Applications of a Prioritization Methodology for Complex Operational Problems and Solutions

Zheng Tao
The MITRE Corporation

ABSTRACT

Federal Aviation Administration (FAA) decision makers are faced with a wide variety of problems and solutions that must be prioritized. They often have to factor in multiple objectives and stakeholders when deciding which alternatives (a problem or solution) are worth allocating resources. This is typically achieved in a manner where Subject Matter Experts and Managers with differing perspectives and stakeholders evaluate competing alternatives through a series of subjective debates that often involve inconsistencies and groupthink. Results are rarely repeatable and lack an agreed-to set of decision criteria.

MITRE's Center for Advanced Aviation System Development (CAASD) recently assisted the FAA's Air Traffic Organization in defining and applying a methodology for prioritizing operational problems and solutions for the Terminal air traffic management domain. This paper details the methodology and the FAA's application of it to select prioritizations.

KEYWORDS

Decision making; Transportation; Prioritization methodology; Aviation; Practical application

INTRODUCTION

Today's decision makers are faced with a wide variety of problems and an even wider variety of potential solutions. The problems and solutions are often complex and decision makers have to factor in multiple objectives and stakeholders when deciding which investments (problems or solutions) require additional resources for research or development. Decision makers have to determine the most pressing problems that require further analysis and study and investments in solutions within their current budget. Given today's challenging budgetary environment, it becomes even more vital to ensure that the right investments are made to successfully achieve the goals of an organization or project.

The FAA is responsible for evaluating and prioritizing the operational problems and solutions across the National Airspace System (NAS). The FAA needs a repeatable methodology for prioritizing operational problems and solutions throughout the various Air Traffic Management (ATM) domains and across the enterprise within their purview. MITRE CAASD assisted the FAA in developing a methodology based on Multiple Objective Decision Analysis, which is commonly used in both private industry and government including the Internal Revenue Service (IRS), Department of Defense (DoD), and U.S. Census Bureau (Makleff, Gruia, Gudka, 2003; DoD, 2005; Keller, Simon, Wang, 2009; Pinto, 2010). This methodology can be used for prioritizations that have a narrow or broad focus. This document describes this prioritization methodology, case studies of its use by the FAA for select prioritizations, how it could be adapted for use by FAA field facility managers, and draws conclusions about the use of the methodology. In this paper an alternative refers to any single problem or solution.

CHALLENGES WITH TRADITIONAL PRIORITIZATION PROCESSES

Determining complex investment priorities is traditionally done differently for each project or organization. Sometimes the prioritization is made by one person, but typically a room of experts, and management evaluate competing alternatives together for several hours without a structured approach or guiding values. These group discussions are emotionally charged and lack objectivity. The prioritization process is not standardized and usually involves lots of white boarding. There are several problems with the traditional approach:

- Prioritizing the issue by yourself introduces "single voice" bias
- The loudest voices are often the most influential
- Decisions become more emotional and egos can take over
- Non-transparent agendas/goals influence individual positions
- Incomplete criteria are used with lack of clear rationale
- Inconsistent evaluations of alternatives are performed

This often results is an illogical, contentious, or dysfunctional prioritization that can lead to the wrong work being done at the wrong time. A systematic approach to prioritization is needed to improve the process.

PROPOSED METHODOLOGY

As input to the methodology, MITRE CAASD adapted portfolio management techniques and processes applied at The MITRE Corporation's Center for Connected Government (MITRE CCG) to ensure that the FAA's prioritization method would be transparent, fair, and repeatable for making prioritization decisions. The methodology includes the processes for defining problems/solutions, defining the criteria and weights, evaluating the range of problems/solutions, governance guidelines, and interpreting results. The methodology uses a values based approach that has been widely used in public and private industry to develop a set of criteria, which could be weighted using pairwise comparisons or other methods (DoD, 2005; Keller et al, 2009; Pinto, 2010).

Defining Values and Criteria

The methodology starts with decision maker(s) defining values that represent aspects of a decision that they care about for a particular prioritization. Notice that it does not start with identifying alternatives. Problems and solutions should be prioritized in separate exercises with their own values and criteria since they represent different phases of an investment decision. Next, a defined set of criteria are identified from those values by the decision maker(s), which provide traceability and rationale for why the criteria were chosen. A scale is defined for measuring each criterion. Each alternative is then evaluated against the set of criteria using the defined scales. It is important that the alternatives are described at a sufficient and consistent level of detail for participants to score against. Figure 1 shows a notional example of potential values (Service Impact, Urgency, Engineering Difficulty, and Enterprise Alignment) and criteria (Flight Efficiency, Solution Readiness, Enabler, etc.) relevant to the FAA when prioritizing operational problems.

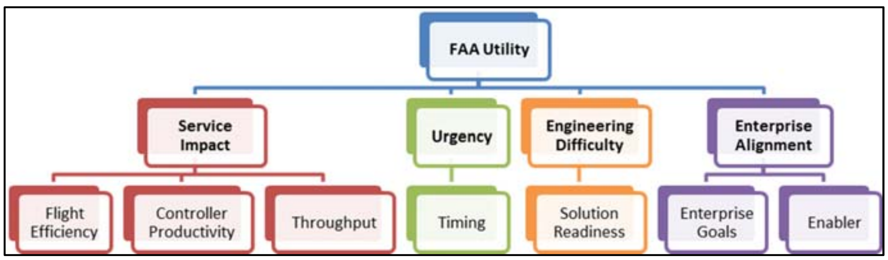


Figure 1. Notional Values (Service Impact, Urgency, Engineering Difficulty, and Enterprise Alignment) and Criteria (Flight Efficiency, Solution Readiness, Enabler, etc.) for Evaluating Operational Problems

Service Impact is intended to capture, on a high level, the impact on daily/routine ATM operations that a problem has. Urgency reflects how soon a problem should be addressed. Engineering Difficulty represents how technically challenging it would be to create a workable solution for the problem. Enterprise Alignment expresses the problem's impact on achieving the goals of the agency and enabling other projects. Examples of other values that could be used depending on the specific prioritization include Security, Cost Efficiency (e.g., savings potential, maintenance costs, and productivity), and Environmental Impact (e.g., knowing that any procedural change will need to consider environmental and noise considerations prior to implementation).

Criteria are posed as questions with a scale that attempts to get the people who will be evaluating the alternatives (participants) thinking about impact in an objective way, such as what is shown in Table 1. Decision makers could also be participants depending on the scope, resources available, and objectives of the prioritization.

Table 1. Example Definitions of Criteria and Scales

Values	Criteria	Description	Scale
Service Impact	Flight Efficiency	To what extent will this alternative increase flight efficiency?	**4:** Significant increase in flight efficiency for an aircraft **3:** Moderate increase in flight efficiency for an aircraft **2:** Minor increase in flight efficiency for an aircraft **1:** No or negligible increase in flight efficiency. No reduction in delay
Engineering Difficulty	Solution Readiness	Are there solutions available or does addressing this require research?	**5:** Likely solutions are mature and readily deployable. **4:** Likely solutions can be modified from other deployed solutions. **3:** Likely solutions are under development. **2:** Likely solutions are only concepts. **1:** No potential solutions have been identified.

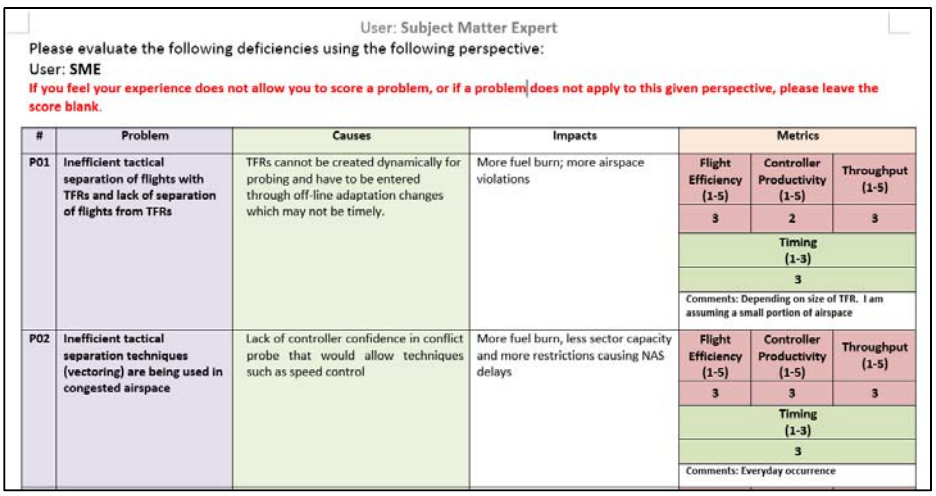
The number of bins required in the scale should reflect the amount of precision required to adequately evaluate each criterion. A scale of 1-3 (low, medium, and high) is typically sufficient, but sometimes participants like to be more granular in their responses. Having different number bins for one or more criterion is mathematically acceptable because the scores are normalized to a scale from 0-1. A scale from 1-3, the scores would be converted to 0, 0.5, and 1.

Participant Makeup

Participants should have a broad vision and deep understanding of the issues and goals at hand. They should have relevant expertise at least at the journeyman level to evaluate the alternatives against the criteria. Having less experience does not allow for an adequate evaluation, and people with much more experience may not be as readily available. Some prioritization applications may benefit from having more diverse age groups or professional backgrounds represented. Thus, knowing the workforce and selecting participants based on expertise and experience is important. The recommended minimum number of participants varies depending on the organization and impact of the prioritization. For small organizations with a narrow focus and impact, 3-5 participants may be sufficient. Applications that have a wider impact may require 5-10. In general, the number of participants should be large enough to include relevant stakeholders, but not be unmanageable or impossible to coordinate availability.

Scoring Questionnaire

Participants provide their input using scoring questionnaires that describe the alternatives. An example of a scoring questionnaire used for evaluating operational problems is shown in Figure 2. The questionnaire describes the operational problems being evaluated, their causes, and impacts. In this particular example, former Air Traffic Controllers (ATC), also known as Subject Matter Experts (SME), were asked to evaluate the problems on the values of Service Impact and Urgency. Engineering experts had a similar questionnaire, but were asked to evaluate the values of Engineering Difficulty and Enterprise Alignment. Participants were asked to leave fields blank if they did not have the confidence or experience to evaluate them.



User: Subject Matter Expert

Please evaluate the following deficiencies using the following perspective:

User: **SME**

If you feel your experience does not allow you to score a problem, or if a problem does not apply to this given perspective, please leave the score blank.

#	Problem	Causes	Impacts	Metrics		
P01	**Inefficient tactical separation of flights with TFRs and lack of separation of flights from TFRs**	TFRs cannot be created dynamically for probing and have to be entered through off-line adaptation changes which may not be timely.	More fuel burn; more airspace violations	**Flight Efficiency (1-5)**	**Controller Productivity (1-5)**	**Throughput (1-5)**
				3	2	3
				Timing (1-3)		
				3		
				Comments: Depending on size of TFR. I am assuming a small portion of airspace		
P02	**Inefficient tactical separation techniques (vectoring) are being used in congested airspace**	Lack of controller confidence in conflict probe that would allow techniques such as speed control	More fuel burn, less sector capacity and more restrictions causing NAS delays	**Flight Efficiency (1-5)**	**Controller Productivity (1-5)**	**Throughput (1-5)**
				3	3	3
				Timing (1-3)		
				3		
				Comments: Everyday occurrence		

Figure 2. Example Scoring Questionnaire for SMEs to Evaluate Operational Problems

Evaluation of Alternatives

An average score is calculated using the participants' scores for each criterion of an alternative. Weighting can be incorporated if not all criteria are equally considered. The weighting for each criteria can be asserted by the decision maker, or calculated using inputs from the scorers. For example, scorers could be asked to rank order, or weight the criteria. The scorers' inputs would then be used to calculate a "consensus" weight for each criterion by using the rank sum formula. The weights and average criterion scores are used to calculate a final utility score for that alternative.

Utility Score for each alternative = $\sum_{i=1}^{number\ of\ criteria}(\text{Criteria's Average Score}_i\ *\ \text{Criteria's Weight}_i)$

Determining Priorities

The utility scores for each alternative are plotted and visualized in a chart such as the one in Figure 3, which shows an example distribution of scores and the identification of breakpoints. Breakpoints can be where alternative scores cluster around each other or where there is a clear break in the slope. This allows for quick identification of high and low priority alternatives, and of ones that require further investigation. It is not meant to compare closely scoring alternatives to determine which is better, but rather to focus follow-on analysis on the high priority alternatives. This assessment provides a threshold for which alternatives move on for more specific decision-making.

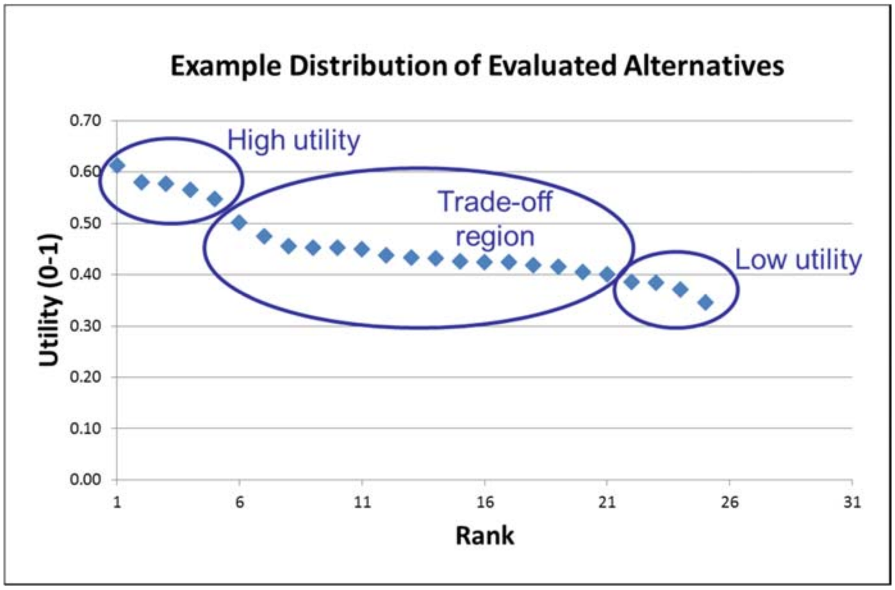


Figure 3. Example Distribution of Utility Scores for a Prioritization

Additional Considerations

Decisions should look over multiple years and have logical sequencing for addressing problems and dependencies. If there are dependencies between alternatives (e.g., an enabling alternative has to be implemented before a high priority one) then those alternatives could be grouped together when scoring, or the enabler automatically makes the cut if it is tied to a high priority alternative. This allows the cost of the enabler to be distributed among its associated alternatives, and increases the benefit of the enabler. External influence may also require some investments to be mandatory.

When applying the methodology, it is important to have a strong governance structure that ensures a consistent process and acceptance of results. The governance structure (a person or a panel) determines how consensus is achieved, who gets involved in the decisions and scoring, the thresholds for determine priorities, exemptions from the threshold, and acceptance of the criteria.

Methodology Conclusion

While the distribution in Figure 3 and the identification of priorities are useful, the more important aspect of this methodology is that it forces decision maker(s) and scorers to go through a structured process to define alternatives; determine values, criteria, and weighting; and consistently evaluate the alternatives. This method facilitates consideration of multiple perspectives, lessens the influence of individual agendas, normalizes the scoring to agency goals, and provides a systematic (repeatable) approach to prioritization. It results in priorities that are aligned with the decision maker(s) values and, by addressing these priorities, should have measurable results. The FAA has applied this method on two Terminal domain projects in order to determine operational priorities for automation enhancements.

FAA APPLICATIONS OF THE METHODOLOGY

Adaptations of the methodology have been used by the FAA to prioritize capabilities of a large acquisition program and a new program to update an existing automation system. In both instances, MITRE worked closely with the FAA to define values, criteria, weightings, and scales. Additionally, MITRE provided the FAA with scoring questionnaire templates and the prioritization tool used to calculate utility scores. The tool and templates allowed the FAA to generate their own scoring questionnaires, execute the evaluation with participants, and generate results by themselves.

Case Study 1: Rescoping a Large Acquisition Program

The FAA had been moving forward with a large acquisition program that would introduce a new system to automate manual ATC tasks as part of the Next Generation Air Transportation System (NextGen). After a while, the program's planned capabilities had outgrown the budget available to it during its investment analysis phase. The program needed to rescope its capabilities so that it could fit within budget. The FAA's role was to provide operational input to identify the highest priority capabilities for the rescoping. With MITRE's support, the FAA developed a set of values, criteria, scales, and weights to conduct the prioritization. The governance structure was provided by a FAA decision maker. A generalized description of the values and criteria are shown in Figure 4.

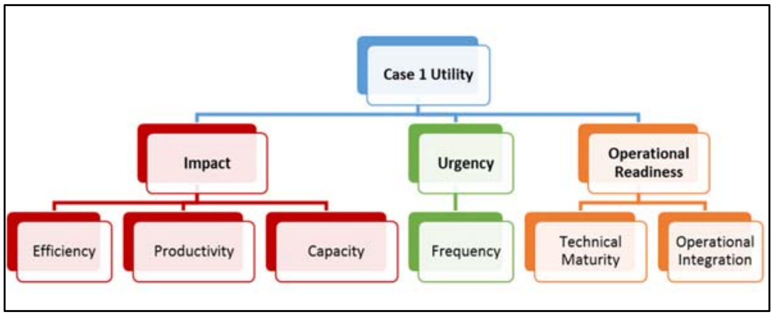


Figure 4. Values and Criteria for Case 1 (Rephrased)

Since the goal was to identify high priority capabilities that could fit within the budget, the values of Impact, Urgency, and Operational Readiness were chosen. These values mean that the FAA wanted to identify capabilities that had large positive impact on operations, were going to be regularly used by controllers, minimized additional research/development, and caused minimal disruption to current controller workflows (so as to be more acceptable by controllers).

The FAA then identified and convened the participants, defined the capabilities using the scoring questionnaires, and oversaw the evaluation. There were over 100 capabilities evaluated and, surprisingly, the participants were able to finish their evaluations within a few hours. The FAA captured the participants' inputs and calculated the utility scores using tools prided by MITRE CAASD. FAA then identified the highest priority capabilities, which heavily influenced the program's final list of capabilities for the investment. The methodology allowed the user community (controllers) to have a fair voice in the rescoping decision, which enabled the program to move forward while maintaining the highest priority capabilities.

Case Study 2

A new FAA program that is aimed at enhancing the software of an existing system was in early investment analysis and needed to determine which of its capabilities should move forward to the next phase. The FAA's role was to narrow down the list of capabilities (from about 50) to move forward. As in the earlier case, MITRE supported the FAA in developing a set of values, criteria, scales, and weights for the prioritization. A generalized description of the values and criteria for Case 2 is shown in Figure 5.

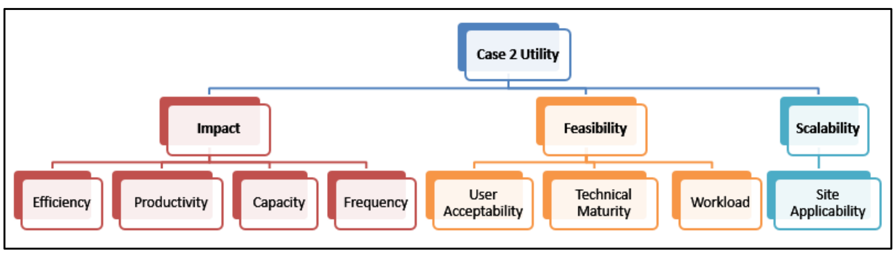


Figure 5. Values and Criteria for Case 2 (Rephrased)

For this case, the values of Impact, Feasibility, and Scalability were chosen. This meant that the FAA was interested in capabilities that had a large positive impact on operations, were going to be ready and acceptable within the timeframe, and were applicable to a wide variety of locations. The FAA identified relevant participants, created the scoring questionnaires, and oversaw the evaluation. The governance structure was provided by the FAA as well. The FAA also utilized MITRE provided tools to capture inputs and calculated utility scores to identify the top capabilities to move forward. The important point here is that the FAA was able to smoothly repeat the prioritization process within a span of a few weeks. The prioritization results served as a starting point for further refinement as the results were shared with other parts of the FAA.

Lessons Learned

When applying the methodology, a variety of lessons were gained. The process is most successful and useful when there is a need for a transparent, fair, and repeatable prioritization from senior management, which is not always the case. Getting buy-in from this level is crucial in obtaining participants and making the results meaningful and actionable. For the FAA case studies, their management wanted to have such a process.

Determining the appropriate values, criteria, and scales for each application is a key part of the process and provides decision makers with significant insight into the core issues involved in a prioritization. This process forces decision makers to reevaluate assumptions about what is important as a differentiator, and helps get them to the heart of what really matters to the organization and its mission.

It is helpful to have an initial session with the participants (scorers) to introduce the methodology and answer their questions. The session should walk through an example of assessing an alternative, and gain feedback on the alternative descriptions and criteria definitions. Participants appreciated this initial engagement, which made it easier to get their buy-in on the process. The descriptions of the alternatives should be kept at a consistent and normalized level. The alternative descriptions should have the proper context and contain enough detail to properly score against the criteria. A fair amount of time was spent in shoring up the alternative descriptions in the FAA use cases to be concise and provide enough detail to score in a reasonable amount of time.

In general, getting to the point in Figure 3 achieves about 70% of the prioritization. Determining enabling alternatives and dependencies should be done before the prioritization is finalized. Also, decision makers should be prepared for the possibility of having external influencers or higher ups wanting to add or replace an alternative.

Adapting the Methodology for Decisions by FAA Field Facility Managers

Managers at FAA field facilities would benefit greatly from the methodology as they typically encounter complex problems and proposed solutions. They may receive a request from FAA Headquarters to consider a particular procedural change available to them, their Service Area may request that they modify an aspect of their operation due to a regional issue, the operational personnel may suggest automation or procedural improvements, and their labor partner may have issues that need the manager's help to resolve. Each of the demands is important, but resources may be constrained – both people and budgets. The figure below shows an example of potential values and criteria that may be relevant to a FAA field facility manager in prioritizing these complex issues.

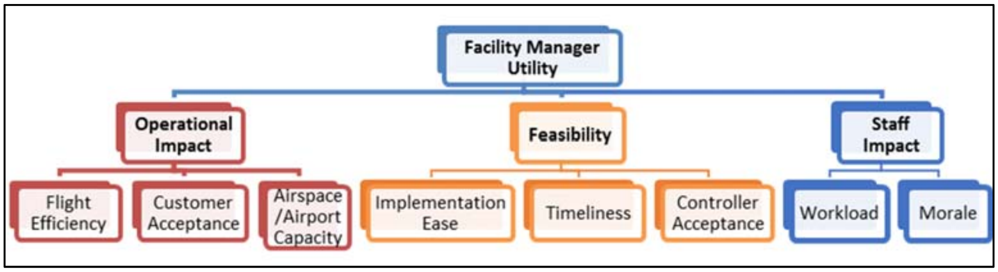


Figure 6. Example Values and Criteria for a FAA Field Facility Manager

The Operational Impact value and associated criteria are considerations that affect ATM services provided by a facility. The Feasibility value and associated criteria regard implementation concerns. The Staff Impact value and associated criteria are considerations that affect the controllers. Examples of other values that could be used include Security, Cost Efficiency (e.g., savings potential, maintenance costs, and productivity), and Environmental (e.g., knowing that any procedural change will need to consider environmental and noise considerations prior to implementation).

CONCLUSION

The methodology has addressed the need for a transparent, fair, and repeatable prioritization process that could be applied to various ATM domains. It is based on widely used Multiple Objective Decision Analysis, which has been applied at other government agencies and in private industry. The methodology minimizes groupthink, mitigates subjective responses, and provides a systematic approach to evaluate alternatives. It results in decisions that are better aligned with the goals of the organization or project by using transparent inputs and clear criteria. The methodology has been successfully applied by the FAA on two projects, and is readily adaptable to any complex prioritization decision involving multiple objectives and stakeholders. It is expected that the FAA will apply the methodology in future complex prioritization decisions.

ACKNOWLEDGMENTS

The author would like to acknowledge Brian Duvall from the FAA who offered valuable contributions toward the innovation of this methodology and the adaptation of it to the FAA's mission. Mr. Duvall also led many aspects of the FAA projects cited as case studies in this paper. The author also thanks Bob Flynn, Monique Exum, Constance Morgan and Suzanne Porter of MITRE CAASD for their inputs, peer review, guidance and oversight.

REFERENCES

Department of Defense. (2005). *Base Closure and Realignment Report Volume I Part 1 of 2: Results and Process.* Washington, DC: Department of Defense.

Keller, R.L., Simon, J., Wang, Yitong., et al. (2009). *Multiple-Objective Decision Analysis Involving Multiple Stakeholders.* Hanover, MD: INFORMS.

Makleff, G., Gruia, M., Gudka, A., et al. (2003). *The Seven Habits of Highly Effective IT Portfolio Management (PPM) Implementations.* New York, NY: UMT Consulting Group.

Pinto, J.K. (2010). *Project Management: Achieving Competitive Advantage* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

Tao, Z. (2014). *Prioritization Methodology for Operational Problems and Solutions*. Understanding Systems Complexity Technical Exchange Meeting (TEM). McLean, VA: The MITRE Corporation.