food sources</li> <li>• Increased government expenditure on relief</li> </ul>	<ul style="list-style-type: none"> <li>• Increased poverty</li> <li>• Migrations (rural to urban areas, cross-border)</li> <li>• Reduction or modification of recreational activities</li> <li>• Disruption of cultural practices and belief/value system</li> <li>• Loss of cultural sites and aesthetic values</li> </ul>
<i>Increased conflicts</i>		<ul style="list-style-type: none"> <li>• Water user conflicts</li> <li>• Political conflicts</li> <li>• Management conflicts</li> <li>• Other social conflicts, e.g., scientific and media-based</li> </ul>
<i>Health</i>	<ul style="list-style-type: none"> <li>• Physical and emotional stress, e.g., anxiety, depression and loss of security</li> </ul>	<ul style="list-style-type: none"> <li>• Health-related low-flow problems, e.g., cross-connection contamination, diminished sewage flows, increased pollutant concentrations and reduced fire fighting capability</li> <li>• Reductions in nutrition</li> <li>• Loss of human life</li> <li>• Public safety from forest and range fires</li> <li>• Increased respiratory ailments</li> <li>• Increased disease caused by wildlife concentrations</li> </ul>

Source: NDMC, University of Nebraska (2006).

The UN IDMP (2014) recommends establishing drought task forces to coordinate drought management. They recommend that these groups use checklists, similar to the following, to define and prioritize the full assets being impacted by drought. No automated tool is offered for this purpose, but, since future generations need to know the full details behind CTAs, analysts are encouraged to add a TEXT csv file, holding the checklist, as the last Indicator.URL TEXT file.



## Annex: Checklist of historical, current and potential drought impacts

To perform an assessment using this checklist, check the box in front of each category that has been affected by drought in your study area. Your checklist selections can be based on either common or extreme droughts, or a combination of the two. For example, if your drought planning was going to be based on the 'drought of record', a historical review would need to be completed to identify the 'drought of record' for your area and to assess the impacts of that drought. The impacts would then be recorded on this checklist by marking the appropriate boxes under the 'Historical' column. Next, with the current knowledge that you have about your local area, if another 'drought of record' were to occur tomorrow, consider what the local impacts may be and record them on the checklist under the 'Current' column. Finally, consider what the impacts of the same drought would be for your area in five or ten years and record these in the 'Potential' column.

If enough time, money and personnel are available, it may be beneficial to conduct impact studies based on common droughts, extreme drought(s) and the 'drought of record' for your region. These analyses would yield a range of impacts related to the severity of the drought, which is necessary for conducting Step 3 of the guide and which could be useful for planning purposes.

H = Historical Drought

C = Current Drought

P = Potential Drought

H	C	P	Economic
			Loss from crop production
✓	✓	✓	· Annual and perennial crop losses
✓	✓	✓	· Damage to crop quality
✓	✓	✓	· Reduced productivity of cropland (wind erosion, etc.)
✓	✓	✓	· Insect infestation
✓	✓	✓	· Plant disease
✓	✓	✓	· Wildlife damage to crops
			Loss from dairy and livestock production

In addition, feedback from the Drought Vulnerability Index (DVI) completed by local stakeholders and used with Indicator 3 can help to further refine this Indicator.

The following properties identify the simpler techniques used in the case study and employed with this Indicator.

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Math Expression:**



DevTreks –social budgeting that improves lives and livelihoods

I2.Q1.distribtype + I2.Q2.QT + I2.Q3.QTUnit + I2.Q4.QTD1+ I2.Q5.QTD1Unit + I2.Q6.QTD2  
+ I2.Q7.QTD2Unit + I2.Q8.normalization + I2.Q9.weight + I2.Q10.quantity

**Indicator.URL TEXT:** Exposure is extrapolated from tables and graphs in the case study and summarized in the following table. The assumptions for farmers include: gross crop income: \$31,000 IndR/year; area farmed: 0.8 hectare; 70% crop income from paddy rice and 30% from wheat. The assumptions for farmworkers dependent upon agricultural employment include: gross agricultural income: \$28,500 IndR/year (the poverty line identified in the case study). Both assets use a normal distribution with standard deviation = 30% of mean. Location 2 decreases Location 1's numbers by 15%.

Indicator 2 Exposure Distribution (\$Indian Rupiah or INDR)													
label	locati	assettype	total	distribtype	QT	QTUnit	QTD1	QTD1Unit	QTD1D2	QTD2Unit	normaliza	weight	quantity
RF1	1	Crop Incon	#####	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF1A	1	Rice	#####	normal	27125.0000	hectare	27125.0000	mean	8137.5000	sd	none	1.0000	0.8000
RF1B	1	Wheat	#####	normal	11625.0000	hectare	11625.0000	mean	3487.5000	sd	none	1.0000	0.8000
RF2	1	Ag Income	#####	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF2A	1	Farmwork	#####	normal	28500.0000	household	28500.0000	mean	8550.0000	sd	none	1.0000	1.0000
RF	1	All Physical	#####	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
TR	1	TotalRisk	#####	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF1	2	Crop Incon	#####	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF1A	2	Rice	#####	normal	23056.2500	hectare	23056.2500	mean	6916.8750	sd	none	1.0000	0.8000
RF1B	2	Wheat	#####	normal	9881.2500	hectare	9881.2500	mean	2964.3750	sd	none	1.0000	0.8000
RF2	2	Ag Income	#####	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RF2A	2	Farmwork	#####	normal	24225.0000	household	24225.0000	mean	7267.5000	sd	none	1.0000	1.0000
RF	2	All Physical	#####	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
TR	2	TotalRisk	#####	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000

## Math Result:

label	location	assettype	total	distribtype	QTM	QTMUnit	QTL	QTLUnit	QTU	QTUUnit	quantity
RF1	1.0000	Crop Incon	0.0000	none	30991.2466	category mean	30502.1123	category low ci	31480.3810	category high ci	1.0000
RF1A	1.0000	Rice	0.0000	normal	21693.8726	total value	21351.4786	lower 90% ci	22036.2666	upper 90% ci	0.8000
RF1B	1.0000	Wheat	0.0000	normal	9297.3740	total value	9150.6337	lower 90% ci	9444.1143	upper 90% ci	0.8000
RF2	1.0000	Ag Income	0.0000	none	28491.9525	category mean	28042.2645	category low ci	28941.6405	category high ci	1.0000
RF2A	1.0000	Farmwork	0.0000	normal	28491.9525	total value	28042.2645	lower 90% ci	28941.6405	upper 90% ci	1.0000
RF	1.0000	All Physical	0.0000	none	59483.1991	sum categorie	58544.3768	category low ci	60422.0215	category high ci	1.0000
TR	1.0000	TotalRisk	0.0000		59483.1991	sum categorie	58544.3768	category low ci	60422.0215	category high ci	1.0000
RF1	2.0000	Crop Incon	0.0000	none	26342.5597	category mean	25926.7955	category low ci	26758.3238	category high ci	1.0000
RF1A	2.0000	Rice	0.0000	normal	18439.7918	total value	18148.7569	lower 90% ci	18730.8266	upper 90% ci	0.8000
RF1B	2.0000	Wheat	0.0000	normal	7902.7679	total value	7778.0386	lower 90% ci	8027.4972	upper 90% ci	0.8000
RF2	2.0000	Ag Income	0.0000	none	24218.1597	category mean	23835.9249	category low ci	24600.3945	category high ci	1.0000
RF2A	2.0000	Farmwork	0.0000	normal	24218.1597	total value	23835.9249	lower 90% ci	24600.3945	upper 90% ci	1.0000
RF	2.0000	All Physical	0.0000	none	50560.7194	sum categorie	49762.7204	category low ci	51358.7183	category high ci	1.0000
TR	2.0000	TotalRisk	0.0000		50560.7194	sum categorie	49762.7204	category low ci	51358.7183	category high ci	1.0000



DevTreks –social budgeting that improves lives and livelihoods

**Indicator.URL 2<sup>nd</sup>** Text: The following partial list shows the Checklist of Impacts TEXT file that has been added to this Indicator. The Checklist is used to help identify assets exposed to drought and potential mitigation and adaptation actions.

<b>Checklist of drought impacts</b>									
Historic, current, and potential impact									
H	C	P	Economic Impacts						
Loss from crop production									
			Annual and perennial crops						
			Damage to crop quality						
			Reduced productivity of cropland (wind erosion etc)						
			Insect infestation						
			Plant disease						
			Wildlife damage to crops						
Loss from dairy and livestock production									
			Reduced productivity of rangeland						
			Forced reduction of foundation stock						
			Closure/limitation of public lands to grazing						
			High cost/unavailability of water for livestock						
			High cost/unavailability of feed for livestock						
			High livestock mortality rates						
			Disruption of reproduction cycles (breeding delays or unfilled pregnancies)						
			Decreased stock weights						
			Increased predation						
			Range fires						
Loss from timber production									
			Wildland fires						
			Tree disease						
			Insect infestation						
			Impaired productivity of forest land						
Loss from fishery production									
			Damage to fish habitat						
			Loss of young fish due to decreased flows						
			Income loss for farmers and others directly affected						

### Indicator 3. Vulnerability Distribution



DevTreks –social budgeting that improves lives and livelihoods

The following image (UNDP CAPNET, 2015) suggests, once again, that the simplified world portrayed in some examples has the potential to miss important analytic details. In this case, important aspects of Indicator 3’s Sensitivity Analysis. The subsequent images demonstrate how the use of disaster-specific Indicator Indexes, such as a Composite Drought Vulnerability Index, can assist with those details.

Appendix B points out that the general technique of developing disaster-specific Indicator Indexes is applicable to any disaster. Example 2 demonstrates how to complete the DVI. Feedback from the DVI collaborative process is used to further refine this Indicator. The UN IDMP (2014) and UNCAPNET (2015) references demonstrate how the use of additional tools, such as “impact tree diagrams”, that focus on causal explanations, can help to further identify the root causes of vulnerability.

At this stage, the data generated using Indicators 1, 2, and 3 can be used to define the mitigation and adaptation interventions (i.e. the project alternatives) that must be assessed with this Indicator. UN IDMP (2014) identifies this step as the “Action Identification” task. The Score’s MCA collaborative process can provide iterative feedback for further refining this Indicator. The Score section also demonstrates the importance of comparing policy alternatives against measurable performance criteria. This Indicator uses an optional 2<sup>nd</sup> TEXT dataset, holding an “Action Identification Table”, that further defines alternatives, or potential mitigation and adaptation actions, in terms of measurable goals or performance criteria.



DevTreks –social budgeting that improves lives and livelihoods

Vulnerability then is depicted in the model as the progression of three stages:

- **Root causes:** a deep-rooted set of factors within a society that together form and maintain vulnerability.
- **Dynamic pressures:** a translating process that channels the effects of a negative cause into unsafe conditions; this process may be due to a lack of basic services or provision or it may result from a series of macro-forces.
- **Unsafe conditions:** the vulnerable context where women and men and property are exposed to the risk of disaster. The fragile physical environment is one element; other factors include an unstable economy and low-income levels.

**TABLE 2.2 | Structure of vulnerability and disasters**

Source: Blaikie *et al.*, 1994

PROGRESSION OF VULNERABILITY Pressure and Release (PAR) Vulnerability Framework			DISASTERS	HAZARDS
ROOT CAUSES	DYNAMIC PRESSURES	UNSAFE CONDITIONS		
<b>Limited access to</b> <ul style="list-style-type: none"> <li>Resources</li> <li>Structures</li> <li>Power</li> </ul> <b>Ideologies</b> <ul style="list-style-type: none"> <li>Political systems</li> <li>Economic systems</li> </ul>	<b>Lack of</b> <ul style="list-style-type: none"> <li>Institutions</li> <li>Training</li> <li>Skills</li> <li>Investment</li> <li>Markets</li> <li>Press freedom</li> <li>Civil society</li> </ul> <b>Macro-forces</b> <ul style="list-style-type: none"> <li>Population growth</li> <li>Urbanization</li> <li>Arms expenditure</li> <li>Debt repayment</li> <li>Deforestation</li> <li>Soil degradation</li> </ul>	<b>Fragile physical environment</b> <ul style="list-style-type: none"> <li>Dangerous locations</li> <li>Unprotected structures</li> </ul> <b>Fragile local economy</b> <ul style="list-style-type: none"> <li>Livelihoods at risk</li> <li>Low income</li> </ul> <b>Vulnerable society</b> <ul style="list-style-type: none"> <li>Groups at risk</li> <li>Little capacity to cope</li> </ul> <b>Public actions</b> <ul style="list-style-type: none"> <li>Lack of preparedness</li> <li>Endemic disease</li> </ul>	<b>RISK</b> = <b>HAZARD</b> + <b>VULNERABILITY</b>	Earthquake Wind storm Flooding Volcano Landslide Drought Virus and pest Heat wave



**FIGURE 2.8** | Techniques of representing vulnerability assessment

Source: Swain, nd.

Indicators of Composite Drought Vulnerability Index (CDVI)							
SI No.	Bio-physical Indicators of Drought Vulnerability			SI No.	Socio-economic Indicators of Drought Vulnerability		
	Indicators	Proxy for Indicator	Weights		Indicators	Proxy for Indicator	Weights
1	Drought Frequency	Frequency of Occurrence of Drought (%)	0.1	7	Irrigation	% Area without any irrigation potential	0.1
2	Drought Intensity	% Decrease in precipitatopn from long-term normal in Drought Years (%)	0.1	8		% Unirrigated area to total cultivable area	0.005
3	Rainfall	Average annual rainfall variability (CV %)	0.05	9	Major crop production	Paddy area variability (CV%)	0.005
4	Soil	Available water holding capacity of soil (Rank*)	0.05	10		Paddy area variability (CV%)	0.045
5	Land topography	Land slope (%)	0.05	11	Poverty	% Households below poverty line	0.075
6	Ground water table	% Decline in post monsoon water level in drought year compared to normal	0.05	12	Social factors	% Landless and marginal labourers to total main workers	0.1
				13		% People illiterate	0.1
				14		% People living in rural area	0.05
				15		Population density (per sq. Km)	0.05
				16	Land use pattern	% of geographical area not covered under forest	0.05
				17		% Barren uncultivable and other follows	0.007
				18	Institutional factors	% Farmers not covered under crop insurance	0.005
						% People not benefited by IRDP	0.008

The following properties identify the simpler techniques employed with the case study and used in Indicator 3.

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Math Expression:**

I3.Q1.distribtype + I3.Q2.5year + I3.Q3.10year + I3.Q4.25year + I3.Q5.50year + I3.Q6.100year + I3.Q7.200year

**Indicator.URL** 1<sup>st</sup> TEXT: This example extrapolates crop loss ratios, in percent, from Figure 6 in the case study. Both crops use the same loss ratios. Agricultural wage loss is calculated as 50% of crop losses (i.e. assuming job substitution or income support are available). Standard deviations are 30% of means and Location 2 suffers equals percent losses as Location 1.



DevTreks –social budgeting that improves lives and livelihoods

Indicator 3 Vulnerability (percent loss per ha)										
label	assettype	loc_distrib	total	distribtype	5year	10year	25year	50year	100year	200year
RF1	Crop Inc	1_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF1	Crop Inc	1_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF1	Crop Inc	1_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF1A	Rice	1_QT	0.0000	normal	20.0000	30.0000	45.0000	55.0000	70.0000	85.0000
RF1A	Rice	1_QTD1	0.0000	normal	20.0000	30.0000	45.0000	55.0000	70.0000	85.0000
RF1A	Rice	1_QTD2	0.0000	normal	6.0000	9.0000	13.5000	16.5000	21.0000	25.5000
RF1B	Wheat	1_QT	0.0000	normal	20.0000	30.0000	45.0000	55.0000	70.0000	85.0000
RF1B	Wheat	1_QTD1	0.0000	normal	20.0000	30.0000	45.0000	55.0000	70.0000	85.0000
RF1B	Wheat	1_QTD2	0.0000	normal	6.0000	9.0000	13.5000	16.5000	21.0000	25.5000
RF2	Ag Incon	1_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF2	Ag Incon	1_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF2	Ag Incon	1_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF2A	Farmwo	1_QT	0.0000	normal	10.0000	15.0000	22.5000	27.5000	35.0000	42.5000
RF2A	Farmwo	1_QTD1	0.0000	normal	10.0000	15.0000	22.5000	27.5000	35.0000	42.5000
RF2A	Farmwo	1_QTD2	0.0000	normal	3.0000	4.5000	6.7500	8.2500	10.5000	12.7500
RF	All Physic	1_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF	All Physic	1_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF	All Physic	1_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TR	TotalRis	1_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TR	TotalRis	1_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TR	TotalRis	1_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF1	Crop Inc	2_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF1	Crop Inc	2_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF1	Crop Inc	2_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF1A	Rice	2_QT	0.0000	normal	20.0000	30.0000	45.0000	55.0000	70.0000	85.0000
RF1A	Rice	2_QTD1	0.0000	normal	20.0000	30.0000	45.0000	55.0000	70.0000	85.0000
RF1A	Rice	2_QTD2	0.0000	normal	6.0000	9.0000	13.5000	16.5000	21.0000	25.5000

**Partial Math Result:**





## DevTreks –social budgeting that improves lives and livelihoods

label	assettype	loc_con	total	distribtype	5year	10year	25year	50year	100year	200year
RF1	Crop Income	1_QTM	22.0438	normal	39.9888	59.9830	89.9746	109.9690	139.9604	169.9520
RF1	Crop Income	1_QTL	21.6959	normal	39.3576	59.0362	88.5546	108.2334	137.7514	167.2696
RF1	Crop Income	1_QTU	22.3917	normal	40.6200	60.9298	91.3946	111.7046	142.1694	172.6344
RF1A	Rice	1_QTM	11.0219	normal	19.9900	29.9900	44.9900	54.9800	69.9800	84.9800
RF1A	Rice	1_QTL	10.8479	normal	19.6800	29.5200	44.2800	54.1200	68.8800	83.6300
RF1A	Rice	1_QTU	11.1959	normal	20.3100	30.4600	45.7000	55.8500	71.0800	86.3200
RF1B	Wheat	1_QTM	11.0219	normal	19.9900	29.9900	44.9900	54.9800	69.9800	84.9800
RF1B	Wheat	1_QTL	10.8479	normal	19.6800	29.5200	44.2800	54.1200	68.8800	83.6300
RF1B	Wheat	1_QTU	11.1959	normal	20.3100	30.4600	45.7000	55.8500	71.0800	86.3200
RF2	Ag Income	1_QTM	5.5109	normal	9.9972	14.9958	22.4936	27.4922	34.9901	42.4880
RF2	Ag Income	1_QTL	5.4240	normal	9.8394	14.7591	22.1386	27.0583	34.4379	41.8174
RF2	Ag Income	1_QTU	5.5979	normal	10.1550	15.2325	22.8486	27.9261	35.5423	43.1586
RF2A	Farmworkers	1_QTM	5.5109	normal	10.0000	15.0000	22.4900	27.4900	34.9900	42.4900
RF2A	Farmworkers	1_QTL	5.4240	normal	9.8400	14.7600	22.1400	27.0600	34.4400	41.8200
RF2A	Farmworkers	1_QTU	5.5979	normal	10.1600	15.2300	22.8500	27.9300	35.5400	43.1600
RF	All Physical	1_QTM	27.5547	normal	49.9860	74.9788	112.4682	137.4612	174.9505	212.4400
RF	All Physical	1_QTL	27.1198	normal	49.1970	73.7953	110.6932	135.2917	172.1893	209.0870
RF	All Physical	1_QTU	27.9897	normal	50.7750	76.1623	114.2432	139.6307	177.7117	215.7930
TR	TotalRisk	1_QTM	27.5547	normal	49.9860	74.9788	112.4682	137.4612	174.9505	212.4400
TR	TotalRisk	1_QTL	27.1198	normal	49.1970	73.7953	110.6932	135.2917	172.1893	209.0870
TR	TotalRisk	1_QTU	27.9897	normal	50.7750	76.1623	114.2432	139.6307	177.7117	215.7930
RF1	Crop Income	2_QTM	22.0438	normal	39.9888	59.9830	89.9746	109.9690	139.9604	169.9520
RF1	Crop Income	2_QTL	21.6959	normal	39.3576	59.0362	88.5546	108.2334	137.7514	167.2696
RF1	Crop Income	2_QTU	22.3917	normal	40.6200	60.9298	91.3946	111.7046	142.1694	172.6344
RF1A	Rice	2_QTM	11.0219	normal	19.9900	29.9900	44.9900	54.9800	69.9800	84.9800

**Indicator.URL Alternatives:** The case study documents that for farmers, Alternative A, Groundwater Irrigation, reduces 100% of losses for events up to 10 years. Alternative B, Crop Insurance, reduces 100% of losses for the 25 year and 50 year events. The case study mentions that more is involved in quantifying both loss reductions, but these are the primary impacts. Alternative C, both Groundwater Irrigation and Crop Insurance, is calculated as a summation of the individual loss reductions. For farmworkers, only Alternative A has loss reductions. Crop Insurance payments are not used to reimburse the workers. As mentioned in the introduction, the distributional impacts of mitigation technologies are important to understand and document.



DevTreks –social budgeting that improves lives and livelihoods

RF1B_C	Wheat	2_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	21.0000	25.5000
RF2_C	Ag Incon	2_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF2_C	Ag Incon	2_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF2_C	Ag Incon	2_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF2A_C	Farmwoi	2_QT	0.0000	normal	0.0000	0.0000	22.5000	27.5000	35.0000	42.5000
RF2A_C	Farmwoi	2_QTD1	0.0000	normal	0.0000	0.0000	22.5000	27.5000	35.0000	42.5000
RF2A_C	Farmwoi	2_QTD2	0.0000	normal	0.0000	0.0000	6.7500	8.2500	10.5000	12.7500
RF_C	All Physic	2_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF_C	All Physic	2_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RF_C	All Physic	2_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TR_C	TotalRis	2_QT	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TR_C	TotalRis	2_QTD1	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TR_C	TotalRis	2_QTD2	0.0000	normal	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

## Partial Math Result:

RF1B_C	Wheat	2_QTM	1.1247	normal	0.0000	0.0000	0.0000	0.0000	69.9800	84.9800
RF1B_C	Wheat	2_QTL	1.1069	normal	0.0000	0.0000	0.0000	0.0000	68.8800	83.6300
RF1B_C	Wheat	2_QTU	1.1424	normal	0.0000	0.0000	0.0000	0.0000	71.0800	86.3200
RF2_C	Ag Income	2_QTM	2.0119	normal	0.0000	0.0000	22.4936	27.4922	34.9901	42.4880
RF2_C	Ag Income	2_QTL	1.9802	normal	0.0000	0.0000	22.1386	27.0583	34.4379	41.8174
RF2_C	Ag Income	2_QTU	2.0437	normal	0.0000	0.0000	22.8486	27.9261	35.5423	43.1586
RF2A_C	Farmworkers	2_QTM	2.0119	normal	0.0000	0.0000	22.4900	27.4900	34.9900	42.4900
RF2A_C	Farmworkers	2_QTL	1.9802	normal	0.0000	0.0000	22.1400	27.0600	34.4400	41.8200
RF2A_C	Farmworkers	2_QTU	2.0437	normal	0.0000	0.0000	22.8500	27.9300	35.5400	43.1600
RF_C	All Physical	2_QTM	4.2613	normal	0.0000	0.0000	22.4936	27.4922	174.9505	212.4400
RF_C	All Physical	2_QTL	4.1940	normal	0.0000	0.0000	22.1386	27.0583	172.1893	209.0870
RF_C	All Physical	2_QTU	4.3285	normal	0.0000	0.0000	22.8486	27.9261	177.7117	215.7930
TR_C	TotalRisk	2_QTM	4.2613	normal	0.0000	0.0000	22.4936	27.4922	174.9505	212.4400
TR_C	TotalRisk	2_QTL	4.1940	normal	0.0000	0.0000	22.1386	27.0583	172.1893	209.0870
TR_C	TotalRisk	2_QTU	4.3285	normal	0.0000	0.0000	22.8486	27.9261	177.7117	215.7930

**Indicator.URL 2<sup>nd</sup> TEXT: Optional Action Identification Table:** The objective of this optional dataset is to define alternatives more transparently, especially in terms of measurable goals or criteria (i.e. the Score MCA criteria). No automated tool is offered for this table, but, since future generations need to know the full details behind CTAs, analysts are encouraged to add a TEXT csv file, similar to the following, as the last Indicator.URL TEXT file. The Action Definitions and Metrics can be considerably more concrete than this example.



DevTreks –social budgeting that improves lives and livelihoods

Indicator 3. Optional Action Identification Table				
Alternative	Name	Action Definition	General Criteria	Metric
A	Groundwater pumping	Employ energy efficient groundwater pumping	Reduce GHG emissions	Reduce GHG emissions by 20 percent by 2035.
B	Crop Insurance	Increase crop insurance payments for cropping practices	Reduce GHG emissions	Reduce GHG emissions by 5 percent by 2035.
C	Both groundwater pumping and crop insurance	Combine energy efficient groundware pumping and higher insurance payments for crop that reduce GHG.	Reduce GHG emissions	Reduce GHG emissions by 25 percent by 2035.

#### Indicator 4. Loss EP Distribution

This Indicator displays the results of calculations run using Indicators 2 and 3.

Selected properties include:

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Math Expression =**

I4.Q1.distribtype + I4.Q2.5year + I4.Q3.10year + I4.Q4.25year + I4.Q5.50year + I4.Q6.100year  
+ I4.7.200year

**Partial Math Result, no Trends:**



DevTreks –social budgeting that improves lives and livelihoods

label	assettype	loc_confid	total	distribtype	5year	10year	25year	50year	100year	200year	quantity
RF1	Crop Income	1_QTM	#####	none	6195.1502	9294.2749	13942.9618	17038.9874	21687.6744	26336.3614	1.0000
RF1	Crop Income	1_QTL	#####	none	6002.8157	9004.2236	13506.3353	16507.7432	21009.8550	25508.9165	1.0000
RF1	Crop Income	1_QTU	#####	none	6393.6654	9588.9240	14386.5341	17581.7927	22376.2547	27173.8648	1.0000
RF1A	Rice	1_QTM	#####	normal	4336.6100	6505.9900	9760.0700	11927.2900	15181.3700	18435.4500	0.8000
RF1A	Rice	1_QTL	#####	normal	4201.9700	6302.9600	9454.4300	11555.4200	14706.9000	17856.2400	0.8000
RF1A	Rice	1_QTU	#####	normal	4475.5700	6712.2500	10070.5700	12307.2500	15663.3800	19021.7100	0.8000
RF1B	Wheat	1_QTM	#####	normal	1858.5500	2788.2800	4182.8900	5111.7000	6506.3000	7900.9100	0.8000
RF1B	Wheat	1_QTL	#####	normal	1800.8400	2701.2700	4051.9000	4952.3200	6302.9600	7652.6700	0.8000
RF1B	Wheat	1_QTU	#####	normal	1918.1000	2876.6800	4315.9600	5274.5400	6712.8800	8152.1600	0.8000
RF2	Ag Income	1_QTM	#####	none	2849.1953	4273.7929	6407.8401	7832.4377	9969.3342	12106.2306	1.0000
RF2	Ag Income	1_QTL	#####	none	2759.3588	4139.0382	6208.5574	7588.2368	9657.7559	11727.2750	1.0000
RF2	Ag Income	1_QTU	#####	none	2940.4707	4407.8118	6613.1649	8083.4002	10285.8590	12491.2120	1.0000
RF2A	Farmworkers	1_QTM	#####	normal	2849.2000	4273.7900	6407.8400	7832.4400	9969.3300	12106.2300	1.0000
RF2A	Farmworkers	1_QTL	#####	normal	2759.3600	4139.0400	6208.5600	7588.2400	9657.7600	11727.2800	1.0000
RF2A	Farmworkers	1_QTU	#####	normal	2940.4700	4407.8100	6613.1600	8083.4000	10285.8600	12491.2100	1.0000
RF	All Physical	1_QTM	#####	none	9044.3454	13568.0677	20350.8020	24871.4251	31657.0086	38442.5920	1.0000
RF	All Physical	1_QTL	#####	none	8762.1745	13143.2618	19714.8927	24095.9800	30667.6108	37236.1915	1.0000
RF	All Physical	1_QTU	#####	none	9334.1360	13996.7359	20999.6989	25665.1929	32662.1138	39665.0768	1.0000
TR	TotalRisk	1_QTM	#####	none	9044.3454	13568.0677	20350.8020	24871.4251	31657.0086	38442.5920	1.0000
TR	TotalRisk	1_QTL	#####	none	8762.1745	13143.2618	19714.8927	24095.9800	30667.6108	37236.1915	1.0000
TR	TotalRisk	1_QTU	#####	none	9334.1360	13996.7359	20999.6989	25665.1929	32662.1138	39665.0768	1.0000
RF1	Crop Income	2_QTM	#####	none	6582.3471	9875.1671	14814.3970	18103.9241	23043.1541	27982.3840	1.0000

**Indicator.URL TEXT: Optional Trend Analysis:** The Semarang case study introduced in Appendix A, Example 2, clearly demonstrates the importance of factoring in demographic trends for this Indicator. In that case study, the city’s population is expected to significantly increase causing the number of exposed assets to increase.

The projected trend rates in the following dataset are multiplied by Indicator 2’s asset valuations to calculate projected damage losses. This partial table shows the data format convention that must be followed. The rows match Indicator 2’s rows and the columns correspond to Indicator 3’s columns. Indicator 3’s project alternatives must be included in the dataset. In many instances, the project alternative trends will have the exact same trends as the baseline. The Categorical and Locational rows are only included for consistency –the trend multipliers in these rows will not be used. The matrix itself contains the multipliers used to adjust asset values in the final damage loss estimates. Because these are simple multipliers, asset valuations that don’t change are given a trend multiplier of 1, not 0.

This file has been referenced as the first URL in the Indicator.URL property. The multipliers must be doubles. This file is optional.



Indicator 4. Trend Analysis (matrix numbers are asset valuation multipliers)										
label	loc_trend	assettype	total	trendtype	5year	10year	25year	50year	100year	200year
RF1	1_yes	Crop Incom	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF1A	1_yes	Rice	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF1B	1_yes	Wheat	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF2	1_yes	Ag Income	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF2A	1_yes	Farmwork	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF	1_yes	All Physica	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
TR	1_yes	TotalRisk	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF1	2_yes	Crop Incom	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF1A	2_yes	Rice	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF1B	2_yes	Wheat	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF2	2_yes	Ag Income	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF2A	2_yes	Farmwork	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF	2_yes	All Physica	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
TR	2_yes	TotalRisk	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF1_A	1_yes	Crop Incom	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF1A_A	1_yes	Rice	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF1B_A	1_yes	Wheat	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF2_A	1_yes	Ag Income	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF2A_A	1_yes	Farmwork	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF_A	1_yes	All Physica	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
TR_A	1_yes	TotalRisk	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF1_A	2_yes	Crop Incom	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF1A_A	2_yes	Rice	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF1B_A	2_yes	Wheat	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF2_A	2_yes	Ag Income	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF2A_A	2_yes	Farmwork	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400
RF_A	2_yes	All Physica	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
TR_A	2_yes	TotalRisk	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF1_B	1_yes	Crop Incom	0.000	exponential	1.000	1.000	1.000	1.000	1.000	1.000
RF1A_B	1_yes	Rice	0.000	exponential	1.000	1.000	1.050	1.100	1.200	1.400

The trend multipliers in this table can be derived by using techniques similar to the simple population calculation (UN ECLAC, 2014) shown in the following image. This technique is appropriate for the residential assets used in the Semarang case study. Crops and other types of industrial output should use calculations based on rates of crop yield and price changes, not this technique. Farmworker income should also be tied to projected changes in output income. Simple natural resource scenario analysis can base the trend multipliers on summary data taken from IPCC scenarios. The “trendtype” column in the dataset can be used as a reminder of the way the trend multipliers were calculated (i.e. exponential, straightline). A future release may



DevTreks –social budgeting that improves lives and livelihoods

use the latter column to calculate the trend loss automatically (again, to leave a better audit trail). Examples 5 and 6 in the Social Performance Analysis tutorial began to introduce fuller population algorithms,

The following population trend calculations are an example of how to estimate asset trend multipliers.								
$P_t = P_o * (e ^ { (r * t) } )$								
Pt	the population at the time of the disaster							
Po	the most recent official estimate of the population							
r	the annual exponential growth rate for the year or period in which the disaster occurs							
t	the length of time in years between the initial projection date used to calculate r and the time of the disaster							

**Partial Math Result, including Trends:**

These results can be compared with the results for the Math Results, No Trends to confirm that the trend variables act as simple multipliers.

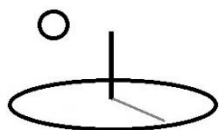


## DevTreks –social budgeting that improves lives and livelihoods

label	assettype	loc_confid	total	distribtype	5year	10year	25year	50year	100year	200year	quantity
RF1	Crop Income	1_QTM	3573.526	none	6195.150	9294.275	14640.110	18742.886	26025.209	36870.906	1.000
RF1	Crop Income	1_QTL	3462.103	none	6002.816	9004.224	14181.652	18158.518	25211.826	35712.483	1.000
RF1	Crop Income	1_QTU	3687.392	none	6393.665	9588.924	15105.861	19339.972	26851.506	38043.411	1.000
RF1A	Rice	1_QTM	2501.468	normal	4336.610	6505.990	10248.080	13120.020	18217.650	25809.630	0.800
RF1A	Rice	1_QTL	2423.472	normal	4201.970	6302.960	9927.160	12710.960	17648.280	24998.740	0.800
RF1A	Rice	1_QTU	2581.174	normal	4475.570	6712.250	10574.100	13537.980	18796.050	26630.390	0.800
RF1B	Wheat	1_QTM	1072.058	normal	1858.550	2788.280	4392.030	5622.870	7807.560	11061.270	0.800
RF1B	Wheat	1_QTL	1038.631	normal	1800.840	2701.270	4254.500	5447.560	7563.550	10713.740	0.800
RF1B	Wheat	1_QTU	1106.217	normal	1918.100	2876.680	4531.760	5801.990	8055.450	11413.020	0.800
RF2	Ag Income	1_QTM	1643.037	none	2849.195	4273.793	6728.232	8615.682	11963.201	16948.723	1.000
RF2	Ag Income	1_QTL	1591.460	none	2759.359	4139.038	6518.985	8347.061	11589.307	16418.185	1.000
RF2	Ag Income	1_QTU	1695.332	none	2940.471	4407.812	6943.823	8891.740	12343.031	17487.697	1.000
RF2A	Farmworkers	1_QTM	1643.037	normal	2849.200	4273.790	6728.230	8615.680	11963.200	16948.720	1.000
RF2A	Farmworkers	1_QTL	1591.460	normal	2759.360	4139.040	6518.990	8347.060	11589.310	16418.190	1.000
RF2A	Farmworkers	1_QTU	1695.332	normal	2940.470	4407.810	6943.820	8891.740	12343.030	17487.700	1.000
RF	All Physical	1_QTM	5216.563	none	9044.345	13568.068	21368.342	27358.568	37988.410	53819.629	1.000
RF	All Physical	1_QTL	5053.563	none	8762.175	13143.262	20700.637	26505.578	36801.133	52130.668	1.000
RF	All Physical	1_QTU	5382.723	none	9334.136	13996.736	22049.684	28231.712	39194.537	55531.108	1.000
TR	TotalRisk	1_QTM	5216.563	none	9044.345	13568.068	21368.342	27358.568	37988.410	53819.629	1.000
TR	TotalRisk	1_QTL	5053.563	none	8762.175	13143.262	20700.637	26505.578	36801.133	52130.668	1.000
TR	TotalRisk	1_QTU	5382.723	none	9334.136	13996.736	22049.684	28231.712	39194.537	55531.108	1.000
RF1	Crop Income	2_QTM	3796.872	none	6582.347	9875.167	15555.117	19914.317	27651.785	39175.338	1.000
RF1	Crop Income	2_QTL	3678.484	none	6377.992	9566.988	15068.005	19293.425	26787.565	37944.513	1.000
RF1	Crop Income	2_QTU	3917.853	none	6793.270	10188.232	16049.977	20548.720	28529.725	40421.124	1.000
RF1A	Rice	2_QTM	2657.810	normal	4607.640	6912.620	10888.580	13940.020	19356.250	27422.740	1.000
RF1A	Rice	2_QTL	2574.939	normal	4464.590	6696.890	10547.600	13505.400	18751.300	26561.160	1.000
RF1A	Rice	2_QTU	2742.497	normal	4755.290	7131.760	11234.980	14384.100	19970.810	28294.790	1.000
RF1B	Wheat	2_QTM	1139.062	normal	1974.700	2962.550	4666.540	5974.290	8295.540	11752.600	1.000
RF1B	Wheat	2_QTL	1103.545	normal	1913.400	2870.100	4520.400	5788.030	8036.270	11383.350	1.000
RF1B	Wheat	2_QTU	1175.356	normal	2037.980	3056.470	4814.990	6164.620	8558.920	12126.340	1.000
RF2	Ag Income	2_QTM	1396.581	none	2421.816	3632.724	5718.997	7323.329	10168.721	14406.415	1.000
RF2	Ag Income	2_QTL	1352.741	none	2345.455	3518.183	5541.138	7095.001	9850.911	13955.457	1.000
RF2	Ag Income	2_QTU	1441.032	none	2499.400	3746.640	5902.250	7557.979	10491.576	14864.542	1.000
RF2A	Farmworkers	2_QTM	1396.581	normal	2421.820	3632.720	5719.000	7323.330	10168.720	14406.410	1.000

### Indicator 5. Costs Distribution

As with the previous Indicators, the following image shows that Cost Indicators can have more dimensions than covered in previous examples. Note that many of the “opportunity costs” mentioned in this image are not quantified using Indicator 5. Many are measured as reductions in damage losses and should be identified using Indicators 2 and 3.



DevTreks –social budgeting that improves lives and livelihoods

The costs in a CBA are the specific costs of implementing a project and consist of investment and maintenance costs. There are the financial costs, which are the monetary amounts that have to be spent for the project. However, of more interest are the so-called opportunity costs, which are the benefits foregone from not being able to use these funds for other important objectives. There is a wide spectrum of potential mitigation, preparedness and risk financing measures that can be taken in order to reduce or finance risk. Table 5 lists a selection of these measures, and in bold concrete interventions studied in the Risk to Resilience project (see Working Paper Nos. 3, 4 & 7).

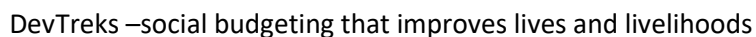
**TABLE 5 | Overview of risk management measures**

Type	Prevention	Preparedness	Risk financing
Effect	Reduces risk	Reduces risk	Transfers risk (reduces variability)
Key options	Physical and structural mitigation works (e.g. <b>Irrigation, embankments</b> )	<b>Early warning systems, communication systems</b>	Risk transfer (by means of (re-) insurance) for public infra-structure and private assets, <b>microinsurance</b>
	Land-use planning and building codes	Contingency planning, networks for emergency response	Alternative risk transfer
	Economic incentives for proactive risk management	Shelter facilities, evacuation plans	National and local reserve funds

Source: Modified based on IDB, 2000.

In addition, the simplified cost calculations demonstrated in previous examples can have far more nuance. The following image from the Capital Input tutorial shows 1 of 3 examples of irrigation pumping costs. These costs are more accurate than the simpler approaches demonstrated here, and can be used with this Indicator for more advanced cost analysis. That tutorial also demonstrates how many advanced calculations, that can't be carried out directly with this algorithm, can be carried out using complementary DevTreks calculators (i.e. most of which, such as crop insurance calculators, haven't even been built yet –IT really is still in its infancy), and then summarized in these types of algorithms.



193



DevTreks –social budgeting that improves lives and livelihoods

The following properties identify the simpler techniques employed with the case study and used in Indicator 5.

**Indicator.URL TEXT:** The irrigation alternative (A) includes costs that are shared for installing a bore well and annual operating and maintenance costs. The crop insurance alternative (B) costs approximately 6.5% of total crop income. In terms of household costs, 50% of the premium is subsidized, resulting in net costs of 3.5% of crop income. The government's share of the subsidy is excluded from the estimation of household costs and benefits, but it must be included in the final decision criteria (i.e. the Score MCA analysis).

Indicator 2's damages are entered on a per hectare basis and then multiplied by the quantity column, 0.8 hectares, to calculate the resultant per household damages. Costs are already calculated on a per household basis, so no further adjustments are needed and isprojectcost can be set to yes.



DevTreks –social budgeting that improves lives and livelihoods

Indicator 5. Cost Distribution (INDR)								
label	alternati	loc_distrib	total	installcost	installdistri	omcost	omdistrib	isprojectcost
AC1A	CurrentP	1_QT	0.00000	100.00000	normal	0.10000	normal	yes
AC1A	CurrentP	1_QTD1	0.00000	100.00000	normal	0.10000	normal	yes
AC1A	CurrentP	1_QTD2	0.00000	10.00000	normal	0.01000	normal	yes
AC1A_A	Irrigation	1_QT	0.00000	2000.00000	normal	240.00000	normal	yes
AC1A_A	Irrigation	1_QTD1	0.00000	2000.00000	normal	240.00000	normal	yes
AC1A_A	Irrigation	1_QTD2	0.00000	600.00000	normal	72.00000	normal	yes
AC1A_B	Croplnsu	1_QT	0.00000	0.00000	normal	1050.00000	normal	yes
AC1A_B	Croplnsu	1_QTD1	0.00000	0.00000	normal	1050.00000	normal	yes
AC1A_B	Croplnsu	1_QTD2	0.00000	0.00000	normal	315.00000	normal	yes
AC1A_C	AandB	1_QT	0.00000	2000.00000	normal	1290.00000	normal	yes
AC1A_C	AandB	1_QTD1	0.00000	2000.00000	normal	1290.00000	normal	yes
AC1A_C	AandB	1_QTD2	0.00000	600.00000	normal	387.00000	normal	yes
AC1A	CurrentP	2_QT	0.00000	100.00000	normal	0.10000	normal	yes
AC1A	CurrentP	2_QTD1	0.00000	100.00000	normal	0.10000	normal	yes
AC1A	CurrentP	2_QTD2	0.00000	10.00000	normal	0.01000	normal	yes
AC1A_A	Irrigation	2_QT	0.00000	2000.00000	normal	240.00000	normal	yes
AC1A_A	Irrigation	2_QTD1	0.00000	2000.00000	normal	240.00000	normal	yes
AC1A_A	Irrigation	2_QTD2	0.00000	600.00000	normal	72.00000	normal	yes
AC1A_B	Croplnsu	2_QT	0.00000	0.00000	normal	1050.00000	normal	yes
AC1A_B	Croplnsu	2_QTD1	0.00000	0.00000	normal	1050.00000	normal	yes
AC1A_B	Croplnsu	2_QTD2	0.00000	0.00000	normal	315.00000	normal	yes
AC1A_C	AandB	2_QT	0.00000	2000.00000	normal	1290.00000	normal	yes
AC1A_C	AandB	2_QTD1	0.00000	2000.00000	normal	1290.00000	normal	yes
AC1A_C	AandB	2_QTD2	0.00000	600.00000	normal	387.00000	normal	yes

### Sensitivity Analysis Data TEXT (stored as csv text data):

The following dataset has been referenced as the second URL in the Indicator.URL property. At least 1 rate and 1 life must be included in this TEXT file (i.e. at least the first 4 columns of data).

label	type	variable	value1	value2
5A	sensitivity	rate	0.05000	0.12000
5A	sensitivity	life	15.00000	25.00000

### Partial Math Results:



DevTreks –social budgeting that improves lives and livelihoods

label	alternative	loc_confid	total	life_15	life_25	isprojectcost
AC1A	CurrentPractice	1_QTM_0.05	96.2671	96.2671	96.6385	yes
AC1A	CurrentPractice	1_QTL_0.05	95.7610	95.7610	96.1305	yes
AC1A	CurrentPractice	1_QTU_0.05	96.7733	96.7733	97.1465	yes
AC1A	CurrentPractice	1_QTM_0.12	89.9584	89.9584	90.0616	yes
AC1A	CurrentPractice	1_QTL_0.12	89.4854	89.4854	89.5881	yes
AC1A	CurrentPractice	1_QTU_0.12	90.4315	90.4315	90.5352	yes
AC1A_A	Irrigation	1_QTM_0.05	4394.6383	4394.6383	5285.8152	yes
AC1A_A	Irrigation	1_QTL_0.05	4325.2782	4325.2782	5202.3899	yes
AC1A_A	Irrigation	1_QTU_0.05	4463.9984	4463.9984	5369.2406	yes
AC1A_A	Irrigation	1_QTM_0.12	3419.3558	3419.3558	3667.0317	yes
AC1A_A	Irrigation	1_QTL_0.12	3365.3884	3365.3884	3609.1553	yes
AC1A_A	Irrigation	1_QTU_0.12	3473.3232	3473.3232	3724.9081	yes
AC1A_B	CropInsurance	1_QTM_0.05	10895.5634	10895.5634	14794.4629	yes
AC1A_B	CropInsurance	1_QTL_0.05	10723.5984	10723.5984	14560.9615	yes
AC1A_B	CropInsurance	1_QTU_0.05	11067.5284	11067.5284	15027.9644	yes
AC1A_B	CropInsurance	1_QTM_0.12	7149.3883	7149.3883	8232.9706	yes
AC1A_B	CropInsurance	1_QTL_0.12	7036.5493	7036.5493	8103.0294	yes
AC1A_B	CropInsurance	1_QTU_0.12	7262.2273	7262.2273	8362.9118	yes
AC1A_C	AandB	1_QTM_0.05	15290.2017	15290.2017	20080.2782	yes
AC1A_C	AandB	1_QTL_0.05	15048.8766	15048.8766	19763.3514	yes
AC1A_C	AandB	1_QTU_0.05	15531.5267	15531.5267	20397.2049	yes
AC1A_C	AandB	1_QTM_0.12	10568.7441	10568.7441	11900.0023	yes

## Indicator 6. Benefit Cost Analysis (BCA)

Unsurprisingly, the simplified benefit cost analyses introduced in previous examples, also fail to capture important dimensions of BCA. Besides the aforementioned shortfalls dealing with equity and tradeoffs, V. Meyer et al (2013) review several economic analysis techniques, such as contingent valuation, that are also appropriate to use in quantifying disaster prevention benefits and costs. IT really is still in its infancy.

The following properties identify the simpler techniques employed with the case study and used in Indicator 6.

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Math Expression =**



DevTreks –social budgeting that improves lives and livelihoods

I6.Q1.distribtype + I6.Q2.200year + I6.3.100year + I6.Q4.50year + I6.Q5.25year + I6.Q6.10year  
+ I6.Q7.5year

### Partial Math Result:

label	assettype	loc_confid	total	RF1_dama	RF1_cost	RF1_A_da	RF1_A_co	RF1_A_bcr	RF1_B_da	RF1_B_co	RF1_B_bcr	RF1_C_da	RF1_C_co	RF1_C_bcr
RF1_A	Crop Incor	1_QTM_0.	0	37091.98	96.2671	14584.13	4394.638	5.2364	27122.71	10895.56	0.9231	4614.864	15290.2	2.1375
RF1_A	Crop Incor	1_QTM_0.	0	50365.08	96.6385	19802.96	5285.815	5.8896	36828.38	14794.46	0.921	6266.261	20080.28	2.2067
RF1_A	Crop Incor	1_QTM_0.	0	24338.8	89.9584	9569.733	3419.356	4.436	17797.23	7149.388	0.9266	3028.155	10568.74	2.0337
RF1_A	Crop Incor	1_QTM_0.	0	28027.66	90.0616	11020.15	3667.032	4.7547	20494.63	8232.971	0.9251	3487.111	11900	2.078
RF1_A	Crop Incor	1_QTL_0.C	0	35935.44	95.761	14127.93	4325.278	5.156	26277.83	10723.6	0.9087	4470.318	15048.88	2.1043
RF1_A	Crop Incor	1_QTL_0.C	0	48794.68	96.1305	19183.51	5202.39	5.799	35681.16	14560.96	0.9066	6069.99	19763.35	2.1724
RF1_A	Crop Incor	1_QTL_0.1	0	23579.91	89.4854	9270.384	3365.388	4.3681	17242.84	7036.549	0.9122	2933.308	10401.94	2.0021
RF1_A	Crop Incor	1_QTL_0.1	0	27153.75	89.5881	10675.43	3609.155	4.6819	19856.21	8103.029	0.9107	3377.889	11712.18	2.0457
RF1_A	Crop Incor	1_QTU_0.i	0	38273.86	96.7733	15048.08	4463.998	5.3182	27987.27	11067.53	0.9376	4761.482	15531.53	2.1712
RF1_A	Crop Incor	1_QTU_0.i	0	51969.89	97.1465	20432.92	5369.241	5.9819	38002.31	15027.96	0.9355	6465.345	20397.2	2.2416
RF1_A	Crop Incor	1_QTU_0.	0	25114.32	90.4315	9874.16	3473.323	4.5051	18364.53	7262.227	0.9412	3124.362	10735.55	2.0657
RF1_A	Crop Incor	1_QTU_0.	0	28920.72	90.5352	11370.72	3724.908	4.8289	21147.91	8362.912	0.9396	3597.9	12087.82	2.1107
RF1A_A	Rice	1_QTM_0.	0	25964.39	96.2671	10208.89	4394.638	3.6655	18985.9	10895.56	0.6462	3230.405	15290.2	1.4963
RF1A_A	Rice	1_QTM_0.	0	35255.56	96.6385	13862.07	5285.815	4.1227	25779.87	14794.46	0.6447	4386.382	20080.28	1.5447
RF1A_A	Rice	1_QTM_0.	0	17037.16	89.9584	6698.813	3419.356	3.1052	12458.06	7149.388	0.6487	2119.709	10568.74	1.4236
RF1A_A	Rice	1_QTM_0.	0	19619.36	90.0616	7714.105	3667.032	3.3283	14346.24	8232.971	0.6476	2440.978	11900	1.4546
RF1A_A	Rice	1_QTL_0.C	0	25154.81	95.761	9889.551	4325.278	3.6092	18394.48	10723.6	0.6361	3129.223	15048.88	1.473
RF1A_A	Rice	1_QTL_0.C	0	34156.28	96.1305	13428.46	5202.39	4.0593	24976.81	14560.96	0.6346	4248.993	19763.35	1.5207
RF1A_A	Rice	1_QTL_0.1	0	16505.94	89.4854	6489.269	3365.388	3.0577	12069.98	7036.549	0.6385	2053.316	10401.94	1.4015
RF1A_A	Rice	1_QTL_0.1	0	19007.63	89.5881	7472.802	3609.155	3.2773	13899.35	8103.029	0.6375	2364.522	11712.18	1.432
RF1A_A	Rice	1_QTU_0.i	0	26791.7	96.7733	10533.65	4463.998	3.7227	19591.09	11067.53	0.6563	3333.038	15531.53	1.5199
RF1A_A	Rice	1_QTU_0.i	0	36378.92	97.1465	14303.05	5369.241	4.1873	26601.62	15027.96	0.6548	4525.742	20397.2	1.5691
RF1A_A	Rice	1_QTU_0.	0	17580.03	90.4315	6911.912	3473.323	3.1535	12855.17	7262.227	0.6588	2187.054	10735.55	1.446
RF1A_A	Rice	1_QTU_0.	0	20244.51	90.5352	7959.501	3724.908	3.3802	14803.54	8362.912	0.6577	2518.53	12087.82	1.4775
RF1B_A	Wheat	1_QTM_0.	0	11127.59	96.2671	4375.24	4394.638	1.5709	8136.813	10895.56	0.2769	1384.46	15290.2	0.6413

### Indicator 7. Cost Effectiveness Analysis (CEA)

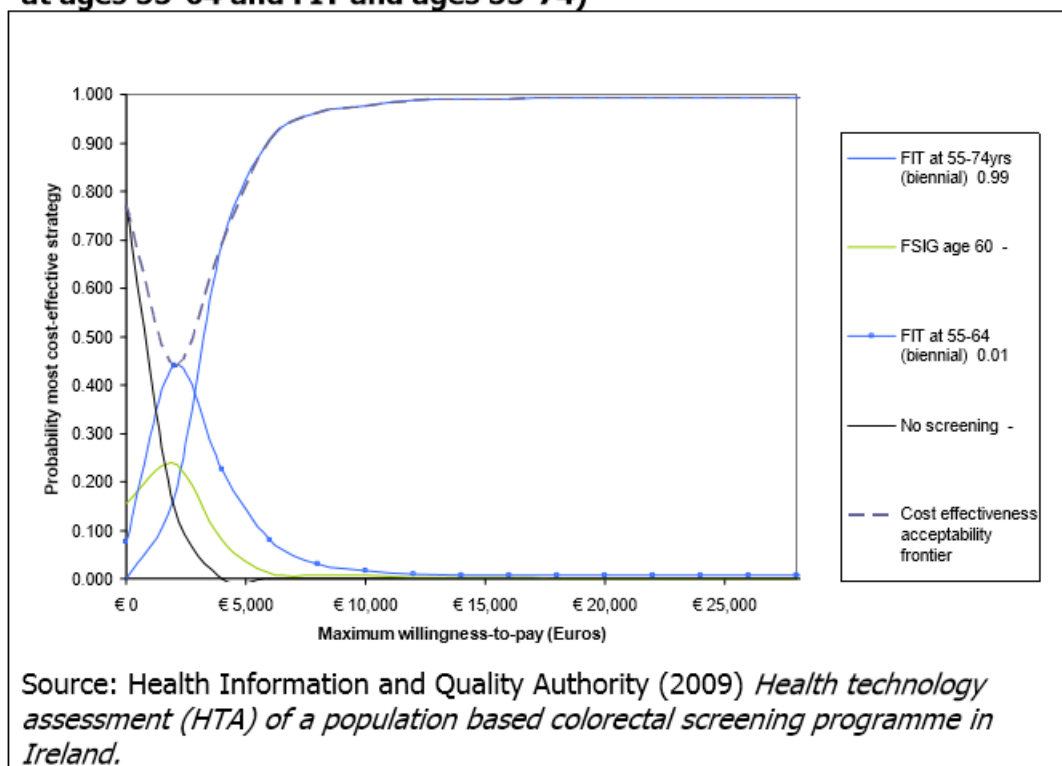
In keeping with this example’s “reality is messy” theme, the health care sector uses CEA in a more comprehensive manner than demonstrated so far. For example, the following cost effectiveness acceptability curves (self-referenced) are often generated from Health Technology Assessment (HTA) results. A useful rule of thumb with algorithm development is to strive to build them in a way that supports general analysis across multiple sectors, rather than narrowly focused on a single sector. The economic concepts, economies of scale and scope, explain why (see the Performance Analysis tutorial for definitions of these terms).



DevTreks –social budgeting that improves lives and livelihoods

*Guidelines for the Economic Evaluation of Health Technologies in Ireland*  
Health Information and Quality Authority

**Figure 5.5 Example of cost-effectiveness acceptability curves and cost-effectiveness acceptability frontier for FSIG (once at age 60 years, FIT at ages 55-64 and FIT and ages 55-74)**



The following properties identify the simpler techniques employed with the case study and used in Indicator 7.

**Math Type and Math Sub Type:** algorithm1, subalgorithm9

**Math Expression:**

$I7.Q1.distribtype + I7.Q2.200year + I7.Q3.100year + I7.Q4.50year + I7.Q5.25year + I7.Q6.10year + I7.Q7.5year$

**Optional Indicator.URL TEXT:** none (Example 2 conducts an independent CEA that will be used for decision support in the Score).



DevTreks –social budgeting that improves lives and livelihoods

## Partial Math Result:

label	assettype	loc_confid	total	RF1_dama	RF1_cost	RF1_A_dai	RF1_A_co	RF1_A_cer	RF1_B_dai	RF1_B_co	RF1_B_cer	RF1_C_dai	RF1_C_co	RF1_C_cer
RF1_A	Crop Incor	1_QTM_0.05_1	0	3573.526	96.2671	1405.069	4394.638	1.9822	2613.064	10895.56	11.2439	444.6066	15290.2	4.856
RF1_A	Crop Incor	1_QTM_0.05_2	0	3573.526	96.6385	1405.069	5285.815	2.393	2613.064	14794.46	15.3029	444.6066	20080.28	6.3868
RF1_A	Crop Incor	1_QTM_0.12_1	0	3573.526	89.9584	1405.069	3419.356	1.5354	2613.064	7149.388	7.35	444.6066	10568.74	3.349
RF1_A	Crop Incor	1_QTM_0.12_2	0	3573.526	90.0616	1405.069	3667.032	1.6495	2613.064	8232.971	8.4781	444.6066	11900	3.7744
RF1_A	Crop Incor	1_QTL_0.05_15	0	3462.103	95.761	1361.117	4325.278	2.0131	2531.666	10723.6	11.4224	430.6807	15048.88	4.9327
RF1_A	Crop Incor	1_QTL_0.05_25	0	3462.103	96.1305	1361.117	5202.39	2.4304	2531.666	14560.96	15.5463	430.6807	19763.35	6.4878
RF1_A	Crop Incor	1_QTL_0.12_15	0	3462.103	89.4854	1361.117	3365.388	1.5592	2531.666	7036.549	7.4665	430.6807	10401.94	3.4019
RF1_A	Crop Incor	1_QTL_0.12_25	0	3462.103	89.5881	1361.117	3609.155	1.6752	2531.666	8103.029	8.6126	430.6807	11712.18	3.834
RF1_A	Crop Incor	1_QTU_0.05_1	0	3687.392	96.7733	1449.766	4463.998	1.9517	2696.358	11067.53	11.07	458.7321	15531.53	4.7805
RF1_A	Crop Incor	1_QTU_0.05_2	0	3687.392	97.1465	1449.766	5369.241	2.3561	2696.358	15027.96	15.0659	458.7321	20397.2	6.2875
RF1_A	Crop Incor	1_QTU_0.12_1	0	3687.392	90.4315	1449.766	3473.323	1.5118	2696.358	7262.227	7.2367	458.7321	10735.55	3.2971
RF1_A	Crop Incor	1_QTU_0.12_2	0	3687.392	90.5352	1449.766	3724.908	1.6242	2696.358	8362.912	8.3472	458.7321	12087.82	3.7159
RF1A_A	Rice	1_QTM_0.05_1	0	2501.468	96.2671	983.5481	4394.638	2.8318	1829.145	10895.56	16.0626	311.2246	15290.2	6.9371
RF1A_A	Rice	1_QTM_0.05_2	0	2501.468	96.6385	983.5481	5285.815	3.4186	1829.145	14794.46	21.8612	311.2246	20080.28	9.1239
RF1A_A	Rice	1_QTM_0.12_1	0	2501.468	89.9584	983.5481	3419.356	2.1934	1829.145	7149.388	10.5	311.2246	10568.74	4.7843
RF1A_A	Rice	1_QTM_0.12_2	0	2501.468	90.0616	983.5481	3667.032	2.3565	1829.145	8232.971	12.1116	311.2246	11900	5.3921
RF1A_A	Rice	1_QTL_0.05_15	0	2423.472	95.761	952.782	4325.278	2.8759	1772.166	10723.6	16.3177	301.4765	15048.88	7.0467
RF1A_A	Rice	1_QTL_0.05_25	0	2423.472	96.1305	952.782	5202.39	3.472	1772.166	14560.96	22.209	301.4765	19763.35	9.2683
RF1A_A	Rice	1_QTL_0.12_15	0	2423.472	89.4854	952.782	3365.388	2.2275	1772.166	7036.549	10.6664	301.4765	10401.94	4.8598
RF1A_A	Rice	1_QTL_0.12_25	0	2423.472	89.5881	952.782	3609.155	2.3931	1772.166	8103.029	12.3037	301.4765	11712.18	5.4772
RF1A_A	Rice	1_QTU_0.05_1	0	2581.174	96.7733	1014.836	4463.998	2.7882	1887.45	11067.53	15.8143	321.1125	15531.53	6.8294
RF1A_A	Rice	1_QTU_0.05_2	0	2581.174	97.1465	1014.836	5369.241	3.3659	1887.45	15027.96	21.5227	321.1125	20397.2	8.9821
RF1A_A	Rice	1_QTU_0.12_1	0	2581.174	90.4315	1014.836	3473.323	2.1597	1887.45	7262.227	10.3381	321.1125	10735.55	4.7101
RF1A_A	Rice	1_QTU_0.12_2	0	2581.174	90.5352	1014.836	3724.908	2.3203	1887.45	8362.912	11.9246	321.1125	12087.82	5.3084
RF1B_A	Wheat	1_QTM_0.05_1	0	1072.058	96.2671	421.5206	4394.638	6.6074	783.9192	10895.56	37.4795	133.382	15290.2	16.1866

## Scores. Multi-Criteria Analysis

Multi-Criteria Analysis uses the following general steps to assist reaching decisions about Indicator 3 to 7's "alternatives", that is, projects, policies, or programs (UK DCLG 2009, UNEP 2011): 1) Identify objectives, 2) Identify options for achieving the objectives (i.e. alternatives), 3) Identify the criteria to be used to compare the options, 4) Analyze the options, 5) Conduct sensitivity analysis, 6) Make choices, and 7) Use feedback to refine the MCA. The following partial image (UNEP 2011) demonstrates that the references cited for this example explain their variants of these steps in more detail.



DevTreks –social budgeting that improves lives and livelihoods

**Box 1: Key steps in implementing the MCA4climate policy evaluation framework**

**1 *Establish the context***

Clarify climate policy goals for mitigation and/or adaptation. Identify the decision makers and main stakeholders. Consider the main national socio-economic, political, institutional and environmental circumstances .

**2 *Identify the options to be evaluated***

Draw up a set of mitigation and adaptation policy options (these can be either single policy actions formulated at different levels of detail or portfolio or mix of policy options).

**3 *Agree on criteria and indicators***

The UNEP (2011) identifies the advantages of using MCA to assist decision involving mitigation and adaptation policies, as follows (14\*):

“MCA techniques can be used to identify a single most preferred option or a mix of options, to rank options, to short-list a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities. ... This approach is particularly well suited to the analysis of climate policies and climate-policy planning for the following reasons ...”.

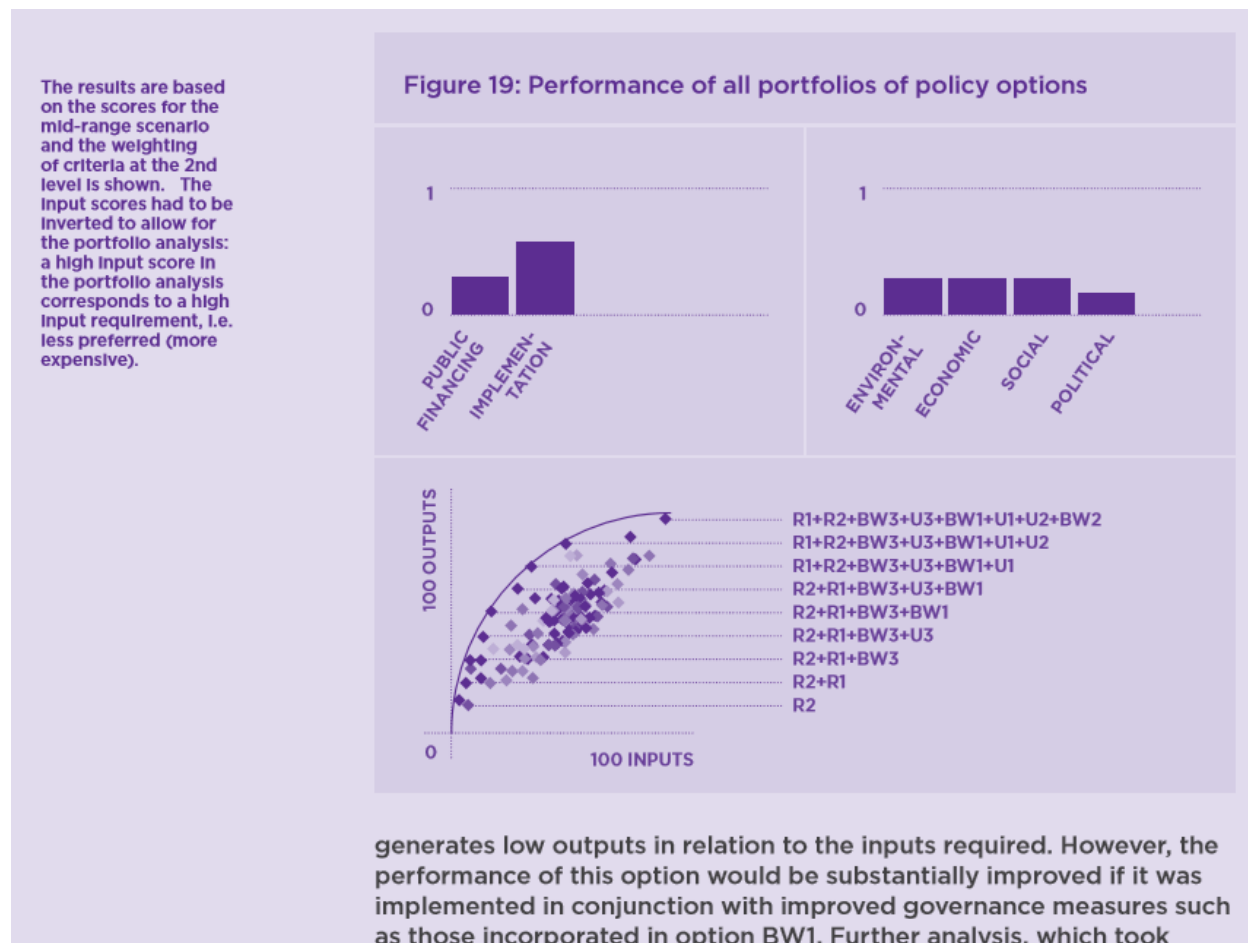
The UNEP (2011) uses the following image to identify the advantages of using MCA to assist decisions involving portfolios of mitigation and adaptation policies. These results are important in the context of drought because the MCA is conducted for integrated water management in the Sana’a Water Basin in Yemen. They describe the MCA graph as follows “The portfolios which are of greatest interest are again those which lie on the efficient frontier, which, in this case is towards the top left-hand corner of the plot”.





DevTreks –social budgeting that improves lives and livelihoods

Miller and Belton (2014) also use the Sana’a Water Basin MCA to reach similar conclusions to those in some of Appendix B’s references –the collaborative process used to complete the MCAs helps to identify “socially acceptable paths forward”.



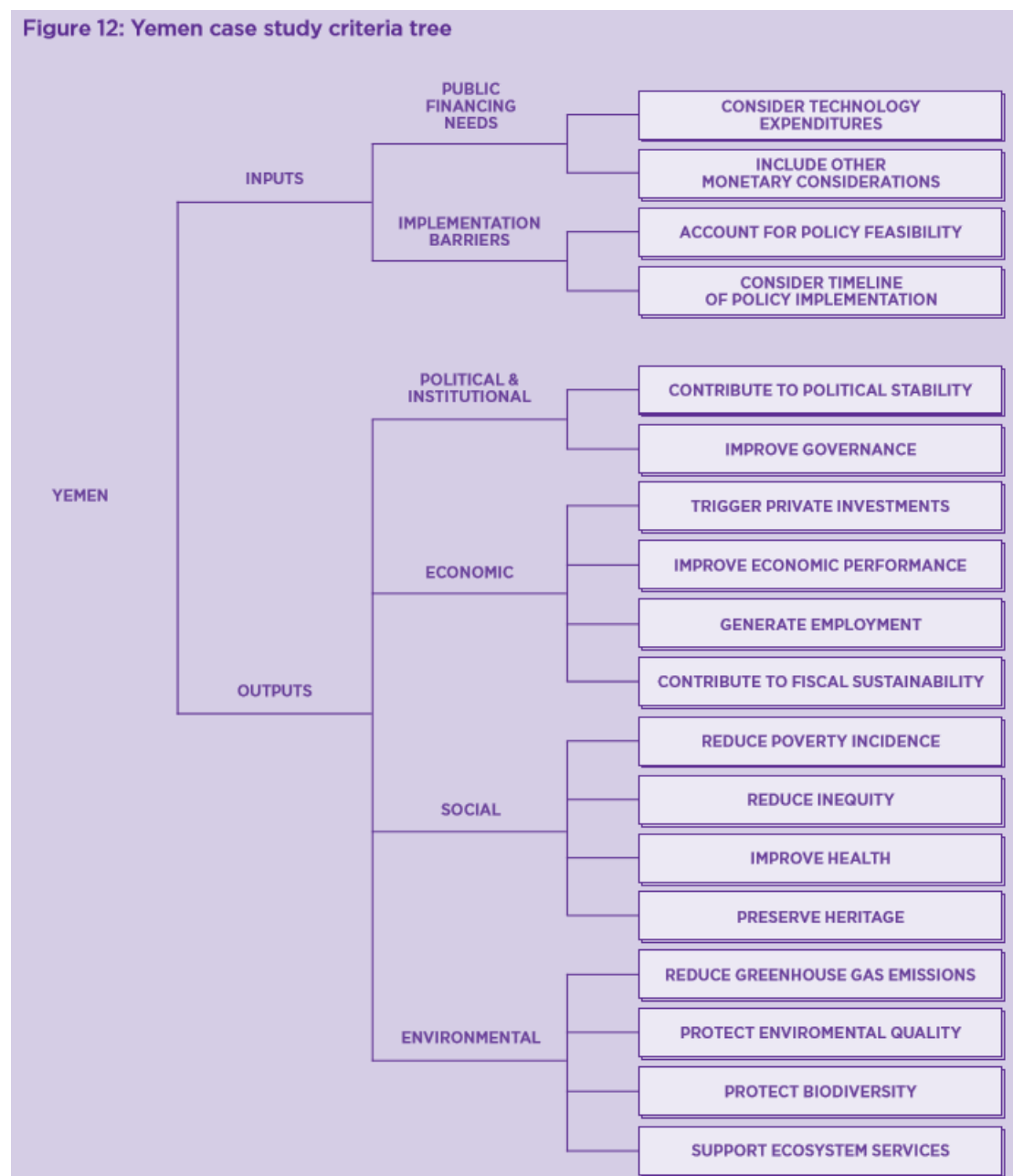
UNEP (2011) uses the following hierarchical system to classify criteria used in Multi-Criteria Assessments that evaluate specific climate change mitigation and adaptation policies. They describe the system as follows:

“At the heart of this framework is a hierarchical criteria tree containing a set of generic criteria, against which climate-policy planners can evaluate proposed climate-policy actions and their



DevTreks –social budgeting that improves lives and livelihoods

potential contribution to a broad range of climate, environmental and socio-economic development objectives”.



A 4<sup>th</sup> level can be added to these criteria that allow more detailed analysis of policy options. UNEP describes this 4<sup>th</sup> level as follows “these indicators ... provide practical measures of performance of policy options against the 3<sup>rd</sup> level criteria [and can be] expressed in monetary or



DevTreks –social budgeting that improves lives and livelihoods

non-monetary terms”. Importantly, they mention that the 4<sup>th</sup> level indicators can be customized for local contexts. They use the following image to demonstrate one set of potential indicators for the 4<sup>th</sup> level.

**Table 14: 3rd-level criteria and indicators for improving energy efficiency and conserving energy**

CRITERION	MAIN INDICATORS
Minimize spending on technology	Overall cost of energy-efficiency improvement policies (including investments in innovation and technical capacity, and subsidies and tax exemptions/deductions)
Minimize other types of spending	Implementation, administration, enforcement and programme costs; as well as investments in training, evaluation and expansion of consumer education and market-based initiatives
Allow for easy implementation	Quality of institutions, including number and size of institutes/organisations involved in policy implementation, execution and monitoring
Comply with required timing of policy intervention	Time required for designing energy efficiency policies and time taken by policies to be effective
Reduce greenhouse-gases and black-carbon emissions	Emission reduction in percentage reduction of greenhouse gases (& black carbon if relevant) compared to a business as usual
Enhance resilience to climate change	Not applicable
Trigger private investments	Whether businesses/households invest in energy efficient equipment and target groups (e.g. number of households that have implemented energy saving measures)
Improve economic performance	Changes in the energy use in industry and households; Costs of measures (e.g. cost per tonne of CO <sub>2</sub> emissions avoided) and share of energy costs in overall costs of industry and household spending
Generate employment	Number of jobs created in energy efficiency services and number of technical staff trained; as well as number of jobs created in other sectors linked to those sectors for which energy efficiency improvements occurred

Miller and Belton (2014) discuss the 4<sup>th</sup> level in greater detail and provide the following example of what they consider to be an important, typical, performance indicator: “For example, if the goal is to increase the reliable yield of a water resource system, an appropriate metric [for the criteria, Minimize Spending on Technology,] would be capital cost per unit of increased yield. Another possible indicator might be capital cost per unit area protected from floods of various



DevTreks –social budgeting that improves lives and livelihoods

specified magnitudes”. In terms of CTAPs, those last metrics are extremely important –they deal with decisions involved with the allocation of money. In addition, they are measurable.

Close examination of the algorithms introduced in Appendix B reveal that Risk Management Indicator algorithms employ similar techniques: 4 level indicator classification systems, rating and weighting, and aggregation into Categorical Indexes, Locational Indexes, and Total Risk Indexes (i.e. MCA scores). Subalgorithms 10, 11 and 12 demonstrate these techniques. The following lists uses the term, SAS, to explain how these algorithms can be used to conduct MCA.

1. **Overall Interactive Decision Support:** SAS require that all raw input data be added to TEXT csv files. SAS cannot accommodate fully interactive MCAs. Other software or spreadsheet programs must be used to complete the initial MCA. In this example, the initial MCA TEXT file is then calculated by the SAS to produce the final MCA results.
2. **Inputs and Outputs:** DevTreks treats these as separate base elements. This example adds the Input and Output criteria and indicators to either base element, but does not split them up into both elements. The final presentation of the raw calculated results have to manually account for the difference, such as producing efficiency frontier graphs.
3. **Indicator System Assessment:** SAS use several steps (i.e. 3 or 7 steps) to complete an indicator system assessment. The background references mention that some MCAs may need to be evaluated in terms of projected disaster events (i.e. Miller and Belton’s 2014 statement: ‘capital cost per unit area protected from floods of various specified magnitudes’). *In other words, the 4 level indicator MCA systems can be used directly with the techniques and algorithms demonstrated in Appendix B.* For this example, the SAS have been modified so that the Score alone can be used to complete the MCA.
4. **Ratings:** SAS rate Indicators using probability density functions rather than point estimates. The references discuss the importance of accounting for climate change risk and uncertainty in MCA. In addition, although not cited, references were found (i.e. USACOE) that demonstrated the use of pdfs to rate MCA criteria. This example makes



no changes. If concerned, use triangular distributions with low, median, and high, values for the ratings. In effect, the distributions are a type of MCA sensitivity analysis.

5. **Normalization:** SAS allow ratings to be normalized, MCAs typically do not. This example sets the normalization values to “none”.
6. **Weights:** SAS allow weights to be assigned to Indicators, Categorical Indexes, and Locational Indexes. MCA typically weights Categorical Indexes, or MCA criteria, alone. This example sets the Indicator and Locational Index weights to 1.
7. **Final Scores:** SAS aggregate Indicators, or criteria, exactly the same as MCA. The final Total Risk Index is equivalent to a final MCA score. This example makes no changes.
8. **Alternatives:** The alternatives presented so far in this example are for project alternatives. The UNEP alternatives are policy alternatives. The difference is semantics and this example makes no changes. In addition, SAS list alternatives vertically, rather than horizontally, in the scoring matrix. This is not important because decision makers are not expected to use the raw data contained in Indicator.Math Results. Analysts are responsible for using that raw data to build multimedia that decision makers will understand. In this example, they supply summary MCA tables and graphs, derived from Score MCAs, to decision makers.
9. **Sensitivity Analysis:** Several references discuss the importance of using sensitivity analysis, particularly to test the weights. The simplest way to conduct sensitivity analysis is to copy CTAs into children Input or Output Series and change each Series member to carry out whatever tests are desired.
10. **Use Feedback:** This example already reinforces the importance of using feedback in an iterative way to refine the overall analysis until consensus emerges about sound mitigation paths. This example makes no changes.

All of the references cited for MCA demonstrate best practices that include: rating criteria using either ordinal or cardinal values, weighting criteria using either explicit or ranking values, iterating through the whole process more than once, and developing media, such as efficiency curves, to communicate the final results to decision makers.



DevTreks –social budgeting that improves lives and livelihoods

To add an element of realism to this example, data from the Yemen case study (UNEP 2011), displayed in a previous image, has been changed for use in this MCA. The issues of equity, externalities, and tradeoffs, are still addressed in the context of drought and integrated water management, but the initial data is based on the Sana'a Basin. Unfortunately, the Yemen case study doesn't include a 4<sup>th</sup> level, so this example has to invent a fictitious set of indicators. Well-funded organizations are in a better position to complete real MCA for local areas such as the Rohini Basin or your local watershed (15\*).

**Score Math Type and Math Sub Type:** algorithm1, subalgorithm12

**Score Math Expression:**

$$\text{I0.Q1.distribtype} + \text{I0.Q2.QT} + \text{I0.Q3.QTUnit} + \text{I0.Q4.QTD1} + \text{I0.Q5.QTD1Unit} + \text{I0.Q6.QTD2} + \text{I0.Q7.QTD2Unit} + \text{I0.Q8.normalization} + \text{I0.Q9.weight} + \text{I0.Q10.quantity}$$

**Score.QT, QTD1, and QTD2:** These properties document the MCA score for the baseline MCA, before any project alternatives are considered. This score is a summation of the TR rows for all locations.

**Score.QTM, QTL, and QTU:** These properties document the MCA score for the project alternative with the highest score. This score is a summation of the TR rows for all locations.

[Version 2.1.4 and 2.1.6 changed from Score.DataURL to Score.JointDataURL in Stock Calculators and Score.URL in M&E Calculators to support machine learning algorithms better.]

**Score.JointDataURL** 1<sup>st</sup> TEXT: For illustrative purposes, this dataset only includes a subset of the full UNEP 18 criteria. This subset addresses this example's priorities: equity, externalities, and tradeoffs. Each indicator is given a fictitious name, such as GHGActionA. Both the UNEP 2011 and Miller and Belton 2014 references includes examples of appropriate indicators, except most are not applicable to this specific example.

To demonstrate some of the UNEP techniques, 3 of the Yemen case study policy alternatives listed in Table 18 will be analyzed: A = BWPLAN, strengthen basin-wide water planning and governance, B = IWM, carry out integrated land and water management, and C = AGINCENT,

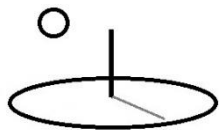


DevTreks –social budgeting that improves lives and livelihoods

create incentives to promote efficient agricultural water use. The three project alternatives presented in the rest of this example are subsumed in these policy options. For example, the Groundwater Irrigation alternative fits under the “carry out integrated water management” policy alternative, and the Crop Insurance alternative fits under the “create agricultural incentives” policy alternative.

Score. Multi-Criteria Assessment (4 level indicator system, 100 point scale)												
label	locatio	indicator	total	distribt	QT	QTUnit	QTD1U	QTD2	QTD2U	normal	weight	quantit
RF1	1	ReduceGHG	0	none	0	none	0	none	0	none	0.33	1
RF1A	1	GHGActionA	0	normal	100	each	100	mean	30	sd	none	1
RF1B	1	GHGActionB	0	normal	100	each	100	mean	30	sd	none	1
RF2	1	ProtectEnvQuality	0	none	0	none	0	none	0	none	0.33	1
RF2A	1	EnvQualityActionA	0	normal	50	each	50	mean	15	sd	none	1
RF2B	1	EnvQualityActionB	0	normal	40	each	40	mean	12	sd	none	1
RF3	1	SupportEcoServices	0	none	0	none	0	none	0	none	0.33	1
RF3A	1	EcoServiceActionA	0	normal	30	each	30	mean	10	sd	none	1
RF3B	1	EcoServiceActionB	0	normal	10	each	10	mean	3	sd	none	1
RF	1	All Environmental	0	none	0	none	0	none	0	none	1	1
FS1	1	ReducePoverty	0	none	0	none	0	none	0	none	0.5	1
FS1A	1	PovertyActionA	0	normal	60	each	60	mean	18	sd	none	1
FS1B	1	PovertyActionB	0	normal	40	each	40	mean	12	sd	none	1
FS2	1	ReduceInequity	0	none	0	none	0	none	0	none	0.5	1
FS2A	1	InequityActionA	0	normal	90	each	90	mean	18	sd	none	1
FS2B	1	InequityActionB	0	normal	60	each	60	mean	18	sd	none	1
FS	1	All Social	0	none	0	none	0	none	0	none	1	1
SR1	1	ImproveEconPerform	0	none	0	none	0	none	0	none	0.5	1
SR1A	1	EconPerformActionA	0	normal	30	each	30	mean	9	sd	none	1
SR1B	1	EconPerformActionA	0	normal	45	each	45	mean	14	sd	none	1
SR2	1	TriggerPrivateInvests	0	none	0	none	0	none	0	none	0.5	1
SR2A	1	PrivateInvestsActionA	0	normal	25	each	25	mean	8	sd	none	1
SR2B	1	PrivateInvestsActionB	0	normal	80	each	80	mean	24	sd	none	1
SR	1	All Economic	0	none	0	none	0	none	0	none	1	1
IB1	1	ReduceImplBarriers	0	none	0	none	0	none	0	none	0.5	1
IB1A	1	ImpBarrierActionA	0	normal	0	each	0	mean	0	sd	none	1
IB1B	1	ImpBarrierActionA	0	normal	25	each	25	mean	8	sd	none	1
IB2	1	MonetaryConsiderations	0	none	0	none	0	none	0	none	0.5	1
IB2A	1	ConsiderationActionA	0	normal	25	each	25	mean	8	sd	none	1
IB2B	1	ConsiderationActionB	0	normal	0	each	0	mean	0	sd	none	1
IB	1	All Implementation Barriers	0	none	0	none	0	none	0	none	1	1
PF1	1	PublicFunding	0	none	0	none	0	none	0	none	1	1
PF1A	1	ReduceTechnologyCosts	0	normal	75	each	75	mean	24	sd	none	1
PF1B	1	ConsiderMonetaryFactors	0	normal	55	each	55	mean	17	sd	none	1
PF	1	All Public Funding	0	none	0	none	0	none	0	none	1	1
TR	1	TotalMCAScore	0	none	0	none	0	none	0	none	1	1
RF1	2	ReduceGHG	0	none	0	none	0	none	0	none	0.33	1

...



DevTreks –social budgeting that improves lives and livelihoods

...

IB2_C	2	MonetaryConsiderations	0	none	0	none	0	none	0	none	none	0.5	1
IB2A_C	2	ConsiderationActionA	0	normal	25	each	25	mean	8	sd	none	1	1
IB2B_C	2	ConsiderationActionB	0	normal	0	each	0	mean	0	sd	none	1	1
IB_C	2	All Implementation Barriers	0	none	0	none	0	none	0	none	none	1	1
PF1_C	2	PublicFunding	0	none	0	none	0	none	0	none	none	1	1
PF1A_C	2	ReduceTechnologyCosts	0	normal	75	each	75	mean	24	sd	none	1	1
PF1B_C	2	ConsiderMonetaryFactors	0	normal	55	each	55	mean	17	sd	none	1	1
PF_C	2	All Public Funding	0	none	0	none	0	none	0	none	none	1	1
TR_C	2	TotalMCAScore	0	none	0	none	0	none	0	none	none	1	1

**Partial Score.Math Result:** The following table displays the partial MCA results.

label	location	indicator	total	distribtype	QTM	QTMUnit	QTL	QTLUnit	QTU	QTUUnit	normaliz	weight	quantity
RF1	1.0000	ReduceGHG	0.0000	none	65.9814	category mean	64.9400	category low	67.0228	category high	none	0.3300	1.0000
RF1A	1.0000	GHGActionA	0.0000	normal	99.9718	mca all locatio	98.3939	lower 90% ci	101.5497	upper 90% ci	none	1.0000	1.0000
RF1B	1.0000	GHGActionB	0.0000	normal	99.9718	mca all locatio	98.3939	lower 90% ci	101.5497	upper 90% ci	none	1.0000	1.0000
RF2	1.0000	ProtectEnvQuality	0.0000	none	29.6916	category mean	29.2230	category low	30.1602	category high	none	0.3300	1.0000
RF2A	1.0000	EnvQualityActionA	0.0000	normal	49.9859	mca all locatio	49.1970	lower 90% ci	50.7748	upper 90% ci	none	1.0000	1.0000
RF2B	1.0000	EnvQualityActionB	0.0000	normal	39.9887	mca all locatio	39.3576	lower 90% ci	40.6198	upper 90% ci	none	1.0000	1.0000
RF3	1.0000	SupportEcoService	0.0000	none	13.1960	category mean	12.9703	category low	13.4216	category high	none	0.3300	1.0000
RF3A	1.0000	EcoServiceActionA	0.0000	normal	29.9906	mca all locatio	29.4646	lower 90% ci	30.5166	upper 90% ci	none	1.0000	1.0000
RF3B	1.0000	EcoServiceActionB	0.0000	normal	9.9972	mca all locatio	9.8394	lower 90% ci	10.1550	upper 90% ci	none	1.0000	1.0000
RF	1.0000	All Environmental	0.0000	none	108.8690	sum categorie	107.1333	category low	110.6046	category high	none	1.0000	1.0000
FS1	1.0000	ReducePoverty	0.0000	none	49.9859	category mean	49.1970	category low	50.7748	category high	none	0.5000	1.0000
FS1A	1.0000	PovertyActionA	0.0000	normal	59.9831	mca all locatio	59.0364	lower 90% ci	60.9298	upper 90% ci	none	1.0000	1.0000
FS1B	1.0000	PovertyActionB	0.0000	normal	39.9887	mca all locatio	39.3576	lower 90% ci	40.6198	upper 90% ci	none	1.0000	1.0000
FS2	1.0000	ReduceInequity	0.0000	none	74.9831	category mean	74.0364	category low	75.9298	category high	none	0.5000	1.0000
FS2A	1.0000	InequityActionA	0.0000	normal	89.9831	mca all locatio	89.0364	lower 90% ci	90.9298	upper 90% ci	none	1.0000	1.0000
FS2B	1.0000	InequityActionB	0.0000	normal	59.9831	mca all locatio	59.0364	lower 90% ci	60.9298	upper 90% ci	none	1.0000	1.0000
FS	1.0000	All Social	0.0000	none	124.9690	sum categorie	123.2334	category low	126.7046	category high	none	1.0000	1.0000
SR1	1.0000	ImproveEconPerfo	0.0000	none	37.4892	category mean	36.8843	category low	38.0940	category high	none	0.5000	1.0000
SR1A	1.0000	EconPerformActio	0.0000	normal	29.9915	mca all locatio	29.5181	lower 90% ci	30.4649	upper 90% ci	none	1.0000	1.0000
SR1B	1.0000	EconPerformActio	0.0000	normal	44.9868	mca all locatio	44.2505	lower 90% ci	45.7231	upper 90% ci	none	1.0000	1.0000
SR2	1.0000	TriggerPrivateInves	0.0000	none	52.4850	category mean	51.6434	category low	53.3265	category high	none	0.5000	1.0000
SR2A	1.0000	PrivateInvestsActic	0.0000	normal	24.9925	mca all locatio	24.5717	lower 90% ci	25.4133	upper 90% ci	none	1.0000	1.0000
SR2B	1.0000	PrivateInvestsActic	0.0000	normal	79.9774	mca all locatio	78.7151	lower 90% ci	81.2397	upper 90% ci	none	1.0000	1.0000
SR	1.0000	All Economic	0.0000	none	89.9741	sum categorie	88.5277	category low	91.4205	category high	none	1.0000	1.0000
IB1	1.0000	ReduceImplBarrier	0.0000	none	12.4963	category mean	12.2859	category low	12.7067	category high	none	0.5000	1.0000
IB1A	1.0000	ImpBarrierActionA	0.0000	normal	0.0000	mca all locatio	0.0000	lower 90% ci	0.0000	upper 90% ci	none	1.0000	1.0000
IB1B	1.0000	ImpBarrierActionA	0.0000	normal	24.9925	mca all locatio	24.5717	lower 90% ci	25.4133	upper 90% ci	none	1.0000	1.0000
IB2	1.0000	MonetaryConsider	0.0000	none	12.4963	category mean	12.2859	category low	12.7067	category high	none	0.5000	1.0000
IB2A	1.0000	ConsiderationActic	0.0000	normal	24.9925	mca all locatio	24.5717	lower 90% ci	25.4133	upper 90% ci	none	1.0000	1.0000
IB2B	1.0000	ConsiderationActic	0.0000	normal	0.0000	mca all locatio	0.0000	lower 90% ci	0.0000	upper 90% ci	none	1.0000	1.0000
IB	1.0000	All Implementation	0.0000	none	24.9925	sum categorie	24.5717	category low	25.4133	category high	none	1.0000	1.0000
PF1	1.0000	PublicFunding	0.0000	none	129.9614	category mean	127.8050	category low	132.1178	category high	none	1.0000	1.0000
PF1A	1.0000	ReduceTechnology	0.0000	normal	74.9774	mca all locatio	73.7151	lower 90% ci	76.2397	upper 90% ci	none	1.0000	1.0000
PF1B	1.0000	ConsiderMonetary	0.0000	normal	54.9840	mca all locatio	54.0899	lower 90% ci	55.8781	upper 90% ci	none	1.0000	1.0000
PF	1.0000	All Public Funding	0.0000	none	129.9614	sum categorie	127.8050	category low	132.1178	category high	none	1.0000	1.0000
TR	1.0000	TotalMCAScore	0.0000	none	478.7660	sum categorie	471.2711	category low	486.2608	category high	none	1.0000	5.0000
RF1	2.0000	ReduceGHG	0.0000	none	32.9907	category mean	32.4700	category low	33.5114	category high	none	0.3300	1.0000





DevTreks –social budgeting that improves lives and livelihoods

As mentioned, the major advantage to using a 4 level MCA based on indicators, is when the indicators are measurable. The previous table does not show any evidence of metrics such as “reduce basin-wide GHG emissions by 25% in 20 years” or “keep capital cost per unit area protected from floods of various specified magnitudes less than 75% of reduced damages”. That’s what the M&E tools demonstrated in Appendix B are designed to do. This example demonstrates a simpler technique. Table 14, shown above, has been modified to include additional columns that further define how project alternatives are being measured. Indicator 3’s 2<sup>nd</sup> TEXT file holds a partial “Action Identification Table” that demonstrates this documentation. For example, for the ReduceGHG criteria, GHGActionA is defined as “reduce basin-wide GHG emissions by 20% in 20 years by taking the following actions: Pump groundwater using energy efficient technologies”. M&E tools, such as those introduced in Appendix B, can be used to measure these goals more comprehensively.

The following image displays the Score properties used in this example. The reason that alternative A has the same MCA as the baseline is that, for convenience, the raw data for each project alternative is exactly the same as the baseline. Fictitious actions and metrics don’t lend themselves to realistic analyses. Obviously, the alternative with the highest MCA should be closely compared to the baseline. Indicators that measure cost effectiveness must be included in the MCAs. As with any decision support tool, the highest MCA (or BCR or CER) may not be the best portfolio, policy, or project alternative.



DevTreks –social budgeting that improves lives and livelihoods

+ Indicator 15	
<b>Altern Type</b>	<b>Target Type</b>
A	benchmark
<b>Score Math Expression</b>	
$I0.Q1.distribtype + I0.Q2.QT + I0.Q3.QTUnit + I0.Q4.QTD1 + I0.Q5.QTD1Unit + I0.Q6.QTD2 + I0.Q7.QTD2Unit + I0.Q8.normalization + I0.Q9.weight + I0.Q10.quantity$	
<b>Score</b>	<b>Score Unit</b>
924.5413	base MCA score
<b>Score D1</b>	<b>Score D1 Unit</b>
910.0722	category low ci
<b>Score D2</b>	<b>Score D2 Unit</b>
939.0103	category high ci
<b>Score Dist Type</b>	<b>Iterations</b>
none	1000
<b>Confidence Interval</b>	<b>Random Seed</b>
90	5
<b>Score BaseIO</b>	
none	
<b>Score Most Likely</b>	<b>Score Most Unit</b>
924.5413	mca all locations for A
<b>Score Low Estimate</b>	<b>Score Low Unit</b>
910.0722	lower 90% ci
<b>Score High Estimate</b>	<b>Score High Unit</b>
939.0103	upper 90% ci
<b>Score Math Type</b>	<b>Score Math Sub Type</b>
algorithm1	subalgorithm12
<b>Score Math Result</b>	
<a href="http://localhost/resources/network_carbon/resourcepack_533/resource_1852/Score-MCA-Result.csv">http://localhost/resources/network_carbon/resourcepack_533/resource_1852/Score-MCA-Result.csv</a>	

## Discussion



DevTreks –social budgeting that improves lives and livelihoods

The references address additional “lessons learned” by practitioners of this approach, including: assessing single interventions vs. portfolios of interventions, analyzing tradeoffs, and testing the final weights. This algorithm requires that these techniques be completed manually, and no examples have been offered. These are obvious shortfalls compared to the UNEP 2011 and Miller and Belton 2014 analyses.

In the CTAP context, the question that must be answered by this example is: “Does this approach really achieve cost effective climate change goals, while still addressing important, related, societal goals?”

The initial answer appears to be a cautious “maybe”. This approach has the potential to make sound recommendations that can be used by decision makers to mitigate and adapt to climate change while also achieving important societal goals, such as equity and natural resources conservation.

The greatest potential shortfall, based on the author’s experience, is that field staff need concrete guidance about what actions to take, backed up with funding. Quantified targets must be set for concrete mitigation and adaptation actions. The targets must then be monitored and evaluated, using formal tools as demonstrated in Appendix B. The process has to provide proof to questions such as “have GHG emissions been reduced by 25% in 10 years”, “have capital cost per unit area protected from drought of various specified magnitudes been kept to less than 75% of reduced damages”, “have farmers’ income stabilized 100% during droughts”, “has malnutrition been 100% eliminated from farmworker families during all periods”, “are natural resource assets been protected 50% better for long term use”, “have the quality of disaster management institutions improved to the point that they can handle 75% of any potential national disaster”. Ultimately, the “how and why” behind the questions and answers, that is, the overall Conservation Technology Assessment, must be transparent, and “learnable” by future generations.

MCA can provide important input about the actions, but it doesn’t necessarily supply the full context for disaster risk management processes or the M&E component. In other words, MCA



DevTreks –social budgeting that improves lives and livelihoods

appears to be one useful ingredient in more comprehensive planning approaches. It doesn't replace watershed planning, ecosystem planning, integrated water management, or civil disaster planning.

The potential greatest benefit from these types of approaches is that they deal squarely with society, messy though it may be. Farmers, farmworkers, fertilizer dealers, and local communities need not be afterthoughts to planning processes dominated by engineers, physical science professionals, safety experts, administrative staffs, and special interest groups. The initial guiding principle, "Experiment and Gain Experience", holds firm. Make sure that the "experiences" are transparent, and learnable by future generations, by using sound IT.



DevTreks –social budgeting that improves lives and livelihoods

## Example 9. Drought Vulnerability Index

### URLs:

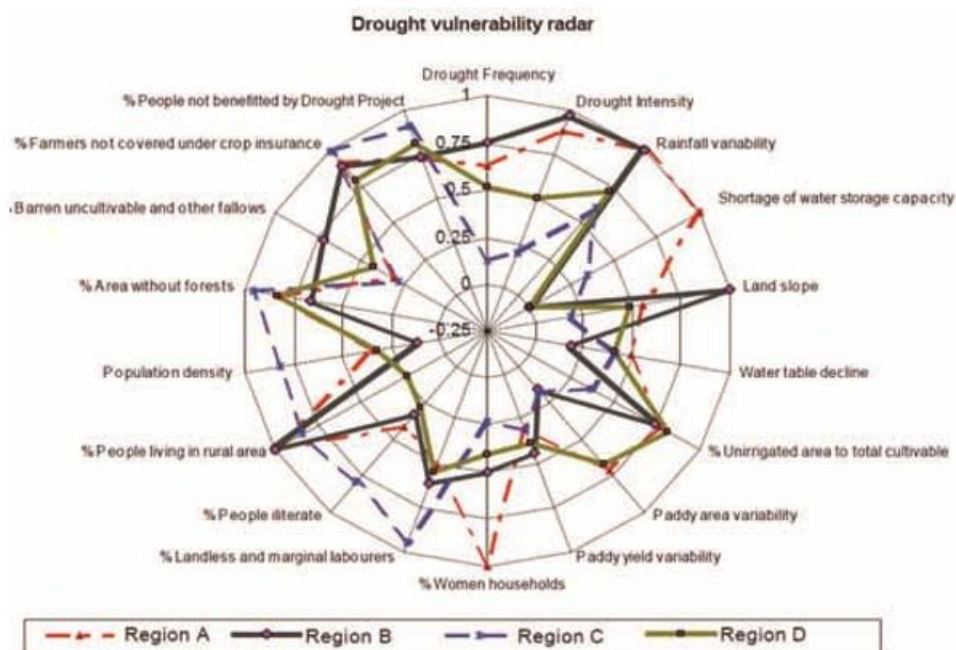
[https://www.devtreks.org/greentreks/preview/carbon/output/CTAP Example 6 - Drought Vulnerability Index/2141223471/none](https://www.devtreks.org/greentreks/preview/carbon/output/CTAP%20Example%206%20-%20Drought%20Vulnerability%20Index/2141223471/none)

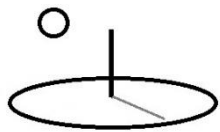
[https://www.devtreks.org/greentreks/preview/carbon/resourcepack/Drought DRR and DSS/1543/none](https://www.devtreks.org/greentreks/preview/carbon/resourcepack/Drought%20DRR%20and%20DSS/1543/none)

[http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 7 - Drought Vulnerability Index/2141223478/none](http://localhost:5000/greentreks/preview/carbon/output/CTAP%20Example%207%20-%20Drought%20Vulnerability%20Index/2141223478/none)

### Indicator 1. Drought Vulnerability Index Distribution

This example uses the data from the following image (UN CAPNET 2015) to conduct a fictitious DVI for Example 1's Uttar Pradesh case study.





DevTreks –social budgeting that improves lives and livelihoods

The previous image shows that this data is not being used with exceedance probabilities, therefore subalgorithm 9 or 10 are not appropriate to use. Instead, it can be completed by using either the Risk Management Index or the Resiliency Index algorithms (subalgorithm 11 or 12) with a separate Output base element.

Selected properties include:

**Math Type and Math Sub Type:** algorithm1, subalgorithm12

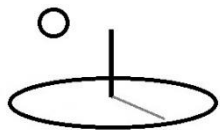
Note that subalgorithm11 can also be used if weighted average calculations are desired for TR rows.

**Math Expression:**

$$\text{I1.Q1.distribtype} + \text{I1.Q2.QT} + \text{I1.Q3.QTUnit} + \text{I1.Q4.QTD1} + \text{I1.Q5.QTD1Unit} + \text{I1.Q6.QTD2} + \text{I1.Q7.QTD2Unit} + \text{I1.Q8.normalization} + \text{I1.Q9.weight} + \text{I1.Q10.quantity}$$

**Indicator.URL TEXT:** Location 1 uses Region A’s values and Location 2 uses Region C’s values. Categories, such as Physical Factors or Social Factors, have been added that are appropriate for these indicators. For convenience, but not realism, the values and weights are set in a manner to return the values in the radar graph. Appendix B shows that weights are usually associated with categories and locations (i.e. the weights for Indicators in the Social Factor category sum to 1). The results of this calculation will be used in Example 1 to supply additional decision support.

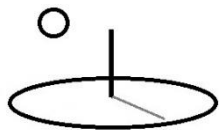
The goal of any Vulnerability Indicator Index system is to help understand the “root causes” of vulnerability. Once root causes are better understood, potential preventative actions can be better identified. The Hochrainer et al reference (Disaster Financing ..., 2011) shows that social scientists have conducted social science surveys in this area, specifically for disaster-related purposes. These surveys included socioeconomic variables, such as perceived disaster risks and moneylender financing after disasters, which are more relevant than the general socioeconomic DVI indicators used in this example. Local survey data, whether formal or informal, can do a better job of identifying “root cause” vulnerability indicators than the initial indicators found in



DevTreks –social budgeting that improves lives and livelihoods

generic indicator systems. More so, when the surveys have been designed for that particular purpose.

Appendix B pointed out that the indicators used with this algorithm should be developed and owned by local stakeholders. These types of Indexes must be customized by locals who receive support from these types of social science experts. The general point is that disaster risk management is too often dominated by engineering, physical science, and safety, experts when it should be dominated by social scientists and community facilitators. Furthermore, this reference demonstrates that social science professionals (1\*) and facilitators must understand IT and must be able to actively assist these important efforts via modern IT technologies (i.e. as contrasted to passive, obsolescent, academic papers).



## DevTreks –social budgeting that improves lives and livelihoods

Indicator 1. Drought Vulnerability Index (100 point scale)													
label	locatio	indicator	total	distribtype	QT	QTUnit	QTD1	QTD1Unit	QTD2	QTD2Unit	normalization	weight	quantity
RI1	1	PhysicalFactors	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI1A	1	DroughtFrequenc	0.0000	normal	60.0000	mean	600.0000	mean	180.0000	sd	none	0.1000	1.0000
RI1B	1	DroughtIntensity	0.0000	normal	90.0000	mean	900.0000	mean	270.0000	sd	none	0.1000	1.0000
RI1C	1	RainfallVariability	0.0000	normal	100.0000	mean	2000.0000	mean	600.0000	sd	none	0.0500	1.0000
RI1D	1	WaterStorageCap	0.0000	normal	100.0000	mean	2000.0000	mean	600.0000	sd	none	0.0500	1.0000
RI1E	1	LandSlope	0.0000	normal	55.0000	mean	1100.0000	mean	330.0000	sd	none	0.0500	1.0000
RI1F	1	WaterTableDeclir	0.0000	normal	50.0000	mean	1000.0000	mean	300.0000	sd	none	0.0500	1.0000
RI	1	AllPhysical	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RR2	1	SocialFactors	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RR2A	1	WomenHousehol	0.0000	normal	50.0000	mean	1000.0000	mean	300.0000	sd	none	0.0500	1.0000
RR2B	1	LandlessLaborers	0.0000	normal	50.0000	mean	1000.0000	mean	300.0000	sd	none	0.0500	1.0000
RR2C	1	IlliteratePeople	0.0000	normal	40.0000	mean	400.0000	mean	120.0000	sd	none	0.1000	1.0000
RR2D	1	RuralResidents	0.0000	normal	75.0000	mean	1500.0000	mean	450.0000	sd	none	0.0500	1.0000
RR2E	1	PopulationDensit	0.0000	normal	30.0000	mean	600.0000	mean	180.0000	sd	none	0.0500	1.0000
RR2F	1	HouseholdsBelow	0.0000	normal	40.0000	mean	533.3333	mean	160.0000	sd	none	0.0750	1.0000
RR	1	AllSocial	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
DM3	1	InstitutionalFacto	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
DM3A	1	FarmersNoCroplr	0.0000	normal	90.0000	mean	180000.0000	mean	54000.0000	sd	none	0.0005	1.0000
DM3B	1	PeopleNoProject	0.0000	normal	75.0000	mean	150000.0000	mean	45000.0000	sd	none	0.0005	1.0000
DM	1	AllInstitutional	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
FP4	1	EconomicFactors	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
FP4A	1	AreaNotIrrigated	0.0000	normal	30.0000	mean	300.0000	mean	90.0000	sd	none	0.1000	1.0000
FP4B	1	PaddyAreaVariabi	0.0000	normal	75.0000	mean	150000.0000	mean	45000.0000	sd	none	0.0005	1.0000
FP4C	1	PaddyYieldVariab	0.0000	normal	35.0000	mean	777.7778	mean	233.3333	sd	none	0.0450	1.0000
FP4D	1	AreaNoForest	0.0000	normal	80.0000	mean	1600.0000	mean	480.0000	sd	none	0.0500	1.0000
FP4E	1	UncultivableLand	0.0000	normal	30.0000	mean	42857.1429	mean	12857.1429	sd	none	0.0007	1.0000
FP	1	AllEconomic	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
TR	1	DroughtVulnerabi	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI1	2	PhysicalFactors	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI1A	2	DroughtFrequenc	0.0000	normal	15.0000	mean	150.0000	mean	45.0000	sd	none	0.1000	1.0000
RI1B	2	DroughtIntensity	0.0000	normal	20.0000	mean	200.0000	mean	60.0000	sd	none	0.1000	1.0000
RI1C	2	RainfallVariability	0.0000	normal	60.0000	mean	1200.0000	mean	360.0000	sd	none	0.0500	1.0000
RI1D	2	WaterStorageCap	0.0000	normal	40.0000	mean	800.0000	mean	240.0000	sd	none	0.0500	1.0000
RI1E	2	LandSlope	0.0000	normal	20.0000	mean	400.0000	mean	120.0000	sd	none	0.0500	1.0000
RI1F	2	WaterTableDeclir	0.0000	normal	40.0000	mean	800.0000	mean	240.0000	sd	none	0.0500	1.0000
RI	2	AllPhysical	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RR2	2	SocialFactors	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RR2A	2	WomenHousehol	0.0000	normal	25.0000	mean	500.0000	mean	150.0000	sd	none	0.0500	1.0000
RR2B	2	LandlessLaborers	0.0000	normal	95.0000	mean	1900.0000	mean	570.0000	sd	none	0.0500	1.0000
RR2C	2	IlliteratePeople	0.0000	normal	80.0000	mean	800.0000	mean	240.0000	sd	none	0.1000	1.0000
RR2D	2	RuralResidents	0.0000	normal	80.0000	mean	1600.0000	mean	480.0000	sd	none	0.0500	1.0000
RR2E	2	PopulationDensit	0.0000	normal	80.0000	mean	1600.0000	mean	480.0000	sd	none	0.0500	1.0000
RR2F	2	HouseholdsBelow	0.0000	normal	80.0000	mean	1066.6667	mean	320.0000	sd	none	0.0750	1.0000
RR	2	AllSocial	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
DM3	2	InstitutionalFacto	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
DM3A	2	FarmersNoCroplr	0.0000	normal	100.0000	mean	200000.0000	mean	60000.0000	sd	none	0.0005	1.0000
DM3B	2	PeopleNoProject	0.0000	normal	90.0000	mean	180000.0000	mean	54000.0000	sd	none	0.0005	1.0000
DM	2	AllInstitutional	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
FP4	2	EconomicFactors	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
FP4A	2	AreaNotIrrigated	0.0000	normal	35.0000	mean	350.0000	mean	105.0000	sd	none	0.1000	1.0000
FP4B	2	PaddyAreaVariabi	0.0000	normal	20.0000	mean	40000.0000	mean	12000.0000	sd	none	0.0005	1.0000
FP4C	2	PaddyYieldVariab	0.0000	normal	30.0000	mean	666.6667	mean	200.0000	sd	none	0.0450	1.0000
FP4D	2	AreaNoForest	0.0000	normal	95.0000	mean	1900.0000	mean	570.0000	sd	none	0.0500	1.0000
FP4E	2	UncultivableLand	0.0000	normal	25.0000	mean	35714.2857	mean	10714.2857	sd	none	0.0007	1.0000
FP	2	AllEconomic	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
TR	2	DroughtVulnerabi	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000
RI1_A	1	PhysicalFactors	0.0000	none	0.0000	none	0.0000	none	0.0000	none	none	1.0000	1.0000

**Partial Math Result:**





## DevTreks –social budgeting that improves lives and livelihoods

label	location	indicator	total	distribtype	QTM	QTMUnit	QTL	QTLUnit	QTU	QTUUnit	normalizat	weight	quantity
RI1	1.0000	PhysicalFactors	0.0000	none	454.8715	category n	447.6923	category k	462.0508	category h	none	1.0000	1.0000
RI1A	1.0000	DroughtFrequency	0.0000	normal	59.9831	ri all locati	59.0364	lower 90%	60.9298	upper 90%	none	0.1000	1.0000
RI1B	1.0000	DroughtIntensity	0.0000	normal	89.9746	ri all locati	88.5545	lower 90%	91.3947	upper 90%	none	0.1000	1.0000
RI1C	1.0000	RainfallVariability	0.0000	normal	99.9718	ri all locati	98.3939	lower 90%	101.5496	upper 90%	none	0.0500	1.0000
RI1D	1.0000	WaterStorageCapa	0.0000	normal	99.9718	ri all locati	98.3939	lower 90%	101.5496	upper 90%	none	0.0500	1.0000
RI1E	1.0000	LandSlope	0.0000	normal	54.9845	ri all locati	54.1167	lower 90%	55.8523	upper 90%	none	0.0500	1.0000
RI1F	1.0000	WaterTableDecline	0.0000	normal	49.9859	ri all locati	49.1970	lower 90%	50.7748	upper 90%	none	0.0500	1.0000
RI	1.0000	AllPhysical	0.0000	none	454.8715	resiliency i	447.6923	category k	462.0508	category h	none	1.0000	1.0000
RR2	1.0000	SocialFactors	0.0000	none	284.9195	category n	280.4226	category k	289.4164	category h	none	1.0000	1.0000
RR2A	1.0000	WomenHouseholds	0.0000	normal	49.9859	ri all locati	49.1970	lower 90%	50.7748	upper 90%	none	0.0500	1.0000
RR2B	1.0000	LandlessLaborers	0.0000	normal	49.9859	ri all locati	49.1970	lower 90%	50.7748	upper 90%	none	0.0500	1.0000
RR2C	1.0000	IlliteratePeople	0.0000	normal	39.9887	ri all locati	39.3576	lower 90%	40.6199	upper 90%	none	0.1000	1.0000
RR2D	1.0000	RuralResidents	0.0000	normal	74.9788	ri all locati	73.7954	lower 90%	76.1622	upper 90%	none	0.0500	1.0000
RR2E	1.0000	PopulationDensity	0.0000	normal	29.9915	ri all locati	29.5182	lower 90%	30.4649	upper 90%	none	0.0500	1.0000
RR2F	1.0000	HouseholdsBelowP	0.0000	normal	39.9887	ri all locati	39.3576	lower 90%	40.6198	upper 90%	none	0.0750	1.0000
RR	1.0000	AllSocial	0.0000	none	284.9195	resiliency i	280.4226	category k	289.4164	category h	none	1.0000	1.0000
DM3	1.0000	InstitutionalFactors	0.0000	none	164.9534	category n	162.3500	category k	167.5569	category h	none	1.0000	1.0000
DM3A	1.0000	FarmersNoCropInsu	0.0000	normal	89.9746	ri all locati	88.5545	lower 90%	91.3947	upper 90%	none	0.0005	1.0000
DM3B	1.0000	PeopleNoProject	0.0000	normal	74.9788	ri all locati	73.7954	lower 90%	76.1622	upper 90%	none	0.0005	1.0000
DM	1.0000	AllInstitutional	0.0000	none	164.9534	resiliency i	162.3500	category k	167.5569	category h	none	1.0000	1.0000
FP4	1.0000	EconomicFactors	0.0000	none	249.9294	category n	245.9848	category k	253.8740	category h	none	1.0000	1.0000
FP4A	1.0000	AreaNotIrrigated	0.0000	normal	29.9915	ri all locati	29.5182	lower 90%	30.4649	upper 90%	none	0.1000	1.0000
FP4B	1.0000	PaddyAreaVariabilit	0.0000	normal	74.9788	ri all locati	73.7954	lower 90%	76.1622	upper 90%	none	0.0005	1.0000
FP4C	1.0000	PaddyYieldVariabilit	0.0000	normal	34.9901	ri all locati	34.4379	lower 90%	35.5424	upper 90%	none	0.0450	1.0000
FP4D	1.0000	AreaNoForest	0.0000	normal	79.9774	ri all locati	78.7151	lower 90%	81.2397	upper 90%	none	0.0500	1.0000
FP4E	1.0000	UncultivableLand	0.0000	normal	29.9915	ri all locati	29.5182	lower 90%	30.4649	upper 90%	none	0.0007	1.0000
FP	1.0000	AllEconomic	0.0000	none	249.9294	resiliency i	245.9848	category k	253.8740	category h	none	1.0000	1.0000
TR	1.0000	DroughtVulnerabilit	0.0000	none	1154.6739	resiliency i	1136.4497	category k	#####	category h	none	1.0000	4.0000
RI1	2.0000	PhysicalFactors	0.0000	none	194.9449	category n	191.8681	category k	198.0217	category h	none	1.0000	1.0000

### Indicator 2. Costs of Alternatives Distribution

This Indicator uses the same costs and project alternatives as Example 1 and no further documentation is offered.

### Indicator 3. Cost Effectiveness Analysis.

Technically, the nature of this analysis should use social science-oriented project and policy alternatives, but for convenience, the same project alternatives as Example 1 return the following results. Example 1's Score MCA, addresses social science-oriented policy options further.

### Partial Math Result:



## DevTreks –social budgeting that improves lives and livelihoods

label	indicat	loc_confid	total	RI1_perfor	RI1_cost	RI1_A_perfo	RI1_A_cost	RI1_A_cer	RI1_B_perfo	RI1_B_cost	RI1_B_cer	RI1_C_per	RI1_C_cost	RI1_C_cer
RI1_A	Physica	1_QTM_0.05_15	####	454.8715	96.2671	454.8715	4394.6383	4298.3712	454.8715	10895.5634	10799.2963	454.8715	15290.2017	15193.9346
RI1_A	Physica	1_QTL_0.05_15	####	447.6923	95.7610	447.6923	4325.2782	4229.5172	447.6923	10723.5984	10627.8374	447.6923	15048.8766	14953.1156
RI1_A	Physica	1_QTU_0.05_15	####	462.0508	96.7733	462.0508	4463.9984	4367.2251	462.0508	11067.5284	10970.7551	462.0508	15531.5267	15434.7534
RI1_A	Physica	1_QTM_0.05_25	####	454.8715	96.6385	454.8715	5285.8152	5189.1767	454.8715	14794.4629	14697.8244	454.8715	20080.2782	19983.6397
RI1_A	Physica	1_QTL_0.05_25	####	447.6923	96.1305	447.6923	5202.3899	5106.2594	447.6923	14560.9615	14464.8310	447.6923	19763.3514	19667.2209
RI1_A	Physica	1_QTU_0.05_25	####	462.0508	97.1465	462.0508	5369.2406	5272.0941	462.0508	15027.9644	14930.8179	462.0508	20397.2049	20300.0584
RI1_A	Physica	1_QTM_0.12_15	####	454.8715	89.9584	454.8715	3419.3558	3329.3974	454.8715	7149.3883	7059.4299	454.8715	10568.7441	10478.7857
RI1_A	Physica	1_QTL_0.12_15	####	447.6923	89.4854	447.6923	3365.3884	3275.9030	447.6923	7036.5493	6947.0639	447.6923	10401.9377	10312.4523
RI1_A	Physica	1_QTU_0.12_15	####	462.0508	90.4315	462.0508	3473.3232	3382.8917	462.0508	7262.2273	7171.7958	462.0508	10735.5504	10645.1189
RI1_A	Physica	1_QTM_0.12_25	####	454.8715	90.0616	454.8715	3667.0317	3576.9701	454.8715	8232.9706	8142.9090	454.8715	11900.0023	11809.9407
RI1_A	Physica	1_QTL_0.12_25	####	447.6923	89.5881	447.6923	3609.1553	3519.5672	447.6923	8103.0294	8013.4413	447.6923	11712.1847	11622.5966
RI1_A	Physica	1_QTU_0.12_25	####	462.0508	90.5352	462.0508	3724.9081	3634.3729	462.0508	8362.9118	8272.3766	462.0508	12087.8199	11997.2847
RI1A_A	Drough	1_QTM_0.05_15	####	59.9831	96.2671	59.9831	4394.6383	4298.3712	59.9831	10895.5634	10799.2963	59.9831	15290.2017	15193.9346
RI1A_A	Drough	1_QTL_0.05_15	####	59.0364	95.7610	59.0364	4325.2782	4229.5172	59.0364	10723.5984	10627.8374	59.0364	15048.8766	14953.1156
RI1A_A	Drough	1_QTU_0.05_15	####	60.9298	96.7733	60.9298	4463.9984	4367.2251	60.9298	11067.5284	10970.7551	60.9298	15531.5267	15434.7534
RI1A_A	Drough	1_QTM_0.05_25	####	59.9831	96.6385	59.9831	5285.8152	5189.1767	59.9831	14794.4629	14697.8244	59.9831	20080.2782	19983.6397
RI1A_A	Drough	1_QTL_0.05_25	####	59.0364	96.1305	59.0364	5202.3899	5106.2594	59.0364	14560.9615	14464.8310	59.0364	19763.3514	19667.2209
RI1A_A	Drough	1_QTU_0.05_25	####	60.9298	97.1465	60.9298	5369.2406	5272.0941	60.9298	15027.9644	14930.8179	60.9298	20397.2049	20300.0584
RI1A_A	Drough	1_QTM_0.12_15	####	59.9831	89.9584	59.9831	3419.3558	3329.3974	59.9831	7149.3883	7059.4299	59.9831	10568.7441	10478.7857
RI1A_A	Drough	1_QTL_0.12_15	####	59.0364	89.4854	59.0364	3365.3884	3275.9030	59.0364	7036.5493	6947.0639	59.0364	10401.9377	10312.4523
RI1A_A	Drough	1_QTU_0.12_15	####	60.9298	90.4315	60.9298	3473.3232	3382.8917	60.9298	7262.2273	7171.7958	60.9298	10735.5504	10645.1189
RI1A_A	Drough	1_QTM_0.12_25	####	59.9831	90.0616	59.9831	3667.0317	3576.9701	59.9831	8232.9706	8142.9090	59.9831	11900.0023	11809.9407
RI1A_A	Drough	1_QTL_0.12_25	####	59.0364	89.5881	59.0364	3609.1553	3519.5672	59.0364	8103.0294	8013.4413	59.0364	11712.1847	11622.5966
RI1A_A	Drough	1_QTU_0.12_25	####	60.9298	90.5352	60.9298	3724.9081	3634.3729	60.9298	8362.9118	8272.3766	60.9298	12087.8199	11997.2847
RI1B_A	Drough	1_QTM_0.05_15	####	89.9746	96.2671	89.9746	4394.6383	4298.3712	89.9746	10895.5634	10799.2963	89.9746	15290.2017	15193.9346
RI1B_A	Drough	1_QTL_0.05_15	####	88.5545	95.7610	88.5545	4325.2782	4229.5172	88.5545	10723.5984	10627.8374	88.5545	15048.8766	14953.1156
RI1B_A	Drough	1_QTU_0.05_15	####	91.3947	96.7733	91.3947	4463.9984	4367.2251	91.3947	11067.5284	10970.7551	91.3947	15531.5267	15434.7534
RI1B_A	Drough	1_QTM_0.05_25	####	89.9746	96.6385	89.9746	5285.8152	5189.1767	89.9746	14794.4629	14697.8244	89.9746	20080.2782	19983.6397
RI1B_A	Drough	1_QTL_0.05_25	####	88.5545	96.1305	88.5545	5202.3899	5106.2594	88.5545	14560.9615	14464.8310	88.5545	19763.3514	19667.2209
RI1B_A	Drough	1_QTU_0.05_25	####	91.3947	97.1465	91.3947	5369.2406	5272.0941	91.3947	15027.9644	14930.8179	91.3947	20397.2049	20300.0584
RI1B_A	Drough	1_QTM_0.12_15	####	89.9746	89.9584	89.9746	3419.3558	3329.3974	89.9746	7149.3883	7059.4299	89.9746	10568.7441	10478.7857
RI1B_A	Drough	1_QTL_0.12_15	####	88.5545	89.4854	88.5545	3365.3884	3275.9030	88.5545	7036.5493	6947.0639	88.5545	10401.9377	10312.4523
RI1B_A	Drough	1_QTU_0.12_15	####	91.3947	90.4315	91.3947	3473.3232	3382.8917	91.3947	7262.2273	7171.7958	91.3947	10735.5504	10645.1189
RI1B_A	Drough	1_QTM_0.12_25	####	89.9746	90.0616	89.9746	3667.0317	3576.9701	89.9746	8232.9706	8142.9090	89.9746	11900.0023	11809.9407
RI1B_A	Drough	1_QTL_0.12_25	####	88.5545	89.5881	88.5545	3609.1553	3519.5672	88.5545	8103.0294	8013.4413	88.5545	11712.1847	11622.5966
RI1B_A	Drough	1_QTU_0.12_25	####	91.3947	90.5352	91.3947	3724.9081	3634.3729	91.3947	8362.9118	8272.3766	91.3947	12087.8199	11997.2847
RI1C_A	Rainfal	1_QTM_0.05_15	####	99.9718	96.2671	99.9718	4394.6383	4298.3712	99.9718	10895.5634	10799.2963	99.9718	15290.2017	15193.9346



DevTreks –social budgeting that improves lives and livelihoods

## **Appendix D. Integrated Local, National, and International CTAP Systems**

This Appendix begins to demonstrate how to aggregate data collected using CTAPs into local, national, and international, data loss systems. More generally, the goal is to aggregate any CTA data (i.e. HTAs) into higher level decision support systems. Attention will focus on the measurable performance indicators introduced in Appendix C, such as “have GHG emissions been reduced by 25% in 15 years?” and “are the mitigation and adaptation interventions equitable?”.

Example 6 in the Social Performance Analysis 3 (SPA3) reference introduced the EU-sponsored INFORM project as an example of a multi-index disaster risk management system that is being used at global scale. The advantage to this MCDA approach is that the authors have been carefully assessing the best available global datasets that contain Indicators that can be combined together in novel ways to support disaster and crisis risk management. The disadvantage is that not all of SPA3’s SDG and Sendai DRR targets can be fully addressed using INFORM alone. In the context of this reference, the INFORM documentation (2018) presents no examples of how well that approach supports national, local (i.e. watershed), and industry, sustainability accounting systems, including their concerns about equity, externalities, and tradeoffs.

[Hold for future possible development]

### **Example 1. Simple National Data Loss System**

This example uses the word “simple” in the title because it does not directly use any of the established data loss collection systems mentioned in the Introduction. Instead, the release demonstrates how to program machines to aggregate CTAP data into any other data loss system, including the existing systems. Application Programming Interfaces (APIs, or microservice Web APIs), document-centric databases (i.e. holding CTAP results), and better tools to communicate results, such as GIS maps, take center stage. A simple example or two may suffice to demonstrate these techniques.



DevTreks –social budgeting that improves lives and livelihoods

## **Appendix E. Resource Stock and M&E Analyzers**

Version 2.1.4 moved the documentation for the Stock and M&E Analyzers to this appendix because they provide ancillary decision support, rather than primary algorithm decision support.

### **Example 6. Resource Stock Progress Analyzers (10\*)**

#### **URLs:**

<https://www.devtreks.org/greentreks/preview/carbon/output/CTAP- BM RI/2141223465/none>

<https://www.devtreks.org/greentreks/preview/carbon/outcomegroup/Stock RI Progress/42/none>

<https://www.devtreks.org/greentreks/preview/carbon/componentgroup/CTAP RI Stocks/662/none>

<https://www.devtreks.org/greentreks/preview/carbon/investmentgroup/CTAP Stock RI/275505682/none>

The calculators and analyzers explained in the Resource Stock Calculation and Resource Stock Analysis tutorials will be used in this Example. The cost and benefit information contained in the underlying base elements is ignored –the objective of the example is to analyze the Indicator data.

#### **RI Output Calculation**

The purpose of this calculation is to filter out the data from Indicator 3 in Example 1 so that only the selected project alternative, along with its Categorical and Locational Index rows, are further analyzed in subsequent Resource Stock Progress Analysis. The Monitoring and Analysis tools can also be used to carry out these analyses. In this example, the Indicator rows are not essential to analyze. The filtered data represents the “benchmark” goals from which subsequent “actual”



DevTreks –social budgeting that improves lives and livelihoods

progress is analyzed. In this example, and in the context of CTAPs, progress is measured in terms of the final column of data, the Cost Effectiveness Ratios. Those ratios will also be computed for actual Indicators to see if goals and targets are actually being met. Alternatively, the underlying net benefit calculation also makes a logical variable to use in these analyses (i.e. (net benefits = (baseline damages – alternative damages) – (alternative costs – base costs))).

Since this data is being used in Resource Stock Progress Analyses, and those analyses only measure progress using four properties (Indicator.QTM, Score.QTM, Score.QTL, Score.QTU), Scores must be set in some manner. For simplicity, this example assumes that stakeholders place greater emphasis on some Indicators than others. They calculate Scores by using weighted additions of Indicators in Score.MathExpressions. Even though Indicator QTL and QTU properties are not analyzed, their relative relationship to QTM (i.e. 15% lower and higher than QTM) can be still be used to add an additional uncertain dimension into the final analysis.

More than 1 Output or Input base element can be used, and often must be used, to measure Stock Progress. For example, if Example 1’s analysis is for a 1 year project, progress might be measured for 4 individual quarters. In that case, the full year’s Indicator data has be broken into 4 separate Output Series. In turn, these “benchmark” Output Series will be compared to four “actual” Output Series as the project proceeds over the course of the year.

In this example, 2 Outputs, each with 4 Output Series, will be used to measure progress for the first year of a 2 year project. Progress will be analyzed every 6 months. The first Output and its children establish the benchmark goals. The second Output and its children document actual accomplishments. The parent Output calculator is copied into each of the children Series, and each Series member is changed to reflect that semiannual period’s benchmark goals and actual accomplishments.

The benchmark Series are changed by using an appropriate divisor in the Indicator.MathExpressions. In this example, 4 semiannual periods with equal progress require division by 4. The actual Series usually require the use of separate TEXT datasets, containing observed actual accomplishments for each 6 month period. For simplicity, and in order to generate “eyeball” verifications, this example uses the same technique as the benchmark Series.



DevTreks –social budgeting that improves lives and livelihoods

The last 2 actual Output Series haven't occurred yet, so their parent Output.Amount is set to 0, and their indicators will all total zero. In general, analyses requiring comparisons should have equal numbers of comparative base elements.

The example's objective is to display a project half way through its project cycle, being completed on-time and on-budget, with simple 25%, 50%, and 100% metrics.

In practice, a similar real project requires that stakeholders hold at least 6 workshops. The initial workshop generates the selected "project alternative" and establishes the planned goals. 4 semiannual workshops generate actual progress reports, and a final workshop assesses how well planned goals were actually accomplished. In the context of CTAPs, cost effectiveness is always a primary objective, and the analysis of CERs, or net benefits, support that objective.

#### **Selected properties include:**

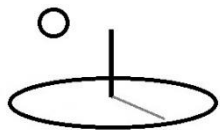
**Score.ConfidenceInterval:** 90. Used with each Indicator's observed descriptive statistics and the Score's Monte Carlo simulation to set QTL and QTU.

[The online example explains that Version 2.1.6 upgraded the calculator patterns to place greater emphasis on the Indicator.URL over the following Score.URL property.]

**Score.DataURL:** The following image displays the TEXT csv data referenced in this property. The object will be to calculate mean QTM's for the six unique Indicators in the dataset. Those Indicators include 5 Categorical Indexes and the final Locational Index, or RMI. The mean is calculated using 1 row, identified by Label, from each of the 3 locations. The numbers are all fictitious.

**Score.MathExpression:** The following expression shows a simple weighted addition of Indicators.

$(I1.QTM * .20) + (I2.QTM * .20) + (I3.QTM * .20) + (I4.QTM * .30) + (I5.QTM * .10)$



DevTreks –social budgeting that improves lives and livelihoods

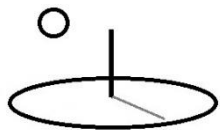
**Score.Math Type and Sub Math Type:** algorithm1 and subalgorithm1. Use Monte Carlo simulation to generate the final confidence interval for the Score.



DevTreks –social budgeting that improves lives and livelihoods

Indicator 1. Categorical and Resiliency Index CERs								
label	indicator	loc_confid	total	base_perf	base_cost	alt_B_perf	alt_B_cost	alt_B_cer
RI1_QTM	LegalInstitutional	1_QTM_0.05_10	0.0000	2.9906	28.8402	5.2305	2853.0984	1260.8858
RI1_QTL	LegalInstitutional	1_QTL_0.05_10	0.0000	2.9832	28.7928	5.2176	2848.4088	1261.9119
RI1_QTU	LegalInstitutional	1_QTU_0.05_10	0.0000	2.9980	28.8876	5.2434	2857.7880	1259.8648
RI2_QTM	AwarenessCapacity	1_QTM_0.05_10	0.0000	1.0966	28.8402	1.9178	2853.0984	3439.1844
RI2_QTL	AwarenessCapacity	1_QTL_0.05_10	0.0000	1.0939	28.7928	1.9131	2848.4088	3441.9141
RI2_QTU	AwarenessCapacity	1_QTU_0.05_10	0.0000	1.0993	28.8876	1.9225	2857.7880	3436.4679
RI3_QTM	CriticalServicesInfrastructure	1_QTM_0.05_10	0.0000	2.9906	28.8402	5.2305	2853.0984	1260.8858
RI3_QTL	CriticalServicesInfrastructure	1_QTL_0.05_10	0.0000	2.9832	28.7928	5.2176	2848.4088	1261.9119
RI3_QTU	CriticalServicesInfrastructure	1_QTU_0.05_10	0.0000	2.9980	28.8876	5.2434	2857.7880	1259.8648
RI4_QTM	EmergencyPreparedness	1_QTM_0.05_10	0.0000	2.9906	28.8402	5.2305	2853.0984	1260.8858
RI4_QTL	EmergencyPreparedness	1_QTL_0.05_10	0.0000	2.9832	28.7928	5.2176	2848.4088	1261.9119
RI4_QTU	EmergencyPreparedness	1_QTU_0.05_10	0.0000	2.9980	28.8876	5.2434	2857.7880	1259.8648
RI5_QTM	DevelopmentPlanning	1_QTM_0.05_10	0.0000	7.2271	28.8402	7.5112	2853.0984	9941.0707
RI5_QTL	DevelopmentPlanning	1_QTL_0.05_10	0.0000	7.2092	28.7928	7.4926	2848.4088	9949.2449
RI5_QTU	DevelopmentPlanning	1_QTU_0.05_10	0.0000	7.2450	28.8876	7.5298	2857.7880	9932.9368
TR_QTM	ResiliencyIndex	1_QTM_0.05_10	0.0000	3.4591	144.2010	5.0241	14265.4920	9023.1891
TR_QTL	ResiliencyIndex	1_QTL_0.05_10	0.0000	3.4505	143.9640	5.0117	14242.0440	9030.2844
TR_QTU	ResiliencyIndex	1_QTU_0.05_10	0.0000	3.4677	144.4380	5.0365	14288.9400	9016.1283
RI1_QTM	LegalInstitutional	2_QTM_0.05_10	0.0000	3.4392	28.8402	6.0151	3503.2516	1348.8146
RI1_QTL	LegalInstitutional	2_QTL_0.05_10	0.0000	3.4307	28.7928	6.0003	3497.4918	1349.8984
RI1_QTU	LegalInstitutional	2_QTU_0.05_10	0.0000	3.4477	28.8876	6.0299	3509.0114	1347.7360
RI2_QTM	AwarenessCapacity	2_QTM_0.05_10	0.0000	1.2610	28.8402	2.2056	3503.2516	3678.1827
RI2_QTL	AwarenessCapacity	2_QTL_0.05_10	0.0000	1.2579	28.7928	2.2002	3497.4918	3681.0984
RI2_QTU	AwarenessCapacity	2_QTU_0.05_10	0.0000	1.2641	28.8876	2.2110	3509.0114	3675.2812
RI3_QTM	CriticalServicesInfrastructure	2_QTM_0.05_10	0.0000	3.4392	28.8402	6.0151	3503.2516	1348.8146
RI3_QTL	CriticalServicesInfrastructure	2_QTL_0.05_10	0.0000	3.4307	28.7928	6.0003	3497.4918	1349.8984
RI3_QTU	CriticalServicesInfrastructure	2_QTU_0.05_10	0.0000	3.4477	28.8876	6.0299	3509.0114	1347.7360
RI4_QTM	EmergencyPreparedness	2_QTM_0.05_10	0.0000	3.4392	28.8402	6.0151	3503.2516	1348.8146
RI4_QTL	EmergencyPreparedness	2_QTL_0.05_10	0.0000	3.4307	28.7928	6.0003	3497.4918	1349.8984
RI4_QTU	EmergencyPreparedness	2_QTU_0.05_10	0.0000	3.4477	28.8876	6.0299	3509.0114	1347.7360
RI5_QTM	DevelopmentPlanning	2_QTM_0.05_10	0.0000	7.6009	28.8402	6.6160	3503.2516	-3527.6794
RI5_QTL	DevelopmentPlanning	2_QTL_0.05_10	0.0000	7.5821	28.7928	6.5997	3497.4918	-3530.8418
RI5_QTU	DevelopmentPlanning	2_QTU_0.05_10	0.0000	7.6197	28.8876	6.6323	3509.0114	-3524.5329
TR_QTM	ResiliencyIndex	2_QTM_0.05_10	0.0000	3.8359	144.2010	5.3734	17516.2580	11298.8989
TR_QTL	ResiliencyIndex	2_QTL_0.05_10	0.0000	3.8264	143.9640	5.3602	17487.4590	11307.5336
TR_QTU	ResiliencyIndex	2_QTU_0.05_10	0.0000	3.8454	144.4380	5.3866	17545.0570	11290.3056
RI1_QTM	LegalInstitutional	3_QTM_0.05_10	0.0000	3.7383	28.8402	6.5381	3566.3730	1263.4610
RI1_QTL	LegalInstitutional	3_QTL_0.05_10	0.0000	3.9453	28.7928	6.9003	4022.1156	1351.3600
RI1_QTU	LegalInstitutional	3_QTU_0.05_10	0.0000	3.9649	28.8876	6.9344	4035.3631	1349.1952
RI2_QTM	AwarenessCapacity	3_QTM_0.05_10	0.0000	1.4502	28.8402	2.5364	4028.7393	3682.1651
RI2_QTL	AwarenessCapacity	3_QTL_0.05_10	0.0000	1.4466	28.7928	2.5302	4022.1156	3685.0839
RI2_QTU	AwarenessCapacity	3_QTU_0.05_10	0.0000	1.4537	28.8876	2.5427	4035.3631	3679.2605
RI3_QTM	CriticalServicesInfrastructure	3_QTM_0.05_10	0.0000	3.9551	28.8402	6.9174	4028.7393	1350.2749
RI3_QTL	CriticalServicesInfrastructure	3_QTL_0.05_10	0.0000	3.9453	28.7928	6.9003	4022.1156	1351.3600
RI3_QTU	CriticalServicesInfrastructure	3_QTU_0.05_10	0.0000	3.9649	28.8876	6.9344	4035.3631	1349.1952
RI4_QTM	EmergencyPreparedness	3_QTM_0.05_10	0.0000	3.9551	28.8402	6.9174	4028.7393	1350.2749
RI4_QTL	EmergencyPreparedness	3_QTL_0.05_10	0.0000	3.9453	28.7928	6.9003	4022.1156	1351.3600
RI4_QTU	EmergencyPreparedness	3_QTU_0.05_10	0.0000	3.9649	28.8876	6.9344	4035.3631	1349.1952
RI5_QTM	DevelopmentPlanning	3_QTM_0.05_10	0.0000	8.7410	28.8402	7.6084	4028.7393	-3531.4988
RI5_QTL	DevelopmentPlanning	3_QTL_0.05_10	0.0000	8.7194	28.7928	7.5897	4022.1156	-3534.6647
RI5_QTU	DevelopmentPlanning	3_QTU_0.05_10	0.0000	8.7627	28.8876	7.6271	4035.3631	-3528.3489
TR_QTM	ResiliencyIndex	3_QTM_0.05_10	0.0000	4.4113	144.2010	6.1794	20143.6967	11311.1322
TR_QTL	ResiliencyIndex	3_QTL_0.05_10	0.0000	4.4004	143.9640	6.1642	20110.5779	11319.7763
TR_QTU	ResiliencyIndex	3_QTU_0.05_10	0.0000	4.4222	144.4380	6.1946	20176.8156	11302.5297





DevTreks –social budgeting that improves lives and livelihoods

The following images display the calculated properties for the first of the six Indicators. Selected properties displayed include:

**Indicator.Math Type and Sub Math Type:** algorithm1 and subalgorithm1. Use the Score.DataURL TEXT dataset to generate observed descriptive statistics for each Indicator. Fill in Q1 to QTU with the results. The units of measurement for most of these properties must be set by hand. When subalgorithm1 is run using a set of observed data, a Monte Carlo simulation is not run (explaining why, in this example, most of the Score properties are not needed to run Indicator calculations).

**Indicator.Math Expression:** The image shows that Q1 to Q5 document the mean of the first five columns of data in the previous image. QT measures the result of the Math Expression, which in this case is only interested in the mean of the final column of data, the CERs. The remaining Indicators still have to be identified in the Expression, because a data convention followed by many algorithms is to only analyze data included in Math Expressions. These columns of data are added together and multiplied by zero.

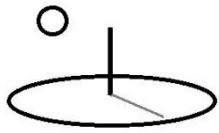
Output base element:

$$I1.Q5.alt\_B\_cer + ((I1.Q4.alt\_B\_cost + I1.Q2.base\_cost + I1.Q3.alt\_B\_perform + I1.Q1.base\_perform) * 0)$$

Output Series base element (the goal is simple 25% and 50% progress metrics):

$$(I1.Q5.alt\_B\_cer / 4) + ((I1.Q4.alt\_B\_cost + I1.Q2.base\_cost + I1.Q3.alt\_B\_perform + I1.Q1.base\_perform) * 0)$$

The QTLs and QTUs are calculated from Example 2's descriptive statistics. The statistics are calculated from the QTM's' observed data.



DevTreks –social budgeting that improves lives and livelihoods

Indicator 1

LegalInstitutional

Indicator 1 Description

This Indicator is used in a CTAP tutorial

Indicator 1 URL

none

Label 1

RI1\_QTM

Rel Label 1

Date 1

03/30/2016

Dist Type 1

none

Q1 1

3.3894

Q1 Unit 1

base\_perform

Q2 1

28.8402

Q2 Unit 1

base\_cost

Q3 1

5.9279

Q3 Unit 1

alt\_B\_perform

Q4 1

3,307.5743

Q4 Unit 1

alt\_B\_cost

Q5 1

1,291.0538

Q5 Unit 1

alt\_B\_cer

Math Operator 1

equalto

BaseIO 1

none



DevTreks –social budgeting that improves lives and livelihoods

equine	none
QT 1	QT Unit 1
1,291.0538	alt_B_cer
Math Type 1	Math Sub Type 1
algorithm1	subalgorithm1
QT D1 1	QT D1 Unit 1
0.0000	none
QT D2 1	QT D2 Unit 1
0.0000	none
QT Most 1	QT Most Unit 1
1,291.0538	alt_B_cer
QT Low 1	QT Low Unit 1
1,243.3853	lower 90 % ci
QT High 1	QT High Unit 1
1,338.7223	upper 90 % ci
Math Expression 1	
I1.Q5.alt_B_cer + ((I1.Q4.alt_B_cost + I1.Q2.base_cost + I1.Q3.alt_B_pr	
Math Result 1	
<p>observed cumulative density function</p> <p>0.33,0.33,0.33,0.33,0.67,0.67,0.67,1.00,1.00,1.00,1.00</p> <p>1260.8858,1260.8858,1260.8858,1260.8858,1263.4610,1263.4610,1263.4610,1348.8146,1348.8146,1348.8146,1348.8146</p> <p>observed descriptive statistics</p> <p>N,Total,Mean,Median,StdDev,Var,Min,Max</p> <p>3,3873.1614,1291.0538,1263.4610,50.0389,2503.8904,1260.8858,1348.8146,</p> <p>observed means</p> <p>QT mean = 1291.0538, Q1 mean = 3.3894, Q2 mean = 28.8402, Q3 mean = 5.9279, Q4 mean = 3307.5743, Q5 mean = 1291.0538,</p>	

The following image confirms that the Version 2.1.6 upgraded calculator pattern emphasized the use of the Indicator.URL property.



LegalInstitutional Indicator 1 Description This Indicator is used in a CTAP tutorial. Version 2.1.4 and 2.1.6 upgraded the calculator patterns by putting greater emphasis on the Indicator.URL over the Score.DataURL. Indicator 1 URL <a href="https://devtreks1.blob.core.windows.net/resources/network_carbon/resourcepack_1541/resource_8033/Ind1-RI-Progress.csv">https://devtreks1.blob.core.windows.net/resources/network_carbon/resourcepack_1541/resource_8033/Ind1-RI-Progress.csv</a> Label 1 RI1_QTM Date 1 12/30/2016 Q1 1 3.3894 Q2 1 28.8402 Q3 1 5.9279 Q4 1 3,307.5743 Q5 1 1,291.0538		Rel Label 1 none Dist Type 1 none Q1 Unit 1 base_perform Q2 Unit 1 base_cost Q3 Unit 1 alt_B_perform Q4 Unit 1 alt_B_cost Q5 Unit 1 alt_B_cer	
--	--	--	--

Math Type 1 algorithm1	Math Sub Type 1 subalgorithm1
QT D1 1 0.0000	QT D1 Unit 1 none
QT D2 1 0.0000	QT D2 Unit 1 none
QT Most 1 322.7634	QT Most Unit 1 alt_B_cer
QT Low 1 310.8463	QT Low Unit 1 lower 90 % ci
QT High 1 334.6805	QT High Unit 1 upper 90 % ci
Math Expression 1 $(I1.Q5.alt\_B\_cer / 4) + ((I1.Q4.alt\_B\_cost + I1.Q2.base\_cost$	
Math Result 1 observed cumulative density function 0.33,0.33,0.33,0.33,0.67,0.67,0.67,1.00,1.00,1.00,1.00 315.2214,315.2214,315.2214,315.2214,315.8652,315.8652, 315.8652,337.2036,337.2036,337.2036,337.2036 observed descriptive statistics N,Total,Mean,Median,StdDev,Var,Min,Max 3,968.2902,322.7634,315.8652,12.5097,156.4932,315.2214, 337.2036, observed means QT mean = 322.7634, Q1 mean = 3.3894, Q2 mean = 28.8402, Q3 mean = 5.9279, Q4 mean = 3307.5743, Q5 mean = 1291.0538,	

The following images show the calculated results for a typical Score and Indicator.



DevTreks –social budgeting that improves lives and livelihoods

#### Output Group: CTAP Output Group Example 5

Output : CTAP Ex 5 - Benchmark RI

Output Series : CTAP Ex 5 - Benchmark RI

#### Indicators

Math Expression: (I1.QTM \* .20) + (I2.QTM \* .20) + (I3.QTM \* .20) + (I4.QTM \* .30) + (I5.QTM \* .10)

Score Amount: 433.5596

Score Unit: alt\_B\_cer

Score D1 Amount: 435.0000

Score D1 Unit: mean

Score D2 Amount: 100.0000

Score D2 Unit: sd

Distribution Type: normal

Math Type: algorithm1

Score Most Amount: 435.5036

Score Most Unit: weighted addition

Score Low Amount: 433.8750

Score Low Unit: lower 90% ci

Score High Amount: 437.1322

Score High Unit: upper 90% ci

Iterations: 10000

Math Sub Type: subalgorithm1

Confid Int: 90

Random Seed: 8

Base IO: none

Score Math Result: sampled descriptive statistics N,Total,Mean,Median,StdDev,Var,Min,Max

10000, 4355036.4202, 435.5036, 435.0835, 98.7035, 9742.3785, 60.2406, 805.3301,

sampled cumulative density function 0.00,0.10,0.20,0.30,0.40,0.50,0.60,0.70,0.80,0.90,1.00

60.2406,309.7356,352.8204,383.9332,410.5728,435.0911,460.4802,487.0560,517.8205,561.087

**Indic 1 Name:** LegalInstitutional

Label: RI1\_QTM

Date: 06/30/2016

Rel Label: none

Math Type: algorithm1

Dist Type: none

Q1 Amount: 3.3894

Q1 Unit: base\_perform

Q2 Amount: 28.8402

Q2 Unit: base\_cost

Q3 Amount: 5.9279

Q3 Unit: alt\_B\_perform

Q4 Amount: 3,307.5743

Q4 Unit: alt\_B\_cost

Q5 Amount: 1,291.0538

Q5 Unit: alt\_B\_cer

Math Express: (I1.Q5.alt\_B\_cer / 4) + ((I1.Q4.alt\_B\_cost + I1.Q2.base\_cost + I1.Q3.alt\_B\_perform + I1.Q1.base\_perform) \* 0)

Math Operator: equalto

QT Amount: 322.7634

QT Unit: alt\_B\_cer

QT D1 Amount: 0.0000

QT D1 Unit: none

QT D2 Amount: 0.0000

QT D2 Unit: none

QT Most Amount: 322.7634

QT Most Unit: alt\_B\_cer

QT Low Amount: 310.8463

QT Low Unit: lower 90% ci

QT High Amount: 334.6805

QT High Unit: upper 90% ci

Math Sub Type: subalgorithm1

Base IO: none

Indic 1 Description: This Indicator is used in a CTAP tutorial

**Indic 2 Name:** AwarenessCapacity

Label: RI2\_QTM

Date: 06/30/2016

Rel Label: none

Math Type: algorithm1

Type: none

Q1 Amount: 1.2693

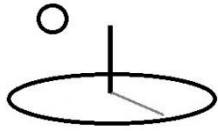
Q1 Unit: base\_perform

## RI Output Progress Analysis



DevTreks –social budgeting that improves lives and livelihoods

The following image displays the results of a Stock Progress Analysis that demonstrates using Output base elements with children benchmark and actual Series. With the exception of the Target Type property, the exact same data and properties were set for the benchmark and actual Output Series so that the results can be verified by “eyeball” (i.e. 100% project accomplishments). This type of analysis may be appropriate for simple, quick, analyses.



DevTreks –social budgeting that improves lives and livelihoods

Output Group : CTAP Output Examples ; A			
Output	All	Alt. 0	
<b>Name</b>	CTAP Example 5 - Progress RI		
<b>Label</b>	RI		
Output Series	All	Alt. 0	Alt. 1
<b>Name</b>	CTAP Example 5 - Benchmark Progress RI		CTAP Example 5 - Actual Progress RI
<b>Label</b>	RI		RI
Indicators	All	Alt. 0	Alt. 1
<b>Target</b>	benchmark		actual
<b>Date</b>	03/30/2016		03/30/2016
<b>Score Observations</b>	1.0		1.0
<b>Score Plan Period</b>	1,751.0073		1,751.0073
<b>Score Unit</b>	weighted added		weighted added
<b>Score Plan Full</b>	1,751.0073		1,751.0073
<b>Score Plan Cumul</b>	1,751.0073		1,751.0073
<b>Score Actual Period</b>	0.0000		1,751.0073
<b>Score Actual Cumul</b>	0.0000		1,751.0073
<b>Score Actual Period Change</b>	0.0000		0.0000
<b>Score Actual Cumul Change</b>	0.0000		0.0000
<b>Score Plan P Percent</b>	0.0000		100.0000
<b>Score Plan C Percent</b>	0.0000		100.0000
<b>Score Plan Full Percent</b>	0.0000		100.0000
<b>Score Low Plan Period</b>	1,747.7501		1,747.7501
<b>Score Low Unit</b>	lower 90% ci		lower 90% ci

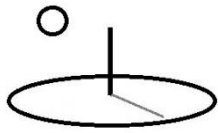


DevTreks –social budgeting that improves lives and livelihoods

<b>Name</b>	AwarenessCapacity	AwarenessCapacity
<b>Label</b>	RI2_QTM	RI2_QTM
<b>Plan Period</b>	3,599.8441	3,599.8441
<b>Unit</b>	alt_B_cer	alt_B_cer
<b>Plan Full</b>	3,599.8441	3,599.8441
<b>Plan Cumul</b>	3,599.8441	3,599.8441
<b>Actual Period</b>	0.0000	3,599.8441
<b>Actual Cumul</b>	0.0000	3,599.8441
<b>Actual Period Change</b>	0.0000	0.0000
<b>Actual Cumul Change</b>	0.0000	0.0000
<b>Plan P Percent</b>	0.0000	100.0000
<b>Plan C Percent</b>	0.0000	100.0000
<b>Plan Full Percent</b>	0.0000	100.0000
<b>Observations</b>	1.0	1.0
<b>Name</b>	CriticalServicesInfrast ructure	CriticalServicesInfrast ructure
<b>Label</b>	RI3_QTM	RI3_QTM
<b>Plan Period</b>	1,319.9918	1,319.9918
<b>Unit</b>	alt_B_cer	alt_B_cer
<b>Plan Full</b>	1,319.9918	1,319.9918
<b>Plan Cumul</b>	1,319.9918	1,319.9918
<b>Actual Period</b>	0.0000	1,319.9918
<b>Actual Cumul</b>	0.0000	1,319.9918
<b>Actual Period Change</b>	0.0000	0.0000
<b>Actual Cumul Change</b>	0.0000	0.0000
<b>Plan P Percent</b>	0.0000	100.0000
<b>Plan C Percent</b>	0.0000	100.0000

The following image displays the structure of the Output data that will be analyzed in this example. 2 Outputs have been added to an Output Group. The benchmark Output has 4 children Output Series. The actual Output has 4 children Output Series. An Output Group Progress





DevTreks –social budgeting that improves lives and livelihoods

Analysis is inappropriate because the first Output has only benchmark Series while the second has only actual Series. In general, Input and Output Group Stock Analysis is discouraged because Series data can just be too large to display properly. Nevertheless, under some circumstances, Aggregators (i.e. Labels), Dates, Target Types, and Alternative Types, can be set in a manner that will carry out legitimate I/O analyses.

Keyword,  
Service,  
Network,  
Category

Outputs

This Club's Agreement Services

All Categories

Start Search

Organic Farming, Crops

2014 Orange, Conventional

This orange crop is grown using conventional practices.

2014 Orange, Organic

This orange crop is grown using organic practices.

CTAP Output Group Example 5

CTAP Ex 5 - Actual RI

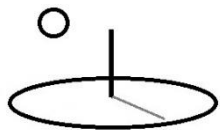
This output is used in a Resource Stock Progress Analysis of a Resiliency Index.

CTAP Ex 5 - Benchmark RI

This output is used in a Resource Stock Progress Analysis of a Resiliency Index.

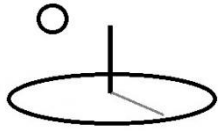
CTAP Output Examples








## RI Outcome and Component Progress Analysis



DevTreks –social budgeting that improves lives and livelihoods

The following images display the Outcomes, and some of the Scores and Indicators for the completed Outcome Progress Analysis. A total of 8 semiannual Outcomes are added to an Outcome Group. 4 of the Outcomes reflect the benchmark and 4 Outcomes reflect the actual progress through the first 2 periods. The last 2 actual Output Series have not been completed yet, so set their Output.Amount = 0. The objective of this data is strictly to obtain the 25%, 50%, and 100% “eyeball” metrics. For this example, ignore the 4 digit rounding precision displayed by Analyzers and the resultant values such as 0.5720 and 1.440. The Earned Value Management tutorial explains the displayed properties.



CTAP RI Progress	
<input type="checkbox"/> CTAP RI BMQ2	
 This data is used in a CTAP tutorial. (< <a href="#">preview IRI</a> )	
<input type="checkbox"/> CTAP RI ACTQ2	
 This data is used in a CTAP tutorial. (< <a href="#">preview IRI</a> )	
<input type="checkbox"/> CTAP RI ACTQ4	
 This data is used in a CTAP tutorial. (< <a href="#">preview IRI</a> )	
<input type="checkbox"/> CTAP RI BMQ4	
 This data is used in a CTAP tutorial. (< <a href="#">preview IRI</a> )	
<input type="checkbox"/> CTAP RI BMQ6	
 This data is used in a CTAP tutorial. (< <a href="#">preview IRI</a> )	
<input type="checkbox"/> CTAP RI ACTQ6	
 This data is used in a CTAP tutorial. (< <a href="#">preview IRI</a> )	
<input type="checkbox"/> CTAP RI ACTQ8	
 This data is used in a CTAP tutorial. (< <a href="#">preview IRI</a> )	
<input type="checkbox"/> CTAP RI BMQ8	



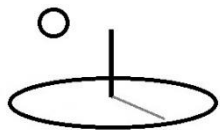
## DevTreks –social budgeting that improves lives and livelihoods

DevTreks [US] <https://www.devtreks.org/greentreks/search/watershed/input/none/0/none>

Outcome Group : Stock RI Progress : B								
Outcome	Alt.	Alt. 0	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
Name	CTAP RI BMQ2	CTAP RI ACTQ2	CTAP RI BMQ4	CTAP RI ACTQ4	CTAP RI BMQ6	CTAP RI ACTQ6	CTAP RI BMQ8	CTAP RI ACTQ8
Date	06/30/2016	06/30/2016	12/30/2016	12/30/2016	06/30/2017	06/30/2017	12/30/2017	12/30/2017
Label	Q2	Q2	Q4	Q4	Q6	Q6	Q8	Q8
Indicators	Alt.	Alt. 0	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6
Target	benchmark	actual	benchmark	actual	benchmark	actual	benchmark	actual
Date	06/30/2016	06/30/2016	12/30/2016	12/30/2016	06/30/2017	06/30/2017	12/30/2017	12/30/2017
Score	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Observations								
Score Plan Period	435.5036	436.0756	435.5036	436.0756	435.5036	0.0000	435.5036	0.0000
Score Unit	weighted RI	alt_B_cer	weighted RI	alt_B_cer	weighted RI	alt_B_cer	weighted RI	alt_B_cer
Score Plan Full	1,742.0144	1,742.0144	1,742.0144	1,742.0144	1,742.0144	1,742.0144	1,742.0144	1,742.0144
Score Plan Cumul	435.5036	435.5036	871.0072	871.0072	1,306.5108	1,306.5108	1,742.0144	1,742.0144
Score Actual Period	0.0000	436.0756	0.0000	436.0756	0.0000	0.0000	0.0000	0.0000
Score Actual Cumul	0.0000	436.0756	0.0000	872.1512	0.0000	872.1512	0.0000	872.1512
Score Actual Period Change	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Score Actual Cumul Change	0.0000	0.5720	0.0000	1.1440	0.0000	-434.3596	0.0000	-869.8632
Score Plan P Percent	0.0000	100.0000	0.0000	100.0000	0.0000	0.0000	0.0000	0.0000
Score Plan C Percent	0.0000	100.1313	0.0000	100.1313	0.0000	66.7542	0.0000	50.0657
Score Plan Full Percent	0.0000	25.0328	0.0000	50.0657	0.0000	50.0657	0.0000	50.0657

DevTreks [US] <https://www.devtreks.org/greentreks/search/watershed/input/none/0/none>

Name	LegalInstitutional	LegalInstitutional	LegalInstitutional	LegalInstitutional	LegalInstitutional	LegalInstitutional	LegalInstitutional	LegalInstitutional
Label	RI1_QTM	RI1_QTM	RI1_QTM	RI1_QTM	RI1_QTM	RI1_QTM	RI1_QTM	RI1_QTM
Plan Period	322.7634	322.7634	322.7634	322.7634	322.7634	0.0000	322.7634	0.0000
Unit	alt_B_cer	alt_B_cer	alt_B_cer	alt_B_cer	alt_B_cer	alt_B_cer	alt_B_cer	alt_B_cer
Plan Full	1,291.0536	1,291.0536	1,291.0536	1,291.0536	1,291.0536	1,291.0536	1,291.0536	1,291.0536
Plan Cumul	322.7634	322.7634	645.5268	645.5268	968.2902	968.2902	1,291.0536	1,291.0536
Actual Period	0.0000	322.7634	0.0000	322.7634	0.0000	0.0000	0.0000	0.0000
Actual Cumul	0.0000	322.7634	0.0000	645.5268	0.0000	645.5268	0.0000	645.5268
Actual Period Change	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Actual Cumul Change	0.0000	0.0000	0.0000	0.0000	0.0000	-322.7634	0.0000	-645.5268
Plan P Percent	0.0000	100.0000	0.0000	100.0000	0.0000	0.0000	0.0000	0.0000
Plan C Percent	0.0000	100.0000	0.0000	100.0000	0.0000	66.6667	0.0000	50.0000
Plan Full Percent	0.0000	25.0000	0.0000	50.0000	0.0000	50.0000	0.0000	50.0000
Observations	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Name	AwarenessCapacity	AwarenessCapacity	AwarenessCapacity	AwarenessCapacity	AwarenessCapacity	AwarenessCapacity	AwarenessCapacity	AwarenessCapacity
Label	RI2_QTM	RI2_QTM	RI2_QTM	RI2_QTM	RI2_QTM	RI2_QTM	RI2_QTM	RI2_QTM
Plan Period	899.9610	899.9610	899.9610	899.9610	899.9610	0.0000	899.9610	0.0000
Unit	alt_B_cer	alt_B_cer	alt_B_cer	alt_B_cer	alt_B_cer	alt_B_cer	alt_B_cer	alt_B_cer
Plan Full	3,599.8441	3,599.8441	3,599.8441	3,599.8441	3,599.8441	3,599.8441	3,599.8441	3,599.8441
Plan Cumul	899.9610	899.9610	1,799.9221	1,799.9221	2,699.8831	2,699.8831	3,599.8441	3,599.8441



DevTreks –social budgeting that improves lives and livelihoods

Capital Budgets require Components with Inputs and Outcomes with Outputs. Inputs are not the primary focus of this example, so for convenience, only 1 sample Input Indicator, with fictitious values, will be used. This Indicator, Risk Knowledge, derives from some of the UN Indicator systems. Both Components and Inputs are structured exactly the same as the Outcome and Outputs. Real Investment Analyses should categorize and use real Input (resource expenditure, or effort required) and Output (resource contribution, or impact) Indicators. That aligns with the best practices of the Economics, Engineering, and M&E fields –that is, Inputs should always be used efficiently in the production of Outputs (i.e. when resources are scarce and their conservation is important).

The following Component Stock Analysis shows that similar data management techniques are used for the Components and Inputs.

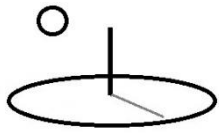


DevTreks –social budgeting that improves lives and livelihoods

Component Group : CTAP RI M and E ; A10									
Component	All	Alt. 0	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
<b>Name</b>		CTAP RI BMQ2	CTAP RI ACTQ2	CTAP RI BMQ4	CTAP RI ACTQ4	CTAP RI BMQ6	CTAP RI ACTQ6	CTAP RI BMQ8	CTAP RI ACTQ8
<b>Date</b>		06/30/2016	06/30/2016	12/30/2016	12/30/2016	06/30/2017	06/30/2017	12/30/2017	12/30/2017
<b>Label</b>		Q2	Q2	Q4	Q4	Q6	Q6	Q8	Q8
<b>Target Type</b>		benchmark	actual	benchmark	actual	benchmark	actual	benchmark	actual
<b>Indicator 1</b>		Awareness Training	Awareness Training	Awareness Training	Awareness Training	Awareness Training	Awareness Training	Awareness Training	Awareness Training
<b>Observations</b>		1	1	1	1	1	1	1	1
<b>Date</b>		06/30/2016	06/30/2016	12/30/2016	12/30/2016	06/30/2017	06/30/2017	12/30/2017	12/30/2017
<b>Label</b>		IAT1	IAT1	IAT1	IAT1	IAT1	IAT1	IAT1	IAT1
<b>Total Unit</b>		most likely	most likely	most likely	most likely	most likely	most likely	most likely	most likely
<b>Total Planned Period</b>		20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000
<b>Total Planned Full</b>		80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
<b>Total Planned Cumulative</b>		20.00	20.00	40.00	40.00	60.00	60.00	80.00	80.00
<b>Total Actual Period</b>		0.00	20.00	0.00	20.00	0.00	0.00	0.00	0.00
<b>Total Actual Cumulative</b>		0.00	20.00	0.00	40.00	0.00	40.00	0.00	40.00
<b>Total Actual Period Progress</b>		0.00	0.00	0.00	0.00	0.00	-20.00	0.00	-20.00
<b>Total Actual Cumul Progress</b>		0.00	0.00	0.00	0.00	0.00	-20.00	0.00	-40.00
<b>Total Plan P Percent</b>		0.00	100.00	0.00	100.00	0.00	0.00	0.00	0.00
<b>Total Plan C Percent</b>		0.00	100.00	0.00	100.00	0.00	66.67	0.00	50.00
<b>Total Plan Full Percent</b>		0.00	25.00	0.00	50.00	0.00	50.00	0.00	50.00

## RI Investment Progress Analysis

The following image shows that 2 self-explanatory Investments have been added to an Investment Group. Each Investment holds 2 Time Periods. Each Time Period holds 2 semiannual Outcomes and Components. Besides the Progress Analysis completed for the Investment Group base element, additional Stock Total, Statistical, and Change by Alternative, Investment



DevTreks –social budgeting that improves lives and livelihoods

Analyses are included with the example. The Change analysis required setting all of the benchmark Alternative Type properties to “A” and the actual to “B”.

Keyword,  
Service,  
Network,  
Category

Capital Budgets

This Club's Agreement Services

All Categories

Start Search

CTAP RI

A CTAP Benchmark RI

This data is used in a CTAP tutorial.

B CTAP Actual RI

This data is used in a CTAP tutorial.

The following images display the results of the aggregated first and second Time Period elements of the benchmark and actual Investments displayed in the previous image. Unlike the next example, the 2017 actual Time Period.Amount does not need to be set to 0, because its descendent Output and Input Amounts have been set to 0.



DevTreks –social budgeting that improves lives and livelihoods

<b>Name</b>	Risk Knowledge	Risk Knowledge
<b>Label</b>	R1I_QTM	R1I_QTM
<b>Plan Period</b>	4.0000	4.0000
<b>Unit</b>	cost	cost
<b>Plan Full</b>	8.0000	8.0000
<b>Plan Cumul</b>	4.0000	4.0000
<b>Actual Period</b>	0.0000	4.0000
<b>Actual Cumul</b>	0.0000	4.0000
<b>Actual Period Change</b>	0.0000	0.0000
<b>Actual Cumul Change</b>	0.0000	0.0000
<b>Plan P Percent</b>	0.0000	100.0000
<b>Plan C Percent</b>	0.0000	100.0000
<b>Plan Full Percent</b>	0.0000	50.0000
<b>Observations</b>	1.0	2.0
<b>Name</b>	LegallInstitutional	LegallInstitutional
<b>Label</b>	RI1_QTM	RI1_QTM
<b>Plan Period</b>	645.5268	645.5268
<b>Unit</b>	alt_B_cer	alt_B_cer
<b>Plan Full</b>	1,291.0536	1,291.0536
<b>Plan Cumul</b>	645.5268	645.5268
<b>Actual Period</b>	0.0000	645.5268
<b>Actual Cumul</b>	0.0000	645.5268
<b>Actual Period Change</b>	0.0000	0.0000
<b>Actual Cumul Change</b>	0.0000	0.0000
<b>Plan P Percent</b>	0.0000	100.0000
<b>Plan C Percent</b>	0.0000	100.0000
<b>Plan Full Percent</b>	0.0000	50.0000
<b>Observations</b>	1.0	2.0

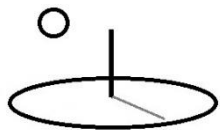




DevTreks –social budgeting that improves lives and livelihoods

<b>Name</b>	Risk Knowledge	Risk Knowledge
<b>Label</b>	R1I_QTM	R1I_QTM
<b>Plan Period</b>	4.0000	0.0000
<b>Unit</b>	cost	cost
<b>Plan Full</b>	8.0000	8.0000
<b>Plan Cumul</b>	8.0000	8.0000
<b>Actual Period</b>	0.0000	0.0000
<b>Actual Cumul</b>	0.0000	4.0000
<b>Actual Period Change</b>	0.0000	0.0000
<b>Actual Cumul Change</b>	0.0000	-4.0000
<b>Plan P Percent</b>	0.0000	0.0000
<b>Plan C Percent</b>	0.0000	50.0000
<b>Plan Full Percent</b>	0.0000	50.0000
<b>Observations</b>	2.0	2.0
<b>Name</b>	LegalInstitutional	LegalInstitutional
<b>Label</b>	R1I_QTM	R1I_QTM
<b>Plan Period</b>	645.5268	0.0000
<b>Unit</b>	alt_B_cer	alt_B_cer
<b>Plan Full</b>	1,291.0536	1,291.0536
<b>Plan Cumul</b>	1,291.0536	1,291.0536
<b>Actual Period</b>	0.0000	0.0000
<b>Actual Cumul</b>	0.0000	645.5268
<b>Actual Period Change</b>	0.0000	0.0000
<b>Actual Cumul Change</b>	0.0000	-645.5268
<b>Plan P Percent</b>	0.0000	0.0000
<b>Plan C Percent</b>	0.0000	50.0000
<b>Plan Full Percent</b>	0.0000	50.0000
<b>Observations</b>	2.0	2.0

The time commitment needed to complete these types of analyses are a factor in their utility. The author hadn't completed a Progress Analysis in several months and forgot how they work. He spent about 2 hours trying to figure out why the elements in the Investment Analysis wouldn't



DevTreks –social budgeting that improves lives and livelihoods

line up, even after closely following the instructions. New features that were added to 1.8.8 broke the “old way” several analyses were run and had to be modified. Additional bugs also had to be fixed for a fully accurate Investment Progress analysis. Additional testing with more datasets, which requires additional resources, can overcome most of these types of issues (**10, 11\***).



DevTreks –social budgeting that improves lives and livelihoods

### **Example 7. M and E 2 Calculators and Analyzers (10\*)**

#### **URLs:**

[https://www.devtreks.org/greentreks/preview/carbon/output/M and E BM RI/2141223467/none](https://www.devtreks.org/greentreks/preview/carbon/output/M%20and%20E%20BM%20RI/2141223467/none)

[https://www.devtreks.org/greentreks/preview/carbon/outcomegroup/M and E RI Progress/43/none](https://www.devtreks.org/greentreks/preview/carbon/outcomegroup/M%20and%20E%20RI%20Progress/43/none)

[https://www.devtreks.org/greentreks/preview/carbon/componentgroup/CTAP RI M and E/663/none](https://www.devtreks.org/greentreks/preview/carbon/componentgroup/CTAP%20RI%20M%20and%20E/663/none)

[https://www.devtreks.org/greentreks/preview/carbon/investmentgroup/CTAP M and E RI/275505683/none](https://www.devtreks.org/greentreks/preview/carbon/investmentgroup/CTAP%20M%20and%20E%20RI/275505683/none)

[http://localhost:5000/greentreks/preview/carbon/output/A- CTAP- Benchmark RI/2141223474/none](http://localhost:5000/greentreks/preview/carbon/output/A-CTAP-BenchmarkRI/2141223474/none)

The calculators and analyzers explained in the M&E Calculation and M&E Analysis 2 tutorials will be used in this Example. The cost and benefit information contained in the underlying base elements is ignored –the objective of the example is to analyze the Indicator data.

Inputs and Outputs are not displayed in some M&E analyses, because the quantity of data becomes difficult to interpret. In this example, that includes a comparative, but not regular, progress analysis of Components and Outcomes, and the Progress Investment analysis. In this example, that means the Output data holding the RI Indexes is not included in the final results of the Investment Analysis. Use a Totals Investment analysis when Inputs and Outputs must be included in the analysis. Those results can also be imported into other software and manipulated to produce the desired analyses.

#### **RI Output M&E Calculation**

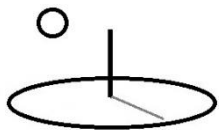


DevTreks –social budgeting that improves lives and livelihoods

Outputs are structured exactly the same way as demonstrated in Example 2. A benchmark Output holds 4 semiannual Output Series that establish benchmark goals. An actual Output holds 4 semiannual Output Series that measure actual accomplishments. The calculations use the same 6 Indicators holding Categorical and Locational Index aggregations. Prior to Version 2.0.4, these calculators did not support data stored in URLs, therefore Example 1's selected project alternative had to be manually entered into the calculators as M&E Indicators. Post Version 2.0.4 M&E calculators offer considerably more flexibility and power than demonstrated in this example.

Given Example 2's results, logical properties to calculate can be either Example 2's QTM, QTL, and QTU, properties for each Index, or the cost, performance, and final CER columns of data found in Example 2's raw dataset. This example uses the former properties. M&E Indicator.Q1, and Indicator.Q2 properties are set equal to Example 2's Resource Stock Index QTL, and QTU, and QTM properties for the selected project alternative, or benchmark goals. M&E Indicator.QT, QTM, QTL, and QTU properties are also set using these properties.

The following image displays a typical Output calculation for 1 Indicator. Please refer to the previous Stock calculation example to see the upgraded patterns recommended as of Version 2.1.6 (i.e. use the Indicator.URL property to store Indicator data).



DevTreks –social budgeting that improves lives and livelihoods

M and E Output 2 Calculat
Get

Media
Mobile
Desktop

Intro
1
2
3
Help

Step 1 of 3. Make Selections

Get Selects
Cancel
Close

Calculator Name
Monitoring and Evaluation 2 Output Calculator

M and E Indicators

Indicator 1

LegallInstitutional

Indicator 1 Description
This Indicator is used in a CTAP tutorial

Indicator 1 URL
none

Label 1
Rel Label 1
RI1\_QTM
none

Date 1
Dist Type 1
12/30/2016
none

Q1 1
Q1 Unit 1
310.8500
lower 90% ci

Q2 1
Q2 Unit 1
334.6800
upper 90% ci

Q3 1
Q3 Unit 1
0.0000
none

Q4 1
Q4 Unit 1
0.0000
none

Q5 1
Q5 Unit 1
0.0000
none

Math Operator 1
BaseIO 1
none
none

QT 1
QT Unit 1
322.7650
most likely q

Math Type 1
Math Sub Type 1
none
none

QT D1 1
QT D1 Unit 1
0.0000
most likely q

QT D2 1
QT D2 Unit 1
0.0000
none

QT Most 1
QT Most Unit 1
322.7650
most likely q

QT Low 1
QT Low Unit 1
310.8500
lower 90% ci

QT High 1
QT High Unit 1
334.6800
upper 90% ci

Math Expression 1
Math Result 1
(I1.Q1 +I1.Q2)/2
none

The following image displays the calculated results for all of the Indicators in 1 Output Series. This image and the remaining M&E images derive from M&E calculations and analyses run



DevTreks –social budgeting that improves lives and livelihoods

prior to Versions 2.0.4 and 2.0.6. The M&E tutorials demonstrate that current M&E calculators work very similarly to the Resource Stock calculators.



DevTreks –social budgeting that improves lives and livelihoods

M and E BM RI

DevTreks [US] https://www.devtreks.org/greentreks/preview/carbon/output/M%

Output Series : M and E BM RI Q4

Indicators Details

**Indic 1 Name:** LegalInstitutional

Weight: 1.000

Math Type: none

Q1 Amount: 310.850

Q2 Amount: 334.680

Total: 322.000

Indic 1 Description: This Indicator is used in a CTAP tutorial

Label: RI1\_QTM

Date: 12/30/2016

Type: nature1

Q1 Unit: lower 90% ci

Q2 Unit: upper 90% ci

Unit: alt\_B\_cer

**Indic 2 Name:** AwarenessCapacity

Weight: 1.000

Math Type: none

Q1 Amount: 866.822

Q2 Amount: 933.100

Total: 900.000

Indic 2 Description: This Indicator is used in a CTAP tutorial

Label: RI2\_QTM

Date: 12/30/2016

Type: nature1

Q1 Unit: lower 90% ci

Q2 Unit: upper 90% ci

Unit: alt\_B\_cer

**Indic 3 Name:** CriticalServicesInfrast ructure

Weight: 1.000

Math Type: none

Q1 Amount: 317.806

Q2 Amount: 342.190

Total: 330.000

Indic 3 Description: This Indicator is used in a CTAP tutorial

Label: RI3\_QTM

Date: 12/30/2016

Type: nature1

Q1 Unit: lower 90% ci

Q2 Unit: upper 90% ci

Unit: alt\_B\_cer

**Indic 4 Name:** EmergencyPreparedness

Weight: 1.000

Math Type: none

Q1 Amount: 317.806

Q2 Amount: 342.190

Total: 330.000

Indic 4 Description: This Indicator is used in a CTAP tutorial

Label: RI4\_QTM

Date: 12/30/2016

Type: nature1

Q1 Unit: lower 90% ci

Q2 Unit: upper 90% ci

Unit: alt\_B\_cer

**Indic 5 Name:** DevelopmentPlanning

Weight: 1.000

Math Type: none

Q1 Amount: -1612.058

Q2 Amount: 2092.374

Total: 240.000

Indic 5 Description: This Indicator is used in a CTAP tutorial

Label: RI5\_QTM

Date: 12/30/2016

Type: nature1

Q1 Unit: lower 90% ci

Q2 Unit: upper 90% ci

Unit: alt\_B\_cer

**Indic 6 Name:** ResiliencyIndex

Weight: 1.000

Math Type: none

Q1 Amount: 2322.347

Q2 Amount: 2949.856

Total: 2636.000

Indic 6 Description: This Indicator is used in a CTAP tutorial

Label: RI6\_QTM

Date: 12/30/2016

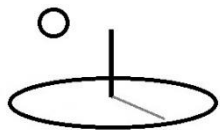
Type: nature1

Q1 Unit: lower 90% ci

Q2 Unit: upper 90% ci

Unit: alt\_B\_cer

Output Series : M and E BM RI Q8



DevTreks –social budgeting that improves lives and livelihoods

## **RI Output M&E Analysis**

M&E Analyzers aggregate Indicator.QTM, Indicator.QTL, and Indicator.QU, properties. The following image displays the results of an M&E Change by Year Analysis that demonstrates running the analysis at an Output base element with children Series. The base element Series were first aggregated into 2 separate years. No changes occur between the two years because all of the 4 Series have Indicators with identical properties (i.e. progress is expected to be equal for each semiannual period).





DevTreks –social budgeting that improves lives and livelihoods

Output Group : M and E RI Output Group ; C			
Output	All	Alt. 0	
Name	A- CTAP- Benchmark RI		
Label	B1		
Output Series	All	Alt. 0	Alt. 1
Name	CTAP - BM RI Q2	CTAP - BM RI Q6	
Label	B220016Q2	B220016Q6	
Alternative	A	A	
Indicator 1	LegallInstitutional	LegallInstitutional	
Change Type	none	none	
Observations	2	2	
Date	06/30/2016	06/30/2017	
Label	RI1_QTM	RI1_QTM	
Total Unit	alt_B_cer	alt_B_cer	
Total	621.700	621.700	
Total Amount Change	0.00	0.00	
Total Percent Change	0.00	0.00	
Total Base Change	0.00	0.00	
Total Base Percent Change	0.00	0.00	
Q1 Unit	lower 90% ci	lower 90% ci	
Q1	621.700	621.700	
Q1 Amount Change	0.00	0.00	
Q1 Percent Change	0.00	0.00	
Q1 Base Change	0.00	0.00	
Q1 Base Percent Change	0.00	0.00	
Q2 Unit	upper 90% ci	upper 90% ci	
Q2	669.360	669.360	
Q2 Amount Change	0.00	0.00	
Q2 Percent Change	0.00	0.00	

## RI Outcome M&E Calculation



DevTreks –social budgeting that improves lives and livelihoods

M&E calculators can be run for all base elements, and base element Indicators are never aggregated into ancestor elements. That is, Output Indicators will not be aggregated into Outcome Indicators, and Outcome Indicators will not be aggregated into Time Period elements. The M&E Introduction reference explains that each base element’s Indicators serve different purposes –an Outcome Indicator is not the same as an Output Indicator. Therefore, new Outcome and Time Period Indicators must be devised.

Outcomes are structured exactly the same way as demonstrated in Example 2. For illustrative purposes, 1 Outcome Indicator, Percent of Firms Increasing Resilience, is added to each Outcome (i.e. by copying it from the Parent Outcome Group). This Indicator measures concrete practices being implemented by firms within the targeted 3 locations to increase their resilience to natural resource disasters. The numbers are fictitious and, for the purpose of “eyeball metrics”, identical for each Outcome. The following image shows that an Outcome M&E Indicator has been copied from a parent Outcome Group and then edited for each separate Outcome.



DevTreks –social budgeting that improves lives and livelihoods

#### Outcome Group: CTAP RI M and E Progress

##### — Indicators Details

<b>Indic 1 Name:</b> Percent firms Increasing resilience	Label: Q2
Weight: 1.000	Date: 12/30/2016
Math Type: Q1_divide_Q2	Type: nature1
Q1 Amount: 100.000	Q1 Unit: firms taking action
Q2 Amount: 10000.000	Q2 Unit: total firms
Total: 0.010	Unit: percent firms
Indic 1 Description: This indicator is used in a CTAP tutorial	

#### Outcome : CTAP RI BMQ4

##### — Indicators Details

<b>Indic 1 Name:</b> Percent firms Increasing resilience	Label: Q2
Weight: 1.000	Date: 12/30/2016
Math Type: Q1_divide_Q2	Type: nature1
Q1 Amount: 100.000	Q1 Unit: firms taking action
Q2 Amount: 10000.000	Q2 Unit: total firms
Total: 0.010	Unit: percent firms
Indic 1 Description: This indicator is used in a CTAP tutorial	

#### Output : CTAP - BM RI Q4

##### — Indicators Details

<b>Indic 1 Name:</b> LegalInstitutional	Label: RI1_QTM
Weight: 1.000	Date: 12/30/2016
Math Type: none	Type: nature1
Q1 Amount: 310.850	Q1 Unit: lower 90% ci
Q2 Amount: 334.680	Q2 Unit: upper 90% ci
Total: 310.850	Unit: alt_B_cer
Indic 1 Description: This Indicator is used in a CTAP tutorial	
<b>Indic 2 Name:</b> AwarenessCapacity	Label: RI2_QTM
Weight: 1.000	Date: 12/30/2016
Math Type: none	Type: nature1
Q1 Amount: 866.822	Q1 Unit: lower 90% ci
Q2 Amount: 933.100	Q2 Unit: upper 90% ci
Total: 866.822	Unit: alt_B_cer

## RI Outcome M&E Analysis

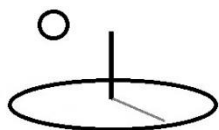
The following image of an M&E Outcome Analysis is run at the Outcome Group base element. The analysis shows that both the Outcome and Output base elements for the last semiannual



DevTreks –social budgeting that improves lives and livelihoods

period are 50% of the target goals because these periods haven't happened yet. This was done by setting the Output.Amount and Outcome.Amount equal to 0. If the same analysis is run using the "Compare Only" option, the children Outputs are not displayed.

The author hadn't run M&E 2 analyses for several months when this tutorial was first released and discovered at least 3 bugs or flaws with the analytic results. That's the specific reason that the 49 additional M&E 1 tools were deprecated in Version 1.9.4 –higher priority was placed on the 49 M&E 2 tools that were upgraded in Version 2.0.4.



DevTreks –social budgeting that improves lives and livelihoods

Outcome									
<b>CTAP RI ACTQ8</b>									
Target Type: <b>actual</b>									
Indicator Property	Plan Period	Plan Full	Plan Cumul	Actual Period	Actual Cumul	Actual Period Progress	Actual Cumul Progress	Plan P Percent ; Plan C Percent	Plan Full Percent
<b>Percent firms increasing resilience OC1</b>									
Date: 12/30/2017; Observations: 1									
Total Unit: percent firms; Q1 Unit: firms taking action; Q2 Unit: total firms									
Total	0.010	0.04	0.04	0.00	0.02	-0.01	-0.02	0.00 ; 50.00	50.00
Q1	100.000	400.00	400.00	0.00	200.00	-100.00	-200.00	0.00 ; 50.00	50.00
Q2	10,000.000	40,000.00	40,000.00	0.00	20,000.00	-10,000.00	-20,000.00	0.00 ; 50.00	50.00
This indicator is used in a CTAP tutorial									
Outputs									
Target Type: <b>actual</b>									
Indicator Property	Plan Period	Plan Full	Plan Cumul	Actual Period	Actual Cumul	Actual Period Progress	Actual Cumul Progress	Plan P Percent ; Plan C Percent	Plan Full Percent
<b>LegalInstitutional RI1_QTM</b>									
Date: 12/30/2017; Observations: 1									
Total Unit: alt_B_cer; Q1 Unit: lower 90% ci; Q2 Unit: upper 90% ci									
Total	310.850	1,243.40	1,243.40	0.00	621.69	-310.85	-621.71	0.00 ; 50.00	50.00
Q1	310.850	1,243.40	1,243.40	0.00	621.69	-310.85	-621.71	0.00 ; 50.00	50.00
Q2	334.680	1,338.72	1,338.72	0.00	669.36	-334.68	-669.36	0.00 ; 50.00	50.00
This Indicator is used in a CTAP tutorial									
<b>AutonomousCapacity RI2_QTM</b>									

The following Component M & E 2 Progress Analysis shows the same relative results as the Outcome Analysis. Because the author hadn't run these analyses in a while, it took a while to



DevTreks –social budgeting that improves lives and livelihoods

understand that the Total Actual Period Progress and Total Actual Cumulative Progress were measuring numeric differences between planned and actual numbers.

Component Group : CTAP RI M and E ; A10									
Component	All	Alt. 0	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
<b>Name</b>		CTAP RI BMQ2	CTAP RI ACTQ2	CTAP RI BMQ4	CTAP RI ACTQ4	CTAP RI BMQ6	CTAP RI ACTQ6	CTAP RI BMQ8	CTAP RI ACTQ8
<b>Date</b>		06/30/2016	06/30/2016	12/30/2016	12/30/2016	06/30/2017	06/30/2017	12/30/2017	12/30/2017
<b>Label</b>		Q2	Q2	Q4	Q4	Q6	Q6	Q8	Q8
<b>Target Type</b>		benchmark	actual	benchmark	actual	benchmark	actual	benchmark	actual
<b>Indicator 1</b>		Awareness Training	Awareness Training	Awareness Training	Awareness Training	Awareness Training	Awareness Training	Awareness Training	Awareness Training
<b>Observations</b>		1	1	1	1	1	1	1	1
<b>Date</b>		06/30/2016	06/30/2016	12/30/2016	12/30/2016	06/30/2017	06/30/2017	12/30/2017	12/30/2017
<b>Label</b>		IAT1	IAT1	IAT1	IAT1	IAT1	IAT1	IAT1	IAT1
<b>Total Unit</b>		most likely	most likely	most likely	most likely	most likely	most likely	most likely	most likely
<b>Total Planned Period</b>		20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000
<b>Total Planned Full</b>		80.00	80.00	80.00	80.00	80.00	80.00	80.00	80.00
<b>Total Planned Cumulative</b>		20.00	20.00	40.00	40.00	60.00	60.00	80.00	80.00
<b>Total Actual Period</b>		0.00	20.00	0.00	20.00	0.00	0.00	0.00	0.00
<b>Total Actual Cumulative</b>		0.00	20.00	0.00	40.00	0.00	40.00	0.00	40.00
<b>Total Actual Period Progress</b>		0.00	0.00	0.00	0.00	0.00	-20.00	0.00	-20.00
<b>Total Actual Cumul Progress</b>		0.00	0.00	0.00	0.00	0.00	-20.00	0.00	-40.00
<b>Total Plan P Percent</b>		0.00	100.00	0.00	100.00	0.00	0.00	0.00	0.00
<b>Total Plan C Percent</b>		0.00	100.00	0.00	100.00	0.00	66.67	0.00	50.00
<b>Total Plan Full Percent</b>		0.00	25.00	0.00	50.00	0.00	50.00	0.00	50.00

## RI Investment M&E Calculation



DevTreks –social budgeting that improves lives and livelihoods

For illustrative purposes, 1 Time Period Indicator, Percent Resilient Firms, is added to each Time Period. This Indicator measures the impacts that this resiliency improvement project is having on firms within the targeted 3 locations. The references cited in the M&E Calculation tutorial emphasize the importance of measuring impacts. Those references point out that money tends to be wasted, sometimes prodigiously, when the impact of the spent money is not measured. Examples abound. Experts explain how to measure this Indicator.

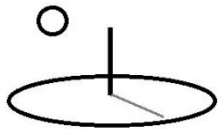
### **RI Investment M&E Analysis**

Investments, including Components and Inputs, are structured exactly the same way as demonstrated in Example 2. The following M&E 2 Progress Analysis demonstrates that M&E Indicators have only been added to the 4 benchmark and actual Time Period elements of this 2 year Investment. The Investment base element has been left out of the analysis because it does not hold separate M&E Indicators.

The full results of the analysis also demonstrate that the Benchmark base elements of Budget analyses won't have correct full "planned" metrics until the last Time Period because, at that point, all Time Period calculations have been run. All of the "actual" metrics are accurate because the benchmark Investment is ordered, and calculations run, before the actual Investment.

In general, Inputs and Outputs are not included in Budget analyses, because the quantity of data becomes difficult to interpret. In addition, references cited in the M&E Calculation tutorial imply that Input and Output Indicators may not be as significant as the remaining base element Indicators. In this example, that means the Output data holding the RI Indexes is not included in the final results. The simplest way to deal with this issue to put the Output Indicators into Outcomes instead and devise different Output Indicators. Alternatively, an M&E Totals analysis displays all elements, including Inputs and Outputs.

For information purposes, additional M&E Totals, Statistics, and Change by Alternative Investment Analyses are included with the example. The Totals analysis includes all base



DevTreks –social budgeting that improves lives and livelihoods

elements, including Inputs and Outputs. The Change analysis required setting all of the benchmark Alternative Type properties to “A” and the actual to “B”.

**Investment Group CTAP RI M and E RI 12/02/2015**

**Investment : A CTAP BM M and E RI RIA 12/02/2015**

**Time Period : 2016 BM CTAP Y1 12/31/2016**

Target Type: **benchmark**

#### Indicator Details

Indicator 1 Name : <b>Percent Resilient Firms</b>	Label : RI1
Date : 12/30/2016	Observations : 1
Unit : percent resilient	Type : none
Total Planned Period : 0.200	Total Plan Full : 0.40
Total Plan Cumul : 0.20	Total Actual Period : 0.00
Total Actual Cumul : 0.00	Total Actual Period Change : 0.00
Total Actual Cumul Change : 0.00	Total Planned Period Percent : 0.00
Total Planned Cumul Percent : 0.00	Total Planned Full Percent : 0.00
Q1 Unit : resilient firms	
Q1 Planned Period : 2,000.000	Q1 Plan Full : 4,000.00
Q1 Plan Cumul : 2,000.00	Q1 Actual Period : 0.00
Q1 Actual Cumul : 0.00	Q1 Actual Period Change : 0.00
Q1 Actual Cumul Change : 0.00	Q1 Planned Period Percent : 0.00
Q1 Planned Cumul Percent : 0.00	Q1 Planned Full Percent : 0.00
Q2 Unit : total firms	
Q2 Planned Period : 10,000.000	Q2 Plan Full : 20,000.00
Q2 Plan Cumul : 10,000.00	Q2 Actual Period : 0.00
Q2 Actual Cumul : 0.00	Q2 Actual Period Change : 0.00
Q2 Actual Cumul Change : 0.00	Q2 Planned Period Percent : 0.00
Q2 Planned Cumul Percent : 0.00	Q2 Planned Full Percent : 0.00

**Description :** This data is used in a CTAP tutorial.

**Outcome : CTAP RI BMQ2 Q2 06/30/2016**

Target Type: **benchmark**

#### Indicator Details

Indicator 1 Name : <b>Percent firms Increasing resilience</b>	Label : OC1
Date : 06/30/2016	Observations : 1
Unit : percent firms	Type : none
Total Planned Period : 0.010	Total Plan Full : 0.02
Total Plan Cumul : 0.01	Total Actual Period : 0.00
Total Actual Cumul : 0.00	Total Actual Period Change : 0.00
Total Actual Cumul Change : 0.00	Total Planned Period Percent : 0.00





DevTreks –social budgeting that improves lives and livelihoods

The following shows that, for this midterm evaluation, the actual TimePeriod.Amount property has been set to zero for the 2017 period. The Planned Full Percent and Planned Cumulative Percent show that 50% of the planned goals have been accomplished. As a result, this project is 100% on time and on budget. That's important information to track for most serious projects, programs, and technology assessments (11\*).

Time Period : 2017 Actual CTAP Y2 12/31/2017									
Target Type: <b>actual</b>									
Indicator Property	Plan Period	Plan Full	Plan Cumul	Actual Period	Actual Cumul	Actual Period Progress	Actual Cumul Progress	Plan P Percent ; Plan C Percent	Plan Full Percent
<b>Percent Resilient Firms RI1</b>									
Date: 12/30/2017; Observations: 1									
Total Unit: percent resilient; Q1 Unit: resilient firms; Q2 Unit: total firms									
Total	0.200	0.40	0.40	0.00	0.20	-0.20	-0.20	0.00 ; 50.00	50.00
Q1	2,000.000	4,000.00	4,000.00	0.00	2,000.00	-2,000.00	-2,000.00	0.00 ; 50.00	50.00
Q2	10,000.000	20,000.00	20,000.00	0.00	10,000.00	-10,000.00	-10,000.00	0.00 ; 50.00	50.00
This data is used in a CTAP tutorial.									
<b>Outcome: CTAP RI ACTQ6 Q6 06/30/2017</b>									
Target Type: <b>actual</b>									
Indicator Property	Plan Period	Plan Full	Plan Cumul	Actual Period	Actual Cumul	Actual Period Progress	Actual Cumul Progress	Plan P Percent ; Plan C Percent	Plan Full Percent
<b>Percent firms Increasing resilience OC1</b>									
Date: 06/30/2017; Observations: 1									
Total Unit: percent firms; Q1 Unit: firms taking action; Q2 Unit: total firms									
Total	0.010	0.04	0.03	0.00	0.02	-0.01	-0.01	0.00 ; 66.67	50.00
Q1	100.000	400.00	300.00	0.00	200.00	-100.00	-100.00	0.00 ; 66.67	50.00
Q2	10,000.000	40,000.00	30,000.00	0.00	20,000.00	-10,000.00	-10,000.00	0.00 ; 66.67	50.00



DevTreks –social budgeting that improves lives and livelihoods

The following image of the last 2 semiannual periods, quarter 6 and quarter 8, shows the same metrics as Example 2 for comparable base elements. Although these analyses display the names of the children Inputs and Outputs, it doesn't analyze their Indicators for the reasons mentioned in the introduction to this example.

#### Outcome: CTAP RI ACTQ8 Q8 12/30/2017

Target Type: **actual**

Indicator Property	Plan Period	Plan Full	Plan Cumul	Actual Period	Actual Cumul	Actual Period Progress	Actual Cumul Progress	Plan P Percent ; Plan C Percent	Plan Full Percent
--------------------	-------------	-----------	------------	---------------	--------------	------------------------	-----------------------	---------------------------------	-------------------

#### Percent firms Increasing resilience OC1

Date: 12/30/2017; Observations: 1

Total Unit: percent firms; Q1 Unit: firms taking action; Q2 Unit: total firms

Total	0.010	0.04	0.04	0.00	0.02	-0.01	-0.02	0.00 ; 50.00	50.00
Q1	100.000	400.00	400.00	0.00	200.00	-100.00	-200.00	0.00 ; 50.00	50.00
Q2	10,000.000	40,000.00	40,000.00	0.00	20,000.00	-10,000.00	-20,000.00	0.00 ; 50.00	50.00

This indicator is used in a CTAP tutorial

#### Output: CTAP - Actual RI Q8 B220016Q8 12/30/2017

#### Component CTAP RI ACTQ6 Q6 06/30/2017

Target Type: **actual**

Indicator Property	Plan Period	Plan Full	Plan Cumul	Actual Period	Actual Cumul	Actual Period Progress	Actual Cumul Progress	Plan P Percent ; Plan C Percent	Plan Full Percent
--------------------	-------------	-----------	------------	---------------	--------------	------------------------	-----------------------	---------------------------------	-------------------

#### Awareness Training IAT1

Date: 06/30/2017; Observations: 1

Total Unit: most likely; Q1 Unit: low; Q2 Unit: high

Total	20.000	80.00	60.00	0.00	40.00	-20.00	-20.00	0.00 ; 66.67	50.00
Q1	10.000	40.00	30.00	0.00	20.00	-10.00	-10.00	0.00 ; 66.67	50.00
Q2	30.000	120.00	90.00	0.00	60.00	-30.00	-30.00	0.00 ; 66.67	50.00

This data is used in a CTAP tutorial.

#### Input CTAP Actual RI Q6 A2016Q6 06/30/2017

#### Component CTAP RI ACTQ8 Q8 12/30/2017

Target Type: **actual**

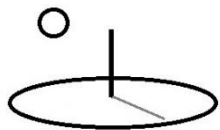
Indicator Property	Plan Period	Plan Full	Plan Cumul	Actual Period	Actual Cumul	Actual Period Progress	Actual Cumul Progress	Plan P Percent ; Plan C Percent	Plan Full Percent
--------------------	-------------	-----------	------------	---------------	--------------	------------------------	-----------------------	---------------------------------	-------------------

#### Awareness Training IAT1

Date: 12/30/2017; Observations: 1

Total Unit: most likely; Q1 Unit: low; Q2 Unit: high

Total	20.000	80.00	80.00	0.00	40.00	-20.00	-40.00	0.00 ; 50.00	50.00
-------	--------	-------	-------	------	-------	--------	--------	--------------	-------



DevTreks –social budgeting that improves lives and livelihoods

## Appendix



DevTreks –social budgeting that improves lives and livelihoods

## Appendix F. Testing on localhost

Pull the data and media files out of db into file system by logging in (kpboyle1, public) and viewing the following URLs on the Preview panel. The default club must be Carbon Emissions Reducers. Testing used the Kestrel server documented in the Source Code tutorial. That tutorial confirms the Version 2.1.6 upgrade to <https://localhost:5001> URLs.

[http://localhost/greentreks/preview/carbon/resourcepack/CTAP Disaster Risk Management/528/none](http://localhost/greentreks/preview/carbon/resourcepack/CTAP%20Disaster%20Risk%20Management/528/none)

NOTE: 1.9.8 required that all indicator datasets must have uniform 4 hierarchical levels (3 levels are no longer supported). Subalgo 11 and 12 datasets have been modified for that purpose.

[http://localhost/greentreks/preview/carbon/resourcepack/SubAlgo 09 DRR 1A/527/none](http://localhost/greentreks/preview/carbon/resourcepack/SubAlgo%2009%20DRR%201A/527/none)

[http://localhost/greentreks/preview/carbon/resourcepack/SubAlgo 09 DRR 2/532/none](http://localhost/greentreks/preview/carbon/resourcepack/SubAlgo%2009%20DRR%202/532/none)

[http://localhost/greentreks/preview/carbon/resourcepack/SubAlgo 10 DRI 1A/529/none](http://localhost/greentreks/preview/carbon/resourcepack/SubAlgo%2010%20DRI%201A/529/none)

[http://localhost/greentreks/preview/carbon/resourcepack/SubAlgo 11 RMI 1A/530/none](http://localhost/greentreks/preview/carbon/resourcepack/SubAlgo%2011%20RMI%201A/530/none)

[http://localhost/greentreks/preview/carbon/resourcepack/SubAlgo 12 RI 1A/531/none](http://localhost/greentreks/preview/carbon/resourcepack/SubAlgo%2012%20RI%201A/531/none)

[http://localhost/greentreks/preview/carbon/resourcepack/Drought DRR and DSS/533/none](http://localhost/greentreks/preview/carbon/resourcepack/Drought%20DRR%20and%20DSS/533/none)

Make the base document for each of the following URLs before running calculations.

Additional Version URLs are documented in related tutorials, such as the Social Performance Analysis tutorials.

### 1.9.2 URLs:

[http://localhost/greentreks/preview/carbon/output/CTAP Example 1 - Hurricane DRR/2141223467/none](http://localhost/greentreks/preview/carbon/output/CTAP%20Example%201%20-%20Hurricane%20DRR/2141223467/none)

[http://localhost/greentreks/preview/carbon/output/CTAP Example 2 - Earthquake DRI/2141223468/none](http://localhost/greentreks/preview/carbon/output/CTAP%20Example%202%20-%20Earthquake%20DRI/2141223468/none)



DevTreks –social budgeting that improves lives and livelihoods

<http://localhost/greentreks/preview/carbon/output/CTAP Example 3 - Generic RMI/2141223469/none>

<http://localhost/greentreks/preview/carbon/output/CTAP Example 4 - Generic RI/2141223470/none>

#### **1.9.4 URLs:**

<http://localhost/greentreks/preview/carbon/outputgroup/CTAP Output Group Example 5/1936433777/none>

<http://localhost/greentreks/preview/carbon/output/CTAP Example 5 - Progress RI/2141223471/none>

<http://localhost/greentreks/preview/carbon/outputgroup/M and E RI Output Group/1936433778/none>

<http://localhost/greentreks/preview/carbon/output/A- CTAP- Benchmark RI/2141223474/none>

These URLs require running the NPV calculator prior to the Progress Analyzer, even though those results are not used with these examples. Make the base document first.

<http://localhost/greentreks/preview/carbon/outcomegroup/CTAP RI Progress/47/none>

<http://localhost/greentreks/preview/carbon/componentgroup/CTAP RI Progress/663/none>

<http://localhost/greentreks/preview/carbon/investmentgroup/CTAP Progress RI/275505683/none>

<http://localhost/greentreks/preview/carbon/outcomegroup/CTAP RI M and E Progress/48/none>

<http://localhost/greentreks/preview/carbon/componentgroup/CTAP RI M and E/664/none>

<http://localhost/greentreks/preview/carbon/investmentgroup/CTAP RI M and E/275505684/none>

#### **1.9.6 URLs:**

<http://localhost/greentreks/preview/carbon/output/CTAP Example 6 - Floods DRR/2141223476/none>

#### **1.9.8 URLs:**

<http://localhost/greentreks/preview/carbon/output/CTAP Example 7 - Drought DRR and DSS/2141223477/none>



DevTreks –social budgeting that improves lives and livelihoods

<http://localhost/greentreks/preview/carbon/output/CTAP Example 7 - Drought Vulnerability Index/2141223478/none>

## **2.0.0:**

Version 2.0.0 upgraded to Microsoft's new Net Core 1 open source initiative. The software was refactored to support the Linux, Mac, or Windows servers supported by that initiative. The Social Budgeting and Source Code tutorials explain more about the refactor. The new technologies included in the refactor may take CTAs a step closer to being an accepted best practice technology for tackling climate change and other serious societal issues.

## **2.0.2 URLs:**

Version 2.0.2 upgraded the technologies used to conduct Conservation Technology Assessments (CTAs). The first WebApi app, DevTreksStatsApi, supporting cross platform CTAs, was released. The Technology Assessment 1 and Source Code tutorials document these upgrades. This reference was further proofed.

## **2.0.4**

Version 2.0.4 upgraded the 49 Monitoring and Evaluation (M&E) calculators and analyzers so that they also can use all of the CTA algorithms.

## **2.0.6 URLs**

All of the CTA algorithms were tested and improved to work with the upgraded Monitoring and Evaluation (M&E) tools. Each of the following URLs contain both Resource Stock and M&E calculations. The existing TEXT datasets used with the original Stock calculator examples did not need to be changed because the algorithms, rather than the M&E calculators, manipulate the data. The M&E and CTA 01 references demonstrate dataset conventions needed for other types of M&E calculations (i.e. datasets replace an Indicator's index position for the Indicator.Label).

<http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 1 - Hurricane DRR/2141223467/none>



DevTreks –social budgeting that improves lives and livelihoods

[http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 6 - Floods  
DRR/2141223476/none](http://localhost:5000/greentreks/preview/carbon/output/CTAP%20Example%206%20-%20Floods%20DRR/2141223476/none)

[http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 2 - Earthquake  
DRI/2141223468/none](http://localhost:5000/greentreks/preview/carbon/output/CTAP%20Example%202%20-%20Earthquake%20DRI/2141223468/none)

[http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 3 - Generic  
RMI/2141223469/none](http://localhost:5000/greentreks/preview/carbon/output/CTAP%20Example%203%20-%20Generic%20RMI/2141223469/none)

[http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 4 - Generic  
RI/2141223470/none](http://localhost:5000/greentreks/preview/carbon/output/CTAP%20Example%204%20-%20Generic%20RI/2141223470/none)

[http://localhost:5000/greentreks/preview/carbon/output/CTAP Example 7 - Drought DRR and  
DSS/2141223477/none](http://localhost:5000/greentreks/preview/carbon/output/CTAP%20Example%207%20-%20Drought%20DRR%20and%20DSS/2141223477/none)

## **2.0.8 URLs**

The Social Performance Analysis tutorial documents 4 new algorithms that begin to measure social performance, including the social impacts of climate change mitigation and adaptation actions.

## **2.1.0 URLs**

The Social Performance Analysis tutorial has the latest URLs. The tutorials that were updated in the past week contain the results of Version 2.1.0 tests. The tests suggest that the “netframework” github branch is now obsolete. We recommend the new .NetCore2.0 github source.

## **2.1.4+ URLs**

The Social Performance Analysis 3 reference has the latest URLs. Example 6 in the Social Performance Analysis 3 reference uses the results of the CTAP algorithms to further support disaster risk management in the content of the Sendai Disaster Risk Reduction goals.