NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

ESTIMATING VARIABILITY IN THE IMPLEMENTATION COST GROWTH OF MILITARY BASE REALIGNMENTS AND CLOSURES USING HISTORIC DATA

by

Sarah A. Martin

June 2019

Thesis Advisor:	Robert F. Dell
Co-Advisor:	Gregory K. Mislick
Second Reader:	Samuel E. Buttrey

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** June 2019	**3. REPORT TYPE AND DATES COVERED** Master's thesis

4. TITLE AND SUBTITLE
ESTIMATING VARIABILITY IN THE IMPLEMENTATION COST GROWTH OF MILITARY BASE REALIGNMENTS AND CLOSURES USING HISTORIC DATA

5. FUNDING NUMBERS

6. AUTHOR(S) Sarah A. Martin

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release. Distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT (maximum 200 words)

The Department of Defense (DoD) periodically conducts a Base Realignment and Closure (BRAC) round to improve the stationing of its force structure, eliminate excess infrastructure, and attain cost savings. The most recent BRAC round in 2005 far exceeded its estimated cost to implement; in a 2012 report, the Government Accountability Office reported that the 2005 BRAC implementation cost grew from the original estimate by 67%. The DoD requires an improved cost estimate and understanding of inherent uncertainty. Using data from 58 observations of BRAC 2005 recommendations, this thesis examines trends in cost growth. The thesis does not find any statistically significant differences in cost increases among subsets of data analyzed by type of DoD recommending agency, presence of Commission amendments, BRAC action complexity, or size of estimate. Variation in implementation cost growth is mildly narrower for BRAC actions that were amended by the Commission and for actions that were more complex. The analysis detects a bias in estimating large BRAC actions, which indicates a systematic hesitancy or inability to fully estimate the most expensive BRAC actions. The distribution of BRAC 2005 actions' cost increases is used to inform an improved, three-point estimate for future BRAC rounds. Under conditions comparable to BRAC 2005, this thesis shows that the true mean of future BRAC actions' cost increases may be expected to be 93% with a 95% confidence interval of [57%, 129%].

14. SUBJECT TERMS
BRAC, base realignment and closure, cost estimation, cost growth, military construction, MILCON, COBRA, BRAC 2005, S-curve, cost estimation bias

15. NUMBER OF PAGES
81

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release. Distribution is unlimited.

ESTIMATING VARIABILITY IN THE IMPLEMENTATION COST GROWTH OF MILITARY BASE REALIGNMENTS AND CLOSURES USING HISTORIC DATA

Sarah A. Martin
Captain, United States Army
BS, U.S. Military Academy, 2009

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
June 2019

Approved by: Robert F. Dell
Advisor

Gregory K. Mislick
Co-Advisor

Samuel E. Buttrey
Second Reader

W. Matthew Carlyle
Chair, Department of Operations Research

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

The Department of Defense (DoD) periodically conducts a Base Realignment and Closure (BRAC) round to improve the stationing of its force structure, eliminate excess infrastructure, and attain cost savings. The most recent BRAC round in 2005 far exceeded its estimated cost to implement; in a 2012 report, the Government Accountability Office reported that the 2005 BRAC implementation cost grew from the original estimate by 67%. The DoD requires an improved cost estimate and understanding of inherent uncertainty. Using data from 58 observations of BRAC 2005 recommendations, this thesis examines trends in cost growth. The thesis does not find any statistically significant differences in cost increases among subsets of data analyzed by type of DoD recommending agency, presence of Commission amendments, BRAC action complexity, or size of estimate. Variation in implementation cost growth is mildly narrower for BRAC actions that were amended by the Commission and for actions that were more complex. The analysis detects a bias in estimating large BRAC actions, which indicates a systematic hesitancy or inability to fully estimate the most expensive BRAC actions. The distribution of BRAC 2005 actions' cost increases is used to inform an improved, three-point estimate for future BRAC rounds. Under conditions comparable to BRAC 2005, this thesis shows that the true mean of future BRAC actions' cost increases may be expected to be 93% with a 95% confidence interval of [57%, 129%].

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

AACSIM	Army Assistant Chief of Staff for Installation Management
BRAC	Base Realignment and Closure
BRACO	Base Realignment and Closure Office
CHAMPUS	Civilian Health and Medical Program of the Uniformed Services
COBRA	Cost of Base Realignment Actions
DBOF	Defense Business Operations Fund
DLA	Defense Logistics Agency
DoD	Department of Defense
E&T	Education & Technology
FY	fiscal year
FYDP	Future Years Defense Program
GAO	Government Accountability Office
HAP	Homeowners Assistance Program
H&SA	Headquarters & Support Activities
IT	information technology
JCSG	Joint Cross-Service Group
LMI	Logistics Management Institute
MILCON	military construction
O&M	Operations and Management
OSAF	Optimal Stationing of Army Forces
OSD	Office of the Secretary of Defense
PCS	permanent change of station
RIF	reduction in force
RPAD	Real Property Assets Database
RSE	relocation service entitlement
S&S	Supply & Storage
TABS	The Army Basing Study

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

The Department of Defense (DoD) periodically conducts a round of Base Realignment and Closure (BRAC) to improve the stationing of its force structure, eliminate excess infrastructure, and attain cost savings. The latest BRAC round in 2005 far exceeded its estimated cost to implement. The Government Accountability Office (2012) reports that the implementation cost grew from the original estimate of $21 billion to $35.1 billion, a 67% cost increase. BRAC cost estimates are historically limited to point estimates. This thesis delivers a better understanding of the sources of cost growth and the inherent uncertainty in BRAC implementation cost estimates.

This thesis studies 58 observations of 2005 BRAC Commission recommendations. The selected BRAC actions may reasonably be expected to resemble a future BRAC round. The majority of the BRAC actions, 43 of 58 actions, grew to cost more than anticipated. We identify military construction as the primary driver of cost increases. Operations and maintenance costs are also significant. Other costs such as Homeowners Assistance Program (HAP), environmental, and military personnel costs are not a significant source of cost growth in BRAC 2005 implementation cost.

The thesis explores the data to determine if subsets of the data experience significantly different cost growth; for such subsets, this may justify applying distinct inflation factors on the estimates in order to improve the accuracy of cost estimates. We look for differences in cost increases among the data according to the type of DoD recommending agency, amendments imposed by the BRAC Commission, complexity of BRAC actions, and the size of the cost estimate. We find no statistically significant differences in cost increases among subsets.

Conspicuously, the analysis detects a bias in the estimation of large BRAC actions. BRAC actions that ultimately are the costliest to implement also experience comparatively greater cost increases. This is not detectable at the time of estimation but appears upon implementation when final costs are realized. Figure 1 shows the marked gap in cost increases between the less costly half of BRAC actions and the costlier half of BRAC

actions. This finding suggests that there is a hesitancy or inability to fully estimate the costliest BRAC actions.

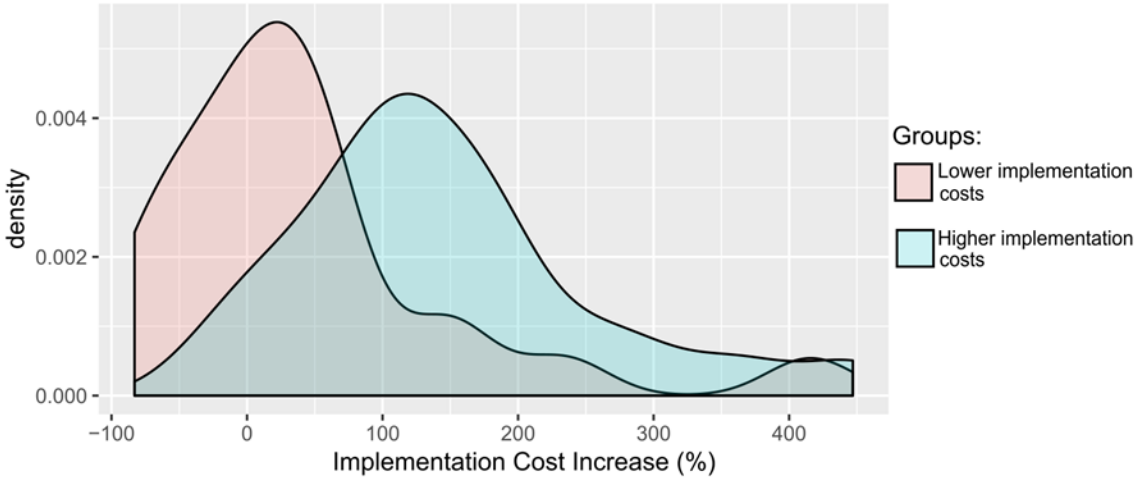


Figure 1. Variation in Implementation Cost Increases for Lower versus Higher Selected BRAC 2005 Implementation Costs

In the absence of suitable cost inflation factors for subsets of the data, the thesis analyzes the distribution of cost increases itself. The distribution informs an improved, three-point estimate for future BRAC rounds. We find with 95% confidence that the true mean of BRAC action implementation cost increases is between a 57.4% and 128.8% increase, with an expected mean of 93.1%. The distribution likewise informs a cumulative distribution function, "S-Curve," which may be used by BRAC planners and decision makers to understand the full range and likelihood of potential cost overruns. Though this thesis uses data from 2005 BRAC to draw its conclusions, the inferences drawn are applicable to future BRAC rounds to the extent that future BRAC rounds are estimated and executed in a comparable way.

Further analysis of uncertainty in BRAC implementation cost growth will be bolstered by improved data quality. The current practice of bundling several base realignment and closures under one aggregated recommendation weakens visibility into the sources of costs and savings. The Government Accountability Office outlines excellent

steps to achieve better data quality in their March 2013 report entitled, “Opportunities Exist to Improve Future BRAC Rounds.”

References

Government Accountability Office (2012) Military base realignments and closures: Updated costs and savings estimates from BRAC 2005. Report GAO-12-709R. Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-12-709R.

Government Accountability Office (2013) Military bases: Opportunities exist to improve future base realignment and closure rounds. Report GAO-13-149. Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-13-149.

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

It is with the utmost sincerity that I thank the many people who guided, supported, and enabled me in completing this research. Foremost, my advisor, Robert Dell, deserves great credit for introducing me to the topic and for his limitless patience and unflagging encouragement. His guidance cannot be exaggerated, as he continually kept me focused as I strove to complete this thesis while performing other duties concurrently. He also coordinated the logistics for me to attend the Base Realignment and Closure Conference at Fort Belvoir, Virginia, which was instrumental in framing my research. I would also like to thank my co-advisor, Greg Mislick, particularly for his assistance with cost estimation techniques.

There are several people who assisted me with obtaining and refining the data, without whom this thesis simply could not have been completed. For helping me acquire the data, I would like to thank Colonel (Retired) Bill Tarantino and the Base Realignment and Closure Office. Colonel (Retired) Tarantino was also a great resource in interviews, painting an on-the-ground picture of the BRAC 2005 estimation process that provided remarkably useful context. I am also truly appreciative to Bill Evans for his technical assistance with reformatting the raw data from the estimation model's reports into readily usable files.

I would also like to thank Sarah Harrop, Rene Carlucci, and Nathan Dietrich from the Center of Army Analysis at Fort Belvoir for connecting me with research resources.

I offer a special thanks to my father for inspiring in me a love of math and operational efficiency and who was always challenging me to make things better. And I am truly grateful for my mother, whose nudging encouragement over the years has proven a reliable complement to inspiration. Finally, I would like to thank my husband, Phillip Martin, for his unwavering support over the years as I strove to balance our daily lives with classes and research.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

The United States actively manages how its defense forces are stationed in order to keep pace with evolving strategic needs. Accordingly, the Department of Defense (DoD) periodically adjusts the stationing of its force structure through a formal process. This process is referred to as a round of Base Realignment and Closure (BRAC), wherein a large set of recommended stationing adjustments are implemented simultaneously.

These stationing adjustments are primarily made to increase the military value of the DoD's force structure. However, a secondary objective is to attain cost savings and reduce excess infrastructure. This secondary objective remains an important consideration when weighing different realignment recommendations, especially where military values are comparable.

Each time a round of BRAC actions is executed, the government incurs a one-time cost in order to implement the force structure changes. This upfront cost is a necessary investment in order to reap the increased military value or eventual cost savings that are expected to result from the BRAC round. The DoD is responsible for providing Congress with an estimate of the implementation cost, and Congress then uses this estimate to appropriate funds to pay for the BRAC round.

Historically, there has been significant growth from the estimate to the actual cost of the implementation. The most recent BRAC round, executed in 2005, was the largest, most complex, and costliest stationing adjustment to occur in recent history (Government Accountability Office [GAO] 2012a). It cost much more than the DoD anticipated. The cost to implement BRAC 2005 was originally estimated to be $21 billion; this amount increased by $14.1 billion, or 67 percent, reaching a final cost of $35.1 billion (GAO 2012a). The GAO considers the 2005 BRAC to be successful in achieving its military value objective (GAO 2005). However, the significant growth in implementation cost is not clearly understood, nor is there a common understanding on what level of cost growth may be expected in future BRAC rounds.

The DoD requires a better estimate of the implementation cost of BRAC rounds. The DoD must provide Congress with an accurate cost estimate so that Congress may suitably appropriate funds. An accurate implementation cost estimate also supports the secondary objective of stationing adjustments, which is to attain cost savings, by providing reliable information to models and decision makers. The total cost savings attained in a BRAC round is the net sum of the implementation cost and recurring costs (or savings) once the BRAC round is implemented. Total cost savings is an important reason that stationing adjustments are executed in the first place. If the implementation cost estimate lacks accuracy, then the total cost savings estimate may also be expected to lack accuracy. This poses a problem for decision makers because the expected total cost savings, which forms a basis for decisions regarding the stationing of the United States force structure, can reasonably be expected to lack accuracy and lead to suboptimal decisions. Thus, improving a BRAC implementation cost estimate and the understanding of its inherent uncertainty may improve decision making.

Several reports examine the cost growth in BRAC implementation costs. Previous work by the GAO determined that the implementation cost increase in BRAC 2005 was caused in large part by increases in military construction (GAO 2012a; GAO 2013), especially from additional requirements that were added after implementation began and that were therefore not captured as inputs in the estimation model (GAO 2013). The Office of the Army Assistance Chief of Staff for Installation Management (AACSIM) corroborates the GAO findings on military construction in its "Critical Analysis of the Army's BRAC 2005 Processes" report, which also discusses the budgetary impact of military construction project delays and how better synchronization efforts may aid in identifying military construction requirements earlier and more completely (College 2011).

BRAC actions have also been the subject of case studies. The GAO and the respective military services responsible for recommending BRAC actions have analyzed individual BRAC actions of interest, both during implementation and retroactively. For example, GAO reported extensively on two supply-related BRAC recommendations involving the Defense Logistics Agency (DLA), in order to examine the extent of cost differences from estimation to implementation and the DLA's challenges in implementing

the recommendations (GAO 2008). During the 2005 BRAC implementation period, DoD services and agencies periodically briefed the Vice Chief of Staff on BRAC recommendations that were exceeding $100 million in implementation cost and specifically reviewed each's significant concerns such as construction delays and cost overruns (GAO 2010). This information is captured in internal, unpublished records and in GAO's subsequent interviews with DoD officials. This valuable body of previous work improves the understanding of the challenges encountered during BRAC 2005 and how the fidelity of future BRAC implementation cost estimates may be improved.

This thesis extends the contributions of existing work by quantitatively examining if BRAC implementation costs may be better predicted from the collective body of data known at the time of estimation. It explores trends in the data to see if different cost estimation inflation factors are appropriate for subsets of data in order to achieve better cost estimates. The thesis examines variation in cost growth to enhance our understanding of the sources of uncertainty in the 2005 BRAC. It confirms the significant factors contributing to cost overruns identified in previous reports and quantifies their impact on the cost estimate by comparing data of 2005 BRAC implementation cost estimates with the actual costs realized upon implementation. Military construction, operations and maintenance, and other-category costs are the specific cost categories analyzed. For the first time, this thesis illustrates the distribution of BRAC 2005 implementation cost increases and quantifies their inherent uncertainty. Ultimately, this information is used to recommend a three-point BRAC implementation cost estimate that offers a low-end, expected, and high-end cost estimate. This is an improvement from the historical practice of a single point estimate for BRAC implementation cost, and it may enable lawmakers and senior DoD officials to better anticipate and plan for BRAC implementation costs in future rounds.

A. OVERVIEW OF THE BRAC PROCESS

A round of base realignment and closures, often referred to simply as a "BRAC," is the mechanism for closing and realigning DoD installations in the United Sates. The process of approving and executing BRAC recommendations is legislatively complex.

Since 1990, it has been largely governed by the Defense Base Closure and Realignment Act of 1990, provided in Title XXIX of the National Defense Authorization Act for Fiscal Year 1991 (101st Congress 1990). The DoD has completed five BRAC rounds. The first was held in 1988, and four more rounds were conducted since Congress passed the act, in 1991, 1993, 1995, and most recently, in 2005.

The BRAC process is politically insulated, which is frequently highlighted as a hallmark of the BRAC legislation's ingenuity (GAO 2005). The process of enacting a BRAC round begins with the DoD receiving Congressional approval to authorize a new round of BRAC. Each service is generally responsible for its set of recommendations. The Army's 2005 recommendations were informed by a decision-support model called Optimal Stationing of Army Forces (OSAF), which uses integer linear programming to prescribe an optimal Army stationing plan (Dell et al. 2008). Recommendations involving more than one service are historically coordinated by a multi-service working group called a Joint Cross-Service Group (JCSG).

The resulting recommendations are then presented to the Secretary of Defense for review. The Secretary of Defense submits the recommendations to an independent BRAC commission that is charged with reviewing the recommendations. The BRAC Commission may make adjustments to the recommendations. The Secretary of Defense then submits the set of BRAC recommendations to the President of the United States for his or her acceptance or rejection in its entirety. Once the President has taken action, Congress may take final action to reject the entire set of BRAC recommendations. If Congress does not take action, the set of BRAC recommendations automatically becomes law and must be implemented.

The DoD then has six years from the date the President forwards the actions to Congress to implement the recommendations. The costs that are incurred over the six-year implementation period are the one-time costs required to implement the BRAC. Collectively, these costs comprise the BRAC round's implementation cost.

B. THE PURPOSE OF THE BRAC

The DoD routinely reshapes its force structure in order to keep pace with changes in strategy, missions, weapons systems, and operations. These periodic adjustments are intended to enhance the efficiency of the DoD and are analogous to how a large corporation may make changes to its plant infrastructure to respond to changes in product demand or technology (Dell et al. 2008, p. 421).

The Defense Base Closure and Realignment Act of 1990 states that the number one priority of a BRAC round is to increase the military value of the DoD's stationing structure (107th Congress 2001, §2913(b)). According to the act, the consideration of military value includes the following at a minimum:

> (1) Preservation of training areas suitable for maneuver by ground, naval, or air forces to guarantee future availability of such areas to ensure the readiness of the Armed Forces.
>
> (2) Preservation of military installations in the United States as staging areas for the use of the Armed Forces in homeland defense missions.
>
> (3) Preservation of military installations throughout a diversity of climate and terrain areas in the United States for training purposes.
>
> (4) The impact on joint warfighting, training, and readiness.
>
> (5) Contingency, mobilization, and future total force requirements at both existing and potential receiving locations to support operations and training.
>
> (107th Congress 2001, §2913(b)(1)-(5))

The act's criteria for military value have been amended several times but with only minor modifications (101st Congress 1990; 107th Congress 2001; 108th Congress 2004).

Other criteria, including the extent and timing of potential costs and savings, are also considered. These criteria are of subordinate importance to military value. However, the act is required to address them. Specifically, the special considerations for the selection criteria of military installations must address at a minimum the following:

> (1) The extent and timing of potential costs and savings, including the number of years, beginning with the date of completion of the closure or realignment, for the savings to exceed the costs.

(2) The economic impact on existing communities in the vicinity of military installations.

(3) The ability of both existing and potential receiving communities' infrastructure to support forces, missions, and personnel.

(4) The impact of costs related to potential environmental restoration, waste management, and environmental compliance activities.

(107th Congress 2001, §2913(c))

Military value is paramount. But cost savings is a critical secondary factor for decision making that may be used to reach a decision when two actions have comparable military value. If two courses of BRAC action achieve the same military value and all other special consideration criteria such as community and environmental impact are equal, the BRAC Commission is expected to approve the action that provides the larger cost savings.

C. HOW BRAC COSTS ARE ESTIMATED

The Cost of Base Realignment Actions (COBRA) model is "an economic analysis model…[that] estimates the costs and savings associated with a proposed base closure or realignment action" (Harvey 2005, p. 4). COBRA was designed by the Logistics Management Institute (LMI) for the Secretary of Defense's Commission on Base Realignment and Closure (Brown 1989) in order to provide, "cost comparisons of proposed base realignment actions using data that was available to Service staffs without extensive field studies" (Brown 1989). COBRA has been utilized in every BRAC round since 1989, with periodic adaptations.

COBRA uses a wide-ranging set of inputs to produce deterministic cost estimates for a specified BRAC action over a period of twenty years, which includes the implementation cost over the six-year implementation period and the recurring cost or savings for the remaining fourteen years. COBRA solicits up to hundreds of inputs for a BRAC recommendation. Examples of such inputs include the number and type of facilities on base, the number and type of employees, and the square footage of new construction, among many other inputs. This information is solicited for each military base involved in

a particular BRAC action, and individual BRAC actions typically involve more than one base.

COBRA then reports aggregated, estimated costs for each BRAC action in cost subcategories. The "Total One-Time Cost Report" in COBRA reports 33 subcategories of cost estimates for each BRAC action. Among the 33 subcategories of cost estimates are military construction costs, civilian Reduction in Force (RIF) costs, information technology costs, freight shipping costs, and mothball costs. COBRA models all one-time activities that are required for an action's implementation to occur within the initial six-year implementation period, and all recurring costs and savings after the six-year period are treated as steady-state. All costs and savings dollar values are reported in constant base-year dollars. For BRAC 2005, the values are reported in 2005 dollars.

The chief output produced by COBRA relevant to decision makers is the "payback year." The payback year is the estimated future date when savings generated from a BRAC action will have fully paid for the cost of the action itself and net savings may begin. If a payback year is never reached within the 20-year time period in the model, then COBRA reports a net cost rather than a net savings. The payback year allows the COBRA user to compare the economic benefit among different courses of action. For example, if two comparable BRAC action scenarios have equal military value, then the one with the earlier payback year is considered more economically beneficial than the one with a later payback year or no payback year at all. COBRA thus offers a means of comparing different BRAC actions for cost effectiveness.

However, COBRA estimates do not fully estimate BRAC implementation costs. For simplicity, some key costs are excluded as inputs or underestimated. COBRA does not include estimates for costs and savings that are shifted to other federal agencies or operations due to a base closure or realignment because it is "unclear what actions an agency might take in response to a BRAC action" (GAO 2007, p. 7). Environmental restoration and cleanup costs are omitted from the COBRA model. DoD expressly excludes these costs, "on the premise that [environmental] restoration is a liability that the department must address regardless of whether a base is kept open or closed" (GAO 2007, p. 7). COBRA also systematically underestimates military construction cost estimates

because certain factors are not identified as inputs in COBRA. Information technology (IT) estimates are similarly underestimated because COBRA does not fully anticipate information technology costs, particularly for BRAC actions involving missions or locations that are heavily reliant on IT capability (GAO 2013). The exclusion of these inputs in COBRA models results in incomplete cost estimates.

The GAO finds COBRA "to be a reasonable estimator for comparing potential costs and savings among candidate alternatives" in BRAC 2005 (GAO 2013). But LMI states that COBRA was "not intended for budgetary purposes" (Brown 1989), and the 2005 version of the Cobra User Manual echoes this. Rather, COBRA is designed "to provide a consistent and auditable method of evaluating and comparing different courses of action in terms of the resulting economic impacts for those costs and savings measured in the model" (Harvey 2005, p. 4).

Despite its known incompleteness as a BRAC cost estimation tool, COBRA estimates are consistently used as the benchmark estimates with which post-BRAC implementation and recurring costs are compared. COBRA produces the cost estimates that are used by the DoD and BRAC Commission to make decisions on BRAC actions. COBRA estimates are also the estimates that are provided to Congress to inform how much funding should be allocated in the BRAC account to pay for a BRAC round. Therefore, there is good reason to understand the limitations of COBRA cost estimates to support their realistic use in future budgetary decisions and to achieve more complete cost estimates.

D. ARRANGEMENT OF THE THESIS

The next chapter presents an overview of the existing literature on the BRAC. Special attention is paid to reasons for BRAC implementation cost growth, areas of uncertainty, and limitations to analysis. Next, the thesis describes the historic data that was selected for analysis. Visualizations of cost increases in military construction, operations & maintenance, and other-category costs provide further insight.

The thesis explores the data to see if there are identifiable trends in cost increases. Specifically, it explores trends in cost growth by the type of DoD recommending agency, the effect of amendments, the degree of BRAC action complexity, and the size of the

estimate. The purpose of this exploration is to see if there are differences among cost growths that support the application of distinct cost inflation factors in order to achieve more accurate cost estimates. The thesis then presents a finding on bias in large BRAC action estimates. The finding is not directly applicable to a quantitative improvement for cost estimates, but awareness of the bias among BRAC estimators and stakeholders may reduce its future impact.

The distribution of the cost increases among BRAC actions is then used to inform a three-point estimate for future BRAC actions using a confidence interval. The distribution of BRAC action percent increases for total cost are used to create a cumulative distribution function "S-curve" illustrating the likelihood of cost growth for an individual BRAC action.

The thesis concludes with a discussion of the significant findings.

THIS PAGE INTENTIONALLY LEFT BLANK

II. LITERATURE REVIEW

This chapter presents the major findings of existing reports on BRAC 2005 implementation costs, possible sources of cost increase, and the limitations that may impact the quality and extent of analysis. The GAO regularly reports on several aspects of previous BRAC rounds. In reporting, the GAO incorporates the observations of senior military service BRAC leaders and other DoD officials involved with the BRAC through interviews and by reviewing their documents. Military services maintain BRAC records in internal, deliberative documents, which are generally not published but are accessed by the GAO for the purpose of their reports. The GAO, LMI, and COBRA User Manual have specifically addressed limitations of the COBRA model.

A. BRAC 2005 REPORTED COST INCREASES

The 2005 BRAC implementation cost was significantly underestimated. GAO analysis of DoD's fiscal year 2011 BRAC-related budget submissions determined that by the conclusion of the six-year implementation period in 2011, the implementation cost increased by 67% from the estimated implementation cost. The final implementation cost totaled $35.1 billion (GAO 2012a), a $14.1 billion increase above the estimated implementation cost of $21 billion.

The GAO analyses of BRAC 2005 capture several salient points. Cost growth was concentrated in a small number of BRAC actions. Fourteen of the 175 BRAC actions accounted for 72 percent of the cost increase (GAO 2012a). GAO also shows that many of the BRAC recommendations experienced extreme cost growth. Five recommendations' implementation costs grew by over 1,000 percent from the BRAC Commission estimates, as shown in Table 1.

Table 1. Five 2005 BRAC Actions Increased by over 1,000 Percent. Source: GAO (2012a).

Table 2: BRAC Recommendations with over 1,000 Percent Increases in One-Time Costs
(Dollars in millions)

BRAC recommendation (Commission number)	2005 BRAC Commission estimate	Fiscal year 2011 DOD budget	Dollar increase	Percentage increase
1. Realign to establish Joint Center for consolidated transportation management training at Fort Lee, VA (#122)	$1.5	$29.1	$27.6	1,840
2. Realign to establish Joint Center of Excellence for religious training and education at Fort Jackson, SC (#124)	1.0	14.9	13.9	1,394
3. Realign Single Drill Sergeant School to Fort Jackson, SC (#50)	1.8	27.2	25.4	1,411
4. Realign to establish Joint Center of Excellence for culinary training at Fort Lee, VA (#123)	5.4	73.1	67.7	1,254
5. Consolidate Army Test and Evaluation command Headquarters at Aberdeen Proving Ground, MD (#136)	7.1	93.0	85.9	1,210
Total	**$16.8**	**$237.3**	**$ 220.5**	

Source: GAO analysis of 2005 BRAC Commission data and DOD's fiscal year 2011 BRAC budget data.

GAO observes that military construction costs in BRAC 2005 were central to the cost growth. Costs related to military construction represented 80% of the additional costs that BRAC 2005 incurred after the original estimate. Military construction costs alone increased from $13.2 billion estimated by the BRAC Commission to $24.5 billion at the conclusion of implementation (GAO 2013).

B. WHY COSTS INCREASED

Retroactive reports and analyses completed as the implementation was ongoing comment on why the BRAC 2005 implementation cost grew so substantially. The findings attribute the 2005 BRAC implementation cost increase to a number of reasons.

1. Additional Requirements

Foremost among these reasons, is that the DoD did not fully identify all requirements at the time when the cost estimates were produced. Many requirements "were added or identified after implementation began" (GAO 2013) and were therefore not included in the estimation model.

Specifically, additional requirements within military construction had a significant impact on implementation cost growth. GAO finds most of the 86 percent of the increase in military construction costs was incurred from requirements that were added or identified after implementation started (GAO 2013). These are requirements that were added post-estimate, as the DoD "identified the need for new and renovated facilities to enhance capabilities" (GAO 2012b). The GAO lists the realignment of the National Geospatial-Intelligence Agency as one substantial example, stating that this single BRAC action, "more than doubled from $1.1 billion to $2.6 billion, with military construction accounting for nearly $726 million of that increase due to additional supporting facilities the agency identified as essential to the mission" (GAO 2012a).

Other additional requirements contributed to cost growth, albeit less significantly than added military construction requirements. Notably, unforeseen information technology costs were significant. The GAO finds that implementation costs increased in part because the DoD did not fully foresee information technology requirements for recommendations whose missions involved considerable reliance on information technology (GAO 2013). For instance, the information technology requirement for one DLA BRAC recommendation that involved, "software development and the synchronization of several existing and evolving information technology requirements," increased from $30.9 to $190 million once its information technology requirements were fully defined because at the time when the estimate was produced, "[DoD officials]…did not have a good sense of what information system would have to be specially designed and what the development of those systems would cost" (GAO 2013).

2. COBRA Model Systematically Underestimates Costs

LMI designed the COBRA model as a comparison tool to choose among similar, proposed BRAC actions. The COBRA model is limited in its ability to provide a full implementation cost estimate because it is only designed to provide a partial estimate of costs. Thus, implementation costs rise when certain costs that were intentionally omitted in the COBRA estimation are realized later during implementation. Citing the COBRA model's function as a cost comparison tool for candidate recommendations, DoD officials

reported to the GAO that some "known requirements, such as furnishings for new buildings, were not entered as inputs into COBRA because analysts assumed that those requirements would be the same regardless of which scenario was chosen, and therefore the costs related to those requirements would not affect the comparison" (GAO 2013, p. 30). The Army's lead BRAC 2005 analyst, Colonel (Retired) William B. Tarantino, describes the cost of curbs and parking lots accompanying new buildings as one such cost that was intentionally omitted. He estimates 26–30% of the cost increase for new military construction projects for office buildings may be attributed to this cost alone (Tarantino 2016).

3. Lack of Requisite Sophistication in the COBRA Model

Some findings point to the lack of sophistication in the COBRA model's standard factors as a contributor to cost growth. Standard factors are static multipliers used to calculate costs, and they are applied universally. However, there are concerns that standard factors may not be appropriate for all circumstances and that poor estimates may have resulted for unique circumstances. A 2013 report by GAO asserts that "the standard factor COBRA uses to calculate cost estimates for information technology may be inaccurate" (p. 23). GAO believes that the information technology (IT) standard factor may be outdated and ineffectively applied. Office of the Secretary of Defense (OSD) officials state that the IT standard factor is applied to all installations equally despite certain installations having a greater dependence on that capability than others (GAO 2013). COBRA also uses a linear standard factor for IT requirements in its 2005 BRAC estimates. In a related criticism, some initial discussion among the community of BRAC analysts suggests that COBRA's IT cost algorithm might consider adopting a step function because that may more closely mirror how some IT costs are incurred, than a linear function (Dietrich et al 2015). For example, if no more than 250 users are recommended for a single server for optimal mission performance, then once 250 users are exceeded, another server is required, whether the number of users is 270 or 490. In this instance, a step function would be an improvement from a linear application of the IT standard factor.

The Army Basing Study (TABS) BRAC 2005 After Action Report voices similar skepticism on whether the standard factors involving renovation costs in COBRA are appropriate for accurately estimating facility reuse. The study reports, "There was a leap of faith that all space was useable and would meet future tenant requirements" (Deputy Assistant Secretary of the Army for Infrastructure Analysis 2006, p. 10). Space that did not meet usability expectations was either renovated or replaced with an additional space requirement. As BRAC 2005 underwent implementation, it became apparent that more renovation or new requirements were needed than originally anticipated. Critics of the renovation standard factor believe that the standard factor assumption for usable space is overly optimistic and calculates that less space will need to be renovated than in actuality. This optimism biases the implementation cost estimate to be lower than would an estimate that used a higher standard factor for renovation.

4. Poor Data Quality

Several sources report that poor data quality confounded decision making and may have been a factor in implementation cost increases. Input data for the COBRA model was solicited through data calls from DoD databases, and some of these databases may not have been accurate. The TABS BRAC 2005 After Action Report states that "historical information regarding facilities, infrastructure and environmental conditions was often insufficient or inconsistent" (Deputy Assistant Secretary of the Army for Infrastructure Analysis 2006, p. 11). A 2016 GAO report on DoD's Real Property Assets Database (RPAD) determined that, "data from RPAD were neither accurate nor complete" and were therefore insufficiently reliable to determine the number, size, and cost of DoD-leased assets (GAO 2016a, p. 49). Inaccurate data introduced uncertainty to the BRAC process and may have resulted in unanticipated implementation cost increases.

Although the cumulative effect of inaccurate data on the growth of BRAC 2005's implementation cost is not clear, inaccurate data is documented as leading to cost growth in several instances. In one notable occurrence, inaccurate RPAD data negatively impacted the DoD's ability to attain cost savings expected through optimal occupation of leased space versus government-owned space during the BRAC 2005 implementation period.

Leased space is typically more expensive than government-owned space. As part of 2005 leasing-related BRAC actions, the DoD planned to vacate 12 million square feet of leased facilities. After vacating, the "DoD reoccupied over 1.1 million square feet in leased space previously vacated when it implemented the 2005 Base Closure and Realignment recommendations," even though less costly government-owned space was available and may have sufficed (GAO 2016a). In this circumstance, decisions to vacate and occupy space were informed by inaccurate RPAD data. Poor RPAD data thus impaired decision making. This resulted in the loss of expected cost savings with a net effect of BRAC implementation cost increase.

5. Unanticipated Costs Incurred outside the BRAC Account

A lack of shared understanding of what costs would be accounted for as BRAC implementation costs may have also contributed to implementation cost growth. DoD management regulation required that some costs incurred by the DoD while mitigating implementation challenges be reported to Congress as BRAC costs, even though GAO reports that they may have been incurred outside the allowable funding of the BRAC account (GAO 2010). Concerning the 2005 BRAC, the DoD had not anticipated that costs outside the BRAC account would be counted as BRAC costs, and therefore they were not part of the implementation estimate. Examples of BRAC-related costs outside the BRAC account that were ultimately accounted for as BRAC costs include those incurred by, "moving temporarily into different buildings while construction and renovations are completed, referred to as swing space, or accelerating the pace of construction to complete permanent facilities by the deadline, potentially incurring additional expenses," and "mitigating some human-capital-related challenges by recruiting new personnel and offering financial incentives to civilian employees to relocate" (GAO 2010). When the DoD later accounted for BRAC costs in accordance with regulatory requirements, the implementation cost grew.

However, the extent to which implementation cost truly grew due to outside costs is further confounded by another aspect. The services within DoD did not have a uniform manner for accounting for outside costs as BRAC costs. Services interpreted the regulation

independently. GAO finds that outside costs were not consistently reported to Congress because services were able to prepare their own BRAC budget justification material and did not apply a common method for considering BRAC-related costs (GAO 2010). This finding dilutes the power of service-to-service comparisons of implementation cost growth, especially concerning the portion of cost growth that was due to outside costs. Despite the irregularity in reporting across military services, the ultimate inclusion of outside costs in Congressional reporting certainly added to overall implementation costs and are a known contributor in the 2005 BRAC implementation cost growth.

6. Unique Timing and Complexity of BRAC 2005

The 2005 BRAC implementation period, from 2005 to 2011, occurred during a time of rapid change across several domains within the DoD. Multiple variables in flux concurrently raised uncertainty. The GAO reports that the timing and complexity of BRAC 2005 made accurate cost estimates exceptionally abstruse. BRAC 2005 is the largest, costliest, and most expensive BRAC round to have been undertaken by the DoD. But BRAC 2005 is also the only BRAC round to be implemented "during a time of conflict" coupled with "significant increases to the defense budget to support ongoing contingency operations" (GAO 2010). A 2010 GAO report describes the environment wherein simultaneous DoD initiatives posed challenges for BRAC 2005 planners and supporting infrastructure.

> Compounding this challenge, DoD is also implementing other extensive worldwide transformation initiatives such as the permanent relocation of about 70,000 military personnel to the United States from overseas; transformation of the Army's force structure from an organization based on divisions to more rapidly deployable, combat brigade-based units; an increase in the active-duty end strength of the Army and Marine Corps by 92,000 members; and the drawdown of combat forces in Iraq while simultaneously increasing the U.S. presence in Afghanistan. (GAO 2010)

The GAO suggests that ongoing demands in 2005 strained existing resources that would have otherwise been directed at improving the fidelity of data or better understanding requirements.

C. LIMITATIONS TO ANALYSIS EFFORTS

The GAO describes limitations they encountered in its analysis efforts.

1. Multiple Bases Bundled into Complex Recommendations

There is no base-level granularity in the reported cost data. In its report to the 2005 BRAC Commission, the "DoD bundled multiple closures and realignments into single, highly complex recommendations…without itemizing the costs and savings associated with each separate major action" (GAO 2013). The DoD's practice of bundling multiple bases into one BRAC action makes it difficult to identify relevant cost growth components. This limits visibility on the source of cost changes within complex BRAC recommendations that involve many bases.

2. Implementation Cost Understated Inconsistently

It is uncertain which BRAC actions' implementation costs may have been understated. As described earlier in the discussion of outside costs, cost accounting was inconsistent as to what was considered a true, BRAC-related cost. The GAO reports that not all 2005 BRAC-related costs were reported as BRAC costs and that the $35.1 billion total implementation cost is "likely somewhat understated" (GAO 2016b, p. 21). Costs incurred by military departments while mitigating various BRAC challenges, including financial incentives for relocating civilian personnel or renovation and leasing costs of BRAC-related swing space, were considered BRAC-related by the GAO. But military departments submitted their own budget data and had the flexibility to determine which costs they considered to be BRAC-related. This practice "led to inconsistencies in what kinds of projects had their costs counted as BRAC implementation costs" (GAO 2016b, p. 26). In one example, U.S. Army Forces Command officials funded an estimated $13 million of BRAC-related expenses to renovate swing space facilities at Ft Bragg, with appropriations from the American Recovery and Reinvestment Act of 2009 and the Army's Sustainment, Restoration, and Modernization account fund; these additional costs were not captured as BRAC implementation costs (GAO 2010).

In total, GAO identified at least $110 million in BRAC 2005 implementation costs that should have been reported to the DoD but were not (GAO 2016b). The GAO also acknowledges that this amount is probably not a full accounting of the understated cost. The exact amount of unreported 2005 BRAC-related costs is uncertain, and so is the degree to which individual BRAC actions are understated relative to another. Therefore, the GAO findings prompts recognition that the reported BRAC implementation costs may have a discrepancy from their true implementation cost, and that the exact degree of this discrepancy is unknown.

D. RECOMMENDATIONS FOR IMPROVEMENT

GAO and military service reports have put forward recommendations on how to improve the accuracy and understanding of BRAC implementation costs.

1. Require Standardized Reporting of All BRAC-Related Costs

In order to ensure that congressional decision makers have a complete picture of incurred BRAC implementation costs, the GAO recommends that the Secretary of Defense ensure that all BRAC-related costs be captured and reported to Congress (GAO 2010). While this was widely accepted as the intent, strict and specific future guidance will be helpful in ensuring this objective is met and will resolve differences in accounting practices between services. GAO recommends that the DoD clarify "in guidance what is to be included as a BRAC implementation cost" (GAO 2016b). GAO finds that a standardized approach will result in a more accurate depiction of BRAC costs across services.

2. Itemize Costs within a BRAC Recommendation

In order to address the limited granularity of costs and savings information available to BRAC decision makers, the GAO recommends that in future BRAC rounds, the "DoD limit the practice of bundling potentially stand-alone realignments or closures into single recommendations" (GAO 2013). If bundling multiple major realignment or closure actions into one complex recommendation is appropriate, GAO suggests that the DoD still "itemize the costs and savings associated with each major discrete action in its

report to the BRAC Commission" (GAO 2013, p. 61). Following this recommendation prevents the loss of valuable data and makes reports more readily analyzable.

III. DATA SELECTION

The next BRAC round decision makers will naturally want to understand the nature of potential implementation cost growth. With this understanding as the framework for analysis, the thesis analyzes a subset of data that may be expected to resemble a future BRAC round. This chapter describes the existing data on the 2005 BRAC and the selected data set which this thesis utilizes for analysis.

A. USE OF 2005 BRAC ROUND DATA

Data from BRAC 2005 is the preferable data choice compared to data from earlier BRAC rounds in 1988, 1991, 1993, and 1995. BRAC 2005 is the most recent BRAC round and may be expected to most closely resemble the next round of BRAC, and the cost estimation practices in the most recent round are most likely to resemble practices in the next round. Cost algorithms for the COBRA model have historically been incrementally adjusted from the most recent BRAC round's model. BRAC 2005 also has the most complete data available for both estimated and implemented costs. It has the largest number of recommended BRAC actions of any BRAC round and thus offers a large amount of observations for analysis. The large data set and relative recency of the 2005 BRAC support its suitability for analysis.

1. Observations

The thesis treats each BRAC recommendation, as it is described by the 2005 Commission in its final report to the President of the United States, as an observation. This treatment is consistent with GAO reporting and enables the findings in this thesis to be comparable with GAO findings and relevant to service-internal documents.

2. Estimated and Implemented Costs

The selected BRAC 2005 data for this thesis is comprised of two distinct parts: data concerning the estimated cost to implement the BRAC round and data concerning the actual cost to implement the BRAC round. Broadly, these are referred to as the estimation cost data and implementation cost data, respectively. The 2005 estimation data was

generated *a priori*. The implementation data records the implementation costs that were incurred at the completion of the six-year implementation period. These two subsets of data enable the study of cost growth in implementation cost estimates.

3. Focus on One-Time Implementation Costs

This thesis focuses solely on the one-time costs required to implement a BRAC round. Recurring costs or savings of BRAC actions are not part of the analysis. Implementation costs are analyzed because they are of immediate concern for budgeting since they cannot be deferred or postponed. BRAC implementation costs are also significant and comprise an important part of understanding the overall extent of DoD cost savings through BRAC actions.

B. SOURCE OF ESTIMATION DATA

The Department of Defense's Base Realignment and Closure Office (BRACO) provided the BRAC 2005 COBRA models, which are the source for the estimation data. COBRA models went through several iterations and modifications throughout the BRAC deliberation process. This thesis uses the cost estimates generated in reports from the final version of the COBRA models prior to the onset of the implementation period.

These final COBRA models' estimates generally align with the estimates presented in the BRAC Commission's report to the President (2005 Defense Base Closure and Realignment Commission 2005). Minor differences are explained by adjustments to the models that were made after the Commission submitted its report but prior to implementation. As is allowable in the standard process, the 2005 BRAC Commission made amendments to some BRAC recommendations during the approval process. Of the 190 DoD recommendations, the Commission approved 119 with no change and accepted 45 with amendments (2005 Defense Base Closure and Realignment Commission 2005).

After the Commission approved these amendments but before the implementation period began, the DoD revised and re-ran some of the more substantively affected COBRA models to obtain internal cost estimates that more closely resembled the Commission's final approved BRAC actions. Where applicable, this thesis uses estimation data from these

updated COBRA models. This is specifically noted because some BRAC actions' estimated costs in the thesis data differ slightly from the estimates submitted to the Commission and which are recorded in the Commission's final report to the President. The Government Accountability Office uses the initial estimates submitted to the Commission in their reports. In places where this thesis's cost estimation data differs from the GAO reports, the use of updated COBRA models' reports are the cause for the difference. The latest-available COBRA models prior to implementation onset are used for analysis because their cost estimates represent the best available estimate prior to implementation.

C. SOURCE OF IMPLEMENTATION DATA

The BRAC Office's 2005 BRAC "Business Plans," as of May 2015, provide the data for the implementation costs. The Business Plans represent budget quality data that tracks the funds obligated for the implementation of BRAC actions from 2005 to 2011, during the six-year implementation period.

They are historic costs, but they have not always been stable. The BRAC Office continued to make adjustments to the funds obligated after the implementation period ended. In 2015, these adjustment amounts were negligible. In 2011, these adjustments amounts were larger. Therefore, in some cases, the implementation data analyzed in this thesis differ slightly from those previously reported and studied by the GAO (GAO 2012a; GAO 2013), where their budget data was obtained in 2011. GAO reports were published with the best budget data available at the time; this thesis uses better quality 2005 BRAC budget data from 2015.

D. DESCRIPTION OF SELECTED DATA

This thesis analyzes 58 observations of BRAC 2005 actions and the associated data relating to each action's estimated and actual implementation costs. Criteria for inclusion are actions estimated to cost more than $25 million. Criteria for exclusion are actions predominantly centered on Reserve Component transformation, classified actions where budget data is unavailable, and actions with inconsistent accounting methods for budget obligations. The resulting selected data set includes BRAC actions from every DoD

recommending agency except Intelligence, and one action added by the BRAC Commission.

1. Explanations of Excluded Data

The thesis data set was selected to reflect a representative sample for a future BRAC round that could provide meaningful insight into cost growth. Many 2005 BRAC actions were estimated to cost a relatively low amount to implement. For the 175 distinct BRAC 2005 actions that became law, the actions' cost estimates ranged from $0.10 million to $3,946 million. The overwhelming majority, 97.1%, of estimated implementation costs were captured in actions that were estimated to cost more than $25 million. Actions that were estimated to be less expensive had relatively little bearing on the ultimate implementation cost. In order to preserve the thesis focus on cost growth, 67 BRAC actions that cost $25 million or less are excluded from analysis.

The 43 actions concerning the Reserve Component are excluded. The largescale transformation of the Reserve Component during BRAC 2005 is unique among historic BRAC rounds, and it is unlikely that the Reserve Component will feature heavily in the next BRAC round.

Two BRAC actions are excluded because their data is classified.

Five actions are excluded because their budget data is inconsistently recorded.

In summary, of the 175 possible BRAC actions to consider, 67 were excluded because their contribution to cost is relatively minor, 43 were excluded because they concerned the Reserve Component, two were excluded because they were classified, and five were excluded because data was incomplete. The excluded data categories and their respective portions of the total estimated implementation cost are summarized in Table 2.

Table 2. BRAC Actions Excluded from Thesis Analysis

Description of Excluded Data Subset	BRAC Actions (*n*)	Percentage of Estimated Cost
Estimated to Cost <$25M	67	2.9%
Reserve Component	43	16.1%
Classified	2	6.0%
Inconsistent Data	5	2.3%

The resulting data for analysis in this thesis is thus aligned with what may be expected in the next BRAC round. The thesis data comprises 58 observations that capture 74% of the estimated implementation cost for BRAC 2005.

2. Explanation of Variables in Estimated Cost Data

Cost estimation data is obtained from the "Total One-Time Cost Report" generated by each BRAC action's respective COBRA model. Each report outputs thirty-one numeric variables that represent estimated costs for a particular category. Their values are the total one-time implementation costs estimated to be incurred during the six-year implementation period, for each cost category. These estimated costs are reported in 2005-year dollars. A description of the categories of estimated costs are summarized in Table 3.

Table 3. Description of Estimated Costs Produced by COBRA

Estimated Cost Variable (as displayed in COBRA)	Description of Estimated Cost Variable
MILCON	Military Construction Costs
Civ RIF	Civilian Reduction in Force (RIF) Costs
Civ Retire	Civilian Retirement Costs
Per Diem	Civilian Per Diem Costs
POV Miles	Civilian Personally Owned Vehicle Management Costs
Home Purch	Civilian House Purchasing Costs
HHG	Civilian Household Goods Costs
Misc	Civilian Miscellaneous Moving Costs
House Hunt	Civilian House Hunting Costs
PPP	Civilian Priority Placement Service Costs
RITA	Civilian Relocation Income Tax Allowance (RITA) Costs
Packing	Packing/Unpacking Costs
Freight	Freight Shipping Costs
Vehicles	Vehicle Shipping Costs
Unemployment	Civilian Unemployment Costs
Info Tech	Information Technology Costs
Prog Manage	Program Management Costs
Supt Contra	Support Contract Costs
Mothball	Mothball Costs
1-Time Move	One-Time Moving Costs
MIL MOVING Per Diem	Military Per Diem Costs
MIL MOVING POV Miles	Military Personally Owned Vehicle Mileage Costs
MIL MOVING HHG	Military Household Goods Costs
MIL MOVING Misc	Military Miscellaneous Moving Out Costs
Elim PCS	Military Eliminated PCS Costs
HAP/RSE	Homeowners Assistance Program/ Relocation Service Entitlement Costs
Environmental	Environmental Non-Military Construction Costs
Misc Contract	Mission Contract Costs
1-Time Other	One-Time Other Costs
Total_Onetime	Total Realignment One-Time Costs (the net sum of all above costs)

The estimation dataset also incorporates qualitative cost data from the 2005 BRAC Commission's Final Report. These variables are described in Table 4.

Table 4. Qualitative Variables in Estimation Cost Data

Estimated Cost Variable	Description of Estimated Cost Variable
Sponsoring Agency	The DoD agency that recommended the BRAC action
Commission Fully Approved	A factor value indicating whether or not the Commission found the recommendation "consistent with the final selection and force structure plan" (Defense Base Closure and Realignment Commission 2005), as described in the "Commission Recommendations" section of its final report. Variable levels are "A" if fully approved, "P" if approved in part.

3. Introduced Estimation Variables

In response to GAO research suggesting that bundled BRAC actions involving more than one base may be more opaque than standalone actions and perhaps subject to more variability in cost growth, two variables assessing complexity are added to the estimation data. The data for these proxy variables of BRAC action complexity are obtained from the "MilconAs" report from each action's respective COBRA model. The *Number of Bases* variable counts the number of distinct bases or locations that were expected to be involved in a particular BRAC action. The *Non-Zero Milcon Bases* variable counts the number of distinct bases or locations that were estimated to require military construction costs, no matter how large. Descriptions of the introduced estimation variables are summarized in Table 5.

Table 5. Proxy Variables for BRAC Action Complexity

Estimated Cost Variable	Description of Estimated Cost Variable
Number of Bases	Count of distinct bases or locations involved in a particular BRAC action
Non-Zero Milcon Bases	Count of distinct bases or locations involved in a particular BRAC action that carry a military construction requirement

4. Data Variables for Implementation Costs

The cost variables in the Business Plans capture the total implementation costs that were incurred over the six-year implementation period. Each cost category records its respective budgetary obligation that was required for implementation in constant 2005-year dollars. In the Business Plan source data, each of these cost variables are broken up into two subcategories: implementation costs incurred within the BRAC account and implementation costs incurred outside the BRAC account. The implementation costs used in this thesis are the sum of the implementation costs across cost subcategories in both the BRAC account and outside the BRAC account. This treatment is chosen because cost accounting inside and outside the BRAC accounts is inconsistent across services, per GAO reporting. Costs outside the BRAC account are also relatively small. Only 2.9% of the BRAC 2005's total implementation costs were obligated with funds outside of the BRAC account. The implementation data variables are show in Table 6.

Table 6. Description of Implemented Costs Recorded in Business Plans

Implementation Cost Variable	Description of Implementation Cost Variable
BP_ MILCON	Military Construction costs
BP_ O&M	Operations & Maintenance (O&M) costs
BP_ Environmental	Environmental costs
BP_ MilPers	Military Personnel Permanent Change of Station (PCS) costs
BP_ HAP	Homeowners Assistance Program costs
BP_ Other	Other costs
BP_GrandTotal	Grand Total of Implementation costs

5. Introduced Implementation Variables

Estimation costs and implementation (business plans) costs are not recorded with the same subcategories, which presents a challenge for direct comparison by subcategory. There are more estimation cost categories than there are implementation cost categories. In order to compare costs between the estimated and implemented data, appropriate COBRA estimated cost variables are summed together to introduce variables that may be

compared directly with Business Plan implementation data. These introduced variables are summarized in the crosswalk shown in Table 7.

Table 7. Crosswalk of Introduced Variables

Introduced Cost Estimation Variable	Cost Estimation Variables Summed (from COBRA model)	Corresponding Implementation Cost Variable
c_environ	*Environmental*	*BP_environmental*
c_milpers	*MIL MOVING Per Diem* *MIL MOVING POV Miles* *MIL MOVING HHG* *MIL MOVING Misc* *Elim PCS*	*BP_milpers*
c_o&m	*Civ RIF* *Civ Retire* *Per Diem* *POV Miles* *Home Purch* *HHG* *Misc* *House Hunt* *PPP* *RITA* *Packing* *Freight* *Vehicles* *Unemployment* *Info Tech* *Prog Manage* *Supt Contra* *Mothball* *1-Time Move*	*BP_o&m*
c_milcon	*milcon*	*BP_Milcon*
c_HAP Other	*HAP/RSE*	*BP_HAP*
c_other	*Misc Contract* *1-Time Other*	*BP_other*

To produce a measure for evaluating the cost increases specific to individual BRAC actions, variables that calculate the percentage cost increase from the cost estimate to the implementation cost are also introduced. These variables are produced for each available subcategory and summarized in Table 8. Cost growth is represented as a percentage and is calculated by dividing the difference in implementation cost minus estimation cost by the estimation cost.

Table 8. Introduced Variables to Measure Cost Growth

Introduced Cost Increase Variable	Description of variable
Milcon Increase	The percentage growth in military construction cost
O&M Increase	The percentage growth in O&M cost
Environmental Increase	The percentage growth in Environmental cost
Other Increase	The percentage growth in Other costs
Total increase	The percentage growth in Total Cost

IV. COST GROWTH TRENDS AND ANALYSIS

This section displays trends in the cost growth from estimated implementation costs to actual implementation costs. All analysis presented here uses the thesis data set of 58 selected BRAC 2005 observations.

A. COST GROWTH BY SUBCATEGORY

Consistent with GAO findings, a comparison of estimated cost with implemented cost highlights that military construction experienced the most significant cost increase among cost subcategories. Operations and Maintenance (O&M) costs also increased significantly, while costs categorized as "Other" decrease. Figure 1 illustrates the cost increase for each category from estimated cost to implemented cost.

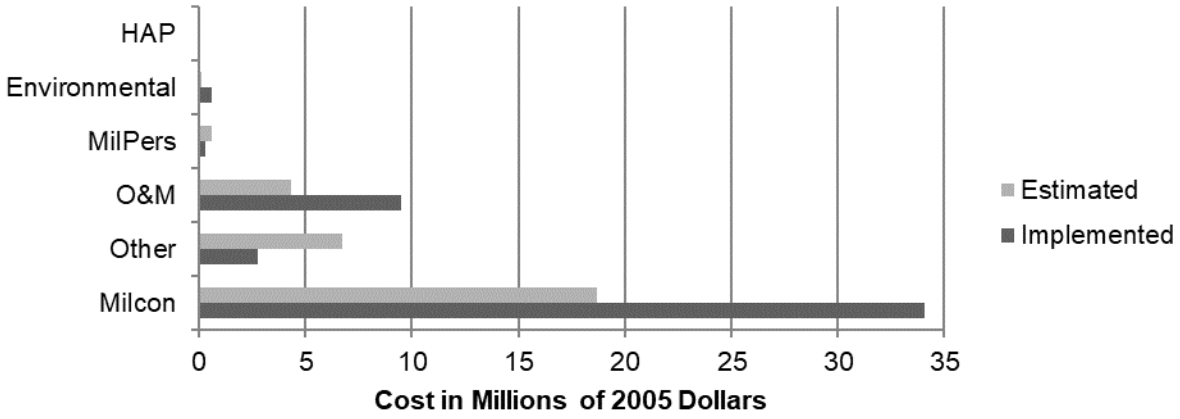


Figure 1. BRAC 2005 Cost Growth among Cost Subcategories

Notably, the overwhelming majority of implementation costs were incurred in just three categories: military construction, operations and maintenance, and other. Homeowners Assistance Program (HAP) costs, environmental costs, and military personnel costs are comparatively small. HAP costs are negligible. These costs are shown in greater detail in Figure 2, measured in thousands of 2005 dollars.

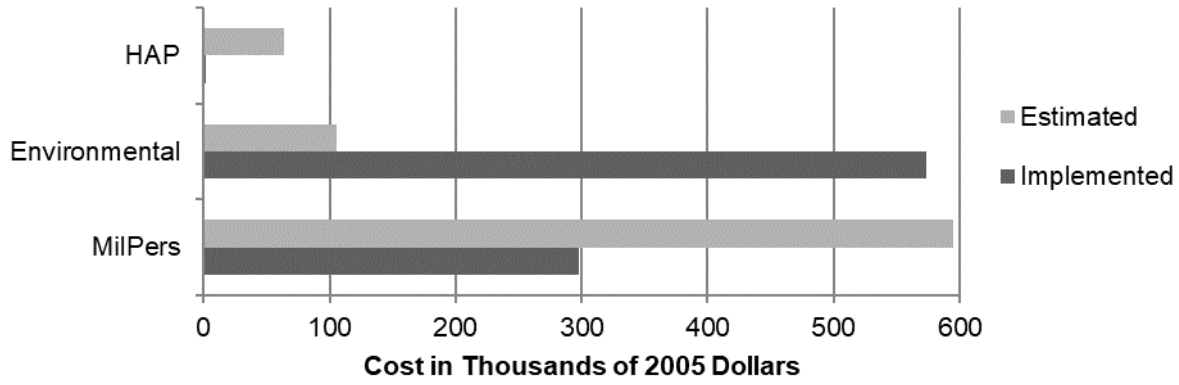


Figure 2. BRAC 2005 Cost Increases for HAP, Environmental, and MilPers

B. TRENDS IN COST GROWTH AMONG INDIVIDUAL ACTIONS

The following visualizations go beyond the aggregate cost increases and examine the trends in cost growth exhibited by individual BRAC actions.

1. Implementation Cost Growth

Analysis of the set of BRAC actions shows that individual BRAC actions also tended to increase in cost, in addition to the observation that the aggregate BRAC implementation cost grew significantly. The total implementation cost increased in 43 of the 58 observations for BRAC actions. Figure 3 plots these estimated versus implemented one-time costs. The red diagonal line represents a case of a "perfect" cost estimation, where an estimated cost equals the implementation cost.

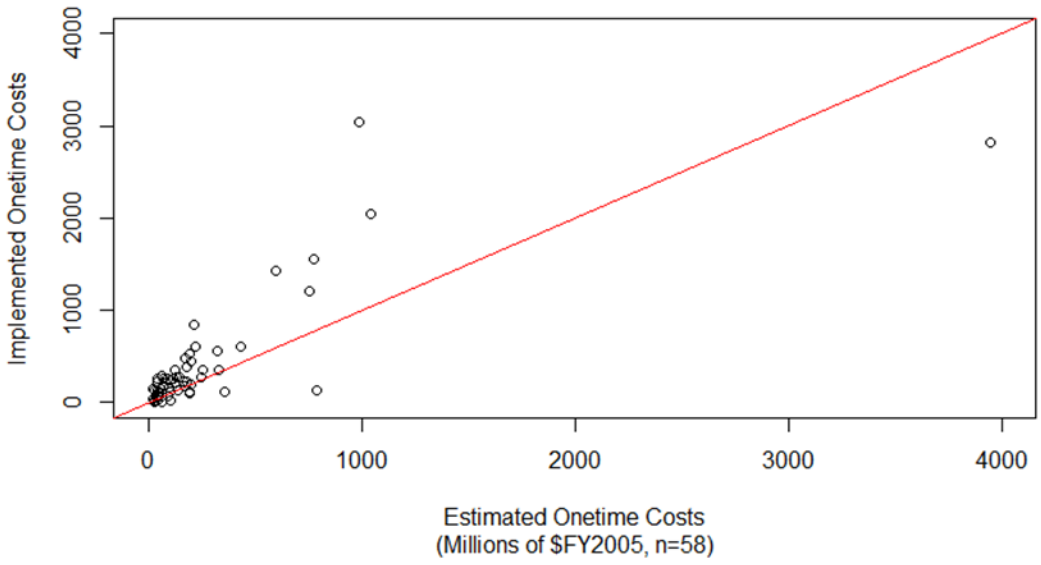


Figure 3. Estimated versus Implemented One-Time Costs

Actions that increased in cost are shown above the red line; actions that decreased in cost are below the red line. Figure 3 shows that the preponderance of observations represent cost increases. To highlight this point, Figure 4 shows the same graph in greater detail with the three most expensive observations omitted. Figure 4 omits BRAC Actions No. 10, 169, and 172.

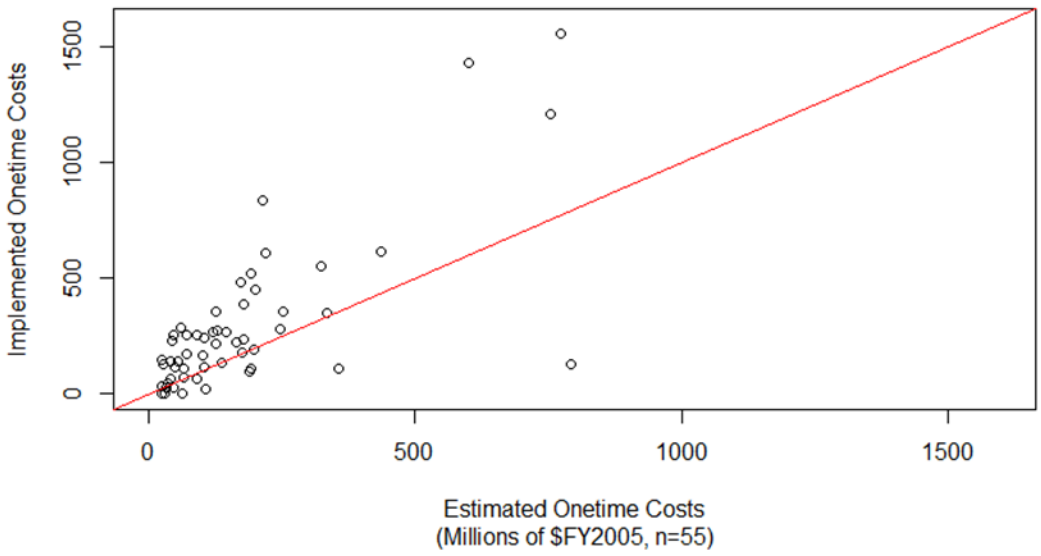


Figure 4. Subset of Estimated versus Implemented One-Time Costs

2. Military Construction Cost Growth

The majority of BRAC actions' military construction estimates experienced cost growth. Of the 58 BRAC actions, 52 experienced increases in military construction costs. Figure 5 displays the cost relationship between the estimated and implemented military construction costs.

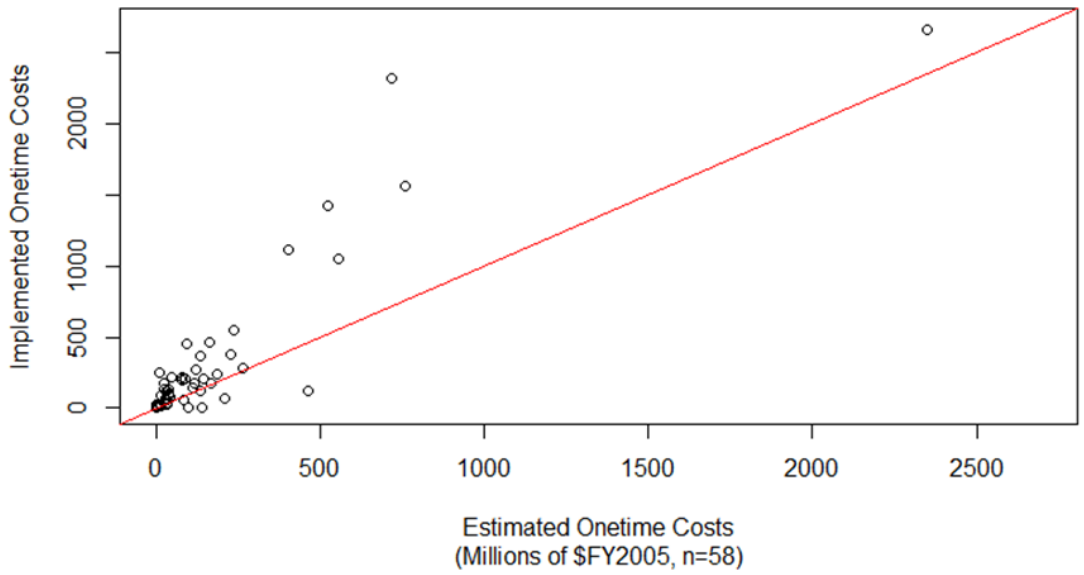


Figure 5. MILCON: Estimated versus Implemented One-Time Costs

To show the cost growth trends clearly for the observations that are tightly grouped in Figure 5, Figure 6 zooms in on a subset representing 52 observations, eliminating 6 extreme observations. Figure 6 omits BRAC Actions No. 10, 169, 172, 9, 133, and 121.

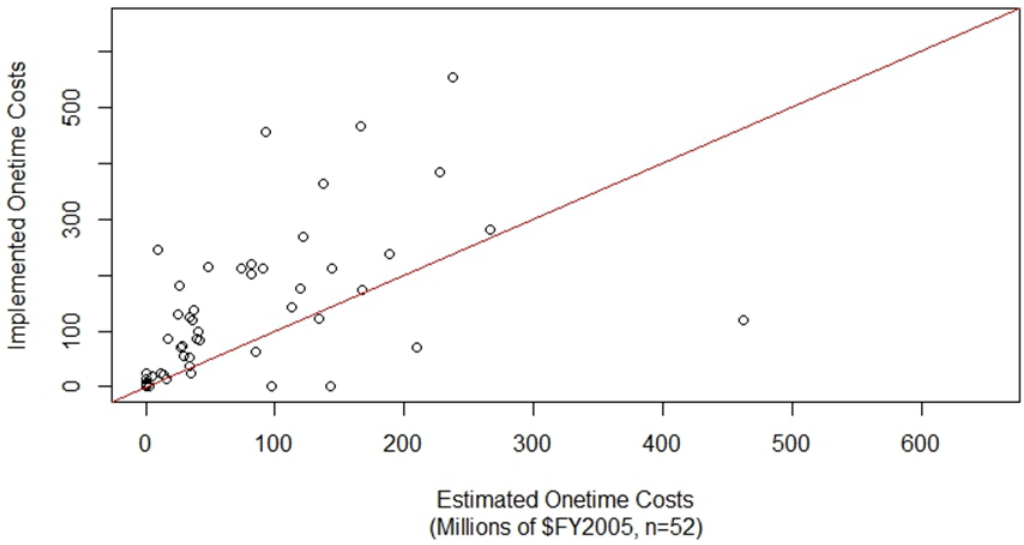


Figure 6. MILCON: Subset of Estimated versus Implemented One-Time Costs

3. Operations and Maintenance Cost Growth

O&M costs also increased in a majority of BRAC actions. Figures 7 and 8 display the cost relationship between estimated and implemented O&M costs and a subset of O&M costs, respectively. The subset is selected to show the tightly grouped observations in greater detail. In Figure 8, the removed extreme observations are BRAC Actions No. 169, 172, and 145. O&M costs increased in 47 of the 58 observations.

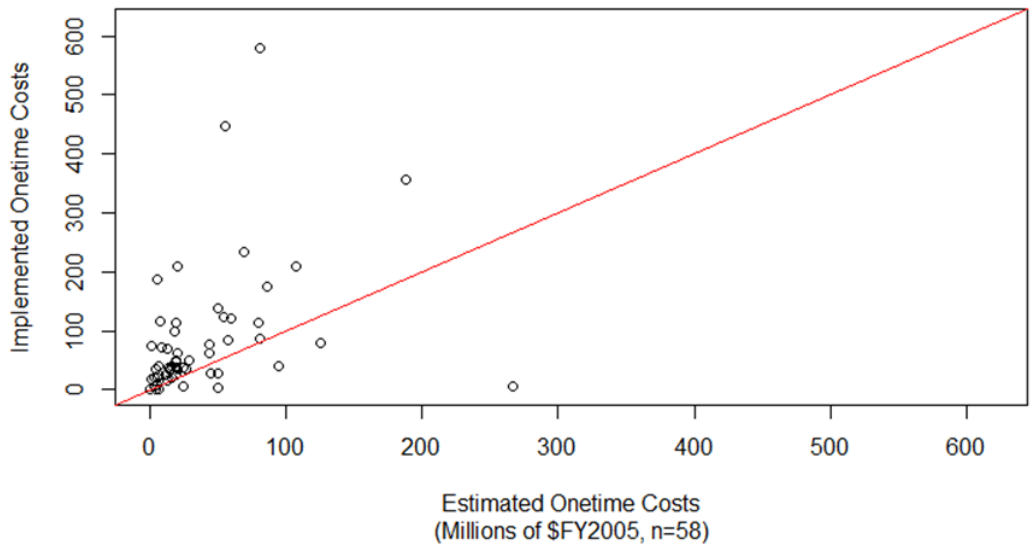


Figure 7. O&M: Estimated versus Implemented One-Time Costs

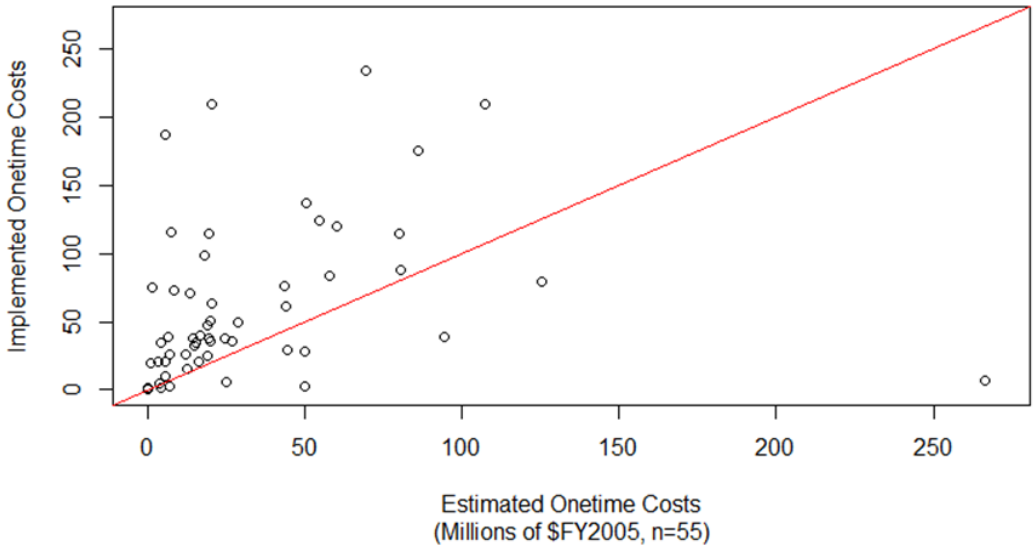


Figure 8. O&M: Subset of Estimated versus Implemented One-Time Costs

4. Other-Category Cost Growth

Cost categorized as "Other" is the only major subcategory of one-time implementation costs that did not experience a general increase. Figures 9 and 10 display the cost relationship between estimated and implemented Other-category costs with all 58 observations and a subset eliminating extreme observations, respectively. Figure 10

eliminates BRAC Actions No. 10, 172, 133, 6, 169, 9, and 7. The preponderance of other-category costs decreased at implementation.

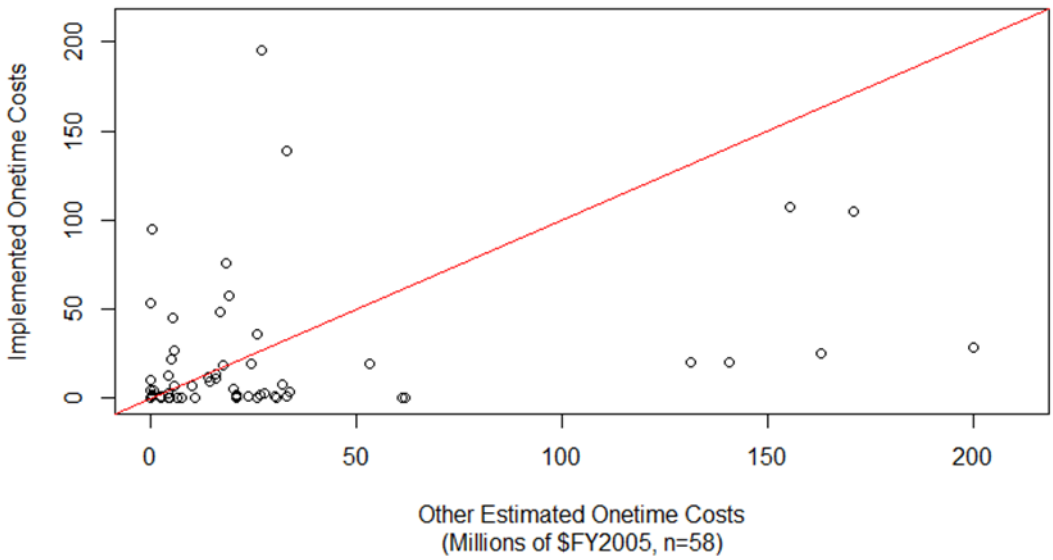


Figure 9. Other: Estimated versus Implemented One-Time Costs

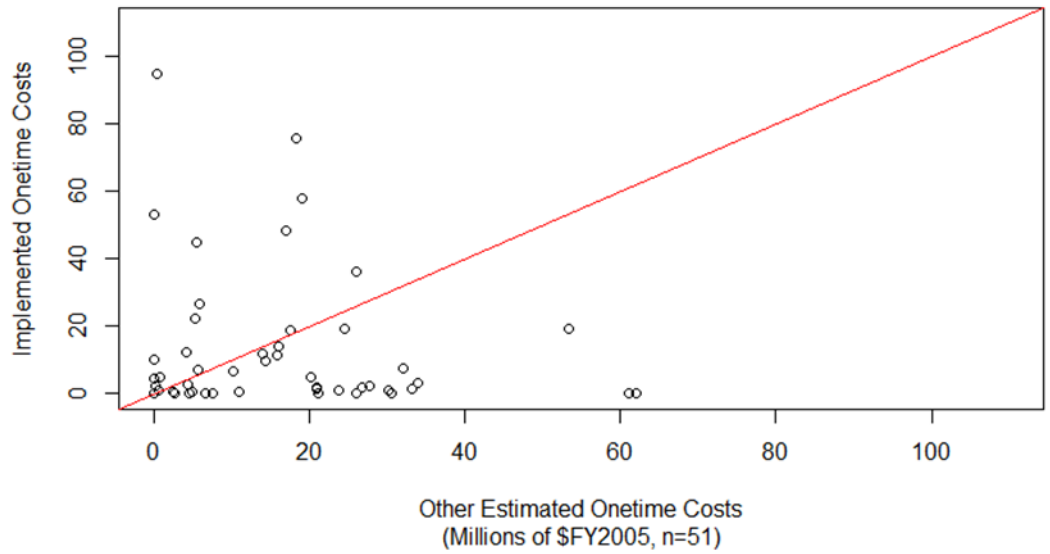


Figure 10. Other: Subset of Estimated versus Implemented One-Time Costs

C. EXPLORATION OF POSSIBLE COST INFLATION FACTORS

Cost inflation factors that inflate estimates at a certain multiple in order to arrive at a more accurate cost may be an effective way to predict implementation cost. As a simple example, the GAO's reported finding of a 67% cost increase in 2005 BRAC implementation cost may inform the use of a flat inflation factor of 167% of the estimated cost, assuming comparable future conditions. Continuing this example, a future BRAC round estimated to cost $10 billion could thus be expected to cost $16.7 billion.

The section explores that data to see if there are ways in which the data may be categorized into subsets where implementation cost increases are markedly different from other subsets. Where such differences exist, this may justify applying unique cost inflation factors to the estimates in the subsets in order to enhance the predictive quality of the estimates. Mean cost increases and variation in cost increases are evaluated for various data subsets.

1. Note on Methodology and Model of Analysis

As applies to the analysis throughout this thesis, the value of using cost inflation factors is dependent on the extent to which future BRAC rounds may be comparable to BRAC 2005. Even if suitable cost inflation factors are discovered to describe 2005 data, it would only be appropriate to apply these cost inflation factors for future BRAC rounds if the natures of those BRAC rounds were similar to BRAC 2005.

This section's analysis also merits a clarification of what is the sample and what is the population. In this analysis, the 58 BRAC 2005 observations under study are considered to be a sample of a larger, hypothetical set of 2005 BRAC observations that could have been expected if additional BRAC actions of a similar nature occurred in 2005. Thus, the sample is the 58 observations, and the population is a theoretical set of similarly-produced observations. This approach is necessary in order to do t-tests and ANOVA that compare the mean cost increases of different types of BRAC actions, for which, if statistically significant, may justify the use of distinct inflation factors for cost increases.

2. Recommending Agency Trends

This section evaluates speculation on whether one military service or DoD recommending agency produces more accurate cost estimates than another.

Every recommending agency except Intelligence is represented in the selected data for this thesis. One BRAC action added by the BRAC Commission is also included. The number of actions for each DoD recommending agency in the selected data is shown in Table 9.

Table 9. Selected Data: BRAC Actions by DoD Recommender

DoD Recommender	Number of BRAC actions (*n*)
Army	8
Department of Navy (DoN)	5
Air Force	7
Education & Training (E&T)	4
Headquarters & Support Activities (H&SA)	16
Industrial	7
Medical	4
Supply & Storage (S&S)	2
Technical	4
Added by BRAC Commission (ADD)	1
Total	*58*

Figure 11 displays a box plot distribution of cost growth for each recommending agency. The mean percentage cost increase for each DoD recommending agency is shown in red.

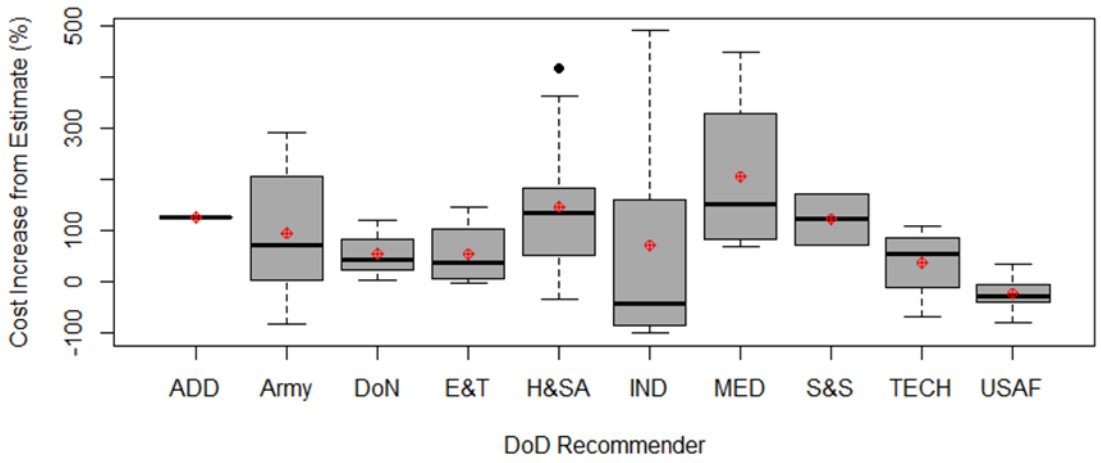


Figure 11. Implementation Cost Growth for BRAC Actions by DoD Recommending Agency

Cost growth varies among DoD recommending agencies. However, the number of observations for each recommending agency is small, and the differences among their mean cost increases are not statistically significant. In addition to the visual indication in Figure 11, a lack of statistical significance is supported by a one-way ANOVA test for equality of all means.

$$H_o: \mu_{Army} = \mu_{DoN} = \mu_{E\&T} = \mu_{H\&SA} = \mu_{IND} = \mu_{MED} = \mu_{S\&S} = \mu_{TECH} = \mu_{USAF}$$

The one-way ANOVA test of this hypothesis results in a p-value of 0.149. This p-value fails to reject the null hypothesis at $\alpha = 0.05$, and we must allow for the possibility that the mean cost increases of BRAC actions may not be different across recommending agencies. These findings do not support the use of distinct cost inflation factors for DoD recommending agencies.

3. Amendments

Some 2005 BRAC actions were amended immediately prior to their implementation. When the 2005 BRAC Commission reviewed and approved the DoD's 2005 BRAC recommendations, the Commission approved 119 BRAC action recommendations exactly as they were originally submitted by the DoD, and 45 DoD BRAC action recommendations were approved with amendments by the Commission. Of the 58 observations this thesis analyzes, 24 were amended.

It is reasonable to speculate whether amendments had an impact on implementation cost growth. 2005 BRAC actions' estimates were generally not based on the amended version of the recommendation; rather, they were based on the original recommendation. Even for amended BRAC actions where the BRACO and military services had an opportunity to revise COBRA model estimates to reflect the Commission's amendments, these updates may have been cursory due to the time constraint of the approaching implementation period. Thus, they may have put forward an estimate that did not resemble what was finally approved. For these reasons, one might expect amended BRAC actions to have more variability in cost growth. On the other hand, the presence of specified amendments resulting from Commission scrutiny may have signaled tighter constraints for amended BRAC actions, either directly through specifically enumerated changes or implicitly. If such were the case, one may expect amended BRAC actions to have less variability in cost growth than BRAC actions that were not amended.

Evaluation of this conjecture finds that the mean cost growth of amended 2005 BRAC actions and non-amended 2005 BRAC actions are not dissimilar. A two-sample t-test fails to reject the null hypothesis that the mean cost increase in non-amended BRAC actions is equal to the mean cost increase in amended BRAC actions at a p-value of 0.469.

$$H_o: \mu_{Amended\ actions'\ cost\ increase} = \mu_{Non-Amended\ actions'\ cost\ increase}$$

The mean cost increase for amended actions is 32.5% and 59.2% for non-amended actions, but the difference is not statistically significant.

However, in evaluating the relative uncertainty in cost growth, amended actions show less variation in their cost increases than non-amended actions, as the box plot in Figure 12 shows.

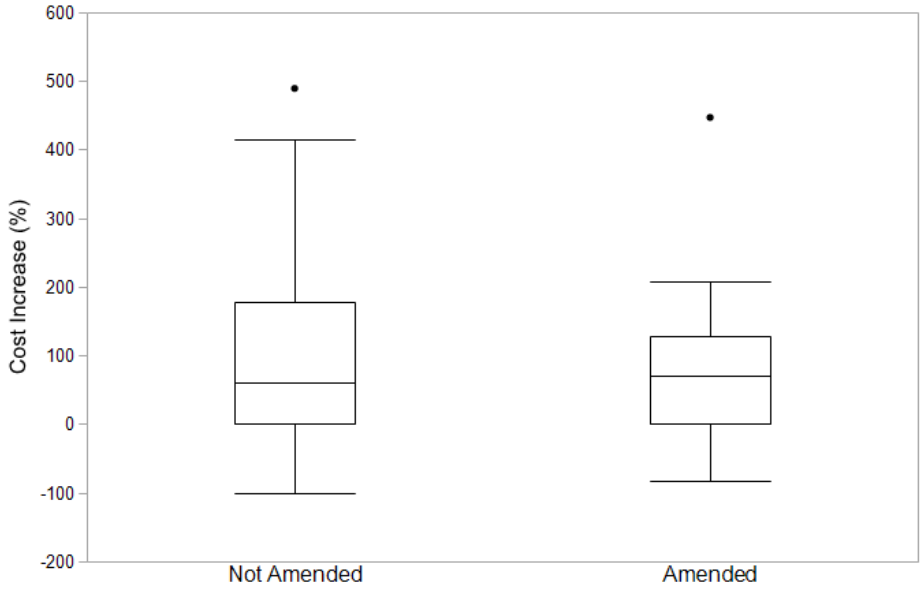
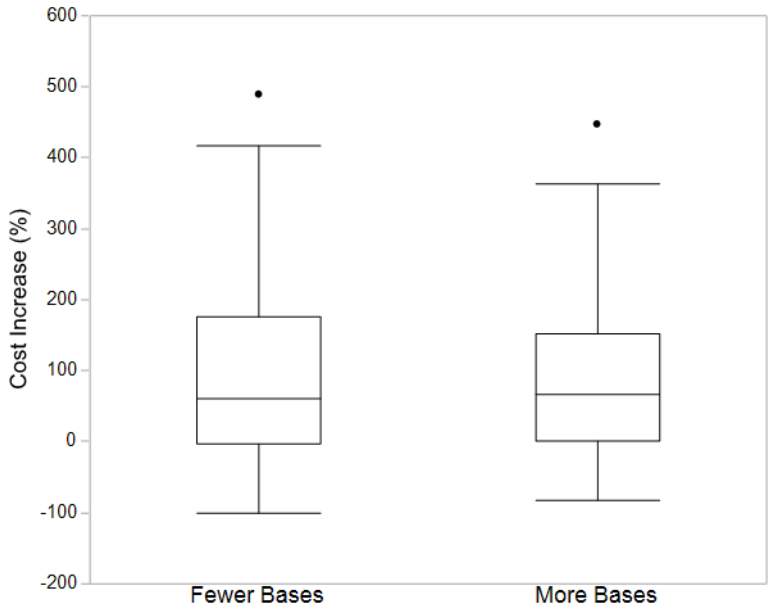


Figure 12. Implementation Cost Growth for Amended and Non-amended BRAC Actions

4. Complexity

The introduced variable, *NumberOfBases*, is a proxy variable for complexity; it is the count of distinct bases that a 2005 BRAC action was expected to involve. Some complex BRAC actions involved several bases whereas simpler BRAC actions involved few bases. Figure 13 shows that the median cost increase is similar among more complex and less complex BRAC actions. “Fewer Bases” are BRAC action observations that were estimated to involve 1–6 distinct bases (n=27). “More Bases” describes BRAC action observations that were estimated to have 7–22 bases (n=28).



Three observations (BRAC Actions No. 146, 143, and 155) were excluded because the number of bases involved in the action could not be determined.

Figure 13. Box Plot of Cost Growth by Action Complexity

The closer quantiles in BRAC actions with more bases indicate that there may be less variation in cost increases among complex BRAC actions. However, this may simply be the default effect of reduced variation when multiple entities with individual uncertainties are grouped, similar to how diversification of several stocks in an investment portfolio prevents a portfolio from going up or down as drastically as would a portfolio with one or few stocks. While this difference in variation is visually noticeable, it is not statistically significant. This finding does not support the use of cost inflation factors on this basis of BRAC action complexity, as measured by the proxy variable, *NumberOfBases.*

5. Size of Estimated Cost

The variation in implementation cost increases is similar for low and high cost estimates. Figure 14 shows the distribution of implementation cost increases for 2005 BRAC actions divided into two equal groups: the half that are the more costly BRAC action estimates (high estimates) and the other half that comprise the comparatively less costly BRAC action estimates (low estimates).

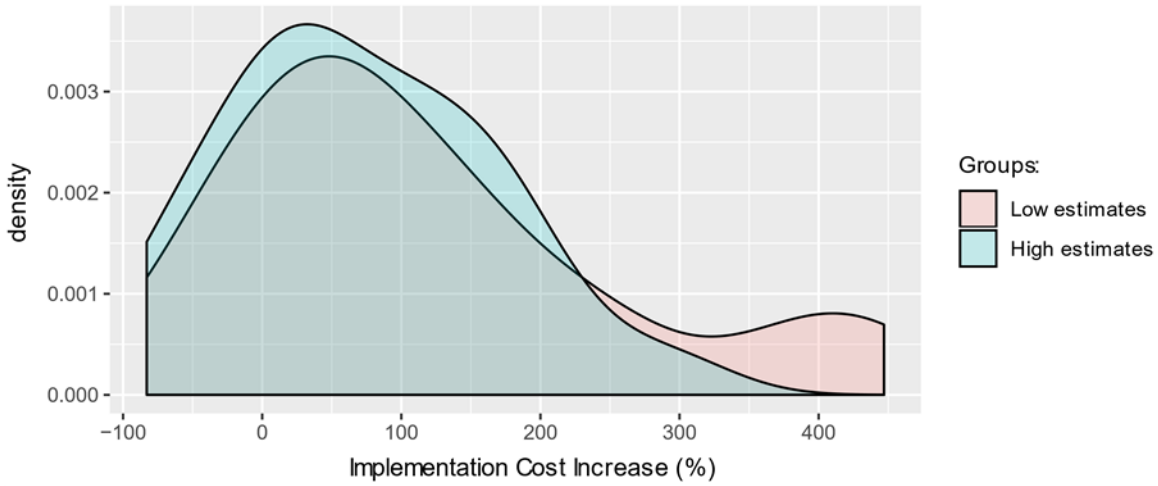


Figure 14. Comparison of Variation in Implementation Cost Growth for Low versus High Estimates

The distribution of the two groups' cost increases shows that they nearly overlap. In addition to the visual indication, the lack of statistical significance is supported by the results of a t-test for equality of mean implementation cost increase between the two groups.

$$H_o: \mu_{low\_estimates} = \mu_{high\_estimates}$$

The t-test for this hypothesis results in a p-value of 0.149, which fails to reject the null hypothesis at $\alpha = 0.05$. This finding does not support the use of distinct cost inflation factors for estimates based on the size of the estimate because there is no significant difference between the two groups.

Despite this finding, the thick right-side tail for low estimates is a notable observation. The thick tail suggests that significant cost increases in excess of 300% or 400% cost growth are more common for lower estimated BRAC actions than higher estimates.

V. BIAS IN ESTIMATING LARGE BRAC ACTIONS

Analysis of *ex post facto* groupings for differences in cost increases cannot alone inform better cost estimates, but it may signal where biases or limitations exist during the estimation phase. This analysis presents a conspicuous finding that there may be a systemic hesitancy to fully or accurately estimate the costliest BRAC actions to be as expensive as they ultimately end up costing.

Figure 15 shows the distribution of implementation cost increases for BRAC actions for two groups after the six-year implementation period is complete and all implementation costs are realized and definitively known. The two equal-sized groups in Figure 15 are the actions that comprise the less costly BRAC actions upon implementation (actions with lower implementation costs) and the costlier half of BRAC actions.

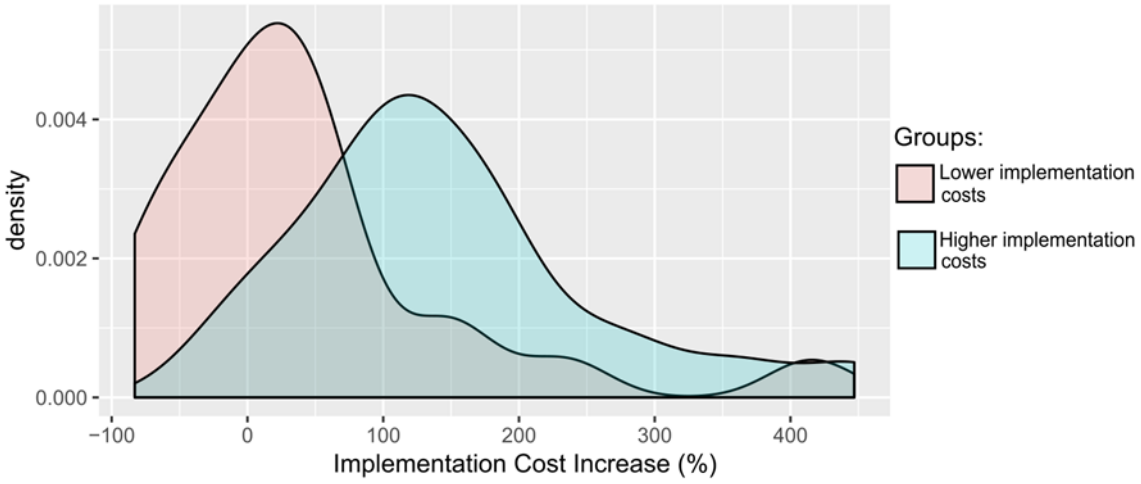


Figure 15. Comparison of Variation in Implementation Cost Growth for Lower versus Higher Implemented Costs

Figure 15 illustrates a noticeable gap in the mean cost increases and variations in cost increases. BRAC actions that are ultimately less expensive exhibit less cost growth, whereas BRAC actions that are ultimately more expensive exhibit more cost growth. This analysis shows that some BRAC actions' implementation costs will experience

significantly more cost growth than others, though it is indiscernible which actions these will be at the time of estimation.

This finding suggests that there is a systematic bias against very large BRAC estimates. The GAO reports that such biases occur often in estimating program costs (GAO 2009). Theses biases "may be cognitive—often based on the estimators' inexperience—or motivational, where management intentionally reduces the estimate or shortens the schedule to make the project look good to stakeholders" (GAO 2009, p. 153).

Promoting awareness of this issue among BRAC planners and stakeholders may be a first start in reducing its adverse impact on accurate cost estimates. BRAC estimators must be encouraged to produce realistic estimates if accurate estimates are expected, and stakeholders should be tolerant of high estimates. The analysis suggests that there will be very costly BRAC actions regardless of whether they are estimated to be so costly. A transparent understanding of this may produce greater comfort with high estimates.

VI. ESTIMATING FUTURE BRAC ROUNDS

Decision makers deserve an understanding of the uncertainty in BRAC action cost estimates. This section quantifies the uncertainty in BRAC actions' one-time cost estimates and delivers an improvement over the historic single-point estimate.

A. THE IMPORTANCE OF UNCERTAINTY ANALYSIS

Uncertainty is inherent in cost estimates because they predict the future. At the time when BRAC estimates are produced, fewer details are known about requirements and the chance of change is greater. As a BRAC round matures toward implementation, more is learned and the uncertainty surrounding its cost narrows. The GAO's Cost Estimating and Assessment Guide describes that programs typically also increase in cost while reducing variance, because more requirements are added as the program is better understood (GAO 2009). Adapted from GAO's guide, Figure 16 shows a typical progression in uncertainty surrounding cost estimates, where the uncertainty is widest at the time of estimation and narrower near implementation.

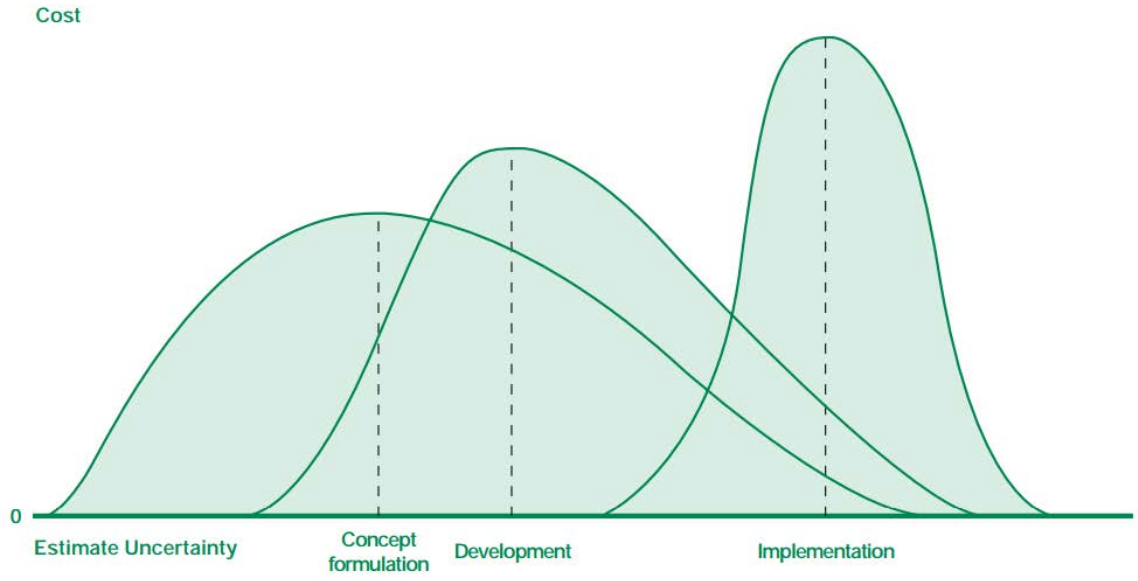


Figure 16. Cost Uncertainty Narrows over Acquisition Cycle. Adapted from GAO (2009).

Historic BRAC rounds have relied on single point estimates for implementation cost; BRAC 2005 was estimated to cost $21.0 billion to implement. Yet a point estimate by itself is insufficient. Point estimates merely provide a value chosen as "most likely" and do not provide any information about the inherent uncertainty.

The point estimates for BRAC action implementation costs produced by the COBRA model also contain a great deal of uncertainty. A COBRA model estimate is composed from a sum of lower-level elements' estimates, each of which comes with its own source of error. The GAO comments further on the flaws of summing lower-level elements, stating that "it is inaccurate to add up the most likely [Work Breakdown Structure] elements to derive a program cost estimate, since their sum is not usually the most likely estimate for the total program, even if they are estimated without bias" (GAO 2009, p. 153).

B. CONFIDENCE INTERVALS FOR BRAC ACTION COST INCREASES

The preferable alternative to a single-point estimate is a confidence interval which provides a range of cost possibilities based on specified probability levels.

The distribution of BRAC actions implementation cost increases provides a means of understanding future BRAC action costs increases. The observations selected in this thesis are chosen to represent what the DoD may realistically expect in a future BRAC round. Provided that a future BRAC round is similar to BRAC 2005 in its estimation and implementation practices, the following analysis may be applicable to decision makers' understanding of BRAC actions' implementation cost increases, and thus, their final, expected cost upon implementation.

1. Variation in Implementation Cost Growth

Implementation cost growth varies widely among 2005 BRAC actions. The fifty-eight observations studied in this thesis have implementation cost increases that range from –100%, a BRAC action implementation that cost half of what was estimated, to 489%, a BRAC action that increased to nearly five times as much as its estimate. The histogram in Figure 17 shows the distribution of BRAC action cost increases among the 58 actions.

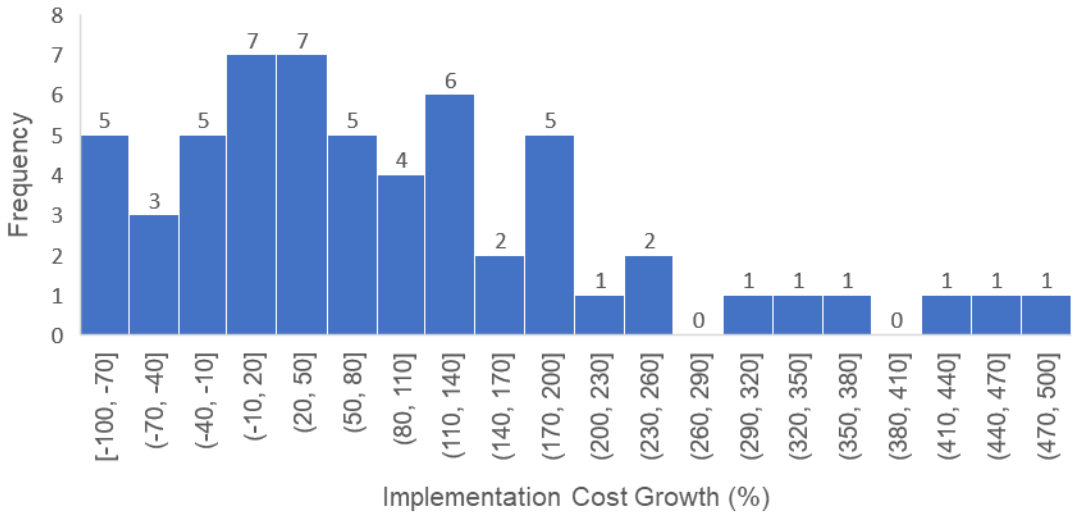


Figure 17. Histogram of Implementation Growth for Selected 2005 BRAC Actions

Selected 2005 BRAC actions' implementation cost increases are non-normal and have a right-skewed distribution. The mean for these cost increases is 93.1%, the median is 63.7%, and the standard deviation is 135.9%.

2. Three-Point Estimates at Various Confidence Intervals

If we assume that future BRAC actions will resemble the 2005 BRAC actions studied in this thesis, we may make several inferences from this distribution. This analysis indicates that we may expect the average future BRAC action to increase 93.1% from its estimate. Using confidence intervals, the distribution in Figure 17 also enables a three-point estimate of the population mean of future, hypothetical BRAC action increases.

The confidence intervals are informed by following formula.

$$\bar{x} \pm t^*_{n-1} \frac{s}{\sqrt{n}}$$

The degrees of freedom, *n - 1*, is 57, the standard deviation, *s*, is 135.9 percent, and sample mean, $\bar{x}$, is 93.1 percent. For a 95 percent confidence interval of a 2-tailed distribution, t^*_{57} is 2.0025. For a 90 percent confidence interval of a 2-tailed distribution, t^*_{57} = 1.6720, and for an 80 percent confidence interval of a 2-tailed distribution, t^*_{57} = 1.297.

Table 10 summarizes the descriptive statistics for the mean of implementation cost increases at various confidence intervals.

Table 10. Estimates for Mean BRAC Action Implementation Cost Growth at 95-, 90-, and 80-Percent Confidence Intervals

Confidence Interval	Mean (%)	Lower Bound (%)	Upper Bound (%)
95 percent	93.1	57.4	128.8
90 percent	93.1	63.3	122.9
80 percent	93.1	69.9	116.2

The confidence intervals contain a wide range of cost increase possibilities. However, it is notable that none of the confidence intervals approach the inclusion of a 0% cost increase, which represents an accurate cost estimate. The model expects, with high confidence, that estimates will be overrun. In fact, the confidence interval for this set of 58 observations would have to extend to a 99.9997% confidence interval before a 0% mean cost increase could be included as a possibility for the true mean of BRAC action cost increases.

C. S-CURVE FOR FUTURE BRAC ACTIONS

The probability distribution shown in Figure 17 delivers additional utility to decision makers in the form of an S-curve. An S-curve illustrates the cumulative probability distribution.

The S-curve in Figure 18 is derived from the actual distribution of selected 2005 BRAC action increases, where each BRAC action is assigned an equal probability of 1/ 58th. It provides future BRAC decision makers with an estimate of the probability that a BRAC action's implementation cost increase will be at some value or lower. Conversely, 1 minus the associated probability is the probability that the BRAC action's cost growth will exceed this level.

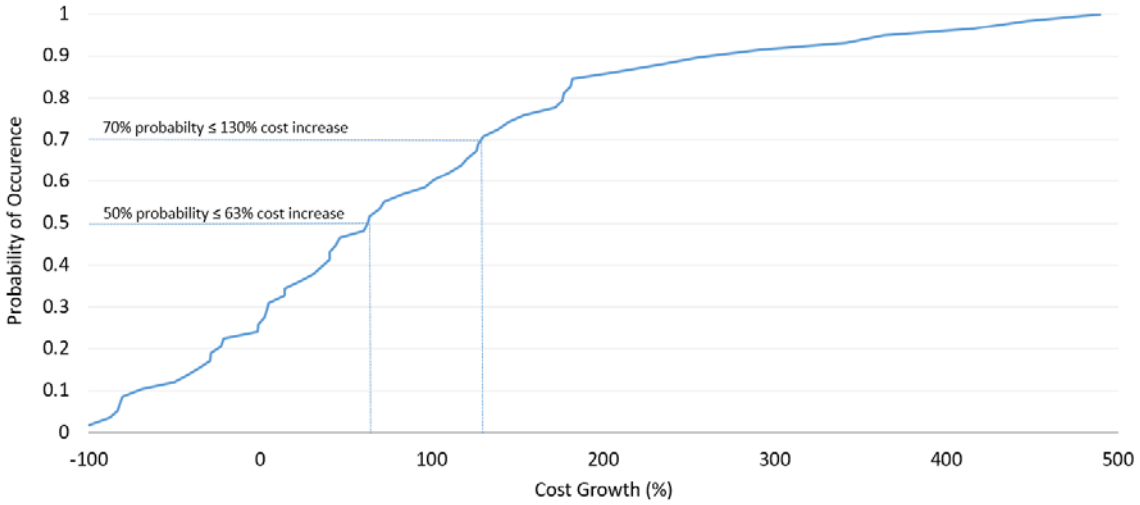


Figure 18. S-Curve for Probability of BRAC Action Cost Growth

Using the S-curve, a BRAC action with an estimated implementation cost of $100 million has a 50% probability that its cost will increase no more than 63%, corresponding to an implementation cost no greater than $163 million. The same $100 million estimate also has a 30% chance that its cost will increase more than 130%, which represents an implementation cost of at least $230 million.

BRAC cost estimators may use this uncertainty analysis to inform stakeholders about future BRAC actions' range of costs. Decision makers may then decide whether the potential cost of a BRAC round fits within their allowable range.

THIS PAGE INTENTIONALLY LEFT BLANK

VII. CONCLUSIONS

The implementation of BRAC 2005 cost much more than originally expected, growing from $21.0 to $35.1 billion. This thesis delivers an understanding of the uncertainty in BRAC action estimates to aid future BRAC planners and decision makers.

(1) Milcon Drives Cost Growth

The most significant source of cost growth in BRAC 2005 was military construction, much of which was driven by additional requirements. Operations & maintenance costs also contributed to cost growth. HAP, environmental, and military personnel costs are not a significant source of cost growth in BRAC 2005 implementation cost.

(2) Distinct Cost Inflation Factors Not Supported

We conclude that it is not appropriate to apply distinct cost inflation factors to subsets of data to achieve more accurate cost estimates. No distinct differences are found in the studied BRAC actions' cost increases when examined in several ways. There is no statistically significant difference in cost increases explained by the type of DoD recommending agency, the presence of Commission amendments, the degree of action complexity, or size of the cost estimate. Variation in implementation cost growth is mildly narrower for BRAC actions that were amended by the Commission and that were more complex.

(3) Bias Detected in Estimating Large BRAC Actions

In general, the BRAC actions that ultimately cost the most to implement experience the most cost growth. This systematic bias goes undetected at the time of estimation but becomes apparent when implementation is complete. This suggests an inability or hesitancy to fully estimate expensive BRAC actions. The bias may have cognitive or motivational origins. Awareness of its existence may prompt BRAC estimators to produce realistic estimates and prompt decision makers to be tolerant of higher estimates.

(4) Three-Point Estimate for Future BRAC Actions

Future BRAC actions' cost increases are informed by the distribution of selected 2005 BRAC actions' implementation cost increases. With 95% confidence, the true mean for BRAC actions' implementation cost increases lies between a 57.4% cost increase and 128.8% cost increase, with a mean of 93.1%. The cumulative distribution S-Curve produced in this thesis maps cost increases with their probability of occurrence. Decision makers may use this S-Curve to understand the potential range of costs for a BRAC action implementation.

(5) Refined Data Collection Will Support Future Analysis

The GAO correctly identifies that the practice of bundling several base realignment and closure actions within one recommendation severely limits detailed understanding of cost growth. Treating each base realignment or closure separately, or at a minimum, itemizing each under a larger recommendation, will greatly enhance data quality for future analysis. Historically, that level of granularity is lost as costs are recorded in aggregate. Budget costs should also be recorded in the same categories in which they are estimated by the COBRA model to enable a direct estimate-to-implementation comparison.

LIST OF REFERENCES

101st Congress (1990) National Defense Authorization Act for Fiscal Year 1991. *Defense Base Closure and Realignment Act of 1990,* Amended per Public Law 101-510, 104 Stat.1485, https://www.govinfo.gov/content/pkg/STATUTE-104/pdf/STATUTE-104Pg1485.pdf.

107th Congress (2001), National Defense Authorization Act for Fiscal Year 2002. *Defense Base Closure and Realignment Act of 1990,* Amended per Public Law 107-107, §3002 Selection criteria, 115 Stat. 1012, https://www.congress.gov/107/plaws/publ107/PLAW107publ107.pdf.

108th Congress (2004) Ronald W. Regan National Defense Authorization Act for Fiscal Year 2005. *Defense Base Closure and Realignment Act of 1990,* Amended per Public Law 108-375, §2832 Specification of final selection criteria for 2005 base closure round, 118 Stat. 1811. https://www.congress.gov/108/plaws/publ375/PLAW-108publ375.pdf.

2005 Defense Base Closure and Realignment Commission (2005) 2005 Defense Base Closure and Realignment Commission report. Report, Arlington, VA. https://www.brac.gov/docs/final/Volume1BRACReport.pdf.

Brown DM (1989) COBRA: The base closure cost model. Report PL809R1, Logistics Management Institute, McClean, VA.

College C (2011) Critical analysis of the Army's BRAC 2005 processes, 5th draft as of 11 November 2011. Unpublished report, Assistant Chief of Staff for Installation Management, Washington, DC.

Dell R (1998) Optimizing Army base realignment and closure. *Interfaces*, 28(6):1–18.

Dell R, Ewing P, Tarantino W (2008) Optimally stationing Army forces. *Interfaces*, 38(6):421–435.

Deputy Assistant Secretary of the Army for Infrastructure Analysis (2006) The Army Basing Study (TABS) BRAC 2005 after action report. Assistant Secretary of the Army for Installations, Environment, and Energy, Washington, DC.

Dietrich N, Pannell M, Bonich V, Harrop S, Zoller N, Wright, B, (2015) CAA Analytic Stationing Team (CAST). Infrastructure Analytics Workshop. Center for Army Analysis November 5, Fort Belvoir, VA.

Government Accountability Office (2005) Analysis of DoD's 2005 selection process and recommendations for base closures and realignments. Report GAO-05-785.Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-05-785.

Government Accountability Office (2007) Military base realignments and closures: observations related to the 2005 round. Report GAO-07-1203R. Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-07-1203R.

Government Accountability Office (2008) Military base realignment and closures: higher c and lower savings projected for implementing two key supply-related BRAC recommendations, Report GAO-08-315. Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-08-315.

Government Accountability Office (2009) GAO cost estimating and assessment guide. GAO-09-3SP, Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-09-3SP.

Government Accountability Office (2010) DoD is taking steps to mitigate challenges but is not fully reporting some additional costs. Report GAO-10-725R. Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-10-725R.

Government Accountability Office (2012a) Military base realignments and closures: updated costs and savings estimates from BRAC 2005. Report GAO-12-709R. Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-12-709R.

Government Accountability Office (2012b) Military base realignments and closures: key factors contributing to BRAC 2005 results (testimony before the Subcommittee on Readiness, Committee on Armed Services, House of Representatives). testimony GAO-12-513T. Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-12-513T.

Government Accountability Office (2013) Military bases: opportunities exist to improve future base realignment and closure rounds. Report GAO-13-149. Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-13-149.

Government Accountability Office (2016a) Defense infrastructure: more accurate data would allow DoD to improve the tracking, management, and security of its leased facilities. Report GAO-16-101. Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-16-101.

Government Accountability Office (2016b) More guidance and information needed to take advantage of opportunities to consolidate training. Report GAO-16-45. Government Accountability Office, Washington, DC, https://www.gao.gov/products/GAO-16-45.

Harvey M (2005) *COBRA User Manual*. Unpublished manual, May 19. https://www.acq.osd.mil/brac/Downloads/Tools/COBRAUsersManual.pdf.

Tarantino W (2016) Interview by Sarah A. Martin, May. Naval Postgraduate School.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California