MILITARY BUDGET DECISIONS: INFERRING TRADE-OFFS USING DECISION ANALYSIS

BY

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THESIS

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ABSTRACT

This thesis uses a decision analytic framework to assess how the United States Army makes trade-offs involving monetary resources and the potential loss of human life. Data for the study looks at the Army budget for a four year period from 2008-2011, with a focus on spending for combat and suicide prevention, and the loss of life experienced in both areas. This data is used to answer two research questions: (i) Does available data suggest the Army makes consistent trade-offs between money and human life? (ii) How can value using inferred trade-offs be used for decisions relating to the Army budget?

To answer the research questions, a basic model is derived from the data. Curve-fitting of historical data is used to infer trade-offs, as a causal relationship is assumed to exist between the spending level and the loss of lives. For the purposes of this study, the best curve-fit is assumed to represent an indifference by the decision maker to increased spending along the line if it results in a corresponding decreased loss of life. In response to the first question, the model shows that there is the potential that the Army makes inconsistent trade-offs across these areas, and explores the possible implications if these trade-offs are truly inconsistent. After addressing the possible implications of the model developed, the model is used to address the second question by showing how a value-based model can be used for the decision of budget allocation for the Army, which is especially pressing given the recently imposed budget cap that impact the US Department of Defense. Limitations of the study are addressed, along with areas for future research to expand on the initial results presented in this study.
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CHAPTER 1
INTRODUCTION

This study will aim to address two central questions by looking at how the Army has made budget allocation requests from 2008-2011, and experienced loss of life due to both combat operations and suicide:

- Does available data suggest that the Army makes consistent trade-offs between money and human life?
- How can value using inferred trade-offs be used for decisions relating to the Army budget?

1.1 Study Focus: Department of the Army Budget Allocation

Annually, the Army must submit a budget request through the Department of Defense. The budget request must cover many different area, from combat operations and training for combat to family support and equipment maintenance. With the current national debt and political disagreement about the overarching federal budget, federal agencies such as the Department of Defense and its military services must be able to understand the value of money spent within different areas. For the Army, a budget request is prepared with inputs from many different staff sections, and ideally, all of these subordinate elements would understand what creates value for the Army, and submit requests accordingly.

The Department of Defense faces a Congressionally mandated budget cap for at least the next five fiscal years (Weisgerber, 2014). For the Army and the other services, this means that requests must be prioritized as each of the services then also faces a cap on spending. Money spent on one program within the budget will reduce the available money for other programs. This creates the need for a tool to allow for comparison between the different alternatives for spending levels in multiple different areas. The application of decision analysis to this problem would allow for comparing alternatives with different spending on different programs. The army
can derive value from measures that reduce spending on programs by freeing up resources to apply to other areas. Additionally, the Army derives value from reducing the risk to those who wear the uniform, since human capital is one of the most important resources, impacting not only performance of the mission, but also morale, and the general well-being of the Army.

Faced with a decision about funding levels for programs that impact on expected loss of life will be a difficult decision with limited resources. With the development of a value model, looking at the trade-off between monetary resources available for spending, and the expected impact to human resources in the loss of human lives, the decision maker is better able to compare alternatives, and understand which alternative to choose from those available.

### 1.2 Areas for Comparison: Combat and Suicide Losses

In the United States Army, one of the eleven principles of unit training as set forth in the Army Doctrine Publication (ADP) 7-0: *Training Units and Developing Leaders*, is the mandate to “Train as you will fight” (p. 5). With these five guiding words, the Army recognizes the requirement to train consistently across the spectrum of operations, from the safety and security of the garrison environment to the rigors and stress of combat operations. Over the past fourteen years, the Army and the other services have simultaneously conducting training, sustainment, and combat operations. To determine how effectively the Army follows its guidance to train as you will fight, this study seeks to address how decision making within the Army has made trade-offs between fiscal and human resources in accordance with normative decision theory.

With the recent history of prolonged conflict in Iraq and Afghanistan, there is ample data available about combat related fatalities, and the measures taken by the Army and other services to prevent casualties. Investment in protective equipment, and measures taken in the theater of operations seek to ensure that American service members are able to survive attacks that would
have proved fatal in previous conflicts. The news media has covered many of these advances, including upgrades to individual protective equipment (body armor, helmets) and vehicles (up-armored vehicles, blast resistant vehicles). There has also been investment in improving medical treatment and evacuation that can help make the difference between life and death. For the Army to meet its mission – to fight and win our Nation’s wars – there is little difficulty in understanding how important it is for the service to be able to prevent the loss of human life in combat operations.

In choosing a non-combat decision with loss of life implications, the subject of suicide in the armed forces is the clear choice given the recent emphasis from the highest levels of the Department of Defense. In June, 2013, the Department of Defense issued Directive 6490.14 which established policy to enact a Department of Defense-wide suicide prevention program that would ensure that service members have access to care and resources to prevent suicidal losses within the military. Military suicides made the headlines of many American papers in early 2013, when it was reported that the number of Soldiers\(^1\) lost to suicide in 2012 exceeded the number of combat deaths in the same year (Briggs, 2013). The emphasis and attention on military deaths by suicide place it on an elevated level of importance, comparable with the oversight provided to combat related deaths in major operations. Additionally, with the likely cessation of combat operations in the near future, military suicides are likely to prove among the most significant reasons for loss of life.

The central question of this study is whether the Army makes consistent decisions about monetary resource allocations in different situations that can result in or prevent the loss of

\(^1\) In accordance with Army Regulation 360-1: The Army Public Affairs Program, paragraph 13-12.b.(4), the word Soldier will be capitalized when referencing a U.S. Soldier.
human life. This study will review concepts applicable to decision analysis, and models that have established value for human life within the agencies of the federal government as a baseline for understanding some of the difficulty in determining the monetary worth of human life. Analysis of trade-offs will follow the principles of normative decision analysis theory, and the basic concepts and principles of decision analysis will be reviewed. This study is focused on a normative model of decision making, but will address descriptive models as well to identify possible reasons for differences in the inferred trade-off function.

The data for this study is derived from publicly available information about suicide related deaths and combat related deaths within the Army, including the associated statistics and spending on the prevention of each loss of life. Assumptions necessary to conduct the analysis and build the model of the trade-off function will be explained with justification, and possible implications considered as future areas of exploration. The decision maker considered for the study would be at the level of the Secretary of the Army, as advised by the Assistant Secretary of the Army for Financial Management and Comptroller. The trade-off function inferred is the author’s interpretation of this publicly available data, and is not to be interpreted as representing official Army policy or decision making criteria.

This study concludes with a discussion of the model developed and the possible impacts that the findings have on the Army’s ability to be consistent in decision making about making trade-offs between monetary and human resources. Areas of future work within the context of assessing trade-offs within the military are identified, as well as possible research concerns impacting on governmental agencies.
CHAPTER 2

THEORY

Prior to addressing the data and the model for this study, this chapter introduces a few background concepts that will help to frame the later chapters. The review is not exhaustive, but addresses some of the key ideas.

2.1 General Theoretical Background

Decision makers are not always rational in their thought processes, and certain behaviors are seen repeatedly. This results in asking the fundamental question of whether models of decision theory should address how decisions are made or how decisions should be made. For determining the optimal course of action, a normative model, focused on rationality and clarity of action is preferred, and will be the goal for this study. To clearly understand the differences, it is necessary to examine what is meant by each.

Research has been conducted within the business (Kunreuther et al., 2002), psychology (Evans & Elqayam, 2011), management science (von Winterfeldt, 1989; Luce & von Winterfeldt, 1994), and other academic communities in an attempt to balance the normative model with process that rely on heuristics based on the descriptive theories addressing how decision making has occurred in the past. The descriptive models can be used to explain why decisions were made in the past, or to enable the application of empirical data to understand decisions after the outcome has been determined. Within the Army, it is possible to observe that some decisions are made that lack adherence to normative decision analysis, and instead emphasize reliance on intuition and use of past experience, including past outcomes, to make future decisions. But this serves to tie the assessment of the action of the decision to the outcome, and the explanation of the normative model will show why this is problematic.
By understanding descriptive theories, it is possible to assess which aspects of the normative process will be most difficult for decision makers to accept because they conflict with ingrained behaviors. However, an understanding of why common pitfalls occur should not be interpreted as justification for choosing a model of decision making that allows for these errors to occur.

One of the primary difficulties that decision makers face is in assessing events of a probabilistic nature, especially when compared to those which are deterministic. Psychologists Kahneman and Tversky performed significant work in the area of descriptive behavioral models. Their paper, “Prospect Theory: An Analysis of Decision under Risk,” is considered to be a foundation for much of the later work in economic models dealing with uncertain events (1979). They also identified common heuristics that people rely on to make decisions, as well as identifying cognitive biases which prevent choosing the most rational response. One of the biases they identified was the framing effect, in which the context and presentation of a decision can impact the risk attitude of the decision maker (Tversky & Kahneman, 1981). In their work, they found that overwhelmingly, decision makers felt a more profound impact from a loss than from an equivalent gain. For the topics considered for this study, combat and suicide losses, this bias is a potential source of error that should be eliminated by a workable model.

From Kahneman and Tversky’s work, it is possible to deduce that decision makers will struggle with decisions that involve uncertainty, and can be swayed in their valuation of alternatives depending on whether it is presented as a loss or gain. However, it is difficult to address how decision makers could make the best decision given the information available. This is the common deficiency with work focusing on descriptive models of decision theory. Descriptive models allow behavioral scientists, economists, psychologists, advertisers, and
others to understand why behaviors occurred. These theories can also pinpoint where difficulties are liable to arise in decision making, provide insight into how to influence decision makers, but they do not offer guidance on how to choose the better alternative, or how to avoid making the logic mistakes that they have identified.

2.2 Framework for the Study: Decision Analysis

In contrast to descriptive theories, normative decision analysis addresses how decisions should be made. As succinctly stated by Howard, “normative theories are important primarily when our natural behavior is not satisfactory to us,” (1992, p. 29). When there is a lack of rationality and precision when decision makers are confronted with issues that complicate decision making, they will be better served with understanding how to improve on their results. Decision analysis moves beyond theory, and elucidates the rules for how decisions can be made that result in clarity of action and making the best decision given the information available. Decision analysis allows for the assessment of trade-offs between different attributes that provide value for the decision maker. To understand the concept of trade-offs, it is first necessary to understand the basic rules that govern the field of decision analysis, which will then allow for the exploration of what trade-offs are and how they can be made for a rational decision maker.

2.2.1 Five Rules of Actional Thought

Within the field of decision analysis there is a wide range of information available, but the background provided herein is in the basic concepts that underpin the field. First, there are rules that must be followed in order to classify actions as being rational, and there must be a commitment to make the decision such that the decision process will involve making a decision or taking action, and is therefore described as being actional thought. There are five such rules that are considered the foundation of making clear, rational decisions (Howard, 1992, p. 33-34;
Howard & Abbas, 2010, Ch.8, p 6-17). These five rules are: the probability rule, the order rule, the equivalence rule, the substitution rule, and the choice rule. Definitions and descriptions of the five rules are derived from discussions in Howard (1992) and Howard and Abbas (2010).

The probability rule has two parts. First, it requires the decision maker to identify decision alternatives, and describe the resulting possibilities as the prospects that are available for that alternative. Secondly, the probability rule requires that the decision maker assign probabilities to the uncertain events associated with each alternative, according to the beliefs and knowledge of the decision maker. This rule enables the decision maker to ensure that the decision is framed with the appropriate uncertainties and understanding of what possible outcomes come with each alternative.

The order rule requires that the decision maker can rank order all prospects from the best to worst, with ties (indifference) being allowed. The rank ordering is consistent, meaning that there can be no changes in the ranking of prospects if one of them is removed without providing updated information. The order rule can be used to identify errors in some proposed decision methodologies, where removing one prospect creates a different ranking between the remaining alternatives.

The equivalence rule addresses uncertainty, and states that if the decision maker has three ordered prospects, there exists a probability value, $p$, such that the decision maker is indifferent between receiving the middle ranked prospect as a sure outcome, or a binary deal with $p$ chance of the best prospect, and $1-p$ of the worst prospect. This value of $p$ is what is termed as the preference probability, and has no impact on the likelihood probability of any events. For the uncertain deal of the best and worst prospects with the preference probability $p$, the middle prospect is considered the certain equivalent of the uncertain deal.
The substitution rule requires that the decision maker is indifferent between a prospect, and any uncertain deal where that prospect is the certain equivalent. This allows the decision maker to simplify the decision problem by substituting preference probabilities into subsequent calculations. With this rule, the decision maker can assign preference probabilities in terms of the best and worst overall prospects.

Finally, the choice rule requires that if the decision maker has two uncertain deals with the same prospects, the decision maker will choose the deal that has the higher probability of winning the best prospect. When the substitution rule has been used to assign preference probabilities for all alternatives in terms of the best and worst overall outcome, the choice rule in turn enables the final decision to be made only in terms of the overall best and worst prospects.

A decision maker who understands the rules of actional thought is well poised to work through a decision that will result in clarity of action, providing the ability to make the best decision given the information available. It does not guarantee the best outcome, because decisions should not be judged by their outcomes, but by the process taken to arrive at the decision.

2.2.2 Trade-Offs

Using the five rules as previously described, it becomes apparent that if a problem can be reduced to a single attribute such as money, it becomes a straightforward choice to make the decision that results in the maximum value for the decision maker. Expanding this to a decision that is characterized in terms of multiple attributes, such as money and human life, alternatives that have higher performance in both attributes are obviously preferred to alternatives that have lower performance in both attributes. Alternatives that are lower on both attributes are dominated, and will have an overall lower value to the decision maker. Where the analysis
becomes more complicated is when it is necessary to compare alternatives that have a higher score in one attribute but a lower score in the other.

When there are conflicting attributes, it becomes necessary to understand the trade-off that the decision maker is willing to make between the attributes. As described by Keeney and Raiffa (1976), at this point the decision maker must assesses trading off the achievement in one objective against the other, or deciding how to determine the amount of “achievement on objective 1... the decision maker [is] willing to give up in order to improvement achievement on objective 2,” (p. 66). The trade space for the two attributes can be viewed as an area defined by minimum value when both attributes are at their minimum, and maximum value when both are at their maximum, as seen in Figure 1.

![Deterministic Trade-Offs](image)

**Figure 1 - Deterministic Trade-Offs**

Returning again to the five rules, when a decision maker is indifferent between an alternative that scores higher on attribute \( x \) and lower on \( y \), and an alternative that scores lower on \( x \) and higher on \( y \), then these two alternative can be understood to have the same value for the decision maker. Abbas and Matheson (2005, 2009) show one possible example formulation for a value function over two generic attributes, \( x \) and \( y \), can be expressed as:

\[
V(x, y) = xy^n
\]
where $\eta$ is the deterministic trade-off between the two attributes $x$ and $y$. The term $\eta$ is “determined by calculating the fractional increase in attribute $x$ compared with the fractional decrease in attribute $y$ that makes the decision maker indifferent,” (2009, p. 5). Graphically, this can be shown with an isopreference contour, which shows a curve of the levels of the different attributes that have the same value to the decision maker, allowing for understanding of how the attributes influence value. If the contour has a steep slope in the direction of one attribute, then small gains in this attribute will contribute greatly towards the overall value. However, if the isopreference contour is a shallow slope, then increases in the performance of the attribute will have little impact the overall value.

If the attributes being considered are not deterministic, then it becomes necessary to look at the utility of the expected outcome rather than a fixed value. The utility function is expressed over the value function, and allows for incorporation of the risk attitude of the decision maker (Abbas & Matheson, 2009). The utility function can be expressed as:

$$U(x, y) = U_V(V(x, y))$$

The utility function will display the same isopreference curves as the value function because of the monotonic transformation from the original value function (p. 5).

2.2.3 Utility

Given that the value function has been specified as described previously, in seeking to address some of the limitations of the basic trade-off model proposed, the first assumption to relax would be the idea that the attributes are deterministic. Therefore, the model would need to be built to address utility, and therefore, to address risk aversion. Following the ideas introduced by Matheson and Abbas (2005), it is possible to develop a utility function over the value function that will allow for the inclusion of the decision maker’s attitude towards value when there is risk.
involved. Once this is specified, this dimension addressing risk attitude can be used to construct further multiattribute utility functions. Matheson and Abbas named the relation between the “risk aversion functions of the individual attributes to the trade-off functions between them…utility transversality,” (p.230).

Work by Abbas and Howard (2005) introduced the idea of attribute dominance utility for situations involving multiple attributes that can be assessed as having preferential independence. This would hold for the decision involving funding and human lives, because when all other attributes are held constant, then less money spent will always be preferred, and the same with the human capital losses. To be able to construct a utility copula, the model requires information about the preferences for the decision maker in order to assign utility values. Given that there currently is limited information about the preferences, and what is available must be assumed from the outcomes that were chosen, traditional methods of eliciting information from the decision maker will not assist in assigning utility.

Abbas (2003, 2006) introduced a method, maximum entropy utility, to assign utility values with partial information. One of the examples within the 2006 paper addressed a value model of the form used in this paper. With information about the domain of the attributes, Abbas showed that, as adapted by previous work from Howard (1980) a maximum entropy assignment would produce “a uniform utility density over value and a corresponding linear (risk-neutral) utility function ,” (p. 287). Therefore, it is possible to extend the original model to build a uniform density utility model if we determine what the domain of the attributes is. If access to the decision maker was made available, the utility function can be improved by gaining additional information from the decision maker. Any additional knowledge will help to refine the shape of the decision maker’s utility function, but it is possible to maximize the improvement
by asking specific questions. Work by Abbas in 2004 presented an optimal algorithm to elicit utility values for a given decision situation.

2.2.4 Application of Bayesian Updating

With access to the decision makers, it will be possible to assess what their initial beliefs were about the probability of loss of life given the chosen funding levels, and combine this information with the actual data each year for the actual loss of life statistics. Karandikar, Schmitz, and Abbas (2014) demonstrated the usefulness of Bayesian inference in providing “a formal way of belief updating when new experimental data is available,” (p. 12). This study was important in establishing that Bayesian inference has usefulness that extends beyond the traditional applications taught in general probability courses, as they applied it to machine milling.

Therefore, it should be possible to use both prior knowledge and the experimental data, in this case the annual loss of life numbers, and improve the overall model through updating. The model should be updated annually with the data available on the actual budget and the number of lives lost in order to enhance the decision maker’s understanding of the uncertainty surrounding the decision to allocate resources to prevent the loss of human life. As additionally highlighted by Karandikar, Schmitz, and Abbas, Bayesian updating reduces the need to obtain data through additional experiments because of this combination of prior knowledge and experimental data. This is of particular interest in this study, because rapid updating of beliefs to improve the decision maker’s understanding of the uncertainty associated with the decision is related to the loss of life rather than capital.
2.3 Federal Government Inconsistencies for Spending Impacting Loss of Life

Placing value on human life is difficult, and something that many are reluctant to try to do. However, in order to assess the economic impacts of national policy, such as environmental rules and regulations, it is useful to have an economic measure that allows for the understanding of the impact. Due to the focus of this study being on the US Army, whose operating funds are part of the federal budget, it is important to understand the policies that are in place at a national level for consideration of the valuation of human life.

The US Office of Management and Budget’s Circular A-4, distributed in 2003, was provided to executive agencies of the federal government in an effort to standardize “the way benefits and costs of Federal regulatory actions are measured and reported,” (p. 1). The 2003 circular introduces the idea of monetizing value in small changes in fatality risks, and assigning the resulting figure as the “value of statistical life” or VSL (p. 29). They further define the VSL as the “measurement of willingness to pay for reductions in only small risks of premature death” but do not suggest that the calculated figure can be taken as the actual value of a human life (p. 29). The circular cites that a “substantial majority of the ruling estimates of VSL vary from roughly $1 million to $10 million per statistical life,” (p. 30). While VSL should not be interpreted as a stand-in for a trade-off assessment between money and human life, it can be interpreted as approximating what the trade-off would be. This establishes the idea that there is an acceptance within the executive branch of the federal government that it is an acceptable evaluation measure to look at trade-offs between monetary resources, and the reduction in risk for death that occurs infrequently.

The discussion of VSL appears throughout reports made by federal agencies, to include the Office of Information and Regulatory Affairs’ 2010 - 2012 reports to Congress. In the 2010
report to Congress, the Office of Information and Regulatory Affairs notes that two federal agencies, the Environmental Protection Agency and the Department of Transportation are the only two federal agencies that have developed specific guidance on the VSL level. At the time of the 2010 report to Congress, the VSL adopted by the Department of Transportation is $6 million dollars (adjusted to 2009 dollars), and the Environmental Protection Agency’s VSL is $6.3 million dollars (adjusted to 2006 dollars) (p. 15-16). In a 2010 Environmental Protection Agency publication, *Guidelines for Preparing Economic Analyses*, Appendix B, is a table that shows 26 different studies, conducted during the period from 1974 to 1991, which assess VSL levels that range from $0.85 to $19.80 millions of dollars, as adjusted to 2006 dollars (p. B-2). There is a consistent lack of standardization for the reference to determine the appropriate level of VSL.

In summary, as publicly acknowledged by the Office of Management and Budget, there is no federal standard for the value of reducing risk to human life. It is accepted practice that protective measures can be expressed as a monetary expense that will reduce the statistical risk of death, but the actual amount varies. A 2012 article from The Review of Economics and Statistics, by Kniesner, Viscusi, Woock, and Ziliak, included analysis of data using different estimates for VSL, and determined that the most preferred models from the Office of Management and Budget and other federal agencies yielded a $4 million to $10 million range for VSL (p. 86). However, the article indicated that one of the key failures of VSL analysis for federal agencies was the lack of any boundaries, which created confusion and discrepancies that have “unduly muddled the policy debate over the use of VSL estimates in benefit calculations for government policies,” (p. 86).
2.4 Study Motivation: The Army Budget and Spending Impacting Loss of Life

With the lack of clarity and consistency on the trade-off between monetary resources and human life at the federal level, it is likely that there are decisions approved within one federal agency that would not be approved by a different agency because the discrepancy in the assessed VSL used by the different agencies will result in different assessments of the value for the decision. This creates a potential problem with the allocation of the federal budget, because not all agencies that make decisions impacting human life place the same value on preventing the loss of life. Therefore, it stands to reason that government agencies may also suffer from internal inconsistencies in their valuation of this trade-off.

If the Army uses inconsistent trade-offs between spending levels and human lives, there is the possibility that the reallocation of money between different spending areas within the budget would yield a net decrease in the number of lives lost for all causes. While the data available is insufficient to allow for the calculation of the absolute value the Army places on a human life, it is interesting to observe if that value possibly changes given the context within which the loss occurs.

2.5 Study Research Questions

Question 1 - Does available data suggest that the Army makes consistent trade-offs between money and human life?

The lack of consistency at the federal level is the motivation for this first question of the study, which will be confined to looking at the Army and comparing measures to reduce fatalities from combat and suicide, and using the available data to explore whether the Army is likely to have an inconsistent valuation of human life.

To address question 1, data will be examined for four years with both combat operations and measures taken to address suicide prevention. The data will be described in Chapter 3.
Using this limited data set, a value function will be determined which will calculate a trade-off value $\eta$, under the assumption that the data is treated as deterministic.

Given that the data set available for this study is small, the answer to research question 1 will suggest whether future work in this area should be undertaken to develop a more robust data set. This study can be used as initial justification in approaching the Army staff to elicit further data, as it will address the significance of calculating a trade-off means for looking at spending and loss of life.

**Question 2 - How can value using inferred trade-offs be used for decisions relating to the Army budget?**

The trade-off values for $\eta$ that are calculated in answering question 1 will be used to develop a basic model to demonstrate the worth of using a value function for decision making for the Army budget. The basic model that will be developed in Chapter 4 will show how the Department of the Army can determine the rank order of different budget alternatives, and facilitate creating clarity of action for the decision maker.

By demonstrating the usefulness of being able to rank order alternatives by preference, even with a basic model, this will provide justification on the usefulness of working to develop a value function based off of consistent trade-offs for the Army. With future work, the model can be expanded beyond consideration of the combat and suicide prevention discussed in this study, and used to ensure that the Army is able to maximize the value from its budget by optimally allocating resources to different program areas.
CHAPTER 3
STUDY DATA

In assessing how the Army makes trade-offs between money and human life, this study addresses combat and suicide as two significant causes of Soldier fatalities. As addressed in the introduction, these causes were chosen due to the documentation of loss statistics and spending related to the prevention of these losses.

As noted briefly in the introduction, this study focuses on data from the time period of 2008-2011 because of the availability of non-classified, publicly available data for the areas of interest to the study. There may be differences between reported data and actual spending based on budget amendments, issues with appropriations, classification of some information, and other areas, but these should not significantly impact the scope of the study to explore whether it is likely that the Army makes inconsistent trade-offs between money and human life.

3.1 Soldiers on Active Duty: 2008-2011

To frame the data for combat and suicide related losses, it is first important to establish the overall end strength (how many Soldiers are serving on active duty) budgeted for the Army during the years considered within the study. Table 1 shows the numbers reported for the end strength of active duty Soldiers in the Army, which are derived from the fiscal year 2008 and fiscal year 2013 U.S. Army Annual Financial Statements. These numbers within these statements are reported within 2% due to the constant state of fluctuation to personnel numbers with continuous accessions and losses occurring. The reporting reflects numbers as of the end of September for the fiscal year reported. The Congressional Baseline numbers are included for reference, as it is noted in the fiscal year 2008 report that a deviation can occur “[w]hen the President declares a State of National Emergency” (p. 6). Therefore, for fiscal years 2008-2010, the actual end strength exceeded that which was authorized. This is important to consider for the
analysis because the baseline number is used for forecasting of the budget, and the extra manpower may require that the Army and Department of Defense amend their budget request during the year, or may mean that there is an unintentional shortage in the amount of funding given that it is calculated for a smaller population than that which it will actually be used to support. The requirement to track different numbers may also add unnecessary complications to the model used to develop the budget request for the given fiscal year, and may create inconsistencies in the budget request.

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Congressional Baseline (# Soldiers on Active Duty)</th>
<th>Actual (# Soldiers on Active Duty)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>525400</td>
<td>543645</td>
</tr>
<tr>
<td>2009</td>
<td>532400</td>
<td>553044</td>
</tr>
<tr>
<td>2010</td>
<td>562400</td>
<td>566045</td>
</tr>
<tr>
<td>2011</td>
<td>569400</td>
<td>565463</td>
</tr>
</tbody>
</table>

Table 1 - Army Active Duty End Strength Within 2% Fiscal Years 2008-2011

*Key Points*
- From 2008-2010, there were more Soldiers on Active Duty than authorized by Congress
- 2011 was the first year where the number of Soldiers on Active Duty decreased

### 3.2 Requested Army Budget: 2008-2011

As a federal agency, budget information for the Army is publicly available, and published on the websites for the Under Secretary of Defense (Comptroller), and the Assistant Secretary of the Army for Financial Management and Comptroller. For each year in this study, the Army requested through the Department of Defense to Congress for a baseline budget for the fiscal year, as well as an additional supplemental budget for funding related to combat operations, which appear as requests for funding for the Global War on Terror (GWOT) or Overseas Contingency Operations (OCO) depending on the year of the request, as there was a change to
the naming convention during this time. Table 2 shows the budget requests by fiscal year for the four year period from 2008-2011. All figures available were rounded to the nearest tenth of a billion dollars.

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Base Budget ($ Bn)</th>
<th>Global War on Terror/Overseas Contingency Operations (Combat) Budget ($ Bn)</th>
<th>Total Budget ($ Bn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>130.0</td>
<td>53.6</td>
<td>183.6</td>
</tr>
<tr>
<td>2009</td>
<td>140.7</td>
<td>51.4</td>
<td>192.1</td>
</tr>
<tr>
<td>2010</td>
<td>142.1</td>
<td>83.1</td>
<td>225.2</td>
</tr>
<tr>
<td>2011</td>
<td>143.4</td>
<td>102.2</td>
<td>245.6</td>
</tr>
</tbody>
</table>

Table 2 - Army Budget by Fiscal Year ($ Billion)

**Key Points**
- From 2008-2011, budget requests increased annually when there was no budget cap
- The budget request for combat almost doubled from 2008 to 2011

### 3.3 Army Combat Data: 2008-2011

For consideration of combat deployments, first it is important to understand how many Soldiers were actually deployed into the theater of combat operations during the given period of the study, and what percentage of the Active Duty Army these numbers of Soldiers represented during the given time period. Table 3 displays the average number of active duty Soldiers deployed to all combat theaters of operations, and the percentage of the Active Duty actual end strength this represents. The number deployed fluctuates at any given time because of personnel and units entering and leaving the theater of operations, with overlap occurring between the departing unit and the newly arriving unit. Numbers are taken from the Department of the Army budget requests for fiscal year 2008 – 2011, and are rounded to the nearest thousand Soldiers.
Table 3 - Army Active Duty Average Numbers Deployed

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th># Active Duty Soldiers Deployed (Thousands)</th>
<th>% Active Duty Soldiers Deployed to Combat</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>154000</td>
<td>28.33%</td>
</tr>
<tr>
<td>2009</td>
<td>130000</td>
<td>23.51%</td>
</tr>
<tr>
<td>2010</td>
<td>113100</td>
<td>19.98%</td>
</tr>
<tr>
<td>2011</td>
<td>54500</td>
<td>9.64%</td>
</tr>
</tbody>
</table>

*Key Points*
- From 2008-2011, the percentage of Active Duty Soldiers deployed to combat operations decreased from 28% to 9.6%
- % Deployed: Calculated by # Deployed divided by Actual # from Table 1
- During the same time period, the budget for combat operations almost doubled

The Defense Casualty Analysis System maintains casualty data for conflicts from the Korean Way to the present, and was the source used to obtain data for losses incurred in combat operations during the time period considered for this study. Reports are published on the Defense Casualty Analysis System website, with casualties categorized by major named combat operation, which for the time period of 2008-2011 includes Operation Iraqi Freedom, Operation Enduring Freedom, and Operation New Dawn. Of note, Operation New Dawn is the named operation for the continuation of US military involvement in Iraq after August 2010, in preparation for the withdrawal of US forces.

The information reported includes both combat hostile related fatalities which are considered killed in action and those who were injured but did not die which are considered wounded in action. Non-hostile deaths and injuries, including in theater suicides, during a combat operation are not included, as they are not considered to be directly caused by combat operations. Suicides while deployed in combat operations were previously included in the data.
for suicide. Table 4 shows the statistics for the same four year period as covered in the suicide death section, first by each named operation and then the totals for the given calendar year.

<table>
<thead>
<tr>
<th>Year</th>
<th>Operation Iraqi Freedom</th>
<th>Operation New Dawn</th>
<th>Operation Enduring Freedom</th>
<th>Annual Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>193</td>
<td>1795</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2009</td>
<td>68</td>
<td>586</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2010</td>
<td>15</td>
<td>288</td>
<td>4</td>
<td>74</td>
</tr>
<tr>
<td>2011</td>
<td>0</td>
<td>0</td>
<td>34</td>
<td>219</td>
</tr>
</tbody>
</table>

Table 4 - Army Combat Deaths 2008-2011

**Key Points**
- From 2008-2011, the number of Soldiers killed in action was fairly constant
- From 2008-2011, the number of Soldiers wounded in action increased
- Wounded in action considered because they represent a loss of capability

For spending in combat related to Army deaths, there are three areas considered that can be directly attributed to preventing loss of life: spending on individual body armor, force protection, and medical and casualty support. As with the general budget data presented previously, the data in Table 5 is derived from the budget requests for the Department of Defense and the Army that are publicly available on the Under Secretary of Defense (Comptroller) and Assistant Secretary of the Army for Financial Management and Comptroller websites. The budget is reported by fiscal year, and reflects the spending for the year as requested by forecasted amount prior to the beginning of the fiscal year.
Table 5 - Combat Budget Request by Functional Category ($ Millions)

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Individual Body Armor ($ Mn)</th>
<th>Force Protection ($ Mn)</th>
<th>Medical and Casualty Support ($ Mn)</th>
<th>Total ($ Mn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>1081.331</td>
<td>1850.883</td>
<td>498.553</td>
<td>3430.767</td>
</tr>
<tr>
<td>2009</td>
<td>639.3</td>
<td>1681.105</td>
<td>272.971</td>
<td>2593.376</td>
</tr>
<tr>
<td>2010</td>
<td>300</td>
<td>1589.855</td>
<td>270</td>
<td>2159.855</td>
</tr>
<tr>
<td>2011</td>
<td>326.959</td>
<td>1105.544</td>
<td>226.834</td>
<td>1659.337</td>
</tr>
</tbody>
</table>

**Key Points**
- Table reflects combat spending levels for areas directly impacting prevention of loss of life (force protection includes measures taken to mitigate hostile action).
- Combat spending for prevention of loss of life decreased with the reduced number of Soldiers deployed.

### 3.4 Army Suicide Data: 2008-2011

The Department of Defense created the Department of Defense Suicide Event Report (DoDSER), in January 2008, to unify surveillance of suicide reporting within all four branches of the uniformed service (Reger, Luxton, Skopp, Lee, Gahm, 2009). Annual reports published from 2009-2012 provide data about suicides within the Department of Defense for calendar years 2008-2011. Due to the merger of reporting for all Department of Defense forces in 2008, the individual Army statistics were not available for years prior to 2008, and the data for 2012 had not yet been published at the time this research was conducted.

The information reported includes suicides that occurred within an active combat zone, because the cause of death is classified as non-combat related. Table 6 shows the statistics for the number of completed Soldier Suicides, as well as the numbers for non-fatal events including suicide attempts, self-harm with no intent to die, and expression of suicidal ideations. The numbers are pulled from the Army chapter of the annual DoDSER for each year. As the DoDSER includes reference to previous years, where there is a discrepancy between the numbers...
reported, the number from the most current DoDSER is reported, as this number addresses some
deaths being categorized as suicides after the previous DoDSER was released.

<table>
<thead>
<tr>
<th>Year</th>
<th>Soldier Suicides</th>
<th>Suicide Attempts</th>
<th>Self Harm</th>
<th>Ideation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>140</td>
<td>570</td>
<td>410</td>
<td>1003</td>
</tr>
<tr>
<td>2009</td>
<td>164</td>
<td>502</td>
<td>347</td>
<td>1198</td>
</tr>
<tr>
<td>2010</td>
<td>160</td>
<td>413</td>
<td>237</td>
<td>918</td>
</tr>
<tr>
<td>2011</td>
<td>167</td>
<td>432</td>
<td>186</td>
<td>859</td>
</tr>
</tbody>
</table>

Table 6 - Army Reported Suicides 2008-2011

<table>
<thead>
<tr>
<th>Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suicides increased after 2008 but remained fairly constant 2009-2011</td>
</tr>
<tr>
<td>Suicidal actions (attempts/self-harm/ideation) that did not result in death are considered because they represent a loss of capability, similar to wounded in action</td>
</tr>
</tbody>
</table>

Spending tied to the prevention of suicide is more difficult to pinpoint because, as noted in a Congressional Research Service 2013 Report by Blakeley and Jansen, there is no specific line item requirements for the Department of Defense budget to address suicide prevention costs since it falls under the Army’s management account (p. 20). Accordingly, the numbers available are for all funding for psychological health, which is not limited to suicide prevention, but includes post-traumatic stress disorder, and traumatic brain injury. Therefore, the spending associated with suicide prevention should be considered a high estimate, and likely a ceiling value, because of the necessary inclusion of other conditions benefitting from the funding. Table 7 reflects the funding reported to Congress for military psychological health.
Table 7- Funding for Psychological Health (including PTSD and TBI) ($ Millions)

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Operations/Maintenance ($ Mn)</th>
<th>Research/Development ($ Mn)</th>
<th>Procurement ($ Mn)</th>
<th>Total ($ Mn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>454.5</td>
<td>506.1</td>
<td>18.9</td>
<td>979.5</td>
</tr>
<tr>
<td>2009</td>
<td>575</td>
<td>163.1</td>
<td>20</td>
<td>758.1</td>
</tr>
<tr>
<td>2010</td>
<td>655.9</td>
<td>230.3</td>
<td>0</td>
<td>886.2</td>
</tr>
<tr>
<td>2011</td>
<td>669.2</td>
<td>112.6</td>
<td>0</td>
<td>781.8</td>
</tr>
</tbody>
</table>

Key Points
- Funding categories reflect budget categories reported to Congress
- Funding is for psychological health, addressing post-traumatic stress and traumatic brain injury in addition to suicide prevention, so values are a ceiling for suicide prevention spending

3.5 Assumptions Made about Data for the Study

The scope of the study is purposefully limited to allow for a focused effort. The population considered for this study is the active duty component of the Army, and Army civilians and the members of the Army Reserve and National Guard are not considered for the study, nor are the other services within the Department of Defense. Future work could include addressing these other components of the Army, the other services within the Department of Defense, or the population of veterans that have left active duty service to determine how the federal government’s trade-offs differ for these different elements.

Figures for combat spending are those which can be directly attributed to the prevention of the loss of life, which excludes spending that may indirectly reduce the loss of life such as training and equipment maintenance for combat operations. Therefore, the reported figures for combat expenditure should be considered as the minimum expenditure, as accounting for the indirect expenditure would only serve to increase the monetary investment. In contrast, the figures for spending on suicide prevention are scarcer, and are not reported in as great a level of
detail. The suicide spending figures therefore include the costs of all mental health disorder treatment and medical or counseling resources that are available for suicide prevention, and associated mental health conditions. Further work could include determining how to account for the impact of these indirect investments, but they will not be included within the study.
CHAPTER 4
MODEL DEVELOPMENT

4.1 Decision Problem

As addressed in the introduction, the mandatory budget caps for the Army are a pressing concern, and requires that the Secretary of the Army understands the value the Army is able to obtain from every funded program. In the current political environment, the future years likely hold a reduction in the number of Soldiers deployed to a combat zone, which should reduce the necessary spending for combat, but this does not reduce the importance of the consideration about the impact of combat operations on loss of human life. Suicide prevention also remains a very politically sensitive topic, receiving scrutiny from Congress due to the uptick in suicide deaths among Soldiers and other service members.

Without looking at the overall Army budget, this study will focus on determining spending levels for just combat operations and suicide prevention. The decision tree for the Secretary of the Army would include the decision of how much to spend on combat and suicide prevention, with each level of spending having an associated probability of loss of human life. The decision tree for this appears in Figure 2. Due to the budget cap, the spending levels can be viewed as choosing between alternative budget proposals, which will include other programs, but the focus for this decision just looks at the spending levels for combat and suicide, indicated as $C, S$, with the subscript $C$ indicating the funding level for combat and the subscript $S$ indicating the funding level for suicide prevention. Each spending level will have associated probability distributions for the number of deaths associated with each event given the funding level chosen for that event. These probability distributions are not publicly available, but would be information provided to the decision maker. The value to the decision maker for each alternative
is dependent on both the amount of money that was spent for each area, and the number of
deaths that occurred in each area.

![Budget Allocation to Request Decision Tree](image)

**Figure 2 - Budget Allocation to Request Decision Tree**

**Key Points**
- Simplified decision tree indicating the need to choose funding levels for
  programs when submitting the overall budget allocation request
- Funding categories reflect budget categories reported to Congress
- Funding is for psychological health, addressing post-traumatic stress and
  traumatic brain injury in addition to suicide prevention, so values are a ceiling for
  suicide prevention spending

4.2 Modeling Assumptions

This study assumes that spending and loss of lives are both monotonically decreasing,
meaning that lower levels are always preferred to higher levels. Therefore, any proposed
alternative that includes both a lower amount of spending and a risk to human life will be
preferred to one in which both are higher. However, the assumption is that increased spending is
necessary for reducing the expected number of casualties. For example, Soldiers wearing body armor will have an increased chance of surviving being shot because the body armor will stop rounds up to a certain caliber that would prove fatal if they were not stopped by the body armor, and therefore increased spending on body armor would expect to decrease the risk to human life in combat. Similarly, providing resources that help Soldiers identify the signs exhibited by a potentially suicidal Soldier cost money to distribute and prepare, but are expected to decrease the risk to human life. This is the reason why these are assessed as a trade-off, because the expectation is that to improve in one attribute, it is necessary to decrease performance in the other. This study does not seek to establish what the accepted trade-off level is for the Army, just whether the trade-off is consistent across different areas. The trade-off between money and human lives is assumed to be consistent within a given area (combat or suicide).

The budget for the fiscal year is taken as being deterministic. Barring any unusual circumstances such as the budget stalemate seen in 2013, the Army submits a budget through Department of Defense to Congress, and it knows what has been approved for the year prior to the start of the fiscal year. The loss of human life, however, is an uncertain event, and there is no way to predict for certain what the losses will be for a given year. Losses can be assumed to have an underlying probability distribution, assessed by the decision maker, which can then be updated as needed using Bayesian updating. In updating the prior distribution, the decision maker can account for advances in technology, changes in the enemy threat, and any other measures taken that are likely to change the likelihood of loss. Without the information used by the Army to assess both the prior distribution and the updated distribution, this study looks at the actual numbers as a substitute for this information, and assumes that they are deterministic. This does introduce a source of error, and with greater access to decision makers at the Army level,
there could be future work involved in understanding how the Army looks at the probability distribution, especially given the work by Howard (1970) that illustrates the issues with using classical statistical methods such as hypothesis testing to make inferences about observed data rather than taking a decision analytical approach.

**Key Points**
- Assume that funding level and expected loss are both deterministic
- Assume that the decision maker is consistent in making trade-offs between money and human life internal to each area (combat or suicide), allowing for curve-fitting internal to each area of consideration

**4.3 Initial Comparison: Raw Composite Data**

Prior to assessing the trade-offs, the raw data for both combat losses and suicide losses is presented side by side. This first look at the raw figures for spending in both areas was the genesis for believing that there exists the possibility that the trade-offs made by the Army are in fact inconsistent between the two areas. Due to the scale, two separate plots are provided to visualize the change from year to year. Figure 3 depicts both combat and suicide losses with death only for each calendar year from 2008-2011. The ratio of Combat to Suicide Deaths is indicated between the relevant lines.
Figure 3 – Deaths for Active Duty Army by Calendar Year

Figure 4 depicts both combat and suicide losses with wounded and lesser suicide events included. The ratio of Combat to Suicide Losses is indicated above the lines.

Figure 4 - Losses for Active Duty Army by Calendar Year
During this four year period, on an annual basis, the Army lost a combined total of less than 0.1% of end strength to combat deaths and completed suicides, and had less than 1% of the end strength impacted by being wounded in combat or by a lesser suicidal event (unsuccessful attempts, self-harm with no intent to die, and expressing suicidal ideations). By visual inspection, the losses are seen as approximately the same scale for the time period addressed within the study. Given the similar number of Soldiers impacted by both causes of loss, it should be expected that the trade-off made to prevent loss of life for either cause should be similar if made following the principles of decision analysis.

A similar side by side comparison of the spending is seen in Figure 5. During 2008, the spending on combat is over three and a half times as great as the spending on mental health, but this ratio narrows to just over two times by the end of the four year period. The change in the ratio of spending looks to be different than the actual losses experienced during this time period, and suggests that there are inconsistencies in the trade-off between the investment of monetary resources and the loss of life.

Key Points
- Figure 3 shows combat and suicide losses due to actual deaths only
- Figure 4 includes all losses to capabilities, including wounded in action for combat, and lesser suicide events (Soldiers that attempted suicide but were unsuccessful, performed self-harm, or expressed the intent to commit suicide)
Figure 5 - Combat and Suicide Spending from Army Annual Budget

<table>
<thead>
<tr>
<th>Year</th>
<th>Combat (Millions)</th>
<th>Suicide (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>3,430.767</td>
<td>979.5</td>
</tr>
<tr>
<td>2009</td>
<td>2,593.376</td>
<td>758.1</td>
</tr>
<tr>
<td>2010</td>
<td>2,159.855</td>
<td>886.2</td>
</tr>
<tr>
<td>2011</td>
<td>1,659.337</td>
<td>781.8</td>
</tr>
</tbody>
</table>

**Key Points**
- Figure 5 indicates that the ratio of combat to suicide spending decreased during the period 2008-2001.
- Potential disconnect between changes in spending ratio versus loss ratio (Figure 3 shows relatively constant ratio of combat deaths to suicide deaths, and Figure 4 shows increasing ratio of combat losses with wounded and suicide including lesser event).

Given the differences shown in the raw data, there is reason to believe that there are inconsistencies in inferred trade-offs. Analysis will include looking at the possible trade-offs inferred for each area, and using the combination of actual losses and lesser events to determine if there could be a formulation that displays consistency.

**4.4 Data Preparation for Developing the Model**

To begin, first the number of combat killed in action and suicide fatalities are plotted against the spending for each area in Figure 6. This does not depict the value or utility
associated with the points, but serves to show the relationship between spending and the loss of human life.

![Figure 6 - Fatalities versus Spending](image)

**Key Points**
- Figure 6 plots the number of deaths against the annual spending for 2008-2011
- These points will be assessed to determine if they can fit on curve with a consistent trade-off

From the plot, it is observed that the mental health spending is lower for all points, and the number of fatalities is lower for all points. As both of these attributes are monotonically decreasing in for value, the decision maker would derive a higher value from the combination of spending and lives lost associated with suicides compared to combat, even without the value function for the decision maker. There is less variation between the fatalities due to suicides than to combat, but there is a greater variation for the amount spent on preventing combat fatalities.
In contrast to the initial plot, which did not account for wounded or attempted suicides, Figure 7 accounts for both killed and wounded, and successful suicides and lesser suicidal events. This results in considering a higher number of Soldiers impacted in both areas.

Figure 7 - Fatalities & Lesser Events versus Spending

**Key Points**
- Figure 7 plots the number of losses (including wounded in action and lesser suicide events) against the annual spending for 2008-2011
- These points will be assessed to determine if they can fit on curve with a consistent trade-off

One reason for looking at the number of wounded in action and lesser suicide events is that these represent lives that could have potentially been lost without the preventive measures taken. Therefore, the greater spread for the number of killed in action plus the number of wounded in action for combat compared to the number of suicides plus lesser events likely indicates that there is a greater variance to the underlying probability distribution for dying in combat compared to the distribution for dying by suicide.
Next, the per-Soldier spending in each area is calculated by dividing the total amount spent for each area by the total number of Soldiers on active duty in the Army. Additionally, the combat spending per-Soldier is also calculated against the average number of Soldiers that served in combat during the time period. All calculated values are shown in Table 8.

<table>
<thead>
<tr>
<th>Year</th>
<th>Combat</th>
<th>Combat (Only Deployed Soldiers)</th>
<th>Suicide</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>$6,310.68</td>
<td>$22,277.71</td>
<td>$1,801.73</td>
</tr>
<tr>
<td>2009</td>
<td>$4,689.28</td>
<td>$19,949.05</td>
<td>$1,370.78</td>
</tr>
<tr>
<td>2010</td>
<td>$3,815.69</td>
<td>$19,096.86</td>
<td>$1,565.60</td>
</tr>
<tr>
<td>2011</td>
<td>$2,934.47</td>
<td>$30,446.55</td>
<td>$1,382.58</td>
</tr>
</tbody>
</table>

Table 8- Spending Per Active Duty Soldier

**Key Points**
- Table 8 indicates how the spending divides for all Soldiers in the Army
- Combat divides the amount spent on combat from Table 5 by the actual number of Soldiers on Active Duty from Table 1
- Combat (Only Deployed) divides the amount spent on combat from Table 5 by the number of deployed Soldiers from Table 3
- Suicide divides the amount spent on suicide from Table 7 by the actual number of Soldiers on Active Duty from Table 1

After exploring the raw data, there does not appear to be a consistent relationship between the amount of money spent on combat operations and suicide prevention, when compared to the losses experienced in each area. The next step will be to explore the data using the principles of decision analysis, with specific focus on trade-offs, and determine if it possible to establish that a consistent trade-off is made between money and human lives for these two different areas.

**4.5 Inferring Trade-Offs from Curve Fitting**

Beyond the assumptions laid out in the theory section of this study, the study relies on inferring trade-offs from the relationship between the historical data for the budget allocation request and the loss of human life in combat and due to suicides. The data for each area of the
study is plotted, with a data point for each year of the study. The next step is to curve-fit these points, using the value trade-off function identified previously. The curve fitting does not directly assess trade-offs since it does not reflect the decision making, but shows the actual outcomes for the historical period. In using this curve-fitting to infer trade-offs, it is assumed that there was a causal relationship between the spending level and the loss of lives. For the purposes of this study, the best curve-fit is assumed to represent an indifference by the decision maker to increased spending along the line if it results in a corresponding decreased loss of life.

4.6 Curve-Fitting Data for Money and Human Life

For establishing the curve-fit that will be used to infer the trade-off between money and human lives, this study initially uses the equation introduced in the theory section, where:

\[ V(x, y) = xy^\eta \]

Although the number of fatalities and wounded are probabilistic, the raw numbers are used for computing value functions in an attempt to simplify the calculation to determine if there is any possible way to establish that similar values of \( \eta \) could be used in determining the spending level across both areas since the decision maker’s risk tolerance is unknown and would make calculating the utility function more complicated. For ensuing calculations, \( x \) is the spending expressed in millions of dollars, and \( y \) is the loss of lives (with indications in each section if wounded in action/lesser suicidal events are included). Spending is the decision variable for the decision maker, as indicated in the decision tree shown in the initial problem set up. The number of expected casualties is conditional upon the level of spending within each area, so it is a dependent variable for this consideration.
In establishing a value for $\eta$, the calculation was made to compare the spending and losses for pairs of years, for both combat and suicide losses, and looking at just deaths and the combinations of deaths and injuries and attempts. The supposition used for this is that the decision maker would seek to arrive at the same value level each year, using the same value for $\eta$. Therefore the equation is solved for the value of $\eta$ by the following equation:

$$V(x_{year\ 1}, y_{year\ 1}) = x_{year\ 1}y_{year\ 1}^\eta = x_{year\ 2}y_{year\ 2}^\eta = V(x_{year\ 2}, y_{year\ 2})$$

There is no clear value for $\eta$ that emerges using this calculation for either area of loss. However, in general, the magnitude of the possible values of $\eta$ seems larger for combat than for suicide. However, the lack of a clear value for $\eta$ could be due to other factors, such as different decision makers during different years, or aiming for different value levels across different years.

**4.7 Estimating the Trade-off for Combat**

Using the values for $\eta$ that were calculated previously, the next step was to plot different contours by conducting curve-fitting with different values for $\eta$ and assess how they compared to the points observed in the data. Given that the calculated values for $\eta$ varied, plots were created using values that included several of the calculated ones, and compared with the actual observed points.
As stated previously, negative values were not considered feasible candidate values for $\eta$ because that would imply that the decision maker would accept a higher level of both attributes, and this is not the case. Accordingly, for combat, contours were plotted using values for $\eta$ that ranged from 1 to 2.5 to obtain the best curve-fit for the data. Based on the comparison of the plots, the contour that best fits the data points is using a value of 1.5 for $\eta$. The resulting plot for this value of $\eta$ is shown in Figure 8.

![Figure 8 - Contour for Combat](image)

The data points for three out of four years from the study falls along this best curve-fit, which allows for the assumption that the Secretary of the Army aims to achieve the same value every year given the amount spent on combat and the number of killed in action and wounded in action expected. Accordingly, this is the value ($\eta = 1.5$) that will be considered for the duration of the study.
If the decision maker assumes that the isopreference contours would follow the same shape at different value levels, the calculated value for the decision maker for a paired funding level and expected number of casualties can be determined for combat.

\[ V_{\text{Combat}}(x,y) = xy^{1.5} \]

However, because the value function is not normalized, the decision maker can only use it to determine the ordering of the alternatives, and cannot assign any importance to the number itself.

4.8 Estimating the Trade-off for Suicide

For suicide, the best curve-fit was plotted that considered values for \( \eta \) that ranged from 0.25 to 1.0, as again the negative values were not considered to be feasible candidates to represent the observed trade-off level between spending and fatalities. Based on the comparison of the plots for the range of values, the contour that best fits the data points is using a value of 0.6 for \( \eta \). The resulting plot can be seen in Figure 9.

Figure 9 - Contour for Suicide
The data points for two out of four years from the study falls along this contour. The data does not match as easily to the contours as it did for the combat data, but the two points that are off the contour are approximately equidistant from the contour. Accordingly, this is the value ($\eta = 0.6$) that will be considered for the duration of the study.

Again, assuming the decision maker assumes that the contours would follow the same shape at different value levels, the calculated value for the decision maker for a paired funding level and expected number of casualties can be determined for suicide prevention.

$$V_{Suicide}(x, y) = xy^{0.6}$$

Again, this will only be useful for determining relative value for the purpose of ordering alternatives, and nothing can be determined about the relative values.

4.9 Model Limitations

The main limitations of the model are trying to use observed decisions to estimate the decision process, and assessing an assumed causal relationship between spending and lives to infer the decision maker’s trade-off between spending and human life. As discussed in the theory section of this study, a truly rational decision process does not assess the outcome of a decision to determine whether the decision maker made a good decision. However, there is no published information about the decision process that went into determining the budget request made by the Army. Instead, by showing the possible implications of the model, using the publicly available data, this study can be used to show the important potential benefits to the Army if a normative decision analysis process is followed.

Additionally, the observed data comes from a narrow window of time. It is possible that the results observed for the four year period would not hold outside this window. Again, the intent is that this study can be used to demonstrate the importance of looking at these areas using
decision analysis, and potentially provide the motivation for the Army to provide additional data and access to decision makers to test the robustness of the basic model developed here. Finally, the model assumes that the decision is deterministic, which eliminates the requirement to understand the decision maker’s risk tolerance level.

4.10 Model Improvement

With access to the decision maker, the primary improvement to the study would be to use the methods to assess utility developed by Howard (1970), and expanded on by Abbas (2003, 2004, 2006, 2009) and others within the field of decision analysis. Entropy methods for utility elicitation could be used to incorporate the idea that the areas considered have inherent uncertainty, and are not adequately addressed using a deterministic model based on historical data.

The model constructed assumes that the attributes (money spent) and casualty loss are both deterministic, and returns a value that is expressed as a function of the funding level, the casualties, and the trade-off for the two attributes, expressed as $\eta$. Given that this study has demonstrated that there is likely future value to be obtained by further assessing budgetary decision making from a decision analytic, a few areas have been identified for ways to improve the basic model. These areas include framing the model in terms of utility as discussed in the theory section of this study, and looking at the use of utility copulas rather than the current trade-off set-up. Additionally, in addressing the framework of the model, it will be important to address the idea of uncertainty, especially as it relates to the loss of human life. Further information about the decision maker’s assessment of the probability of loss of life would allow for the use of Bayesian updating of the probability distributions given the observed data.
CHAPTER 5

RESEARCH QUESTION 1

Having developed a basic model for establishing value using a trade-off between money and human lives for spending on both combat and suicide prevention, the results can be used to address the first research question of the study:

Does available data suggest that the Army makes consistent trade-offs between money and human life?

**Key Points**
- For analysis all numbers are assumed to be deterministic and consistent within the area considered
- Assessed trade-offs only indicate indifference, they do not guarantee outcomes or a reduction in casualties with additional spending
- The focus for this question is trade-offs in different areas (combat and suicide) since each area is assumed to be internally consistent to construct the model.

5.1 Identified Values for $\eta$

In order to assess whether trade-offs are consistent for money and human life, the two equations developed in Chapter 4 are considered:

\[
V_{\text{Combat}}(x, y) = xy^{1.5}
\]

\[
V_{\text{Suicide}}(x, y) = xy^{0.6}
\]

In each equation, $x$ is the spending expressed in millions of dollars, and $y$ is the loss of lives including wounded in action and lesser suicidal events, so there is no difference in the variables due to differences in units. Therefore, since each formulation has a distinct value for $\eta$, this indicates that with the data that was assessed for this study, a different trade-off is made between spending and expected loss of lives for combat than for suicide prevention. The values are not close, so the results would indicate that the potential does indeed exist that the Army does not make consistent trade-offs across all areas of the budget.
Given the limited data available for this study, there is insufficient evidence to state unequivocally that the trade-off is different between these two areas. It would require further work, and possibilities to explore this through future research are addressed shortly. It can only be stated that with the limited data available, there likely still exists the possibility that the trade-off inferred is different. Therefore, it is worthwhile to explore what the practical significance of different values for $\eta$ mean when looking at budget allocations across both areas.

5.2 Interpreting Different Values for $\eta$

Taking the value calculated for $\eta$ in section 4.6, the next step was to determine what the significance was of the trade-off value inferred by the model by looking at points that fall along an isopreference contour. This was accomplished for both combat and suicide by maintaining a constant value, and taking steps of either $1$M or $1$ casualty. As the slope of the value function changes, the relationship between the increase in money spent relative to the number of casualties changes, when assessing the points at which the decision maker remains indifferent.

5.2.1 Combat Interpretation of $\eta = 1.5$

Table 9 was calculated using the isopreference contour identified for combat with a value of $1.5$ for $\eta$. When different points were assessed along the contour, it was found that at lower funding levels ($1.4B$), each increase of $1$ million needed to result in a greater decrease to the expected number of casualties than when the funding was considered at the higher end ($2.5B$) in order for the decision maker to remain indifferent between the points. This was calculated by using the trade-off identified, and solving for the value of $d$ (the decrease in casualties) that would balance the following equation:

$$V_{\text{Combat}}(x, y) = V_{\text{Combat}}(x + 1 \text{ Million}, y - d)$$
The resulting values of $d$ indicate the number by which the expected number of combat casualties would need to decrease to offset the increase in spending the additional $1$ Million.

<table>
<thead>
<tr>
<th>Funding Level ($Mn$)</th>
<th># Casualties</th>
<th>Decrease in Casualties for $1$ Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>1400</td>
<td>4813.191</td>
<td>2.291</td>
</tr>
<tr>
<td>1500</td>
<td>4596.754</td>
<td>2.042</td>
</tr>
<tr>
<td>1600</td>
<td>4403.170</td>
<td>1.833</td>
</tr>
<tr>
<td>1700</td>
<td>4228.758</td>
<td>1.658</td>
</tr>
<tr>
<td>1800</td>
<td>4070.650</td>
<td>1.507</td>
</tr>
<tr>
<td>1900</td>
<td>3926.537</td>
<td>1.377</td>
</tr>
<tr>
<td>2000</td>
<td>3794.537</td>
<td>1.264</td>
</tr>
<tr>
<td>2100</td>
<td>3673.099</td>
<td>1.166</td>
</tr>
<tr>
<td>2200</td>
<td>3560.932</td>
<td>1.079</td>
</tr>
<tr>
<td>2300</td>
<td>3456.954</td>
<td>1.002</td>
</tr>
<tr>
<td>2400</td>
<td>3360.248</td>
<td>0.933</td>
</tr>
<tr>
<td>2500</td>
<td>3270.033</td>
<td>0.872</td>
</tr>
</tbody>
</table>

Table 9 - $\eta$ Significance – Indifference Calculations Combat (Funding)

Key Points

- Given the funding level and the current number of casualties, Table 9 shows the decision maker would be indifferent to spending an additional $1$ Million and reducing the expected number of casualties by the amount shown in the far right column.
- This was calculated by using the trade-off identified, and solving for the value of $d$ (the decrease in casualties) that would balance the following equation:

$$V_{\text{Combat}}(x,y) = V_{\text{Combat}}(x + 1\text{ Million}, y - d)$$

Having varied the funding level in the step of $1$ Million, the next way of looking at the assessed trade-off was to use the isopreference contour to calculate the increase in funding that would make the decision maker indifferent given that they were able to reduce the number of casualties by 1. The results in Table 9 were calculated by using the trade-off identified, and solving for the value of $i$ (the increase in funding) that would balance the following equation:

$$V_{\text{Combat}}(x,y) = V_{\text{Combat}}(x + i, y - 1)$$
The resulting values of \( i \) indicate the additional funding, in millions, required for which the decision maker would be indifferent given a reduction in the expected number of casualties by one. At the given casualty level, this amount could be interpreted as an approximation for the Army’s VSL.

<table>
<thead>
<tr>
<th># Casualties</th>
<th>Funding Level ($ Mn)</th>
<th>Increase in Funding for Reduction 1 Casualty ($ Mn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>16826.93</td>
<td>25.27</td>
</tr>
<tr>
<td>1250</td>
<td>12040.37</td>
<td>14.46</td>
</tr>
<tr>
<td>1500</td>
<td>9159.42</td>
<td>9.17</td>
</tr>
<tr>
<td>1750</td>
<td>7268.55</td>
<td>6.23</td>
</tr>
<tr>
<td>2000</td>
<td>5949.22</td>
<td>4.46</td>
</tr>
<tr>
<td>2250</td>
<td>4985.76</td>
<td>3.33</td>
</tr>
<tr>
<td>2500</td>
<td>4256.91</td>
<td>2.56</td>
</tr>
<tr>
<td>2750</td>
<td>3689.83</td>
<td>2.01</td>
</tr>
<tr>
<td>3000</td>
<td>3238.34</td>
<td>1.62</td>
</tr>
<tr>
<td>3250</td>
<td>2871.97</td>
<td>1.33</td>
</tr>
<tr>
<td>3500</td>
<td>2569.82</td>
<td>1.10</td>
</tr>
<tr>
<td>3750</td>
<td>2317.17</td>
<td>0.93</td>
</tr>
<tr>
<td>4000</td>
<td>2103.37</td>
<td>0.79</td>
</tr>
<tr>
<td>4250</td>
<td>1920.53</td>
<td>0.68</td>
</tr>
<tr>
<td>4500</td>
<td>1762.73</td>
<td>0.59</td>
</tr>
<tr>
<td>4750</td>
<td>1625.42</td>
<td>0.51</td>
</tr>
<tr>
<td>5000</td>
<td>1505.05</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Table 10 -- \( \eta \) Significance – Indifference Calculations Combat (Casualties)

**Key Points**

- Given the funding level and the current number of casualties, Table 10 shows the decision maker would be indifferent to decreasing expected casualties by 1, and increasing the funding by the amount shown in the far right column.
- This was calculated by using the trade-off identified, and solving for the value of \( i \) (the increase in funding) that would balance the following equation:

\[
V_{\text{Combat}}(x, y) = V_{\text{Combat}}(x + i, y - 1)
\]

- Given casualty numbers for 2008-2011, the assessed trade-off function implies the Army’s VSL would be between approximately $790 K and $4.46 Million.
5.2.2 Suicide Interpretation of $\eta = 0.6$

Table 11 was calculated using the isopreference contour identified for suicide with a value of 0.6 for $\eta$. As was done for combat, the next step was to determine what the significance was by looking at points that fall along the isopreference contours. Looking at steps of $1$ million dollars, results showed that at lower funding levels ($700M$), each $1$ million has a higher decrease in the number of casualties at the same value level compared to a change in $1$ million when at a higher funding level ($1.15B$) in order for the decision maker to remain indifferent between the points. This was calculated by using the trade-off identified, and solving for the value of d (the decrease in casualties) that would balance the following equation:

\[ V_{\text{Suicide}}(x, y) = V_{\text{Suicide}}(x + 1 \text{ Million}, y - d) \]

The resulting values of d indicate the number by which the expected number of suicide casualties would need to decrease to offset the increase in spending the additional $1$ Million.

<table>
<thead>
<tr>
<th>Funding Level ($\text{Mn}$)</th>
<th># Casualties</th>
<th>Decrease in Casualties for $\text{1 Mn}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td>2560.157</td>
<td>6.084</td>
</tr>
<tr>
<td>750</td>
<td>2282.064</td>
<td>5.062</td>
</tr>
<tr>
<td>800</td>
<td>2049.337</td>
<td>4.262</td>
</tr>
<tr>
<td>850</td>
<td>1852.387</td>
<td>3.626</td>
</tr>
<tr>
<td>900</td>
<td>1684.066</td>
<td>3.114</td>
</tr>
<tr>
<td>950</td>
<td>1538.948</td>
<td>2.696</td>
</tr>
<tr>
<td>1000</td>
<td>1412.852</td>
<td>2.652</td>
</tr>
<tr>
<td>1050</td>
<td>1302.510</td>
<td>2.065</td>
</tr>
<tr>
<td>1100</td>
<td>1205.338</td>
<td>1.824</td>
</tr>
<tr>
<td>1150</td>
<td>1119.267</td>
<td>1.621</td>
</tr>
<tr>
<td>1200</td>
<td>1042.624</td>
<td>1.446</td>
</tr>
<tr>
<td>1300</td>
<td>912.412</td>
<td>1.169</td>
</tr>
<tr>
<td>1400</td>
<td>806.399</td>
<td>0.959</td>
</tr>
<tr>
<td>1500</td>
<td>718.805</td>
<td>0.798</td>
</tr>
<tr>
<td>1600</td>
<td>645.501</td>
<td>0.672</td>
</tr>
</tbody>
</table>

Table 11 - $\eta$ Significance – Indifference Calculations Suicide (Funding)
Having varied the funding level in the step of $1 Million, the next way of looking at the assessed trade-off was to use the isopreference contour to calculate the increase in funding that would make the decision maker indifferent given that they were able to reduce the number of casualties by 1. The results in Table 12 were calculated by using the trade-off identified, and solving for the value of $i$ (the increase in funding) that would balance the following equation:

$$V_{Suicide}(x, y) = V_{Suicide}(x + $1 Million, y - 1)$$

The resulting values of $i$ indicate the additional funding, in millions, required for which the decision maker would be indifferent given a reduction in the expected number of casualties by one. At the given casualty level, this amount could be interpreted as an approximation for the Army’s VSL.

**Key Points**

- Given the funding level and the current number of casualties, Table 11 shows the decision maker would be indifferent to spending an additional $1 Million and reducing the expected number of casualties by the amount shown in the far right column.
- This was calculated by using the trade-off identified, and solving for the value of $d$ (the decrease in casualties) that would balance the following equation:

$$V_{Suicide}(x, y) = V_{Suicide}(x + $1 Million, y - d)$$
### Table 12 - $\eta$ Significance – Indifference Calculations Suicide (Casualties)

<table>
<thead>
<tr>
<th># Casualties</th>
<th>Funding Level ($ Mn)</th>
<th>Increase in Funding for 1 Casualty</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>3692.32</td>
<td>8.89</td>
</tr>
<tr>
<td>500</td>
<td>2436.02</td>
<td>2.93</td>
</tr>
<tr>
<td>750</td>
<td>1909.97</td>
<td>1.53</td>
</tr>
<tr>
<td>1000</td>
<td>1607.17</td>
<td>0.97</td>
</tr>
<tr>
<td>1250</td>
<td>1405.78</td>
<td>0.68</td>
</tr>
<tr>
<td>1500</td>
<td>1260.11</td>
<td>0.50</td>
</tr>
<tr>
<td>1750</td>
<td>1148.79</td>
<td>0.39</td>
</tr>
<tr>
<td>2000</td>
<td>1060.34</td>
<td>0.32</td>
</tr>
<tr>
<td>2250</td>
<td>987.99</td>
<td>0.26</td>
</tr>
<tr>
<td>2500</td>
<td>927.47</td>
<td>0.22</td>
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<tr>
<td>2750</td>
<td>875.92</td>
<td>0.19</td>
</tr>
<tr>
<td>3000</td>
<td>831.36</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Table 12 - $\eta$ Significance – Indifference Calculations Suicide (Casualties)

### Key Points
- Given the funding level and the current number of casualties, Table 12 shows the decision maker would be indifferent to decreasing expected casualties by 1, and increasing the funding by the amount shown in the far right column.
- This was calculated by using the trade-off identified, and solving for the value of $i$ (the increase in funding) that would balance the following equation:

  \[
  V_{Suicide}(x, y) = V_{Suicide}(x + i, y - 1)
  \]

- Given casualty numbers for 2008-2011, the assessed trade-off function implies the Army’s VSL would be between approximately $260K and $500K.

### 5.2.3 Comparison of Interpretations

The interesting comparison is looking at Table 9 and Table 11, and comparing where funding levels overlap. For $1.6B, the bottom of the range considered for combat and the top of the range considered for suicide prevention, significantly different results are expected for increasing or decreasing the budget by $1M. Considering just this point along each curve, a decision maker would be indifferent to adding $1M to the budget for combat and reducing the number of combat casualties by 1.833. The same decision maker would indifferent to adding
$1M to the budget for suicide while reducing the number of expected suicide casualties by 0.672. For $1M to have the same impact, combat operations would be funded around $1.7B, and suicide prevention would be funded at just below $1.15B. Then, the decision maker would be indifferent to adding $1M to either program while reducing the number of expected casualties by about 1.6.

Looking at the comparison for Table 10 and 12, there is a clear difference in the amount of increased spending that would make the decision maker indifferent between reducing casualties by 1 and the increased spending. Using the data on the number of casualties for the years 2008-2011, the VSL for combat casualties is in a range that is between 3 to 9 times higher than what is implied by the trade-off inferred for suicide prevention. Both inferred trade-offs yield a VSL that is below the levels indicated by other government agencies as addressed in Chapter 2.

5.3 Value Trade-off between Combat and Suicide

Having determined that the given data suggests that there is no consistent trade-off value for money and loss of life for combat and suicide, the final analysis with the developed model looks at whether there is the possibility of a consistent value trade-off for the decision maker between combat and suicide. The following equation was used to calculate the value for $\eta$:

\[ V_{overall\ year\ 1}(V_{Combat}, V_{Suicide}) = V_{overall\ year\ 2}(V_{Combat}, V_{Suicide}) \]

\[ V_{Combat\ 1}V_{Suicide\ 1}^\eta = V_{Combat\ 2}V_{Suicide\ 2}^\eta \]

This calculation mirrors the original setup of the model described in Chapter 4. As a reminder, the formulation calculated using the original model was as follows:

\[ V_{Combat}(x, y) = xy^{1.5} \]

\[ V_{Suicide}(x, y) = xy^{0.6} \]
Figure 10 shows the points for the four years considered for the study, and also includes the isopreference contour that best fits the data. The best fit was obtained using a value of -0.08 for $\eta$, which would yield the following trade-off between combat and suicide:

$$V_{overall} = V_C V_S^{-0.08}$$

Figure 10 - Value Trade-Off between Combat and Suicide

However, this result is problematic because of the negative value for $\eta$, which suggests that the decision maker is indifferent between increasing value in both areas or decreasing values in both areas. Given that the value derived is a function of two attributes (spending and loss of life) that are both monotonically decreasing, this would violate one of the basic assumptions of this study. Since this study assumes that spending and loss of lives are both monotonically decreasing, lower levels are always preferred to higher levels. Therefore, any proposed
alternative that includes both a lower amount of spending and a risk to human life (value) should be preferred to one in which both are higher.

Given the understanding of what the decision maker’s preferences are, and how they influence the calculation of value, the trade-off shown in Figure 10 is incompatible with suggesting that there is a consistent value trade-off between the two areas.

### Key Points
- There is an attempt to address whether there is a consistent value trade-off for the decision maker between combat and suicide. An overall value contour that fits three out of four points is obtained by curve fitting using the following formula:
  \[ V_{overall} = V_C V_S^{-0.08} \]
- A negative value for \( \eta \) violates the assumption that the value function will demonstrate monotonicity.
- This formulation does not indicate a consistent trade-off that accounts for the preferences of the decision maker.

### 5.4 Future Research

To reiterate, the data available for this study is insufficient to declare the values found to be truly representative of the Army for periods outside the four years considered for this study. However, they were useful in providing insight into the significance of having a different assessed trade-off value, and using this as justification for why this topic area has merit for further consideration, using the previously mentioned applications of utility analysis, including using different methods of utility elicitation in order to assess the decision maker’s trade-off rather than trying to infer it from the data obtained for the study.

To enhance the results found in this study, there are several possibilities for future work that would build upon these initial findings. One such possibility would be to obtain further information about data for years that are not currently published on publicly available websites. This could require asking for data using a Freedom of Information Act request, and the initial
results found in this study can be used as justification for why access to further information is necessary and could provide valuable feedback to senior Army decision makers that help to shape the budget alternatives presented to the Secretary of the Army for decision.

Another possible direction for future research would be to conduct direct assessment of value and trade-offs by eliciting responses from senior decision makers. With access to senior decision makers within the Army, it would be insightful to solicit assessments that would allow for construction of a value function based off of both monetary resources and human life, and see the range of responses given. Based on the difficulty, both culturally and personally, in placing value on human life, the anticipation is that the feedback received would further indicate a lack of consistency.
CHAPTER 6

RESEARCH QUESTION 2

Assuming that the basic model calculated in Chapter 4 is correct, it is now used to address the second research question:

*How can value using assessed trade-offs be used for decisions relating to the Army budget?*

6.1 Application to the Decision Problem

Using the value functions calculated for both combat and suicide, the decision maker can return to the decision tree in Figure 9, and can calculate the value derived from the paired spending alternatives. With the given information, each alternative can be given a preference ordering for how it fares for both combat and suicide. This can assist in further identifying alternatives that are dominated by the value from each area. It cannot be assumed that value is additive, such that the value for combat and suicide can be added together, so the current model allows for the decision maker to understand the comparison between the funding levels with regards to the rank ordering for each subcategory. Following up on the issue of dominance that was addressed previously, the calculation of value for each alternative may allow for further reduction among the number of alternatives considered if there are alternatives that are now dominated by their ranking in both combat and suicide spending.

6.2 Significance to the Army Budget

The use of the trade-off value functions can help the decision maker gain a clarity of action about the decision. The decision maker can clearly understand the rank ordering of each pairing of funding level and resultant expected casualties. Instead of looking at numbers for spending and expected number of casualties, the decision maker only has to consider one number for combat and one for suicide, and knows how each alternative ranks compared to the others. Given that the Order Rule is one of the Five Rules of Actional Thought, this ability to establish
preferences between the alternatives is a crucial step for the decision maker to be able to achieve the normative decision process.

Therefore, having this model is an important step for the decision maker within the context of enabling a normative decision analytic process to occur with further work. Primarily, it allows for a clear comparison between alternatives. However, if information is provided about the impact of spending on the expected reduction in casualties, it can also provide a framework that can be used to understand how to allocate additional resources in order to maximize the expected result, or conversely, where to be able to remove monetary resources with the minimal expected impact. Having a model that looks at the value from different funding levels could also prove beneficial to the Army in justifying budget requests through the Department of Defense and Congress. The trade-off function would allow for clearly communicating what losses the Army is indifferent to accepting, given that they are working with a budget that allows for a proposed reduction in monetary resources.

6.3 Potential Model Refinements

The most obvious, and simplest, refinement to the model would be to update the formulas with additional data from years that are not currently considered within the study, if they can be obtained from the relevant Department of Defense officials. Having additional points to fit to the curve for the value function would improve the accuracy of the trade-off value that is assessed for both combat and suicide prevention.

If, with additional data available to support the conclusion, the decision maker determines that there are inconsistencies in the trade-off between money and human life and decides that all areas within the budget should use the same trade-off function, then a single result for value can then be calculated for each alternative since they will all be scaled the same. This would allow
for the overall ordinal ranking of all of the various alternatives based on the value calculated using the combined funding level and combined expected number of casualties for both areas.

The model could also be updated to include information about the probability distributions for expected casualties. Currently, the model looks at these as if they are deterministic values, and does not address the issue of uncertainty using risk tolerance. The tree can be expanded to include the probability distribution for the expected number of casualties, using a method such as assessing the low, base, high for the distribution, or using the information known about the event to fit a curve in accordance with the maximum entropy principle. There are many possibilities for including this uncertainty, and any would add greater fidelity to the model. This would be an important refinement to the model, but will also require additional input from the decision maker to understand what the Army’s risk tolerance is as an organization.

6.4 Future Research

The lack of a clearly defined decision problem for the decision maker and the subordinate staff may also be creating some of the inconsistencies observed for the trade-off values. Therefore, it would be likely be beneficial to conduct future research that focused on starting with the decision maker and ensuring that the budget is properly framed. This aim of this work should be to create a decision tree with greater information about what decisions have to be made while developing the budget, and what the associated uncertain events are.

Additionally, work on the potential refinements to the model should be considered as possible future research, especially looking at the inclusion of uncertainty and risk tolerance within the model. Future research should focus on interaction with those senior leaders who act as decision makers for the Army budget, or those who help to shape the budget proposals. By
interviewing those who develop the budget, it should be possible to understand what they believe
the decision maker’s criteria is. It would be beneficial to have access to historical budget
ces, including both the final, approved request, and those alternatives that were rejected.
This would allow for the application of the model to compare alternatives, and see what the
decision analytic result would have been versus the actual budget that was approved.
CHAPTER 7
CONCLUSION

7.1 Study Summary

The focus of this study was to answer two different questions:

- Does available data suggest that the Army makes consistent trade-offs between money and human life?

- How can value using inferred trade-offs be used for decisions relating to the Army budget?

To answer these questions, the study relied on using the information that was published regarding combat and suicide spending and loss of life during the four year period from 2008-2011 as it pertained to the active duty army.

In Chapter 1, the general area of interest for the study was identified as the Army budget, which is under increased pressure for the upcoming years due to the mandatory federal budget cap for the Department of Defense. Given the budget cap, there is a requirement to look at how money is spent, as increased spending on one program or area means that there are fewer resources available for the remaining areas. Therefore, it is important to be consistent in maximizing the value of the monetary resources available, especially when looking at measures that can impact the loss of human life within the Army.

In Chapter 2, the study conducted a review of relevant theory from decision analysis to ensure that a framework was established for the study. Next, the study introduced identified inconsistencies in spending related to human lives by the federal government as reason to suspect that there might be inconsistencies in how the Army makes trade-offs between money and human life. This information was used as motivation for the study, and led to the development of the two primary research questions.
Chapter 3 introduced data that would be used for the study, identified where it was obtained, and included information regarding loss of life and spending during the period from 2008-2011. Assumptions about the data and how it was interpreted were also addressed.

Chapter 4 used the data to build a basic value model for the trade-off between the level of spending and the number of casualties expected. This model included actual deaths and lesser events such as being wounded or attempting suicide. Two different value functions, for combat and suicide, were derived from the data, and used as the basis for the remainder of the study.

Chapter 5 addressed the first research question. Given that the values calculated for $\eta$ in chapter 4 were different for combat and suicide, the implications of having inconsistent trade-offs were explored as rationale for why it is important to do further research to address whether this finding is robust beyond the four year period addressed in the study.

Chapter 6 looked at the second research question. For this, the model developed in chapter 4 was assumed to be correct, and the equations calculated were used to describe how they could reduce the number of alternatives that the decision maker had to address, as well as to facilitate understanding the ordinal rankings of the different alternatives.

7.2 Study Limitations

As addressed throughout the paper, the central limitation of the study was that it relied on curve-fitting of historical data to infer trade-offs. This was possible because a causal relationship was assumed to exist between the spending level and the loss of lives. For the purposes of this study, the best curve-fit was assumed to represent an indifference by the decision maker to increased spending along the line if it results in a corresponding decreased loss of life. This allowed for analysis of the relationship inferred from the curve-fit line, but there is no guarantee that the relationship shown is actually the decision maker’s trade-off between money and human
life. The study relied on examining the importance of this inferred trade-off to demonstrate the importance of seeking consistency in making the actual trade-off.

The data is limited in scope to a well-documented four year period during which the Army experienced losses due to both combat and suicide. This study does not attempt to establish definitely what the Army views as the acceptable standard for the trade-off, merely to show whether the data for this time period suggests that there are inconsistencies as expected due to the lack of a consistent standard at the federal level for governmental spending and economic analyses. Therefore, any figures shown in this study should be understood to be interpretations based on the publicly available data provided during the time period. With only a small amount of data available, actual numbers may differ from the values calculated in the study. However, the study had provided a framework for analysis, which can accommodate a larger data set when obtained in the future, using the same primary assumptions.

For looking at the overall budget allocation, the study only looks at the resources committed for combat and suicide prevention, when the reality is that the budget is significantly more complex. Other areas were not addressed for this study to allow for the presentation of a clear, concise model that can then be expanded in the future. The model can be updated with increasing complexity given further available data, and will provide more robust results with more data available for analysis.
REFERENCES


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