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A Value Measure for Public-Sector Enterprise Risk Management: A TSA Case Study

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This article presents a public value measure that can be used to aid executives in the public sector to better assess policy decisions and maximize value to the American people. Using Transportation Security Administration (TSA) programs as an example, we first identify the basic components of public value. We then propose a public value account to quantify the outcomes of various risk scenarios, and we determine the certain equivalent of several important TSA programs. We illustrate how this proposed measure can quantify the effects of two main challenges that government organizations face when conducting enterprise risk management: (1) short-term versus long-term incentives and (2) avoiding potential negative consequences even if they occur with low probability. Finally, we illustrate how this measure enables the use of various tools from decision analysis to be applied in government settings, such as stochastic dominance arguments and certain equivalent calculations. Regarding the TSA case study, our analysis demonstrates the value of continued expansion of the TSA trusted traveler initiative and increasing the background vetting for passengers who are afforded expedited security screening.

KEY WORDS: Risk; utility; value

1. INTRODUCTION

Several definitions of "risk" adopted by U.S. government departments and agencies emphasize the negative consequences related to the mission and strategic objectives of those organizations. As an example, the U.S. Department of Homeland Security (DHS) defines risk as "the potential for an unwanted outcome resulting from an incident, event, or occurrence, as determined by its likelihood and the associated consequences."(1) Similarly, the Environmental Protection Agency defines risk as "the chance of harmful effects to human health or to ecological systems resulting from exposure to an environmental stressor."(2) This common perception of risk as a negative outcome is evolving toward an understanding of the whole distribution of outcomes as more government departments and agencies are adopting formal risk management programs, and adapting frameworks and techniques developed and refined in the public sector.

In July 2016, the White House Office of Management and Budget (OMB) released *Circular No. A-123: Management's Responsibility for Enterprise Risk Management and Internal Control* (A-123). This document requires all departments and agencies in the executive branch to implement formal risk management programs.(3) In the accompanying "playbook," OMB defined risk as "the effect of uncertainty on achievement of objectives. An effect is a deviation from the desired outcome—which may present positive or negative results."(4) Defining risk simply as uncertainty more closely aligns with normative decision analysis,(5) and it explicitly reflects that risk can

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entail negative consequences and present upside opportunities.

An underlying principle of enterprise risk management (ERM) and strategic decision making in the private sector is that organizations exist to create value for their stakeholders.[6] With "for-profit" organizations, value (the profit) is relatively straightforward to determine in monetary terms. In fact, "every decision either increases, preserves, or erodes value."[7] Once stakeholder value is determined, management can project future value as a function of the risk and expected value (or expected utility) of their decisions. This concept applies equally to decision making in government organizations. However, without a clear equivalent to "profit" earned from public-sector activities, this essential measure of value is not readily available to government organizations. This deficiency makes it difficult to achieve a full implementation of ERM concepts in the federal government, and it precludes the use of decision analysis techniques, such as certain equivalent and value of information calculations[8] and stochastic dominance arguments.[9] At a time when effective ERM is arguably more important than ever, government organizations need a measure of value that supports using the full range of decisional analysis techniques and ERM concepts.

Managing risk in the federal government also presents unique challenges that private-sector organizations do not necessarily encounter. First, federal departments and agencies experience frequent changes in political leadership. New political leaders often arrive with ideas and initiatives that differ from their predecessors', and they are frequently focused on short-term versus strategic goals for the organization. The focus on short-term objectives often leads to decisions that seek to avoid potential negative losses (or consequences) over a short period of time, even if alternative decisions are available that provide greater long-term value. This directional instability is often exacerbated by the federal budgeting process, which is increasingly uncertain regarding long-term resource stability. Second, frequent leadership turnover can also result in inconsistent commitment to effective ERM and a focus on avoiding negative outcomes, despite the upside potential of available programs. Without a clear value measure, it is difficult to quantify the loss of value resulting from short-term versus long-term focus or from a focus on avoiding negative consequences at all cost. This type of behavior is associated with extreme risk-averse behavior.[5, p. 255] It is also not straightforward to incorporate basic tools from ERM, such as stochastic dominance, certainty equivalents, and value of information calculations without a clear value measure. Third, as opposed to a single monetary value used in "for-profit" firms, in the government setting, a variety of attributes are used to characterize and measure the value of policy decisions to the country (see, for example, Keeney *et al.*,[10] who elicit direct value attributes in policy decisions, and Gregory and Keeney,[11] who use the direct values to create more policy alternatives). Several approaches have thus used a multiple-attribute utility approach to address these policy alternatives and determine the best decision by assigning a utility function over each of the attributes.[12,13] To incorporate the various components of public value in our formulation, we investigate their monetary effect on the public.

We propose adopting a public value account that identifies the enduring elements of public value delivered to the American people through government programs and activities. This account can be used within the expected utility framework. This approach helps government decisionmakers to quantify the effects of short-term versus long-term value and the effects of operating to avoid potential negative consequences, even when they occur with low probability. Using the Transportation Security Administration (TSA) as an example, Section 2 identifies the basic social cost and social benefit (outcome) components of a TSA public value account, defines these elements in monetary terms to compute a TSA Public Value Account, and then demonstrates short-term versus long-term impact considerations on public value. Section 3 quantifies public value under uncertainty and demonstrates its application in addressing several important strategies faced by the TSA. Section 4 demonstrates that by monetizing government value, it is possible to understand how to achieve a full incorporation of risk tolerance concepts into public-sector ERM programs and how to quantify the effects of focusing on negative outcomes by comparing the expected utility approach to the value-at-risk criterion that is commonly used in government enterprises. The final section presents the authors' conclusions and identifies several opportunities for future research.

2. CONSTRUCTING THE TSA PUBLIC VALUE ACCOUNT

Moore[14] proposes adopting the traditional financial balance sheet format from the private

Table I. Moore's Schematic Version of Public Value Account

Public Value Account	
Use of Collectively Owned Assets and Associated Costs	Achievement of Collectively Valued Social Outcomes
Financial costs	Mission achievement
Unintended negative consequences	Unintended positive consequences
	Client satisfaction
	Service recipients
	Obligates
Social costs of using state authority	Justice and fairness
	At individual level of operations
	At aggregate level in results

sector to construct a public value account. As shown in Moore's example in Table I, balance sheet "assets" are replaced with achievement of collectively valued social outcomes (benefits), and "liabilities" are replaced with use of collectively owned assets and associated costs.

Moore's work focuses on improving government performance measures and accounting systems by providing a "functional equivalent of the revenue measure" used extensively for business evaluation and performance measurement in the private sector.[14] In this article, we demonstrate the use of Moore's public value account concepts in government risk response decision analysis using the TSA as a case study. To begin, we must answer the fundamental question: What are the enduring elements of public value to include in a TSA public value account? With these enduring values identified, it is then possible to determine the monetary value of the associated social costs and social outcomes and then apply that value to analyze TSA risk response decisions.

As part of the response to the terrorist attacks of September 11, 2001, the U.S. Congress established TSA through enactment of the Aviation and Transportation Security Act,[15] which assigns TSA the following responsibilities: (1) security of all transportation modes; (2) transportation security research and development; and (3) transportation-security-related intelligence and threat information.

- Security of all transportation modes
  - Deter, detect, and prevent terrorist attacks on transportation.
  - Establish, enforce, and evaluate transportation security regulations.
  - Develop strategies, policies, and plans to respond to threats.
  - Conduct background checks on transportation workers.
- Transportation security research and development
  - Promote transportation security research and development.
  - Establish standards for transportation security technology.
  - Evaluate and certify transportation security technology.
  - Deploy and maintain transportation security technologies to address threats.
- Transportation-security-related intelligence and threat information
  - Receive, assess, and distribute transportation-security-related intelligence information.
  - Assess threats and risks to transportation.

A fourth primary objective, ensuring the movement of people and commerce, is derived from the TSA Mission Statement. This additional objective includes assessing traveler and commerce risk and assessing the effectiveness of security measures against that risk. These four direct objectives, and their supporting subobjectives, form the beginnings of the social outcome (benefit) side of the TSA balance sheet.

Several important social benefits must also be accounted for in the balance sheet to account more fully for TSA's contribution to public value. Adapting Keeney and von Winterfeldt's Homeland Security Strategic Objectives detailed in their conceptual homeland security value model,[16] we have added promoting travel and trade, facilitating counterterrorism investigations, and mitigating the spread of highly communicable diseases. These eight objectives and their supporting subobjectives are as follows:

- Minimize costs of government intervention
  - Social impacts
  - Economic impacts
  - Environmental impacts
  - Regulations and oversight
  - Direct government cost
- Protect civil liberties

Table II. Proposed Components of TSA Public Value Account

Transportation Security Administration Public Value Account	
Social Costs	Social Benefits
TSA financial costs	Transportation security
Cost of government intervention	Prevent terrorist attacks on transportation
Social impacts	Establish, enforce, and evaluate transportation security regulations
Environmental impacts	Respond to terrorist threats
Industry economic impacts	Transportation worker vetting
National economic impacts	Facilitate legitimate travel and trade
Regulatory and oversight impacts	Assess traveler risk
Terrorist incident consequences	Assess commerce risk
Economic impacts	Evaluate security measure effectiveness
Fatalities and morbidity	Transportation security research and development
Social impacts	Promote transportation security research and development
Terrorist use or exploitation of transportation systems	Establish standards for transportation security technology
Civil liberties impacts	Evaluate and certify technology
Civil rights impacts	Deploy and maintain security technology to address threats
Privacy impacts	Transportation security threat and intelligence information
	Receive, assess, and distribute transportation-security-related intelligence
	Assess threats and risks to transportation
	Raise transportation security standards
	Domestic standards
	International standards
	Facilitate counterterrorism investigations
	Mitigate spread of highly communicable diseases via transportation systems

TSA, Transportation Security Administration.

  - Minimize impacts on civil rights
  - Minimize impacts on privacy

- Prevent terrorist use or exploitation of transportation systems
- Minimize consequences of terrorist incident
  - Economic impacts
  - Fatalities and morbidity
  - Social impacts
- Raise transportation security standards
  - Domestic standards
  - International standards
- Promote travel and trade
- Facilitate counterterrorism investigations
- Mitigate spread of highly communicable diseases

The combined lists of important direct and indirect social costs and benefits provide the elements needed to construct the TSA public value account, with the proposed balance sheet depicted in Table II. For the remainder of this article, we provide a partial example with social costs and social benefits (outcomes) limited to passenger security screening and preventing terrorist attacks against commercial airlines using an improvised explosive brought aboard by a passenger, although some costs may also apply to other attack pathways.

2.1. Monetizing Social Costs and Social Benefits

2.1.1. Social Costs

Using several of the TSA public value account objectives in Table II, we will calculate the social costs using the objectives, associated metrics, and value in millions of dollars reflected in Table III. The threat scenario in this partial solution is catastrophic destruction of a large commercial aircraft during flight from a terrorist detonation of an improvised explosive device.

Throughout this article, we use publicly available information to determine social costs. According to DHS, TSA expended $3.229 billion to prevent terrorist attacks on commercial aviation during fiscal year 2015.(17) This figure does not include the costs of TSA intelligence functions, which are accounted for separately in the full public value account

Table III. Proposed Partial TSA Public Value Account Values

Objectives	Metric	Unit Value
Social costs		
TSA financial costs	Millions of dollars	3,229
Cost of government intervention		
Passenger costs	Passenger security fee (millions of dollars per million travelers)	1,600
Social costs	Minutes travel delay for security screening (per million travelers)	0.42
Industry 9/11 security fee	Millions of dollars	420
Decrease demand from security requirements	Millions of dollars of lost industry revenue	10,128
Social benefits (outcomes)		
Transportation security		
Prevent terrorist attack	Airline attacks prevented	0.25
Air travel demand	Millions of dollars in decreased demand	1
Fatalities and morbidity	Number of fatalities prevented	9.6
Industry economic impact	Millions of dollars of loss avoided	1
Direct impact on society	Millions of dollars loss prevented	1
Facilitate travel and commerce		
Assess traveler risk	Minutes of time saved from expedited screening (per million travelers)	0.42

TSA, Transportation Security Administration.

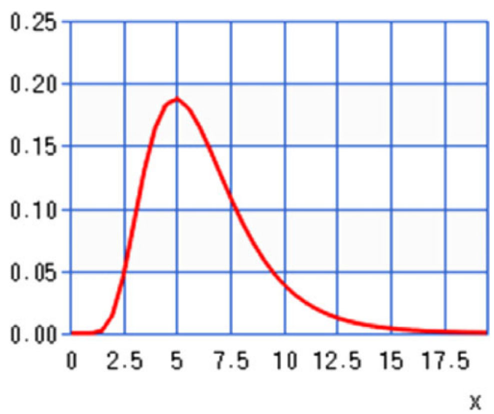

Fig. 1. Expedited screening wait times.

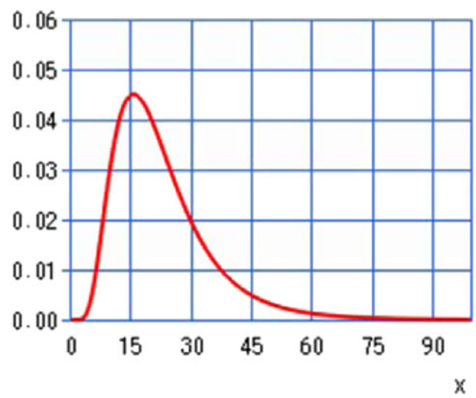

Fig. 2. Standard screening wait times.

(Table II). In addition, passenger costs for aviation security totaled $1.6 billion ($5.60 security fee per one-way trip), and security fees paid by commercial air carriers equaled $420 million for fiscal year 2015.[17] Blalock *et al.*[18] estimate that post-9/11, aviation passenger security requirements decrease passenger demand by 6%. The U.S. Department of Transportation Bureau of Transportation Statistics reports that during 2015, the average round-trip ticket price was $377, with total passenger enplanements of 895.5 million for domestic and international U.S. flights; this resulted in annual lost industry revenues of $10.128 billion. Using these data, the partial social costs of aviation security—without factoring the cost of passenger delay—total $15.377 billion.

Considering passenger delays resulting from TSA security requirements during 2015, 44% of all passengers received expedited screening, with an average wait time of approximately five minutes with a lognormal distribution (as in Fig. 1). For the 56% of passengers who were processed through standard screening, the average wait time was approximately 15 minutes with a lognormal distribution (as in Fig. 2). Using a weighted average time cost of $25 per hour,[18] the cost per minute delay because of security screening is $0.42. These data result in a social cost of $3.984 billion exerted on passengers because of security screening delays during 2015. The combined social cost of preventing terrorist attacks against commercial airlines using an improvised explosive device in 2015 in this partial example was $19.362 billion.

Table IV. Social Benefit Variables

Outcome Objective	Upper Limit, *a*	Lower Limit, *b*	Mean	Discrete or Continuous
Air travel demand	–10%	–3%	–6.29	Continuous
Number of fatalities	375	75	176.45	Discrete
Society economic impact	$20.83B	$6.24B	$13.1B	
Industry economic impact				
Lost revenue	$12.1B	$3.62B	$7.59B	Continuous
System shutdown	48 hours	4 hours	6.86 hours	Continuous
Wait times—standard	60 minutes	5 minutes	15.0 minutes	Continuous
Wait time—expedited	15 minutes	1 minute	5.0 minutes	Continuous
Number of attacks prevented	4	1	1.425	Discrete

2.1.2. Social Benefits

Considering our example threat scenario, the primary desired social benefit from TSA's aviation security efforts is the prevention of a terrorist attack aboard a commercial passenger airplane using an improvised explosive device. To compute the value of this outcome, we will use the avoidance of the negative effects of such an attack plus the social benefits of TSA's risk-based passenger screening efforts.

With respect to fatalities, we use a value of statistical life (VSL) of $9.6 million,[(19)] with an assumption that terrorists will seek to maximize the value of such an attack and not direct an attack against small passenger aircraft with fewer than 50 passengers. These larger aircraft types account for nearly 93% of the U.S. commercial aircraft fleet, with the distribution of wide body, narrow body, and regional jet types of 16.63%, 23.34%, and 57.03%, respectively.[(20)] Across the various aircraft seating configurations, we assume normal distribution for an average of 75, 175, and 375 people, respectively, per aircraft category to determine an expected mean number of fatalities of 176.45 per successful attack (lower limit of 50, and upper limit of 500 fatalities), which equates to a VSL saved of $1.694 billion per attack.

The catastrophic loss of an aircraft in flight could result in a temporary suspension of commercial air service, with a lower limit of four hours and an upper limit of 48 hours. Using Balvanyos and Lave's 2005 estimate of the economic impact of $2 billion per day,[(21)] and a mean of 6.86 hours, such a shutdown would cost the industry $571 million. The direct industry impact resulting from decreased air travel demand following this type of terrorist attack is estimated between $3.62 billion and $12.1 billion, with a mean of $7.59 billion in lost revenue. These industry impacts would total $8.16 billion. The economic impact on society is estimated as a mean of $13.1 billion,[(22)] but could be as low as $3.62 billion or as high as $20.83 billion. The 394 million enplanements that waited an average of 10 minutes less to process through security add a social benefit for reduced passenger delays of $1.65 billion. Assuming a mean of 1.425 terrorist plots targeting U.S. commercial aviation during 2015 (upper limit of 4 and lower limit of 1), the value of the social benefit in this partial example is $34.85 billion. The social benefit values are summarized in Table IV.

2.2. Determining Public Value

Throughout this article, we will use the value delivered to the American people by a particular program as our measure of value. We define the public value (PV) delivered to the public in a given year as:

$$PV = SB - SC, \tag{1}$$

where social benefit SB (social benefit) represents the cumulative benefit realized by society from government programs and activities at a given year and SC (social cost) represents the cumulative cost to society to provide those benefits.

We further define the net present public value by modifying Segal's[(23)] "company value" formula by replacing "distributed cash flow" with societal benefits and societal costs, and substituting Gross Domestic Product (GDP) growth rate for discount rate to calculate the cumulative public value delivered over the lifetime of the program as:

$$PV_n = \sum_{n}^{\infty} \left(\frac{SB - SC}{(1+d)^n} \right), \tag{2}$$

where PV represents net present public value, n is the year of projection, and d is the public value discount rate.

Table V. Short-Term versus Long-Term Public Value Example

Year n	Public Value (no new technology)	Implementation and R&D Costs	Cost of Security Delay	Net Present Public Value
1	\$15.82 billion	\$50 million	\$3.984 billion	\$15.77 billion
2	\$16.16 billion	\$50 million	\$3.984 billion	\$16.06 billion
3	\$16.51 billion	\$50 million	\$3.984 billion	\$16.35 billion
4	\$16.86 billion	\$550 million	\$3.188 billion	\$16.14 billion
5	\$17.22 billion	\$0	\$3.188 billion	\$17.64 billion
6	\$17.59 billion	\$0	\$3.188 billion	\$19.59 billion

R&D, research and development.

Inserting the SB and SC values into Equation (2), with d set to the average real GDP growth rate of 2.1%, and for this partial example the PV is \$15.82 billion with $n = 1$, and \$16.51 billion with $n = 3$ preventing terrorist attacks using an improvised explosive device that resulted in the catastrophic loss of a commercial passenger aircraft.

2.3. Short-Term versus Long-Term Considerations for the Future Public Value

The example above assumed that the social costs and social outcomes were equivalent in the time duration. Considering the federal budget process and an average 2.5-year tenure of administration political appointees,[24] we used $n = 1$ and $n = 3$ in Equation (2) as representative durations for a government decisionmaker. The choice of the duration is an important consideration that should not be chosen arbitrarily. To illustrate, suppose that there is a potential new technology that requires an investment of \$700 million, but can reduce long-term social costs. This technology requires \$50 million for research and development during years 1 through 3, and \$550 million to purchase and implement the technology during year 4. Consider even the simple case in which there is no uncertainty about the success of this research. Once implemented, the technology would decrease passenger dissatisfaction by reducing average wait time for both standard and expedited screening by 20% after n years, thereby increasing the public account. This would make the public value with a decision to pursue the technology as calculated by Equation (2) much more appealing in the long term, for $n > 4$, but less appealing in the short term. A decisionmaker who is considering only the short-term versus strategic benefits could be tempted to consider staying with the less advanced existing technology.

Table V highlights this idea and shows the public account values for six years, and the present value outcome of the decision to pursue or not to pursue this technology versus the time duration, n.

As shown from Table V, the public value derived from implementing the research and development costs over a six-year period is higher than not investing in research and development, and is equal to \$19.59 billion. However, over a two-year period, the cost of maintaining the status quo is higher than investing in new technology. The difference in public value between the two in a six-year period (\$19.59 vs. \$17.59) is \$2 billion, a significant amount for the American people. This example shows the effects of short-term versus long-term incentives in ERM, and it demonstrates the importance of considering the impact on value over multiple time horizons when evaluating decision alternatives. If the sensitivity analysis determines that various strategies will become more appealing over the long term, then the decisionmaker can better understand (and quantify) the impact of the shorter time horizons on value.

3. QUANTIFYING FUTURE PUBLIC VALUE FOR DECISION ANALYSIS UNDER UNCERTAINTY

3.1. Decision Analysis Using Public Value

The public value account model proposed above enables a quantification of various deterministic outcomes. Because uncertainty is always present, any intervention may present an upside desirable outcome or a severe negative outcome even if it occurs with a very low probability. Decisionmakers are often judged by the outcome that occurs instead of the decision-making process that is invoked. This type of incentive can induce a decisionmaker to focus on not exceeding a certain threshold value (the downside) regardless of the potential (upside) benefits that are possible. There is no method of decision making that guarantees the best outcome. Therefore, it is important to rely on a sound decision process. Normative decision analysis suggests that a decisionmaker who is evaluating an intervention strategy should choose the alternative that maximizes the expected utility (see, for example, Howard and Abbas[5]). This choice criterion implies that the whole distribution of potential outcomes should be invoked into the analysis and not just the downside risk.

We now consider two potential risk events related to TSA's aviation security mission that could impact public value: (1) an unidentified high-risk traveler accepted into the trusted traveler population and (2) a new and novel threat currently undetectable with current technology and security procedures. For these risk events, we will use the likelihood of occurrence of 15% and 10%, respectively. Beyond maintaining the status quo (baseline), there are several plausible response strategies to these risk events.

This first group of strategies focuses on downside risk by directly addressing these risk events:

(1) Strategy 1: Reduce expedited screening
(2) Strategy 2: Increase vetting for trusted travelers
(3) Strategy 3: Decrease probability of novel threat use
(4) Strategies 2 and 3 hybrid: Increase vetting and reduce probability of novel threat use

Two strategies that pursue potential upside opportunities include:

(5) Strategy 4: Increase expedited screening
(6) Strategy 5: Increase vetting and expedited screening

For each strategy, we consider whether the traveler went through expedited or standard screening, whether the high-risk traveler attempts an attack, and the probability that the attempted attack was successful.

3.1.1. Baseline Status Quo

For this risk event example, we will use the 44% expedited screening rate TSA reported for 2015 and then assign the probability of a high-risk (threat) passenger being accepted into the trusted traveler population at 15%. As the risk level of passengers who receive standard screening is unknown, we assume a 50% probability of a threat passenger being in this group. Because of the reduced level of physical security measures for expedited screening, the probability that a threat passenger in the trusted traveler population is more likely to attempt an attack is set at 30%, compared with a threat passenger who undergoes standard screening having a 10% probability of attempting an attack. For both screening paths, the probability of a novel threat is set at 10%, and because this threat is undetectable with current security technology and procedures, we will assign a 90% probability of a successful attack using a novel threat device. Considering the number of attempted and successful terrorist attacks against commercial passenger aircraft worldwide since 9/11, we assign the probability of a successful attack using a nonnovel threat device at 60%. Fig. 3 shows a simple event tree for these two threat events for both expedited and standard screening for the baseline case.

Where:

$\mathbf{E_1}$ = successful attack by threat passenger with novel threat through expedited screening
$\mathbf{E_2}$ = unsuccessful attack by threat passenger with novel threat through expedited screening
$\mathbf{E_3}$ = successful attack by threat passenger with nonnovel threat through expedited screening
$\mathbf{E_4}$ = unsuccessful attack by threat passenger with nonnovel threat through expedited screening
$\mathbf{S_1}$ = successful attack by threat passenger with novel threat through standard screening
$\mathbf{S_2}$ = unsuccessful attack by threat passenger with novel threat through standard screening
$\mathbf{S_3}$ = successful attack by threat passenger with nonnovel threat through standard screening
$\mathbf{S_4}$ = unsuccessful attack by threat passenger with nonnovel threat through standard screening

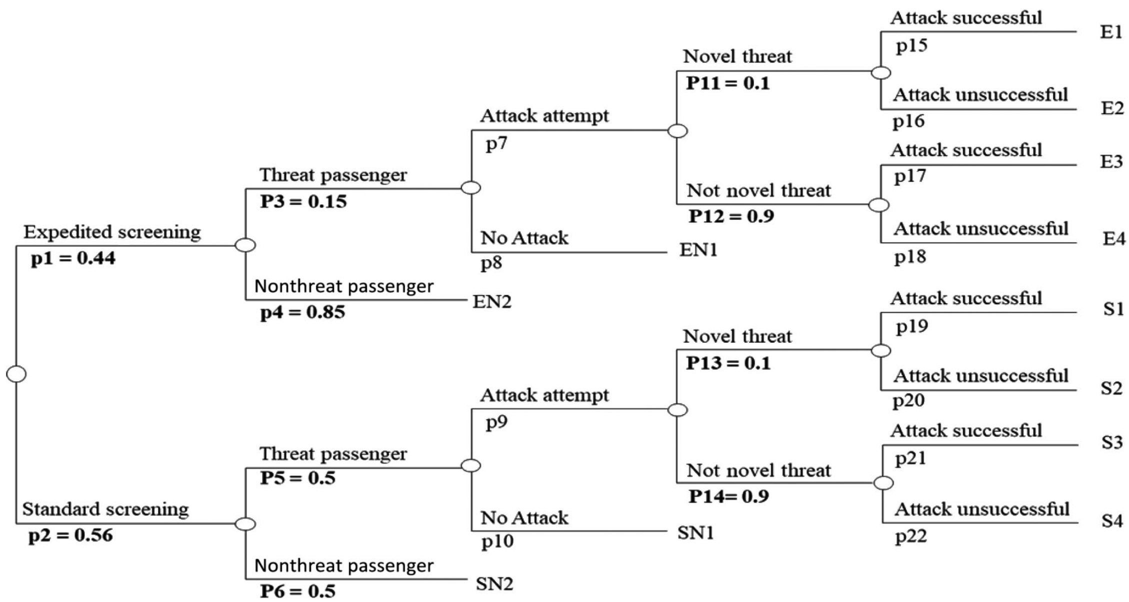

Fig. 3. Trusted traveler risk event tree.

To complete the list of possibilities for each strategy, we also consider:

$\mathbf{EN_1}$ = Threat passenger passes through expedited screening but does not attempt an attack
$\mathbf{EN_2}$ = Nonthreat passenger through expedited screening who does not attempt attack
$\mathbf{SN_1}$ = Threat passenger passes through standard screening but does not attempt an attack
$\mathbf{SN_2}$ = Nonthreat passenger passes through standard screening but does not attempt an attack

Considering our decision strategies through the lens of traditional government definitions of risk, federal decisionmakers may limit their thinking to short-term efforts to mitigate downside consequences. The following discussion shows the effects of strategies 1, 2, and 3 and our hybrid decision.

3.1.2. Impact of Strategy 1: Reduce Expedited Screening

Implementing strategy 1 is easily achieved through a change to public policy, but doing so would increase social costs and decrease social benefits, as demonstrated by the results of two major policy changes TSA adopted in the fall of 2015.[3] Those changes reduced the overall percentage of expedited screening by roughly 12%, and they were implemented without additional security personnel to offset increased standard screening passenger volume. Security screening delays skyrocketed at major airports across the nation with wait times exceeding 30 minutes or more, and more than 60 minutes in some instances. In our example, we assume a 50% reduction in expedited screening, and a corresponding modest 50% increase in average wait time for both screening categories. These assumptions reduce p1 to 0.22 and raise average wait times for expedited and standard screening to 7.5 minutes and 22.5 minutes, respectively. Considering just the change in security screening delays, adopting strategy 1 would increase social costs by $3.232 billion and reduce the value of social benefits by $589.2 million.

3.1.3. Impact of Strategy 2: Increase Vetting for Trusted Travelers

Strategy 2 directly addresses the first risk event. We assume that improved vetting is possible and that it would reduce the probability of a threat actor being accepted into the trusted traveler population to 5%.

[3]Elimination of Managed Inclusion II and reduction in the percentage of travelers selected for expedited screening with prescreening risk assessments.

To achieve this outcome, we assume that it would cost TSA an additional $300 million to raise identity verification standards, increase vetting standards for the trusted population, and implement biometric identity verification of these travelers at airport security checkpoints. The additional costs associated with strategy 2 increase *SC* to $19.662 billion without impacting *SB*.

3.1.4. Impact of Strategy 3: Decrease Probability of Novel Threat Use

To address the potential use of an undetectable novel threat device, the most effective option available to the decisionmaker is to prohibit passengers from carrying items that can be used to conceal the device. We assume that these potential concealment items are typically carried by 10% of all passengers, and the impact of this policy will reduce passenger demand from this group by 5%. These effects raise social costs by $823.615 million and reduce social benefits by $11.78 million.

3.1.5. Impact of Strategies 2 and 3 Combined: Hybrid Increased Vetting and Decreased Novel Threat Probability

The decisionmaker might also want to consider the impact of raising vetting standards to directly address both risk events. We assume that the implementation costs and impacts remain the same for each individual decision. Under this criterion, total social costs would increase by $1.124 billion and total social outcomes would drop by $11.784 million.

3.1.6. Impact of Strategy 4: Increase the Percentage of Expedited Screening

Strategy 4 involves simply increasing the percentage of passengers processed through expedited screening from 44% to 55%. For this decision, we assume that there is no cost associated with implementing the strategy and that all other baseline event probabilities remain constant. Using this criterion, the social costs of passenger wait times reduce total social costs by $489.6 million. Because there is no impact on social outcome, the reduction in social costs contributes directly to an increase in *PV* above baseline, creating an upside opportunity. Although this result maximizes expected utility, increasing the percentage of expedited screening alone does nothing to address the two risk events directly or indirectly; therefore, it may be politically unacceptable to the decisionmaker.

3.1.7. Impact of Strategy 5: Decrease Probability of Novel Threat Use and Increase Expedited Screening

Strategy 5 supports the decisionmaker seeking the upside opportunity while directly addressing both risk events. As is the case for strategy 4, the percentage of passengers sent through expedited screening is increased to 55% in conjunction with increased vetting and reducing the probability of novel threat use associated with strategies 2 and 3. The $300 million cost of increased vetting and the negative impact on travel demand resulting from banning the novel threat concealment items raise total social costs by $712.2 million. This increase is partially offset by increased passenger satisfaction from the 10-minute wait time reduction for the additional 11% of passengers processed through expedited screening, with a total social outcome of $574.5 million above baseline. The cumulative impact results in a change in *PV* of less than 1%.

Table VI summarizes the probabilities of the various consequences under the different decision strategies. The public value account for the event consequences under the various decision strategies (in $ billions) is shown in Table VII.

3.2. Cumulative Probability Distributions over Public Value

Using the public value measure enables us to plot the cumulative probability distributions over value for the different strategies and to explore the possibility of stochastic dominance relations among them. When these dominance relations exist, the determination of the best strategy is significantly simplified. As reflected in the cumulative probability distributions of Fig. 4, our baseline condition shows first-order stochastic dominance with respect to strategies 1 and 3, and almost stochastically dominates strategy 2. This implies immediately that a decisionmaker who follows the axioms of normative decision making should prefer the baseline strategy over strategies 1 and 3. To ensure maximum expected utility, the rational decisionmaker must consider the whole range of potential outcomes, including strategies with potential upside opportunities.

Fig. 5 shows the cumulative probability distributions of our two intervention strategies that pursue

Table VI. Probabilities of Various Consequences under the Different Strategies

Event	Baseline	Decision 1	Decision 2	Decision 3	Hybrid	Decision 4	Decision 5
p1	0.44	0.22	0.44	0.44	0.44	0.55	0.55
p2	0.56	0.78	0.56	0.56	0.56	0.45	0.45
p3	0.15	0.25	0.05	0.15	0.05	0.15	0.05
p4	0.85	0.75	0.95	0.85	0.95	0.85	0.95
p5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
p6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
p7	0.3	0.3	0.3	0.3	0.3	0.3	0.3
p8	0.7	0.7	0.7	0.7	0.7	0.7	0.7
p9	0.1	0.1	0.1	0.1	0.1	0.1	0.1
p10	0.9	0.9	0.9	0.9	0.9	0.9	0.9
p11	0.1	0.1	0.1	0	0	0.1	0
p12	0.9	0.9	0.9	1	1	0.9	1
p13	0.1	0.1	0.1	0	0	0.1	0
p14	0.9	0.9	0.9	1	1	0.9	1
p15	0.9	0.9	0.9	0.9	0.9	0.9	0.9
p16	0.1	0.1	0.1	0.1	0.1	0.1	0.1
p17	0.6	0.6	0.6	0.6	0.6	0.6	0.6
p18	0.4	0.4	0.4	0.4	0.4	0.4	0.4
p19	0.9	0.9	0.9	0.9	0.9	0.9	0.9
p20	0.1	0.1	0.1	0.1	0.1	0.1	0.1
p21	0.6	0.6	0.6	0.6	0.6	0.6	0.6
p22	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Table VII. Public Value Account for Event Consequences of Various Strategies

Outcome	Baseline	Decision 1	Decision 2	Decision 3	Hybrid	Decision 4	Decision 5
E1	(7.135)	(11.039)	(7.441)	(7.988)	(8.294)	(6.634)	(7.275)
E2	5.960	2.056	5.654	5.107	4.801	6.461	5.820
E3	(7.135)	(11.039)	(7.441)	(7.988)	(8.294)	(6.634)	(7.275)
E4	5.960	2.056	5.654	5.107	4.801	6.461	5.820
S1	(7.135)	(11.039)	(7.441)	(7.988)	(8.294)	(6.634)	(7.275)
S2	5.960	2.056	5.654	5.107	4.801	6.461	5.820
S3	(7.135)	(11.039)	(7.441)	(7.988)	(8.294)	(6.634)	(7.275)
S4	5.960	2.056	5.654	5.107	4.801	6.461	5.820
EN1	14.993	11.296	14.687	14.144	13.838	15.700	14.651
EN2	14.993	11.296	14.687	14.144	13.838	15.700	14.651
SN1	12.663	5.319	12.356	11.825	11.519	13.859	13.155
SN2	12.663	5.319	12.356	11.825	11.519	13.859	13.155

upside opportunities. As depicted, the baseline condition is dominated by strategies 4 and 5 with first-order stochastic dominance. When considering the whole range of decision options, any rational decisionmaker must prefer strategy 4 or 5 to any other intervention option. However, it is not irrational for a highly risk-averse decisionmaker to choose strategy 5 over strategy 4.

Figs. 4 and 5 further demonstrate the benefits of using the public value measure. Such analysis of stochastic dominance would not have been feasible by investigating only the effects of each of the individual attributes without a value measure.

3.3. Expected Utility Calculations

The cumulative probability distribution curves were sufficient to determine the ordering of several TSA strategies when stochastic dominance exists. For example, we were able to determine that the baseline strategy is preferred to strategies 1 and 3, and that both strategies 4 and 5 are preferred to the baseline strategy. When dominance relations do not exist, we may still use the value measure to rank the different strategies using expected utility and certainty equivalent calculations. The certainty equivalent of our public value measure for a given strategy

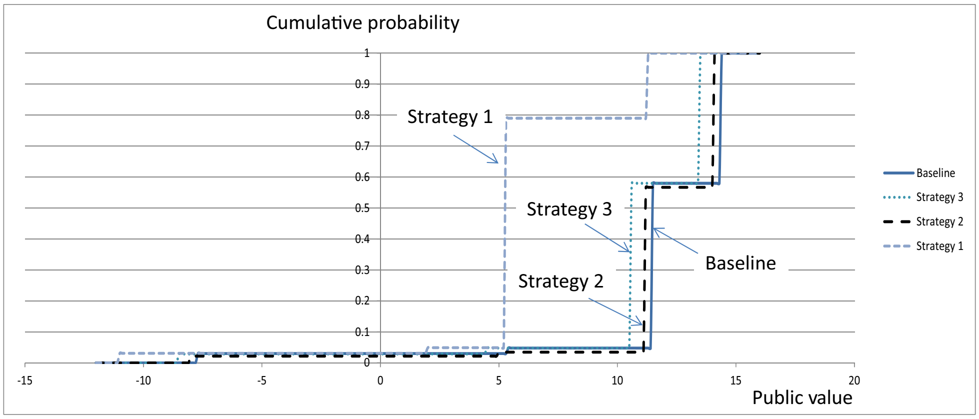

Fig. 4. Stochastic ordering of downside intervention strategies against baseline.

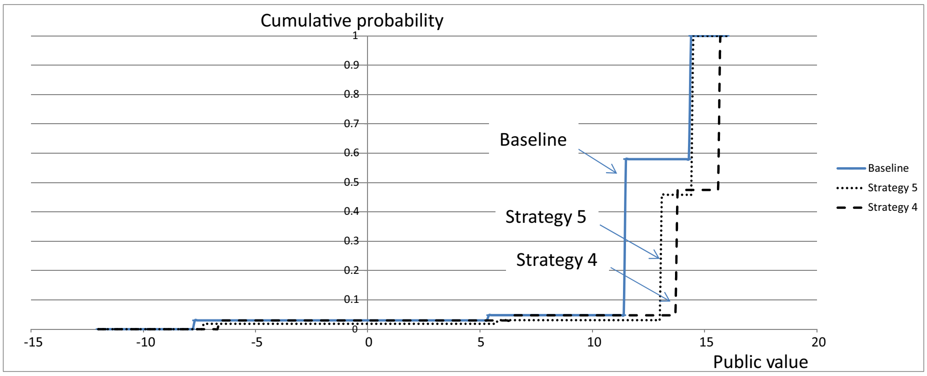

Fig. 5. Stochastic ordering of upside opportunity strategies against baseline.

is our measure of proposed value for a strategy when uncertainty is present.

To determine the certain equivalent, we first determine the expected utility of each strategy taking into account the whole distribution as follows:

$$\text{ExpectedUtility} = \sum_{i=1}^{n} p_i U(x_i), \quad (3)$$

where p_i is the probability of a consequence i, x_i is the value of the consequence i, and $U(x_i)$ is its utility value. We will use an exponential utility function in our analysis:

$$U(x) = 1 - e^{-\gamma x}, \quad (4)$$

where γ is the risk aversion coefficient. The certain equivalent is then:

$$\text{CertainEquivalentofPublicValue} = U^{-1}\left(\sum_{i=1}^{n} p_i U(x_i)\right), \quad (5)$$

where U^{-1} is the inverse of the utility function.

The certain equivalent provides a public value measure under uncertainty. Figs. 6 and 7 plot a sensitivity analysis of the certain equivalent of various strategies to the risk aversion coefficient, γ. The expected value of each strategy corresponds to the certainty equivalent when $\gamma = 0$. One would expect that the government would operate with a risk-neutral (linear) utility function. But providing the certain equivalent for different levels of risk aversion interprets various choices in terms of the various risk aversion coefficients by which an enterprise would operate and highlights the effects of some of the incentive structures. Fig. 6 shows that taking no action and remaining with the current baseline dominates strategy 1 (reduce expedited screening) on all levels of risk attitude (as expected by the stochastic dominance curves of Fig. 4) and that it ranks closely with strategy 2 (increasing vetting for trusted travelers). It also dominates the combined strategies 2 and 3 on all levels of risk. Fig. 7 shows that either strategy 4 or 5 dominates the baseline strategy,

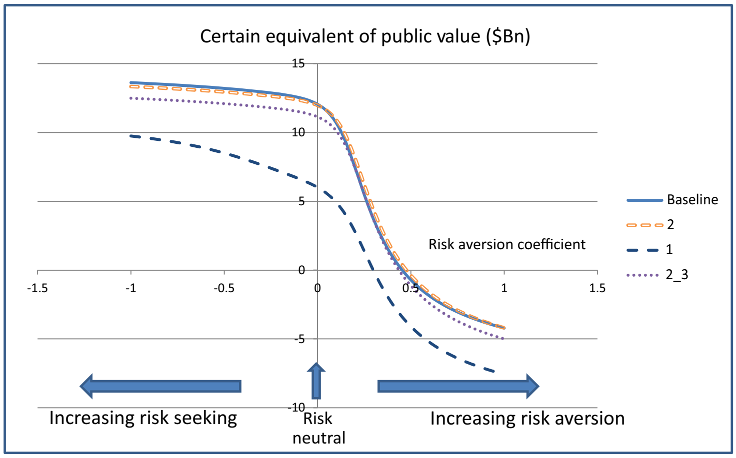

Fig. 6. Baseline strategy dominates strategy 1 on all levels of risk aversion.

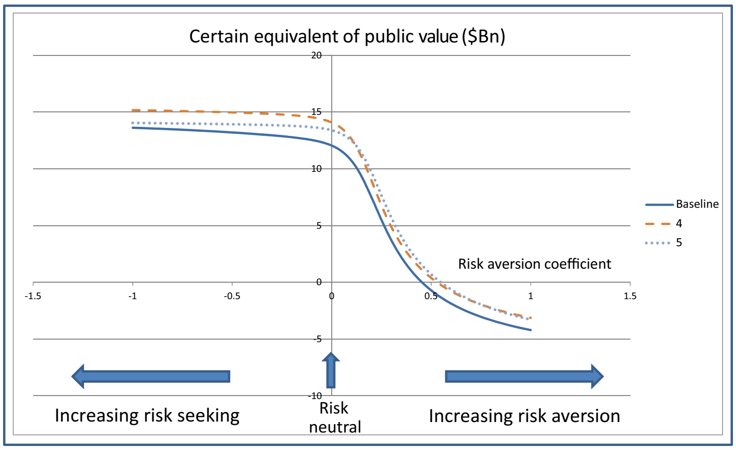

Fig. 7. Strategies 4 and 5 dominate the baseline strategy on all levels of risk aversion.

and either of these decision options provide upside opportunity.

Figs. 6 and 7 also illustrate that in this setting, the assessment of risk aversion is not a major challenge. First, we would expect that the government be risk neutral; however, the sensitivity analysis shows that strategies 4 and 5 are close, and they remain first- and second-best strategies even at high levels of risk aversion or even risk-seeking behavior, and that decreasing expediting screening is the worst strategy at all levels of risk attitude.

4. USING VALUE AT RISK TO DETERMINE THE EFFECT OF FOCUSING ON RISK THRESHOLDS

Other analytical methods have been proposed and are still used by the federal government to select decision strategies in the face of uncertainty. One method is value at risk (VaR); it is used extensively in public-sector ERM programs. The VaR metric focuses on the probability of exceeding a negative outcome (risk threshold) of each strategy in comparison to a baseline strategy instead of focusing on the whole distribution of outcomes. The public value measure we propose above enables government ERM programs to adopt public value at risk, and it enables comparison of decision options across a range of discrete risk tolerance thresholds. We do not advocate the VaR approach. We present it merely to highlight how it is used in government settings, and the effects of focusing on risk thresholds when analyzing government strategies. VaR analysis will yield different decision recommendations based on the chosen risk threshold. The comparison of the expected utility recommendation and that determined by VaR enables the government to quantify the effects of focusing on only the negative outcomes versus the whole distribution.

Table VIII. Baseline Event Tree: Outcome, Probability, and Value at Risk

Outcome	Probability	Value at Risk (millions)
E1	0.001782	$28.19
E2	0.000198	$3.13
E3	0.010692	$169.15
E4	0.007128	$112.77
S1	0.00297	$39.87
S2	0.00033	$4.43
S3	0.01782	$239.20
S4	0.01188	$159.47

Table IX. Strategy 1: Outcome, Probability, and Value at Risk

Outcome	New Probability	Difference	New Value at Risk (millions)	Difference (millions)
E1	0.001485	(0.00297)	$17.69	($10.50)
E2	0.000165	(0.000033)	$1.97	($1.17)
E3	0.00891	(0.001782)	$106.18	($62.98)
E4	0.00594	(0.001188)	$70.78	($41.98)
S1	0.00099	(0.00198)	$11.79	($28.07)
S2	0.00351	0.00318	$41.83	$37.40
S3	0.02106	0.00324	$250.96	$11.76
S4	0.01404	0.00216	$167.31	($7.84)

To illustrate, suppose that the risk threshold established is that the public value measure after implementing a given strategy should vary by no more than 6% from its value at the baseline strategy. Using the previously computed deterministic public value of $15.82 billion for $n = 1$ for the baseline strategy in our example, the change in public value should vary by no more than ±$949.2 million. The next step determines the sum of the baseline *PV* for all outcomes resulting from an attack corresponding to the two risk events. This corresponds to calculating the sum of *PV* for the outcomes E1, E2, E3, E4, S1, S2, S3, and S4, which is denoted as the VaR. In our example, this VaR is equal to $756.22 million. Table VIII illustrates the attack outcomes and the corresponding VaR for the baseline strategy.

4.1. Impact of Strategy 1: Reduce Expedited Screening

Strategy 1 reduces the public value by 24.68% to $11.92 billion in year 1, which falls outside the established risk threshold of 6%. Furthermore, with a smaller *PV* figure, the total VaR drops to $668.51 million (11.6%). The changes in each outcome and associated VaR are shown in Table IX.

Table X. Strategy 2: Event Tree Outcome and Value at Risk

Outcome	New Probability	Difference	New Value at Risk (millions)	Difference (millions)
E1	0.000594	(0.00188)	$9.22	($18.98)
E2	0.000066	(0.000132)	$1.02	($2.11)
E3	0.003564	(0.007128)	$55.29	($113.86)
E4	0.002376	(0.0004752	$36.86	($75.91)
S1	0.00297	0	$39.10	($0.77)
S2	0.00033	0	$4.34	($0.86)
S3	0.01782	0	$234.57	($4.63)
S4	0.01188	0	$156.38	($3.09)

Table XI. Strategy 3: Event Tree Outcome and Value at Risk

Outcome	New Probability	Difference	New Value at Risk (millions)	Difference (millions)
E1	0	(0.001782)	0	($28.19)
E2	0	(0.000198)	0	($3.13)
E3	0.01188	(0.001188)	$177.81	$8.66
E4	0.00792	(0.000792)	$118.54	$5.77
S1	0	(0.00297)	0	($39.87)
S2	0	(0.00033)	0	($4.43)
S3	0.0198	0.00198	$251.45	$12.12
S4	0.0132	0.00132	$167.63	$8.16

Table XII. Strategy 5: Event Tree Outcome and Value at Risk

Outcome	New Probability	Difference	New Value at Risk	Difference
E1	0.000000	(0.001782)	$0	($28,192,010)
E2	0.000000	(0.000198)	$0	($3,132,446)
E3	0.004950	(0.005742)	$77,614,905	($91,537,155)
E4	0.003300	(0.003828)	$51,743,270	($61,024,770)
S1	0.000000	(0.002520)	$0	($39,867,489)
S2	0.000000	(0.000280)	$0	($4,429,721)
S3	0.013500	(0.001620)	$211,677,013	($27,527,920)
S4	0.009000	(0.001080)	$127,006,208	($32,463,747)

4.2. Impact of Strategy 2: Increase Vetting for Trusted Travelers

This additional cost increases the social cost to $20.225 billion and reduces public value by 1.94% to $15.51 billion in year 1, which is within the risk tolerance threshold. The total VaR for this strategy drops by 29.0% to $536.78 million, a reduction of $219.43 million. Table X shows the new probabilities and VaR outcomes for each event tree branch.

4.3. Impact of Strategy 3: Decrease Probability of Novel Threat Use

These effects will raise the social costs by $820.79 million and reduce social outcomes by $11.78 million.

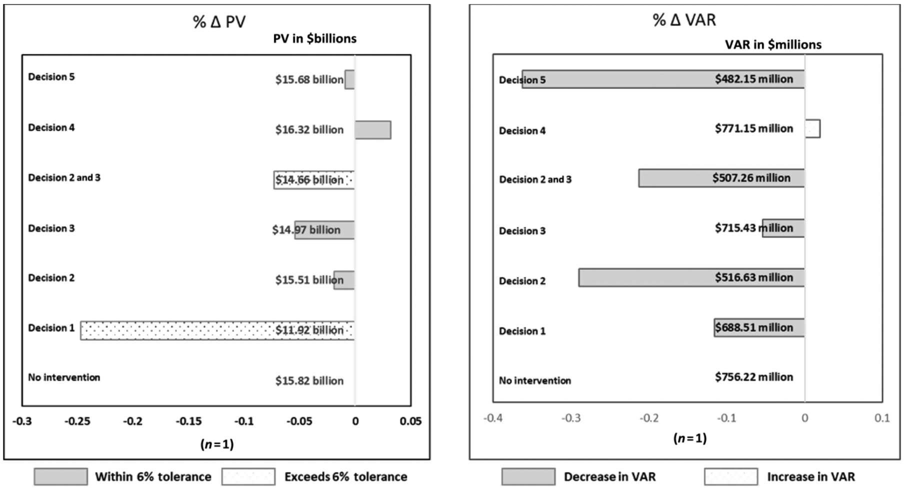

Fig. 8. Comparison graph: change in various decision strategies (*PV* and VaR) versus baseline.

Table XIII. Summary of Risk Event Decision Outcomes

Intervention Decision	Public Value ($n = 1$)	% Δ	Total VAR	% Δ	Within Tolerance
No intervention	$15.82 billion	0	$756.22 million	0.0	Yes
Strategy 1	$11.92 billion	(0.247)	$688.51 million	(0.116)	No
Strategy 2	$15.51 billion	(0.019)	$516.63 million	(0.290)	Yes
Strategy 3	$14.97 billion	(0.054)	$715.43 million	(0.054)	Yes
Strategies 2 and 3	$14.66 billion	(0.073)	$507.26 million	(0.213)	No
Strategy 4	$16.32 billion	0.032	$771.15 million	0.02	Yes
Strategy 5	$15.68 billion	(0.009)	$482.15 million	(0.362)	Yes

Table XIV. Summary of Risk Event Decision Outcomes

Intervention Decision	Risk Threshold							
	3%	4%	5%	6%	7%	8%	9%	10%
No intervention	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Strategy 1	No	No	No	No	No	No	No	No
Strategy 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Strategy 3	No	No	No	Yes	Yes	Yes	Yes	Yes
Strategies 2 and 3	No	No	No	No	No	Yes	Yes	Yes
Strategy 4	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Strategy 5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

With a revised *PV* of $14.39 billion, the new total VaR is $759.67 million in year 1. The changes in probabilities and VaR for each event tree outcome are shown in Table XI.

4.4. Impact of Strategy 5: Decrease Probability of Novel Threat Use

Strategy 5 (increased vetting, prohibiting the novel threat device, and increasing expedited screening) raises public value to $15.68 billion (0.89% increase) and reduces total VaR to $482.15 million (36.2% reduction) compared with the baseline. Table XII shows the changes in probability for the individual event outcomes and the difference in outcome VaR.

4.5. Change in Public Value and Change in VaR Comparisons

Fig. 8 provides a comparison of the strategy effects on *PV* (left graph) and VaR (right graph) as compared with the baseline of no intervention strategy in both dollar terms and percentage change.

As shown, implementing either strategy 2 or 3 has a positive impact on addressing both risk events, although strategy 3 is near the limit of the established risk threshold of 6% of *PV*. However, implementing both strategies 2 and 3 exceeds the risk threshold, although this decision combination provides the lowest VaR of all options that focus on mitigating downside consequences, as shown in Table XIII. With respect to addressing both risk events while preserving public value in this example, implementing strategy 5 provides the best percentage reduction in VaR and preserving the baseline *PV*.

As shown in Table XIV, the chosen risk threshold value can have a significant impact on which possible risk response strategies are considered viable. For example, reducing the risk threshold to 3% results in strategy 4 falling outside of the acceptable boundary. Conversely, expanding the threshold to 10% places hybrid strategies 2 and 3 within the risk threshold limit. Table XIV details the outcome of each decision with respect to risk tolerance between a risk-averse 3% and a risk-tolerant 10%.

Accepting these two risk events and taking no intervention action, strategy 2 (increase vetting) provides the best course of action to mitigate downside risk, and strategy 5 (increase both vetting and expedited screening) should be preferred for the decisionmaker who seeks to pursue upside opportunity across this range of risk behavior. We can now quantify the effects of selecting the optimal risk response strategy based on VaR versus the expected utility approach to determine the gap resulting from focusing on the negative outcomes. For example, if the gap is 3%, then only the baseline strategy, strategy 2, and strategy 5 would be selected. This would eliminate the choice of strategy 4 even though it has the highest public value with the utility analysis. Rejecting this alternative because of a focus on negative outcomes would result in a loss of value to the American people. Our VaR analysis illustrates how setting arbitrary risk threshold limits can change the optimal risk response strategy; however, VaR is widely used in government settings.

5. CONCLUSION

A key objective of ERM is to create or protect value. In for-profit organizations, value is easily determined in monetary terms, with the impact on future value considered as a function of risk and expected return of management decisions. Without a clear equivalent to profit, we must think in terms of the value to the public derived from government programs and activities to fully implement ERM principles in the federal government.

Implementing effective risk management programs and ERM techniques at the government level is in many respects more challenging than in the private sector for several reasons. First, the nature of the problems addressed by government is exceedingly complex with high levels of uncertainty. Decision making under uncertainty needs to consider the whole distribution over time, and not just negative outcomes and short-term gains. This change in vision requires a government decision culture of decision-making processes supported by careful analysis of the impact on public value instead of a mere judgment by the outcome. Because no method of decision making guarantees the outcome when uncertainty is present, there is more of a need to rely on sound decision-making processes supported by robust analysis. Focusing only on the negative outcomes leads to suboptimal, risk-averse behavior and missed opportunities.

A second challenge is the incentive structure by which leaders or senior managers operate. The focus on short-term gain versus long-term benefit could also detract from long-term investments that yield much larger value to the public in the long term. This challenge is aggravated by frequent changes in political leadership with ideas and initiatives that may differ sharply from their predecessors'.

A third challenge is consistency and transparency in the tradeoffs among multiple attributes, and how political leaders understand risk and what they consider public value. Frequently, arbitrary attributes and weights are assigned in a multiattribute setting, without proper justification for the weights, or even the nature of the objective function that is used.

We have proposed a public value measure, constructed a public value account, and quantified the related social cost and social benefit (outcome) elements to reduce the multiattribute problem to a single value measure—the value to the public. We have illustrated how this measure can be used to aid risk response decision making using two risk events related to TSA's aviation security responsibilities. We showed the importance of incorporating an appropriate time horizon and quantified the impact of using a short versus long time horizon on public value. We also incorporated uncertainty and risk preference using the public value measure and demonstrated its use with expected utility analysis. Finally, we showed the impact on public value of focusing on only negative outcomes using our value measure, and we used VaR to illustrate how setting arbitrary risk threshold limits can change the optimal strategy.

The results of our analysis demonstrate that the proposed public value measure is compatible with other analytical methods, such as utility theory, net present value, cost–benefit analysis, and value at risk, and they may be useful to support risk response decision processes in government settings.

Our analysis produced several interesting results. First, the results identified two of the three best options as decisions that involved no action (baseline and strategy 4) to address the example risk events directly. In addition, both these nonintervention options ranked higher than all the decision options that focused only on reducing the likelihood of negative consequences. Although taking no risk intervention action is an alternative, the nature of the risk events confronting a government organization could make such a decision politically unacceptable. In addition, should the risk event occur, the overall societal impact could be greater, as noted in recent research into behavioral responses to terrorist attacks against commercial aviation.[22] These outcomes reinforce the importance of managers considering the whole distribution versus perceptions of negative consequences, and the need for sound analysis and transparent assumptions. The use of a value measure enables the use of several insightful analyses, such as stochastic dominance arguments and certainty calculations, that would not be feasible using a traditional multiattribute utility approach.

During our research, we identified several important considerations when using our proposed public value measure. First, to minimize the impact of political variations, it is important to select social outcomes that reflect enduring value to the public. Although changes in political leadership will shift the emphasis and balance of any specific public value attribute, these values will endure over time. Once the enduring values are identified, the associated social costs are easier to identify and quantify in monetary terms. Second, it is important to clearly understand the risk behavior preference of the decisionmaker to assess the decision outcomes appropriately. This is true in understanding where on the risk behavior curve the analyst should be considering the results when analyzing decision options. Although risk neutrality would be a reasonable assumption in government settings, the results showed that strategies 4 and 5 were dominant across all levels of risk. The results also identified the sensitivity of the results to the risk threshold when using the value-at-risk approach. As shown in our example, either strategy 4 or 5 is preferred depending on risk attitude, and a change in risk threshold can include or exclude strategies from the subset under consideration. Finally, the time horizon used in the evaluation should not be chosen arbitrarily because it can have a significant impact on the decision outcome. As illustrated by our example, a technology investment decision will look differently if the decisionmaker sets a short time horizon versus considering the longer term effect on total public value. Similarly, the societal impact of a risk event could be exponentially higher over a multiple-year time frame versus a single year, which could significantly influence the results of both analytical approaches.

The public value approach outlined in this article supports future research, including value gained from intelligence and information, value of hybrid decision strategies, and social costs versus social benefits of obtaining additional intelligence. We look forward to the application of this public value approach in other settings and research.

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