

**Optimal Allocation of Resources to Counter Terrorism**  
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## 1. Overview

There is widespread recognition of the need for effective analytic approaches for risk-based allocation of resources to counterterrorism. The overarching goal is to provide rigorous and defensible analyses and recommendations regarding the best use of limited funds for counterterrorism measures intended to deter attackers, defend potential targets, or mitigate the consequences of a successful attack. 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. This research resulted in:

- Development of an overall modeling framework for optimal resource allocation to counterterrorism risk management based on risk analysis of individual sites or threats
- Development of new methods for robust optimal allocation of resources when assessments of threats, vulnerability, consequences, or the impact of countermeasures on the same are incomplete or ambiguous

The results of this research have been documented in five published journal articles and reports.

## 2. Research Accomplishments

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

- Decision and risk analysis models require quantitative threat assessments that are expressed as the probability of an attack. These can be difficult to obtain, although it may be easier to express judgments of relative threat or to rank order threats.
- Accurate assessments of the vulnerability of potential target sites require expert analyses that can be both expensive and time consuming, particularly when the list of potential targets is long. As a result, resource allocation may have to depend on vulnerability assessments that are incomplete, out of date, or both.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.
- A case study that was a pilot demonstration of an analytic process and set of tools that could be used by the State of California, Office of Homeland Security to support future grant allocation decisions.

Optimal resource allocation for counterterrorism is an inherently integrative activity. The primary focus is risk management, but it critically depends upon both risk and economic assessment, since these are critical inputs for the risk management models. This project's basic research component involves

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extending recent developments in robust optimization techniques into decision and risk analysis modeling contexts. The model development effort involves formulating and testing different computational approaches. The main focus of our case study is infrastructure protection—perhaps the most obvious but far from the only candidate for application of these methods.

This research resulted in two principle research accomplishments. First, conventional methods of optimal resource allocation have been adapted to fit homeland security resource allocation. This process involved defining the parameters of costs and effectiveness, identifying the relationships to other types of risk and consequence analysis, and identifying available data to implement the model. As discussed below in Section 3 (Applied Relevance), this research constituted an advance in the decision support tools used by the State of California to allocate DHS grant funding.

The second research result involved extending resource allocation models to more appropriately account for the ambiguities surrounding assessment of terrorist threat, target vulnerabilities, and countermeasure effectiveness. Decision analysis models can become difficult to use or interpret when model parameters are incomplete. Thus, this research developed an approach capable of identifying robust solutions that perform well across a range of plausible parameter values. A traditional way to do this is through sensitivity analysis. However, this research has taken advantage of a more powerful and compelling alternative, a new method called Robust Portfolio Modeling (RPM), previously applied to multi-criteria projects under certainty, by applying it to the area of risk-based resource allocation.

RPM 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). The results from this algorithm include a project-level index that indicates which risk management projects or countermeasures are robust funding candidates, in the sense that they would either always or never be recommended for funding even if more complete information were to be obtained. On the other hand, projects that are not robust are those that would benefit from further refinement of parameter estimates.

As part of the resource allocation project for Year 3, a basic algorithm for RPM in infrastructure protection has been developed and tested for a portfolio of approximately 30 sites. The Year 4 goals for this project will be (a) to test and validate this algorithm, particularly to determine how well it scales up to very large problems with hundreds rather than dozens of sites; (b) develop a working software tool that implements the algorithm and promotes its ease of use; (c) evaluate the algorithm in one or more case studies, whether in infrastructure protection or some other DHS application area, as opportunities permit. Subsequent years will focus on additional extensions and modifications of the approach, and comparative evaluations of RPM and alternative methods for resource allocation analysis. This project is complementary to and provides methodological guidance to applied resource allocation and risk management efforts at CREATE, including applied analyses in support of DHS or state/local agencies.

### **3. Applied Relevance**

The State of California is responsible for allocating grant funding provided by the U.S. Department of Homeland Security. This project focused on the decisions required as part of the Buffer Zone Protection Program. This grant program is intended to provide additional preparedness resources to local jurisdictions within which sit high risk critical infrastructure assets. In fiscal year 2006, the State of California had to select among approximately 90 eligible sites, but only had funding to support projects in approximately 10-20 of them.

This research has resulted in the development of a demonstration Robust Portfolio Allocation tool. Initial development of the Robust Portfolio Modeling approach and algorithms has been accomplished using LINGO version 10, a commercial optimization package that includes both linear and nonlinear optimization capabilities.

This application constituted a collaboration between CREATE and the California Office of Homeland Security. The interaction with the State of California was requested by Matt Bettenhausen, Director of the California Governor's Office of Homeland Security. The collaboration involved CREATE participation in several meetings to discuss the State of California's BZPP grant program, decision strategy, and ultimate decisions.

At each meeting, CREATE was asked to provide comment on specific decisions to be made and shared findings based on application of risk assessment and the optimal resource allocation frameworks. This analysis incorporated data obtained from CREATE analysis as well as that obtained from insurance industry risk models (RMS and AIR), site specific analyses performed by consultants to the state (SRA), and vulnerability analyses conducted by other research organizations (FSIVA and HOPS).

The CREATE analysis suggested that the State of California depart from its previous practice of distributing grant funding equally across eligible jurisdictions and instead concentrate grant funding across those sectors that analysis showed to be at greatest risk from terrorism. As a result, the State decided to allocate resources primarily to jurisdictions associated with chemical facilities and large dams. The work by CREATE was cited as the basis for the FY06 grant allocation decisions and subsequently used as the framework for making decisions in FY07.