

**ACRP 02-78**  
**Climate Resilience and Benefit Cost Analysis –**  
**A Handbook for Airports**

**Final Report Summary**

Prepared for:

ACRP  
Transportation Research Board  
of  
The National Academies

TRANSPORTATION RESEARCH BOARD  
OF THE NATIONAL ACADEMIES  
PRIVILEGED DOCUMENT

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**GRA, Inc.**  
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## **Acknowledgements**

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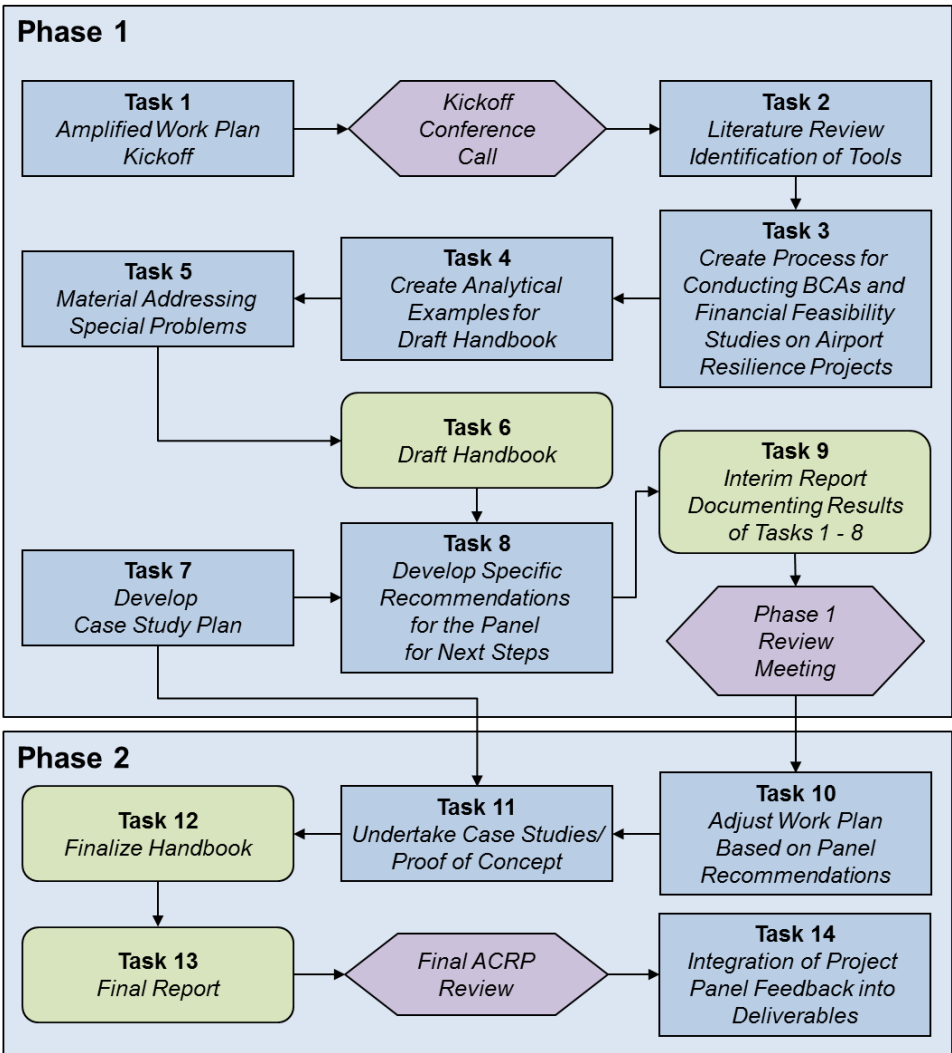
Frank Berardino of GRA, Inc. was the Project Manager. Dr. William H. Spitz, Ph.D., of GRA, Inc. was the Principal Investigator.

# 1. Project Scope and Work Plan

The purpose of this project is to develop a Handbook is to help airport practitioners assess the benefits, costs and financial feasibility of infrastructure projects that are designed to improve resilience to the impacts of climate change and extreme weather events. The Handbook presents up-to-date methods for conducting both benefit-cost and financial feasibility analyses that explicitly recognize risks and uncertainties that are inherent in long-term climate projections and their potential effects on long-lived airport infrastructure.

A Work Plan for this project was developed as part of the initial proposal. Based on responses from the project panel, this was superseded by an Amplified Work Plan (AWP) that was submitted in May 2017. The tasks to be undertaken, as detailed in the AWP, are shown below in Exhibit 1.

**Exhibit 1: Task Schematic**



While the AWP is a standalone document that will not be reprinted here, it was specifically designed to address the primary objectives and associated requirements laid out in the initial RFP for this project. Exhibit 2 below shows the linkages between each Task in the work plan with these objectives and requirements.

**Exhibit 2: Task Linkages to Project Requirements**

<b>RFP Objectives and Requirements</b>	<b>Work Plan Project Tasks</b>
Identify types of projects and applications that lend themselves to BCA	Task 2 Literature Review (FAA and OMB BCA Guidance; ACRP Guidance, Publications and Tools; Other Modes and Venues Guidance) Task 5 Special Problems (When to Conduct a BCA and Appropriate Level of Effort; Identifying Vulnerable and Critical Infrastructure)
Delineate components of BCA that need to be taken into account, including guidelines on incorporating both market and non-market valuation strategies, and qualitative/quantitative data and methods	Task 2 Literature Review (State-of-the-Art Quantification of Climate Risks and Airport Infrastructure) Task 3 Create Process for Conducting BCAs Task 5 Special Problems (all sub-tasks)
Identify and explain role of key data and assumptions in the climate-risk enhanced BCA process	Task 2 Literature Review (Risk Management Tools and Literature) Task 4 Create Analytical Examples for Draft Handbook
Identify environmental and social costs and benefits as input to the analytical process	Task 5 Special Problems (Quantifiable vs. Hard-to-Quantify Impacts; Social Benefits and Costs in BCA's)
Describe how components of climate risk and uncertainty can be incorporated into BCA	Task 4 Create Analytical Examples for Draft Handbook Task 5 Special Problems (Accounting for Risk and Uncertainty; Discounting)
Describe how current project funding options and constraints affect applicable BCA; identify cost-effective risk management methodologies within the BCA process to facilitate decision-making	Task 3 Create Process for Conducting BCAs Task 5 Special Problems (When to Conduct a BCA and Appropriate Level of Effort; Description of the Project; Information Needed by Decision Makers)

Identify potential tools and techniques useful to analysts as well as decision-makers	Task 2 Literature Review Task 5 Special Problems (Evaluating Alternative Resilience Approaches)
Prepare user-friendly handbook to facilitate analytical process and decision-maker responsibilities, accounting for scalability and implementability	Tasks 6-14 (Draft Handbook, Case Study Plans, Interim Report, Panel Recommendations, Case Studies / Proof-of-Concept, Finalize Handbook, Final Report) Excel/PowerPoint files (latter submitted with AWP)

With this background, the project team developed a Handbook that was:

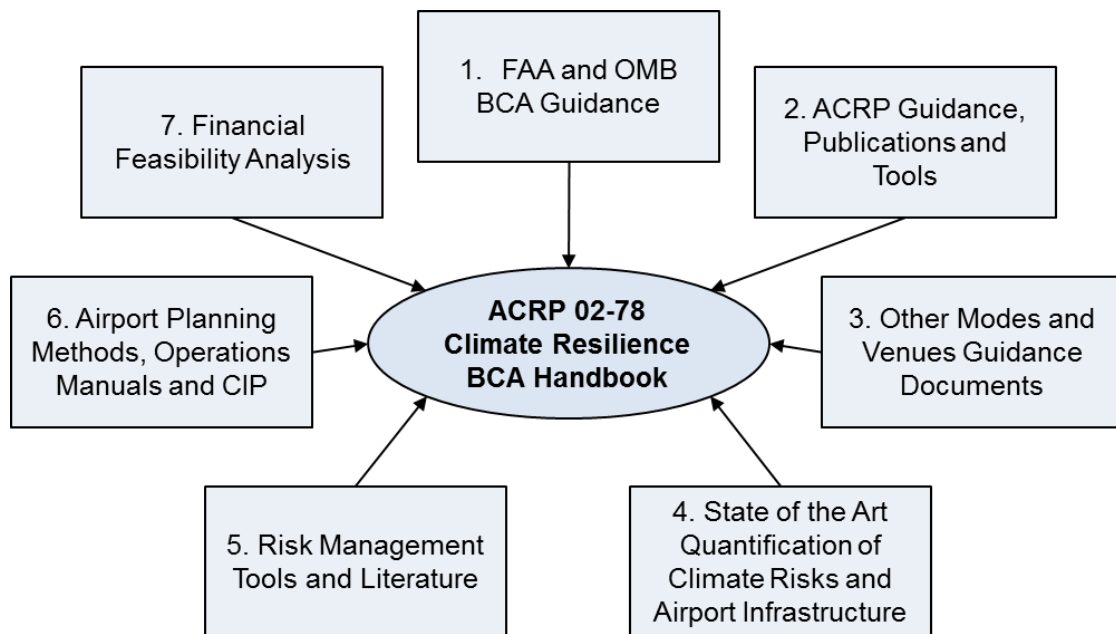
1. **Based on Climate Analysis Precedents:** The handbook takes advantage of existing guidance on dealing with the risks and uncertainties pertaining to the impacts of climate change on infrastructure resilience, and benefit-cost analysis. Wherever possible, the Handbook relies on and cites prior ACRP, FAA and other resources that provide guidance on these topics and their relevance for US airports.
2. **Accessible to Airport Practitioners:** The handbook is designed to be accessible to a wide audience, with more technical placed in Appendices to provide greater detail. The following steps were taken to ensure accessibility:
  - ➔ Integrating past ACRP reports and guidebooks with FAA Airport BCA Guidance as part of a step by step process to create BCA's and associated financial analysis that assist decision-makers.
  - ➔ Development of a consistent set of examples to illustrate the main features of a BCA that account for climate change exposure, with sourced references to the latest literature.
  - ➔ Including consideration of cases where the decision to move forward may depend on use agreements, revenue and financial sources, and other factors not necessarily incorporated in a BCA.
3. **Based on the Latest Current Technical Information:** The handbook references the latest knowledge on the effects of climate change, the economics and financial literature on decision-making with uncertainty, including accounting for the different decision criteria used in BCA's and airport financial analysis.
4. **Developed for Implementation:** The handbook provides answers that are useful to practitioners at both large and small airports.

## 2. Literature Review

The literature review in Task 2 was meant to capture the relevant documents, methodologies and other literature that could then be used subsequently to create a process for conducting benefit-cost studies and financial feasibility analyses for airport resilience projects.

The literature review was divided into seven components as illustrated in Exhibit 3 below. Each of these components contributed to the development of a practical Handbook.

**Exhibit 3: Literature Review and Identification of Tools**



The Literature Review is also a standalone document, and it was completed and submitted early on in the project cycle (June 2017). Not surprisingly, subsequent to its submission the project team has discovered and developed additional sources of material. To be clear, all inputs and sources relevant to the draft Final Handbook are recognized and cited in the Handbook document itself, even if they were not incorporated into the Literature Review.

## 3. Draft Handbook Development, Next Steps and Feedback

The primary output of this project is the Handbook itself. After completing developmental work in Tasks 3, 4 and 5, the project team prepared a draft Handbook (Task 6) and submitted it for panel review in late 2017. The draft contains all of the material promised in the Amplified Work Plan, including the following primary components and topics:

- ➔ Quick Start Guide (recast as Executive Summary)

- Incorporating climate change decision-making into existing airport organizations
- Evaluation methods under risk and uncertainty
  - Assessing climate risk with limited resources
  - Assessing climate risk using Monte Carlo and value-at-risk methodologies – *these are the key methodological outputs from the study*
- Accessing state-of-the-art climate measures
- Identifying potential airport impacts
- Identifying potential airport responses and adaptations, including financial constraints
- Discussion of various content topics including FAA guidance on benefit-cost analysis, handling hard-to-quantify impacts, financial feasibility analysis, options to delay investments, etc.
- Numerical examples showing how the proposed methodologies can be implemented

After submission, the project panel provided very valuable feedback on various aspects (including both content and layout) of the draft Handbook document. During this time, the project team also undertook Tasks 7, 8 and 9, which included the development of a case study plan, specific recommendations for next steps, and an interim report documenting Phase 1 Tasks 1-8.

An in-person meeting involving the entire project team and the project panel was held in Washington DC in January 2018 to review and address all relevant aspects of the project. Agreement was reached to incorporate significant comments, recommendations and feedback from the panel into the Handbook; in addition, the Phase 2 case study plan to test out the Handbook with a small number of different-sized airports was reviewed.

#### **4. Adjusted Work Plan and Handbook Changes**

Based on the meeting discussions, agreement was reached to make significant changes to the Handbook, including:

- Creation of a short high-level executive summary
- Movement of most technical and background material to Appendices
- Elimination of methodology distinctions directed specifically at small or large airports

In addition, it was agreed that resources should be utilized to further develop two Microsoft Excel files; these files would serve as templates to allow airport analysts (or their consultants)

to undertake analyses using the suggested numerical methodologies described in the Handbook.

Agreement was also reached on changes to the remainder of the work plan involving the Phase 2 case studies; this is discussed further below.

## **5. Phase 2 Case Studies**

The primary purpose of the case studies was to introduce the concepts and methods in the Handbook to relevant personnel at selected airports, and to use the feedback to further improve the Handbook. Four such case studies were undertaken:

- ➔ New Orleans International Airport (MSY) – study of the effects of future sea level rise on airport infrastructure
- ➔ Phoenix Sky Harbor International Airport (PHX) – study of the effects of increased incidence of high temperatures on potential flight cancellations
- ➔ Boston Logan International Airport (BOS) – study of the effects of future sea level rise on airport infrastructure
- ➔ Little Rock National Airport (LIT) – study of the effects of increased incidence of high temperatures on aircraft takeoff weight restrictions for potential new long-haul destinations

Overall, all airport participants appeared to be generally familiar with the potential threats from climate change. In addition, they had no problem following the methodologies for conducting the Monte Carlo and value-at-risk examples that were presented for their airports. Specific insights and comments from each were useful in revising some of the language and explanatory information included in the Handbook.

Participants were also introduced to the two-step process described in the Handbook for assessing climate risk. The first step involves screening for problems (using tools like ACROS and VAST); where the screening turns up significant potential exposure, the analyst would proceed to Step 2 featuring a risk-adjusted evaluation featuring Monte Carlo techniques that are a main feature of the Handbook. All of the participants were receptive to the process, and had no problem following it.

## **6. Microsoft Excel Template Files**

Significant resources were expended to develop two Excel files, each focusing on a specific area of climate change likely to affect airports: 1) the potential for extreme flooding events due to storm surge and sea level rise near coastal airports; and 2) the potential for rising temperatures to require weight restrictions on aircraft takeoffs at airports in warmer climates. These specific forms of climate change are also the primary focus of discussion in the



draft Final Handbook as well. While other types of climate change may also impact airports (for example, increasing likelihood of localized thunderstorms or air turbulence affecting takeoffs and landings), the methodologies presented in the Handbook and the Excel files focus on these two specific areas because specific quantifiable projections are currently available for these climate measures. In the future, as more quantifiable projections are produced, the general format developed in the spreadsheets should be broadly applicable.

A very important feature of the spreadsheet models is that they are designed to allow an airport to evaluate their own climate risks. The extreme flooding spreadsheet incorporates forecasts for water rise for 153 airports. The high temperature spreadsheet features a format for capturing the voluminous data required to evaluate impacts on future operations.

Descriptions of the use of these templates (including numerical examples) have been incorporated directly into the draft Final Handbook.

## **7. Final Panel Review**

The panel reviewed all of the above-mentioned deliverables and suggested some minor changes and updates, which have been incorporated into the final version of the Final Handbook.

## **8. Final Handbook and Other Deliverables**

The Final Handbook incorporates many significant changes, updates and revisions suggested by both the project panel and the case study airports, including substantial re-working of both content and layout. In addition, it includes descriptions of the airport case studies and the Excel template files, as well as a discussion of study limitations and recommendations for future research.

The Handbook is designed to guide an analyst through a practical two-step evaluation process described earlier, featuring the application of modern risk analysis tools to potential exposures of airport infrastructure to climate change stressors. The Excel spreadsheets that accompany the Handbook can be used to evaluate real world airport climate exposures. The Handbook also makes a major effort to describe how climate risk analysis fits into existing airport organizations and activities.

A standalone Executive Briefing document and a technical memorandum titled "Implementation of Research Findings and Products" have also been submitted. Finally, at the request of the panel, a video tutorial to accompany the extreme water events Excel template was also developed and delivered.