

**Risk-Based Allocation of Resources to Counter-Terrorism**  
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**1. Overview**

This research will (a) develop one or more comprehensive methodologies for risk-based resource allocation among discrete counterterrorism measures; (b) perform feasibility testing of these methods through application using actual data on threat assessments and proposed threat reduction measures; (c) identify methods and approaches particularly suitable to situations where data and estimates are limited and ambiguous; (d) perform feasibility testing of these methods through application to the problem of allocating state grants; (e) summarize and evaluate the conceptual and practical soundness of alternative risk-based resource allocation strategies, including comparing the methods developed to allocations developed by other methods and approaches.

**2. Research Accomplishments**

There is widespread recognition that there is a need to development sophisticated and effective analytic approaches for risk-based allocation of resources to counterterrorism. Implementing these methods requires credible and accurate quantitative assessments of the threats, vulnerability, and consequences of terror attacks, as well as valid assessments of how countermeasures will impact the nature and degree of threat, vulnerability, and consequences. There are three topics associated with this project.

Topic 1: Robust Portfolio Methods for Resource Allocation

Experience suggests that efforts to implement these models will often encounter difficulties in obtaining credible inputs. Several difficulties are particularly salient:

- Quantitative threat assessments expressed as the probability of an attack can be difficult to obtain, although it may be easier to express judgments of relative threat or to rank order threats.
- Vulnerability assessments of potential targets require expert analyses that can be both expensive and time consuming, particularly when the list of potential targets is long. Resource allocation may have to depend on vulnerability assessments that are incomplete, out of date, or both.
- Consequence assessments ought to include both direct consequences (fatalities, injuries, damage to property) as well as indirect economic consequences of an attack. While researchers at CREATE and elsewhere have made significant progress in the economic modeling of indirect consequences, it is not uncommon for different estimates to diverge, in some cases across a fairly wide range.

Decision analysis models can become difficult to use or interpret when model parameters are vague and incomplete. I have developed an approach to identify robust solutions that perform well across a range of plausible parameter values. A traditional way to do this is through sensitivity analysis. A more powerful

"This research was supported by the United States Department of Homeland Security through the Center for Risk and Economic Analysis of Terrorism Events (CREATE) under grant number 2007-ST-061-000001. 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."

and compelling alternative is to extend a method called Robust Portfolio Modeling (RPM), previously applied to multi-criteria projects under certainty, to the area of risk-based resource allocation. This is a computationally intensive approach that relies on a dynamic programming algorithm for computing all non-dominated portfolios of counterterrorism measures, subject to incomplete information about risks and risk management plans (e.g., ordinal threat assessments and/or range-based rather than point estimates other parameters). During the past year, a basic algorithm for RPM in infrastructure protection has been developed and tested for a portfolio of approximately 30 sites. Further testing and validate of this algorithm in the domain of Internet Information Technology Infrastructure security and disaster recovery planning, using disguised real world data from Strata Decision Technology, a software application developer based in the Midwest, has been initiated; and work has begun on a prototype for a working software tool that implements the algorithm and promotes its ease of use. Finally, the framework has been further adapted to the problem of selection of critical infrastructure sectors for vulnerability analysis, and, collaborating with Henry Willis of RAND Corp. and CREATE, a case study was carried out for California's Office of Homeland Security. The results appear promising.

This project is complementary to and provides methodological guidance to applied resource allocation and risk management efforts at CREATE, including potential applied analyses in support of DHS or state/local agencies.

#### Topic 2: Why use Optimization Methods for Resource Allocation Decision Making?

A number of investigators have proposed using risk-based resource allocation methods that rely on various ad-hoc rules of thumb or heuristic methods to assess risk and prioritize counter-terror measures. This work evaluates the value-added from using optimization methods compared to these less formal approaches, with a particular focus on identifying situations where optimization will be of greatest use. The objective of this work is to provide practical guidance on when to use formal mathematical optimization versus when rules of thumb are likely to suffice. A secondary objective is to provide a tutorial on optimization methods for an audience for whom these techniques might not be familiar. The work has been focused on reanalyzing available data from other projects. An initial source is a RAND technical report on reducing terror risk at shopping centers. To date, I have formulated and solved a non-linear optimization model for this problem that improves on the rule of thumb solution proposed by RAND.

### **3. Applied Relevance**

The entire focus of this stream of work is to develop methods and insights about how to apply rigorous analytical techniques in real-world settings where problems of missing or incomplete information are the rule rather than the exception. The applied work with California OHS has demonstrated that the methods are both relevant and feasible for application.

### **4. Collaborative Projects**

As noted above, the participation of California OHS has been critical to moving this project forward. Our original work assisting OHS with their BZPP allocations in 2006 helped to identify the issues associated with limited information quality and missing information. Their participation in the summer 2008 case study promises to be the first real-world implementation of the robust portfolio optimization approach for risk management.

The robust optimization approach builds on theoretical and computational developments by a team supervised by Professor Ahti Salo, at the Systems Analysis Laboratory of the Helsinki University of

Technology. Salo and members of his team have heard several presentations on my work, most recently at the International Federation of Operations Research Societies Triennial Conference in South Africa. As a result, we have initiated a collaboration to further develop and extend these methods to a broader range of risk management settings, and to allow for certain types of nonlinearity, including risk aversion.

## 5. Research Products

Research Products (Please detail below)		#
5a	# of peer-reviewed journal reports published	
5a	# of peer-reviewed journal reports accepted for publication	
5a	# of non-peer reviewed publications and reports	2
5a	# of scholarly journal citations of published reports	
5b	# of scholarly presentations (conferences, workshops, seminars)	7
5b	# of outreach presentations (non-technical groups, general public)	3
5c	# of products delivered to DHS, other Federal agencies, or State/Local	
5c	# of patents filed	
5c	# of patents issued	
5c	# of products in commercialization pipeline (products not yet to market)	
5c	# of products introduced to market	

### 5.1. Publications and Reports

Kleinmuntz, Don - University of Southern California	Ref	Not Ref
1. Kleinmuntz, D., "Risk-Based Robust Portfolio Methods for Counter-Terrorism Risk Management," in preparation		x
2. Kleinmuntz, D., "Prioritizing Terrorism Vulnerability Analyses Across Critical Infrastructure Sectors Using Robust Portfolio Allocation," in preparation		x

### 5.2. Presentations

#### Conferences

- Kleinmuntz, D., "Robust Portfolio Methods for Risk-Based Counterterrorism Resource Allocation," *International Federation of Operational Research Societies Conference*, Sandton, South Africa, July 14, 2008
- Kleinmuntz, D., "Resource Allocation Models for Terrorism," *Risk Management. Decision Analysis Affinity Group Conference*, Baltimore, MD, April 16, 2008
- Kleinmuntz, D., "Resource Allocation Models for Terrorism Risk Management," *INFORMS*, Baltimore, MD, April 14, 2008
- Kleinmuntz, D., "Robust Portfolio Methods for Risk-Based Counterterrorism Resource Allocation," *Los Alamos National Laboratory Risk Symposium*, Santa Fe, NM, March 12, 2008
- Kleinmuntz, D., "Risk-based Multi-objective Resource Allocation for Infrastructure Protection," Department of Industrial and Enterprise Systems Engineering, University of Illinois at Urbana-Champaign, February 21, 2008
- Kleinmuntz, D., "Risk-based Multi-objective Resource Allocation for Infrastructure Protection," Department of Industrial Engineering and Management Science, Northwestern University, January 15, 2008
- Kleinmuntz, D., "Robust Risk-Based Resource Allocation for Counter Terrorism," *INFORMS Annual Conference*, Seattle, November 5, 2007

Outreach

- Kleinmuntz, D., “Critical Infrastructure Site Prioritization and Resource Allocation,” USC-CREATE International Homeland Security Executive Education program, August 14, 2008
- Kleinmuntz, D., “Critical Infrastructure and Key Resources: Site Prioritization and Resource Allocation,” briefing for Security Analysts, Port of Los Angeles/Port of Long Beach, Los Angeles, CA, August 13, 2008
- Kleinmuntz, D., “Robust Portfolio Management for Risk-Based Counterterrorism Resource Allocation,” briefing for Critical Infrastructure Division, California Governor’s Office of Homeland Security, Los Angeles, CA, July 30, 2008

**5.3. Models, Databases, and Software Tools and Products**

Work has focused on developing a Risk-Based Robust Portfolio Modeling algorithm that is capable of being applied to data extracted from risk assessments databases, and that uses commercially available optimization tools to implement the algorithm. The current prototype program, written using the LINGO version 10.0 optimization software, is designed to extract data from a Microsoft Excel spreadsheet, apply the Robust Portfolio methodology, and to write results back to the spreadsheet for further analysis.