**National Center for Risk and Economic Analysis of Threats and Emergencies**
**University of Southern California**

# Centers of Excellence Landscape III

## Lessons Learned from the Applications of 25 Benefit-Cost Analyses to Evaluate Homeland Security R&D Projects

## Executive Summary

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January 20, 2022

"This research was supported by the United States Department of Homeland Security through the National Center for Risk and Economic Analysis of Threats and Emergencies (CREATE) under Basic Ordering Agreement No. HSHQDC10BOA19. However, any opinions, findings, and conclusions or recommendations in this document are those of the authors and do not necessarily reflect views of the United States Department of Homeland Security or the University of Southern California."

**Basic Ordering Agreement HSHQDC10BOA19**
**Department of Homeland Security**

## ABOUT CREATE

The National Center for Risk and Economic Analysis of Threats and Emergencies (CREATE) was the first university-based Center of Excellence (COE) funded by the Office of University Programs (OUP) of the Science and Technology (S&T) Directorate of the Department of Homeland Security (DHS). CREATE started operations in March of 2004 and has since been joined by additional DHS centers. Like other COEs, CREATE contributes university-based research to make the nation safer by taking a longer-term view of scientific innovations and breakthroughs and by developing the future intellectual leaders in homeland security.

*CREATE's mission is to improve homeland security decisions to make our nation safer. We are accomplishing our mission through an integrated program of research, education and outreach that is designed to inform and support decisions faced by elected officials and governmental employees at the national, state, and local levels. We are also working with private industry, both to leverage the investments being made by the DHS in these organizations and to facilitate the transition of research toward meeting the security needs of our nation.*

CREATE employs an interdisciplinary approach merging engineers, economists, decision scientists, and system modelers in a program that integrates research, education and outreach. This approach encourages creative discovery by employing the intellectual power of the American university system to solve some of the country's most pressing problems. The Center is the lead institution where researchers from around the country come to assist in the national effort to improve homeland security through analysis and modeling of threats. The Center treats the subject of homeland security with the urgency that it deserves, with one of its key goals being to produce rapid results by leveraging existing resources so that benefits accrue to our nation as quickly as possible.

By the nature of the research in risk, economics, risk management and operations research, CREATE serves the need of many agencies at the DHS, including the Transportation Security Administration, Customs and Border Protection, Immigration and Customs Enforcement, Federal Emergency Management Agency and the US Coast Guard. In addition, CREATE has developed relationships with clients in the Offices of National Protection and Programs, Intelligence and Analysis, the Domestic Nuclear Detection Office and many State and Local government agencies. CREATE faculty and students take both the long-term view of how to reduce terrorism risk through fundamental research, and the near-term view of improving the cost-effectiveness of counter-terrorism policies and investments through applied research.

## Centers of Excellence Landscape III

### Lessons Learned from the Applications of 25 Benefit-Cost Analyses to Evaluate Homeland Security R&D Projects

## Executive Summary

The Science and Technology Directorate (S&T) of the Department of Homeland Security (DHS) has a budget of about $1 billion. Much of this is allocated to the funding of research and development (R&D) projects aimed at improving decision-making and operations of DHS components such as the Transportation Security Administration (TSA), U.S. Customs and Border Protection (CBP), the U.S. Coast Guard (USCG), and the Federal Emergency Management Agency (FEMA). Examples of successful R&D projects include the development of three-dimensional computer tomography tools to improve the detection of illicit materials at TSA checkpoints and the development of smart routing algorithms to improve the scheduling of USCG patrol boats in U.S. harbors.

A relatively small part of the S&T budget, about $40 million per year, goes to the Office of University Programs (OUP), which funds basic and exploratory research. While the original mission of this office was to support university-based research with a longer-term view of eventual impacts and benefits, the emphasis has also shifted to shorter-term component needs and impacts.

A frequently asked question is: What is the return on these investments that S&T made into R&D? This question is hard to answer, especially for university-based research, which often generates knowledge products that have no immediate impact on decision-making or operations by DHS components. Methodologies like benefit-cost analysis and decision analysis were designed to answer this question, but they have rarely been applied to research projects and products that are often far removed from direct application and use.

Starting in 2016, OUP challenged economists, risk analysts, and decision analysts at the Center for Risk and Economic Analysis of Threats and Emergencies (CREATE) at the University of Southern California to use risk and economic models and tools to answer the return-on-investment question. In response, CREATE researchers conducted 25 benefit-cost analyses (BCAs) on a wide range of OUP- and S&T-funded projects and the research products that resulted from them. These BCA projects were known as the Centers of Excellence Landscape Studies I and II (see CREATE, 2018, 2020).

Table 1 shows the 25 research projects and products for which the CREATE team conducted BCAs. Table 2 provides a summary of the main results in terms of the costs, median net benefits, and the benefit-cost ratio (BCR) for eight retrospective case studies. Table 3 provides the same information for 17 prospective case studies.

**Table 1. Case Studies for Benefit-Cost Analysis**

| Research Product | Description | DHS Component |
|---|---|---|
| WTS | *Wait Time Study* to determine the economic benefits of reducing wait times by adding CBP officers | CBP |
| ARMOR | *Assistant for Randomized Monitoring Over Routes* | USCG & LAX |
| ADCIRC | *Advanced Circulation* storm surge model | USCG |
| BOARD | *Bus Operator Awareness R&D* training module | USCG |
| CGSARVA | *Coast Guard Search and Rescue Visual Analytics* | USCG |
| E-CAT | *Economic Consequence Analysis Tool* | USCG |
| ENGSWABS | Improved *swab design* for collecting explosives residue at TSA checkpoints | USCG & TSA |
| GeoXray | Spatial representation of social media key words | USCG |
| HOAX Calls | Voice pattern analysis to identify *hoax calls* | USCG |
| PROTECT | *Port Resilience Operational/Tactical Enforcement to Combat Terrorism* for smart randomization of patrols | USCG |
| TraffiCop | Social media search tool to identify sex traffickers | USCG |
| IRIS | *Intelligent Randomization in Scheduling* Federal Air Marshals | TSA |
| EMWS | *Enhanced Millimeter-Wave Scanner* to improve detection of explosives at TSA checkpoints | TSA |
| 3DCT | *3D Computed Tomography Datasets* and Automatic Threat Recognition algorithm | TSA |
| PAS | *Passive Acoustic Sensors* for low-flying aircraft | CBP |
| TRS | *Trafficking Risk Score* | CBP |
| RPM | *Remote Power Module* | CBP |
| GARI | *Gang Graffiti Automatic Recognition and Interpretation* | CBP |
| SMART | *Social Media Analytics and Reporting* | CBP |
| PCR | *Prepaid Card Reader* | S&T |
| RIC-M | *Radio Internet Protocol Communication Module* | S&T |
| WLFF PPE | *Wildland Firefighter Advanced Personal Protection Equipment* | S&T |
| NRS - FPP | *National Resilience Standards for Flood Proofing Products* | S&T |
| FIS | *Flood Inundation Sensors* | S&T |
| OFE | *Observed Flood Extent Project* | S&T |

**Table 2. Results of Case Studies for Eight Retrospective BCAs**

| Research Products | Cost (in 2017 Dollars) | Median NPV (50th Percentile) | DHS Component | BCR |
|---|---|---|---|---|
| WTS Wait Time Study | $408,561 | $282,331,032 | CBP | 692.0 |
| IRIS | $1,750,443 | $529,831,040 | FAMS | 303.7 |
| PROTECT | $710,350 | $35,505,095 | USCG | 51.0 |
| ARMOR | $1,056,460 | $28,969,043 | TSA | 28.4 |
| RIC-M Rado Internet Communications* | $312,700 | $4,264,081 | S&T, FRG | 14.6 |
| NRS-FPP National Resilience Standards* | $22,866,151 | $272,483,596 | S&T, FRG | 12.9 |
| CGSARVA | $803,000 | $5,247,000 | USCG | 7.5 |
| WWLFE-PPEildland Firefighter APP Systems | $7,062,384 | $12,286,670 | S&T, FRG | 2.7 |
| **TOTALS** | **$34,970,049** | **$1,170,917,557** | **Median** | **21.5** |

**Table 3. Results of Case Studies for 17 Prospective BCAs**

| Research Products | Cost (in 2017 Dollars) | Median NPV (50th Percentile) | DHS Component | BCR |
|---|---|---|---|---|
| GeoXray | $273,088 | $18,404,000 | CBP | 68.4 |
| TRS Trafficking Risk Score | $139,050 | $8,300,061 | CBP | 60.7 |
| ADCIRC | $7,094,771 | $286,209,000 | USCG | 41.3 |
| EMWS Enhanced Millimeter Wave Scanner | $3,260,599 | $122,194,372 | TSA | 38.5 |
| Hoax Calls | $182,934 | $4,645,692 | USCG | 26.4 |
| 3D CT Datasets and ATR | $4,898,926 | $117,741,020 | TSA | 25.0 |
| ENGSWBS Engineered Swabs | $1,867,322 | $22,528,000 | TSA | 13.1 |
| SMART Social Media Analytics | $320,349 | $2,946,802 | CBP | 10.2 |
| PCR Prepaid Card Reader* | $466,761 | $4,067,839 | S&T, FRG | 9.7 |
| TraffiCop | $1,412,600 | $10,443,892 | CBP | 8.4 |
| PAS Passived Acoustic Sensing | $4,006,100 | $20,893,771 | CBP | 6.2 |
| RPM Remote Power Module | $1,583,640 | $5,541,829 | USCG | 4.5 |
| GARI Gang Graffiti Recognition | $371,869 | $1,097,247 | CBP | 4.0 |
| OFE Observed Flood Extent Project* | $7,062,384 | $18,427,082 | S&T, FRG | 3.6 |
| BOARD Bus Operator Training | $1,017,561 | $2,435,000 | USCG | 3.4 |
| FIS Flood Innundation Sensors* | $675,358,046 | $1,180,230,017 | S&T, FRG | 2.7 |
| E-CAT | $945,000 | $806,000 | TSA | 1.9 |
| **TOTAL** | **$710,261,000** | **$1,826,911,624** | **Median** | **9.7** |

*2019 Dollars

During 2020 and 2021, an additional study was initiated to summarize the lessons learned from the 25 BCAs, to conduct training on conducting BCAs for S&T- and OUP-funded projects, and to identify and close gaps identified during this process. The project had four tasks:

1. Developing Practical Lessons and Training/Workshop Curriculum for COEs
2. Filling Gaps in Current BCA Models
3. Expanding Set of Benefit and Cost Categories
4. Providing Data Analytics Support for OUP for Performance Measurement

The activities and findings developed under the four tasks are summarized in this Executive Summary. Additional reports on each of the four tasks are referenced in the text and at the end of this summary.

**Task 1: Develop Practical Lessons and Training/Workshop Curriculum for COEs (von Winterfeldt, Farrow, John, Rose, Wei)**

The first activity in this task was to summarize the lessons learned from the 25 BCAs conducted during the Landscape I and II projects. To this end, we conducted a survey of the CREATE team members (listed as authors of this Executive Summary) who conducted the 25 BCAs to identify the lessons they personally learned and found important. Below are the major lessons (see also von Winterfeldt et al., 2021, which describes these lessons in more detail).

1. Order-of-magnitude BCAs can be conducted for most R&D research products proposed for an evaluation; the BCAs by CREATE were peer reviewed with favorable results.
2. Benefits exceeded the costs in all 25 selected case studies, with a median benefit-to-cost ratio of over 20.
3. The most defensible BCAs were for research products that had been transitioned and used.
4. The BCAs could be clustered into five BCA models and 10 benefit categories.
5. Decision analysis and traditional BCA approaches, while formally equivalent, produce different insights into risk and uncertainty of benefits and costs.
6. Estimating the baseline performance (prior to the use of the research project) is both challenging and indispensable.

7. Benefits estimation is the most challenging task, but relative improvement in benefits can be sufficient to estimate benefits.
8. Cost estimation is usually easier, but some challenges remain, especially with respect to downstream costs.
9. Indirect benefits and costs can play a role in some BCAs.
10. Discounting of past costs and benefits is controversial in the economics field.

The five benefit models and 10 benefit categories (item 4 above) are listed below:

1. Improved performance and/or cost savings
    a. Cost savings (ARMOR) or savings by stretching expenses (CGSARVA)
    b. Improvement of performance (Prepaid Card Reader)
2. Reduced risk/increased security
    a. Reduction of threat (Hoax Calls)
    b. Reduction of vulnerability (PROTECT)
    c. Reduction of negative consequences (Wildland Firefighter Garments)
3. Improved signal detection
    a. Reduction of false alarm rates (Enhanced MM Wave Scanner)
    b. Improvement of detection rates (3D CT Datasets and ATRs)
4. Value of information
    a. Reduction of uncertainty (Flood Inundation Sensors)
    b. Improvement of decisions (ADCIRC)
5. Value of training
    a. Improved operational performance (BOARD Bus Operator Training)

Based on these lessons and the experiences of the CREATE team with BCAs, we conducted a training workshop on December 15 and 16, 2020, with about 35 participants, which included program managers from OUP, other S&T staff, and COE directors and their research staff. The first day of the workshop provided an overview of the 25 BCAs and lessons learned, as well as a more detailed guide to conducting BCAs. The second day consisted of hands-on experiences with BCAs, conducted in small break-out groups. The workshop agenda is shown in Appendix 1.

In preparation for this workshop, we conducted an internal lessons-learned survey, which was summarized in the introductory session (see von Winterfeldt et al., 2021). One of our team members, Scott Farrow, developed and presented a training module on “Conducting a BCA” at the workshop. After the workshop, Farrow also drafted a "Frequently Asked Questions" (FAQs) document with answers about conducting BCAs. Appendix 2 contains the questions and Farrow (2020) contains the answers.

**Task 2: Fill Gaps in Current BCA Models (von Winterfeldt, Farrow, John)**

One of the gaps identified during the first two phases of the Landscape studies was the difficulty in assessing the benefits of research projects that produce information without specifically improving performance or saving money. We initially developed a value-of-information (VOI) approach to facilitate benefits assessments for these types of projects and applied it to the Flood Inundation Sensors project and the ADCIRC hurricane forecasting model. However, these applications of BCA did not strictly follow the decision-analytic VOI approach. In the current set of projects, we expanded this work in two directions: First, we demonstrated the use of a traditional VOI approach to a specific decision problem faced by the USCG and showed how ADCIRC helped improve that specific decision (see Appendix 3); second, we developed alternative approaches based on time savings and willingness-to-pay elicitation to address more complex VOI problems.

To demonstrate the use of VOI analysis to assess the benefits of information, we interviewed several USCG stakeholders to determine how they used ADCIRC in specific decisions. ADCIRC provides wind speed and inundation information that improves on the usual NOAA-type prediction models. The USCG had used ADCIRC in decisions to relocate their headquarters and fleet from Portsmouth and Norfolk to St. Louis prior to Hurricane Sandy and in relocating helicopters prior to Hurricanes Irma and Maria in Puerto Rico. We interviewed Admiral Brown to obtain a better understanding of the latter two cases. At issue was the question of whether to move the fleet of helicopters out of the paths of the hurricanes or to shelter them in an old hangar that was at some risk of collapsing if wind speeds would exceed a maximum withstand level.

This application of ADCIRC is described in Appendix 3 and resulted in significant savings through the decision not to remove the helicopters. This decision turned out to be a good choice, as the hangar withstood the maximum windspeeds during both hurricanes. The expected value of using ADCIRC vs. a traditional NOAA-type forecast was estimated at $4.5 million for each of these two decisions alone.

We also attempted to develop a VOI-type model to assess the information benefits of a database, specifically for the Global Terrorism Database (GTD), which is widely used by many researchers and organizations. We recognized that a traditional VOI approach is not easily implemented for databases, because there is no or only a weak link to decisions made with or without the database. We developed two alternative approaches. The first approach is based on the time savings of the users of the database. With many individual users, the time savings could be substantial compared to collecting the data from scratch or to using other, less comprehensive databases. The second approach is based on a willingness to pay or contingent valuation paradigm. In this approach, a representative sample of users would be asked the (hypothetical) question, how much they would be willing to pay (per month, per year) to access the database. We discussed these approaches with the leadership of START, the developer of the GTD, but we were not able to implement either approach in the time frame of the current project.

In addition to exploring the possibilities of using VOI and related methodologies to assess the benefits of information products or databases, we learned at the training workshop that a major gap existed in assessing the benefits of border security measures. In particular, there are great difficulties in predicting and valuing the outcomes of border security enhancements. Motivated by this gap, Scott Farrow began work on valuing border apprehensions. As the task became more complex, the approach evolved into one of building a benefit-cost tool for CBP border management focusing on those not initially admitted into the U.S. The problem was structured as choosing between the baseline management "technology" of 2017 compared to an alternative that the user might define that changes outcome probabilities or values.

Numerous gaps in BCA were addressed in the analysis of border management. Among these were valuing the apprehension of a criminal or a successful asylee, valuing the statistical life of a foreign national, and equity or distributional adjustments for impacts on low-income or high-income individuals when DHS policy mandates that the value of a statistical life (VSL) is constant. In the process, Professors Farrow and von Winterfeldt demonstrated that both decision analysis and benefit-cost analysis compute the same expected bottom line value. However, each method disaggregates information into different categories (outcomes, or consequences across outcomes) such that new information is available for a decision-maker when both methods are used.

An extended report on the BCA of border management was delivered to DHS (Farrow, 2021). Publications may result from the above work but have not to date, although several papers from the earlier Landscape projects were published during this project timespan. However, the analysis of border management and several of the issues addressed there are possible paper topics and have been accepted for presentation at the Society for Risk Analysis and the Society for Benefit-Cost Analysis annual meetings.

**Task 3: Expand Set of Benefit and Cost Categories (Rose, Wei)**

*3.1. Evaluation of an Extended Set of Cost Categories for Landscape BCA Studies*

The cost side of the BCA ledger, including major components such as R&D costs and capital and operating costs of projects, is typically thought to be more straightforward than its counterpart on the benefit side. The cost elements are relatively more concrete and near-term than the generally relatively more long-term, uncertain, and sometimes intangible benefits. Still, complications do arise even in some of the more straightforward cost categories, and there is a possibility that not all relevant cost categories have yet been incorporated into the Landscape project BCA template. The purpose of this portion of Task 3 of the Landscape III project is to investigate the possibility of extending a BCA in general with further explorations into the cost side of the ledger.

An organizing framework for the analysis was developed by Professors Wei and Rose in which they first discussed the definitions and characterizations of additional cost categories, with comparisons to cost terminologies used in the general economics literature. They also provided examples of each additional cost category, discussed the contexts in which these costs should be considered in BCA studies, summarized the challenges of adequately measuring them, and proposed adjustments or improvements in methods of measurement. The six extended cost categories evaluated include: 1) Auxiliary Costs, 2) Capital Upgrade Costs, 3) Salvage Values, 4) General Equilibrium Impacts, 5) Externality Effects, and 6) Broader Effects of Unemployment.

The researchers then conducted a comprehensive review of the 25 BCA studies CREATE performed for the Landscape project to evaluate the extent to which the studies included these additional cost categories in the BCA calculations. In the cases where some cost categories are not included, Wei and Rose (2021) also documented the major reasons and the potential impact of such omissions. The review results indicated that auxiliary costs and capital upgrade costs had already been explicitly or implicitly considered in some of the original Landscape studies. Fewer studies included analysis of salvage values of the products, costs of negative externalities, and broader effects of unemployment. However, in most cases these categories of costs were either not relevant for the specific technology products being evaluated (e.g., the adoption of more advanced computing algorithms or tools is unlikely to result in environmental or health-related negative externalities) or omissions of these costs were unlikely to result in major impacts on the bottom-line results of the BCA evaluations (e.g., any residual values of the products are likely to be negligible after 10 years of use, and reductions in staffing time as a result of the application of advanced technologies are unlikely to lead to any major employment effects). The researchers also identified the BCA studies that have included the evaluation of a relatively comprehensive set of extended categories of cost (for example, ARMOR, Wildland Firefighter Garments, and Flood Inundation Sensors) (Wei and Rose, 2021).

### *3.2. Upper Bounds for the Estimation of the Economic Consequences of Disasters*

Research projects sponsored by the U.S. Department of Homeland Security that lead to the implementation of mitigation/interdiction/resilience measures generate many types of benefits. These can range from rather limited reductions in property damage resulting from improved portable flood protection devices to savings of tens of thousands of lives and tens of billions of dollars of economic activity in expediting a pandemic vaccine supply chain or deterring a major terrorist attack. The estimation of the latter set of these benefits is not always straightforward, as it can involve complexities associated with increasing direct business interruption, as well as off-site effects, such as exacerbated behavioral responses. A key example is the finding that more than 80% of the approximately $150 billion loss in GDP stemming from the 2001 World Trade Center attacks was due to the almost two-year reduction in airline travel and related tourism that followed that event.

The prevention of economic losses due to disasters represents the benefits of mitigation/interdiction and resilience/recovery tactics (once they have been adjusted for the probability of occurrence). The estimates can be complicated in many cases, and analysts could benefit from guidance on their range of values.

Rose (2021a) presents a bounding exercise for the estimation of costs of terrorist attacks, natural disasters, and technological accidents in and of themselves, and for their use in benefit-cost analyses. It provides some guardrails for analysts and policymakers regarding these estimates. It also provides some perspective on the relative size of various categories of disasters, and ultimately on the allocation of resources for risk management purposes. The current COVID-19 pandemic has, in part, stimulated this inquiry in that it has generated a new upper-bound for disaster impacts.

Based on analyses of actual events and simulations of hypothetical ones during the 21st century, we arrive at the following boundaries for estimates of GDP impacts for various categories of disasters:

- Natural disasters: <$100 billion
- Major terrorist attacks: <$200 billion
- Great Recession: <$2 to $3 trillion
- COVID-19:[1] <$3 to $5 trillion

### *3.3. Indirect Consequences of Disasters*

The concept of indirect effects of disasters has evolved considerably. Because the field of hazard loss estimation was originally dominated by engineers, property damage was considered the direct loss, and everything else was considered an indirect loss. This perspective began to be challenged in two ways by the early 1990s. First, economists pointed out a fundamental distinction between stocks and flows. Property, or physical assets, are a stock that reflects wealth but does not directly contribute to the economic welfare (well-being) of society. It is the flow of goods and services, measured by gross product output (sales value) or net output (value-added or GDP), that is the direct link to welfare through the analysis of markets, or through non-market valuation where needed. When a disaster strikes, property damage and output reduction occur simultaneously; but while both begin then, the latter continues until recovery is complete. Thus, there is no reason to consider the flow losses as secondary or indirect.

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[1] A version of this report focusing on economic losses and deaths of COVID-19, as opposed to disasters more broadly and their impact on economic welfare, was published as: Rose, A. 2021. "COVID-19 Economic Impacts in Perspective: A Comparison to Recent U.S. Disasters," *International Journal of Disaster Risk Reduction*, electronic preprint. doi.org/10.1016/j.ijdrr.2021.102317

Second, both stock and flow losses have true indirect counterparts. Examples of the former are fires and toxic spills following earthquakes, causing damages to power lines or containers, respectively. In economic impact analysis, the antecedent of more modern economic consequence analysis, the direct/indirect distinction has been well-established for several decades. Direct impacts in the case of disasters relate to lost production in businesses directly hit by ground-shaking, floodwaters, intense winds, explosions, etc. Indirect losses refer to the implications to their suppliers and customers through the supply chain.

The above four-part classification framework is now reasonably well-established. Early aspects of it showed up in the development of HAZUS, FEMA's loss estimation software tool, which has separate modules for property damage, ancillary damages, direct business interruption, and indirect business interruption. This framework is well articulated in the literature and codified in the work of researchers in the field of economic consequence analysis, such as in a 2012 National Research Council Report on Disaster Resilience, though it is not necessarily fully appreciated by those with limited benefit-cost analysis experience.

There are other categories of disaster economic consequences that can lead to indirect effects, and thus the above framework is expanded to include all of the following major categories of direct effects, each likely to have an associated set of indirect effects (Rose, 2021b):

- Property Damage
- Business Interruption
- Externalities
- Behavioral
- Health

### *3.4. Behavioral Economic Consequences of Disasters*

Many disasters generate dread and fear among the directly affected population, and often also among those who believe they may be subsequently affected by the current, or a similar future, event. This fear can cause behavior that often exacerbates the direct losses. For example, 9/11 not only destroyed the World Trade Center and caused business interruption among its former tenants, but it also caused a decline in airline travel and related tourism in the U.S. for nearly two years. The COVID-19 pandemic has resulted in a similar effect on air travel, as well as more general trepidation about venturing out of the house to engage in a broad range of other types of economic activity. Further, behavioral reactions are not limited to consumers. Workers may be apprehensive about returning to jobsites due to fear of lingering contamination (even after an all-clear sign has been issued) from a dirty bomb attack, toxic spill, or disease epidemic. Business owners may board up and shut down their stores in anticipation of riots. Governments may react prudently, or even overreact, in forcing evacuations of entire regions in the path of a hurricane or shutting down all non-essential businesses in their jurisdiction during a pandemic.

A major question is whether these behavioral consequences should be included in BCAs of projects, products, or policies intended to reduce disaster losses. We know that these effects take place, so one of the main issues is whether they can be isolated and measured in a way that avoids overlaps or double-counting with other effects in particular and in a way that is consistent with BCA principles in general.

A cornerstone of BCA is the measurement of impacts on resource utilization. In the case of behavioral effects, this often extends beyond the original affected market into other markets, such as in the airline travel examples.

Rose (2021c) develops an economic framework for analyzing and estimating the behavioral effects of disasters and their consequences for disaster losses.[2] The reduction of these losses represents some of the benefits of pre-disaster mitigation/interdiction and post-disaster resilience/recovery. The paper provides conceptualizations, definitions, classifications, examples, and empirical results of this category of economic consequences. It also examines methods used to measure the effects of behavioral reactions to fear and provides insight into improving their delineation and legitimate inclusion in BCA.

**Task 4: Provide Data Analytics Support for OUP for Performance Measurement (Maya)**

The following provides an overview of the task to support OUP's data analytics and performance measurement task. A more detailed description can be found in Maya (2021).

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[2] This paper was split into two parts for publication. The first paper focuses on the case for including behavioral considerations in BCA (Rose, A. Behavioral Economic Consequences of Disasters: A Basis for Inclusion in Benefit-Cost Analysis," *Economics of Disasters and Climate Change*, forthcoming), while the second provides a general synthesis of the literature on behavioral consequences and a classification framework for analysis (Rose, A. "Behavioral Consequences of Disasters," in M. Skidmore [ed.]. *Handbook of Disasters*, Cheltenham, UK: Edward Elgar, forthcoming).

### 4.1. *Office of University Programs' Annual COE Accomplishments (formerly Matt Stats) Data Review*

The overall objective of this data analytics support to OUP was to recommend modifications to the annual performance measures, the COE Accomplishments database (formerly known as "Matt Stats"), to improve data collection efficiency and effectiveness and, further, to enable the use of benefit-cost analyses (BCAs) in the National Defense Authorization Act (NDAA) of Fiscal Year 2017 (P.L. 114-328) tracking and reporting using the collected metrics. The collection of the COE Accomplishments data is an annual process aimed at capturing the progress and achievements of the COEs. Through this effort, recommendations were developed for modifications to the format and content of COE Accomplishments.

The effort combined deep understanding of the COE Accomplishments database with insight into the BCA benefit categories and NDAA reporting requirements to provide specific recommendations for modifying the collection of data constituting the annual COE Accomplishment measures. An associated result of this effort was to demonstrate to COE directors and OUP leadership that the recommended revised approach to COE Accomplishments would be more efficient than the previous method and would enable both more effective recordkeeping and improved use of the data in demonstrating the value of OUP's R&D and education efforts. A key achievement was the positioning of the COE Accomplishments data collection to enable the evolution from ordinal counts of transition-related successes to an analytical assessment of BCA/ROI impact/value of R&D to DHS component recipients.

The data support to OUP for this effort was to review and reconcile OUP transition milestones in the S&T official system of record, the S&T Analytical Tracking System (STATS), with the workflow management system used by the Transition Branch for tracking transitions per NDAA transition tracking and reporting requirements. STATS reflects the official financial status of projects and is managed by a different organizational entity than ServiceNow, which reflects workflow progress and accomplishments status. Since the two systems do not communicate electronically or allow for data transfer between them, for this effort the official data from STATS reflecting OUP's transition milestones was downloaded into an Excel spreadsheet. The data in the spreadsheet was then uploaded manually into ServiceNow. This procedure was followed for OUP's FY20 Transition Milestones to first demonstrate the process, then to highlight areas of importance for accurate NDAA reporting, confirm consistency with current practices, and establish realistic expectations for FY21 and FY22 transition milestone tracking and reporting. An example are the OUP Transition Milestones entries in ServiceNow Detailed discussions of the ServiceNow entries were held with OUP program managers and support staff to convey the process and to plan efforts to facilitate the data management aspects of transition planning, tracking, and reporting in future years.

In addition, detailed feedback was provided to OUP on both its STATS Milestones and Transition Milestones. The documents containing the project descriptions associated with these milestones were downloaded from STATS and consisted of an extensive database of information on OUP projects. Feedback provided consisted of review comments identifying those STATS Milestones that could perhaps be better classified as Transition Milestones, and Transition Milestones that appeared to be better classified as STATS Milestones. Examples of such entries are not provided herein due to the sensitive nature of the projects, but they are available upon request with appropriate need-to-know and Non-Disclosure Agreement protections. The ensuing discussions of the feedback comments, and a fuller understanding of OUP's methods and rationale for their original milestone classifications, led to clearer mutual understanding between TST and OUP, and improved processes for better alignment across the S&T organization.

### *4.2. OUP Input to Knowledge Product (KP) Transition Classification and NDAA Transition Tracking Alignment*

One of the challenges facing not just OUP, but also the overall S&T organization, is the characterization of knowledge products (KPs) in classifications that would enable and facilitate their NDAA tracking and reporting requirements. Since OUP is a major producer of KPs, it was important for the Technology Scouting and Transition (TST) division responsible for developing the KP characterization and classifications to leverage OUP's insight in this domain. Thus, as part of this effort for TST, OUP's input was obtained on the data reporting issues with KPs, such as: multiple reports of R&D results in various publications, presentations, etc., being produced for a single project; differentiating technology/domain-specific KPs from education and training KPs; and the annual/progress reporting of KPs. OUP's data-reporting considerations were thus factored into the classification/definition categories being adopted within S&T. It was also a good opportunity to ensure that the KP classification met OUP's needs and enabled recognition of OUP's track record of productivity in delivering KPs of value to its Components.

Discussions with OUP on KP classifications also influenced the development of a tiered approach to NDAA technology transition tracking impact assessment pathways. The three types of pathways would designate some KPs to only be counted during the year they are originally developed. Then for the next phase, during Years 1 through 3 of the NDAA tracking period, for those KPs that are subsequently used by the Components, such as in an acquisition program for technology providing an operational benefit, a revised Standard Operating Procedure (SOP) improving, for example, efficiency or effectiveness would be designated for BCA/ROI-related data collection, enabling quantification of more meaningful measures of impact/value derived by DHS from the KP than just simple ordinal counts. The table showing the KP transition classification descriptions and impact assessment pathways is provided in Appendix XXX.

### *4.3. Inclusion of BCA Approach in S&T R&D Customer Satisfaction Feedback (CSF) Methodology*

This effort leveraged CREATE's working relationship with both TST and OUP to connect the new Customer Satisfaction Feedback (CSF) methodology (developed by CREATE for TST) to the BCA approach to benefits assessment (developed for OUP). The CSF methodology was crafted in response to a U.S. Government Accountability Office (GAO) recommendation to S&T to "develop standard processes and procedures for collecting and analyzing customer feedback, applicable to components conducting R&D, for improving the usefulness of existing customer feedback mechanisms to assess R&D efforts and for implementing such mechanisms where absent." A key component of the methodology is surveying Component stakeholders on their expected outcomes, benefits, and ROI of the R&D results provided to them by S&T. This assessment by the Component stakeholders directly relates to the benefit categories implemented in the BCA approach. The BCA approach then also provides the methodology guidance for assessing the benefits derived from the R&D result, informing the Components' responses to the CSF survey questions.

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## APPENDIX 1

## Workshop Agenda

BCA Training - Workshop Agenda

December 15 and 16, 2020

*Workshop – Day 1*

| | |
|---|---|
| • Introduction and overview of the workshop | 1:00 PM |
| • Thinking in terms of return on investment | 1:15 PM |
| • Applications to 25 research projects | 1:45 PM |
| • Lessons learned | 2:15 PM |
| **15-minute break at 2:30 PM** | |
| • Conducting a BCA | 2:45 PM |
| • Discussion and end first session | 3:30 PM |

**End of Day 1 at 4:00 PM**

*Workshop – Day 2*

| | |
|---|---|
| • Introduction of the break-out sessions | 1:00 PM |
| • Break-out sessions | 1:15 PM |
| – Identify a problem/project suitable for a BCA | |
| – Identify the baseline: How are things done now? | |
| – Identify benefits model and categories | |
| – Identify metrics & data to assess impact of project | |
| – Identify challenges with transition and BCA | |
| **15-minute break at 2:00 PM** | |
| • Debriefing by break-out teams | 2:15 PM |
| • Challenges for BCAs of S&T research | 3:00 PM |
| • Discussion of Next Steps | 3:45 PM |

**End of Day 2 at 4:00 PM**

# APPENDIX 2

## Frequently Asked Questions and Challenges for Benefit-Cost Data and Implementation

Table of Contents

**Frequently Asked Questions/shorter issues**



**Challenges/longer answers**



The answers to these questions are provided in Farrow (2020).

# APPENDIX 3

## Example of a Value-of-Information Analysis

This appendix provides a brief summary of a value-of-information (VOI) analysis of a specific decision situation faced by the USCG, which was aided by information from the ADCIRC hurricane prediction model. The information for this BCA was collected in interviews with USCG staff members, including Admiral Brown, who was in charge of the decision.

The decision was whether or not to move four MH65 helicopters out of harm's way prior to the arrival of Hurricane Irma in 2017. The helicopters were parked in an old hangar, and there was a chance that the hangar would collapse under very high wind speeds. Evacuating the helicopters to Guantanamo was the safer option, but this action would delay the rescue operations by two days after the hurricane had passed. Admiral Brown and his staff used ADCIRC to predict Irma's maximum wind speeds. Based on the ADCIRC results, they decided to leave the helicopters in the hangar, which did in fact survive the hurricane. The helicopters were thus ready the next morning to help with rescue operations, likely saving lives.

When contemplating the use of ADCIRC with the VOI approach, one first has to model the decision and subsequent uncertainties and outcomes without the use of ADCIRC – in this case, using traditional NOAA hurricane prediction models. This decision is shown in the lower part of Figure A3.1. The expected cost of this decision is $21 million, primarily due to the large uncertainty about the hangar's ability to withstand the maximum wind speed predicted by the traditional model. Using ADCIRC would allow the probability of collapse to be improved. Before making the decision to use ADCIRC, one has to consider the possibilities that ADCIRC would provide a more positive outlook or a more negative outlook on the maximum windspeed, leading to a revision of the prior probability of hangar collapse. Given the model parameters in Figure A3.1, the use of ADCIRC lowers the expected cost to $16.5 million, for a net gain of $4.5 million.

Figure A3.2 shows the inputs and outputs of this VOI analysis. Changing the sliders on the right of this figure changes the respective expected costs and the associated net benefit (reduction of expected cost). It should be noted that for some parameter settings, the net benefit (value of information) is zero, a not-uncommon result in VOI analysis.

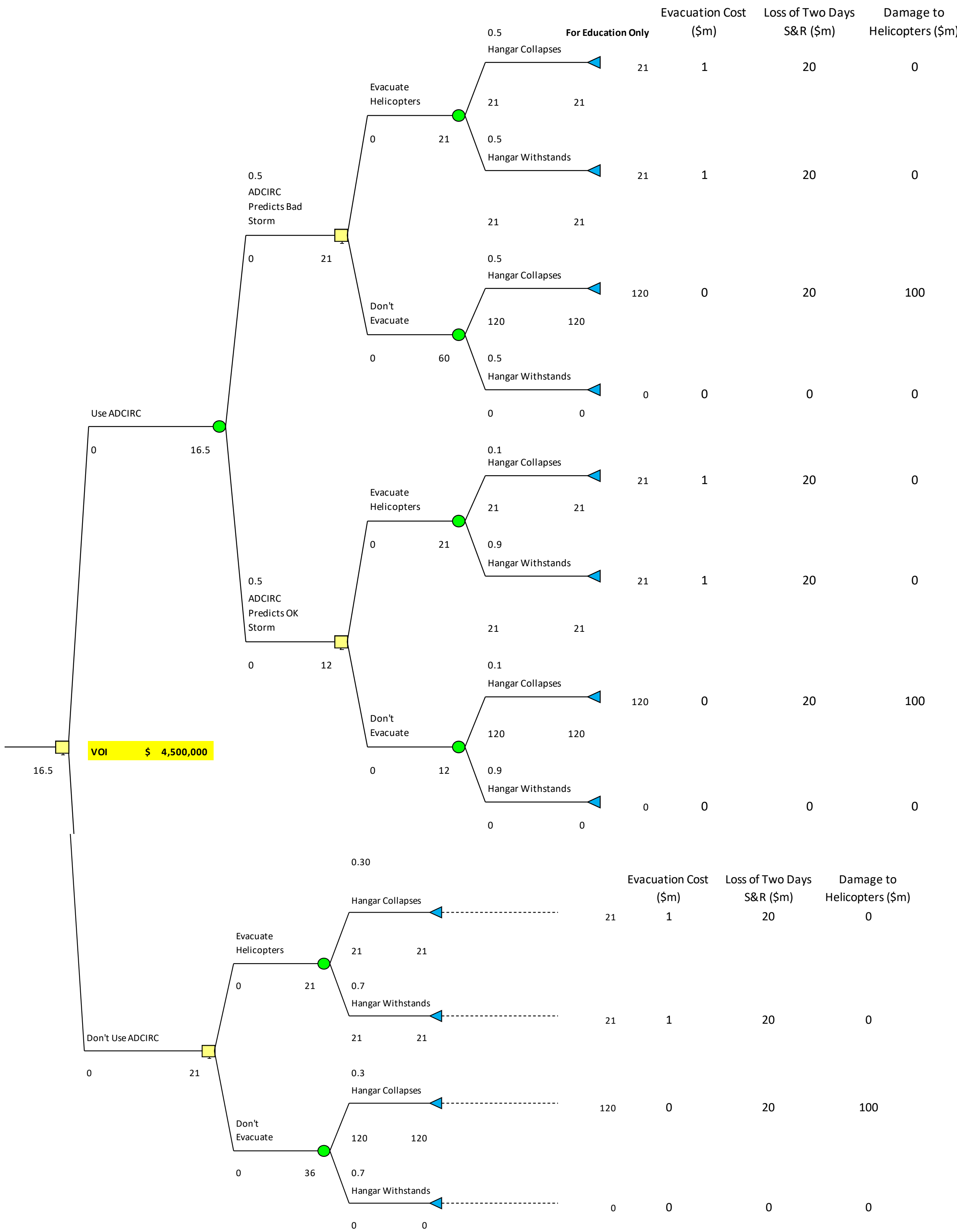
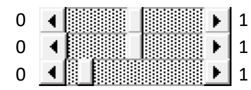



*Figure A3.1. Decision Tree for the VOI Analysis of ADCIRC*

**User Controls for ADCIRC - VOI**

| | |
|---|---|
| Probability of ADCIRC - Bad Strom | 0.50 |
| Probability of Hangar Collapse\|Bad Storm | 0.50 |
| Probability of Hangar Collapse\|OK Storm | 0.10 |
| Probability of Hangar Collaps without ADCIRC | 0.30 |
| Cost of Evacuation (in millions) | 1 |
| Cost of missing 2 days of Search and Rescue | 20 |
| Cost of Helicopter Losses (4 @ $25m) | 100 |
| Expected Cost of with ADCIRC (in millions) | 16.5 |
| Expected Cost without ADCIRC (in millions) | 21.0 |
| EVSI (in millions) | 4.5 |



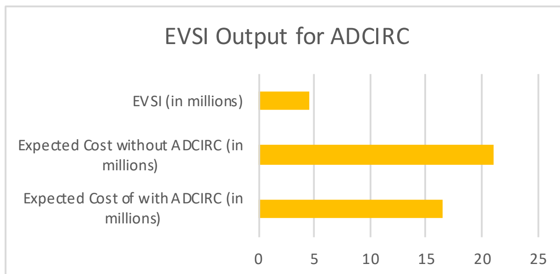




*Figure A3.2. User Interface with Inputs and Outputs of the VOI Model*