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Business Case Analysis: Continuous Integrated Logistics Support-Targeted Allowance Technique (CILS

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Business Case Analysis: Continuous Integrated Logistics Support-Targeted Allowance Technique (CILS–TAT)

30 May 2013

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BUSINESS CASE ANALYSIS: CONTINUOUS INTEGRATED LOGISTICS SUPPORT-TARGETED ALLOWANCE TECHNIQUE (CILS–TAT)

ABSTRACT

In this research, we examine the Naval Sea Logistics Command's Continuous Integrated Logistics Support–Targeted Allowancing Technique (CILS–TAT) and the feasibility of program re-implementation. We conduct an analysis of this allowancing method's effectiveness onboard U.S. Navy Ballistic Missile Defense (BMD) ships, measure the costs associated with performing a CILS–TAT, and provide recommendations concerning possible improvements to the existing CILS–TAT model. In this project, we study the impact of CILS–TAT on allowance effectiveness and identify any correlations between allowance effectiveness rates, percentage of time free from casualty reports, and CILS–TAT costs. In addition, the report addresses the impact of the brownout period of allowancing processes due to the implementation of the U.S. Navy Enterprise Resource Planning program. Our research concludes that CILS–TAT was directly responsible for improved allowance effectiveness for more than one third of our sample during two separate analysis windows. We also noted that the process behind CILS–TAT could be improved through the addition of mission criticality codes to the existing model.

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LCDR Thomas E. Arnold
LCDR Anthony P. Bannister
LT Daniel T. Jones

I would like to thank my wife, Sara, for her love and understanding during the course of this project and my pursuit of a master's degree. Without her patience and support, none of my achievements would be possible.

LCDR Thomas E. Arnold

I would like to thank my wife, April, and my daughters, Madison and Emily, for their love and support during this project, because without them, this project and the ultimate degree would not have been possible. Additionally, I would like to thank my parents, Gary and Sue, for their guidance and mentoring, which has made me who I am today.

LCDR Anthony P. Bannister

I would like to thank my wife, Allison, and my children, Grace and Noah, for their continued love and encouragement throughout this process—without them, none of this would be possible. I would also like to thank my parents, Ron and Debbie, who throughout the years have continued to provide guidance and listening ears when life seems overwhelming.

LT Daniel T. Jones

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ABOUT THE AUTHORS

LCDR Arnold is currently studying at the Naval Postgraduate School and pursuing a Master of Business Administration with a concentration in acquisition and contract management. Following graduation, he will report to Defense Logistics Agency, Richmond, VA. A native of Saint Cloud, FL, LCDR Arnold graduated from Saint Cloud High School in 1995. He earned his bachelor's degree in environmental science from Maryville College, TN, in 1999 and was selected for Officer Candidate School in 2001. He was commissioned in February 2002 and attended Navy Supply Corps School in Athens, GA. His operational assignments include disbursing officer, USS *Detroit* (AOE-4), supply officer, USS *Henry M. Jackson* SSBN 730 (Gold), supply officer, USS *Nebraska* SSBN 739 (Blue), J4 Logistics OIC for Task Force 373 (Afghanistan), and principal assistant for logistics, USS *George H. W. Bush* (CVN 77). Arnold's shore assignment was as the Staff Logistics Officer to the Royal Navy's Flag Officer for Scotland, Northern England and Northern Ireland (FOSNNI) under the Personnel Exchange Program. His personal awards include the Defense Meritorious Service Medal, the Navy and Marine Corps Commendation Medal with two gold stars, and the Navy and Marine Corps Achievement Medal with one gold star. He is a qualified Naval Aviation Supply officer, Surface Warfare Supply Corps officer, and Submarine Warfare Supply Corps officer. Lieutenant Commander Arnold is married to Sara Moore Arnold of Long Island, NY. The Arnolds currently reside in Monterey, CA.

LCDR Bannister is currently studying at the Naval Postgraduate School pursuing a Master of Business Administration with a concentration in supply chain management. Directly following graduation, he will deploy as a foreign military sales officer to the Afghanistan National Army as part of Combined Security Transition Command–Afghanistan. A native of Kalamazoo, MI, LCDR Bannister enlisted in the Navy in 1995. After graduating from Basic Hospital Corps School, he was assigned as a general duty hospital corpsman and, subsequently, was assigned to Naval Hospital Pensacola, FL. He earned his bachelor's degree in business management from Troy University and was selected for Officer Candidate School in Pensacola, FL. Following his commissioning in 2001, he attended Navy Supply Corps School in Athens, GA. LCDR Bannister also holds a Master of Public Administration from Troy University and is a graduate of the University of North Carolina's LOGTECH Advanced Program in Logistics and Technology. His sea duty assignments include disbursing officer and sales officer, USS *Arleigh Burke* (DDG 51) and aviation supply division officer, USS *Harry S. Truman* (CVN 75). LCDR Bannister's shore assignments include supply officer, Navy Recruiting Orientation Unit, Pensacola, FL, and aviation support division officer, COMFAIRFWD, Atsugi, Japan. His awards include the Navy and Marine Corps Commendation Medal with two gold stars, the Navy and Marine Corps Achievement Medal with two gold stars, and various campaign and unit awards. He is a qualified Aviation and Surface Warfare Supply Corps officer. Lieutenant Commander

Bannister is married to the former April Danielle Whitmore of Pensacola, FL. They have two lovely daughters, Madison Gayle and Emily Grace. The Bannisters reside in Monterey, CA.

LT Jones is currently studying at the Naval Postgraduate School pursuing a Master of Business Administration with a concentration in financial management (energy specialty). Following graduation, he will report to Submarine Officer Advanced Course in Groton, CT. A native of Clarkston, MI, LT Jones graduated from Clarkston High School in 2001. He earned his bachelor's degree in mechanical engineering from Purdue University, IN, in 2005. Following graduation, LT Jones pursued the standard nuclear power training pipeline via the S5W prototype in Charleston, SC. In 2007, he reported to USS *Chicago* (SSN 721) where he made two Western Pacific deployments and served as reactor control assistant, chemistry-radiological assistant, damage control assistant, and assistant engineer. From 2010 to 2011, he started as a submarine watch officer for Commander Task Force 69 in Naples, Italy, and subsequently moved to Commander DESRON Six Zero, Task Force 65, serving as assistant operations officer and anti-submarine watch officer. During his time there, he deployed in support of Operation Odyssey Dawn providing procedural oversight of 106 TLAM firings. LT Jones is authorized to wear the Navy Commendation Medal (two awards), the Joint Achievement Medal, and the Navy Achievement Medal (two awards), in addition to other unit and service awards. Lieutenant Jones is married to the former Allison Kendra Spinweber of Clarkston, MI. They have two children, Grace and Noah. The Joneses currently reside in Monterey, CA.

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LIST OF ACRONYMS AND ABBREVIATIONS

3M	Maintenance, Material, and Management
A_o	Operational Availability
A_i	Inherent Availability
APL	Allowance Parts List
AEL	Allowance Equipage List
ASI	Automated Shore Interface
AT	Allowance Type
BA	Budget Activity
BCA	Business Case Analysis
BKP	Bounded Knapsack Problem
BMD	Ballistic Missile Defense
C2, C3, C4	Category 2, Category 3, Category 4
CASREP	Casualty Report
CBA	Cost-Benefit Analysis
CDMD–OA	Configuration Data Managers Database–Open Architecture
CFFC	Commander, Fleet Forces Command
CG	Guided Missile Cruiser
CIS	Corporate Information Systems
CILS–TAT	Continuous Integrated Logistics Support–Targeted Allowancing Technique
CNO	Chief of Naval Operations
COG	Material Cognizance Code
COSAL	Coordinated Shipboard Allowance List
DAU	Defense Acquisition University
DDG	Guided Missile Destroyer
DLR	Depot-Level Repairable
DoD	Department of Defense
DoN	Department of the Navy

ERP	Enterprise Resource Planning
FFG	Guided Missile Frigates
FY	Fiscal Year
GAO	General Accounting Office (before July 7, 2004)
	Government Accountability Office (from July 7, 2004)
ILS	Integrated Logistics Support
IMEC	Item Mission Essentiality Coding
IOC	Initial Operational Capability
ISEA	In-Service Engineering Activity
KP	Knapsack Problem
M	Predicted Maintainability
MAWG	Maritime Allowance Working Group
MCC	Mission Criticality Code
MCM	Mine Countermeasures Ships
MEC	Military Essentiality Code
MLDT	Mean Logistics Delay Time
MSD	Material Support Date
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
NAVSEA	Naval Sea Systems Command
NAVSUP	Naval Supply System Command
NC	Not Carried
NIIN	National (or NATO) Item Identification Number
NIS	Not in Stock
Non-DLR	Non–Depot-Level Repairable
NPV	Net Present Value
NSLC	Naval Sea Logistics Center
NWCF	Navy Working Capital Fund
O&M	Operations & Maintenance
O&M,N	Operations & Maintenance, Navy

O&S	Operations and Sustainment
OMB	Office of Management and Budget
OPN	Other Procurement, Navy
OPNAVINST	Chief of Naval Operations Instruction
OPTAR	Operating Target
ORCAS	Outfitting Requisition Control Accounting System
OSA	Outfitting Support Activity
OSD	Office of the Secretary of Defense
PMICS	Pushed Material Inventory Control System
POTF	Percentage of Time Free
PV	Present Value
R	Predicted Reliability
RFI	Ready for Issue
SIM	Selective Item Maintenance
SRF	Stock Record File
SSE	Sum of the Squared Error
SSN	Fast-Attack Submarines
SURFOR	Commander, Naval Surface Forces
TOC	Total Ownership Cost
TYCOM	Type Commander
UCL	Upper Confidence Level
UKP	Unbounded Knapsack Problem
WSS Mech	Weapons System Support, Mechanicsburg
WSF	Weapons System File

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I. INTRODUCTION

A. BACKGROUND

During a time period when the discussion of defense budget cuts and sequestration dominates the pages of national and defense news, what strategy is the military employing to operate more efficiently? The wars in Iraq and Afghanistan are coming to a close, and with that, a further reduction in operating budgets is expected across the Department of Defense (DoD). The need for a prudent and accountable expenditure of taxpayer dollars has reached its pinnacle with the requirement for the DoD to be 100% auditable by 2017, per Secretary of Defense Panetta's direction. The priority of fiscal responsibility has gone as far as to be embedded in the *National Security Strategy*, as stated in the following excerpt:

> Cost-effective and efficient processes are particularly important for the Department of Defense, which accounts for approximately 70 percent of all Federal procurement spending. We will scrutinize our programs and terminate or restructure those that are outdated, duplicative, ineffective, or wasteful. The result will be more relevant, capable, and effective programs and systems that our military wants and needs. (President of the United States, 2010, p. 34)

In addition to spending funds more wisely, further motivation behind this research is to improve the overall condition of readiness experienced across the Navy's fleet. Readiness is measured in various ways, ranging from detailed ship-wide assessments to the submission of an individual casualty report (CASREP). A CASREP is a report made to the ship's operational chain of command concerning a significant equipment malfunction that cannot be corrected within a 48-hour period. Due to the frequency and specific nature of CASREPs, these reports played a significant role in the analysis discussed in this paper.

In a 2012 report, the Government Accountability Office (GAO) provided evidence, with results displayed in Figure 1, concerning a noticeable increase in the number of CASREPs reported from 2008 to 2012; as the GAO (2012) noted, an increase in the number of CASREPs would indicate a decline in overall material readiness. In our research, we used CASREP frequency and severity as a measure of effectiveness, and most important, we considered only those CASREPs that require additional repair parts due to onboard allowance shortages.

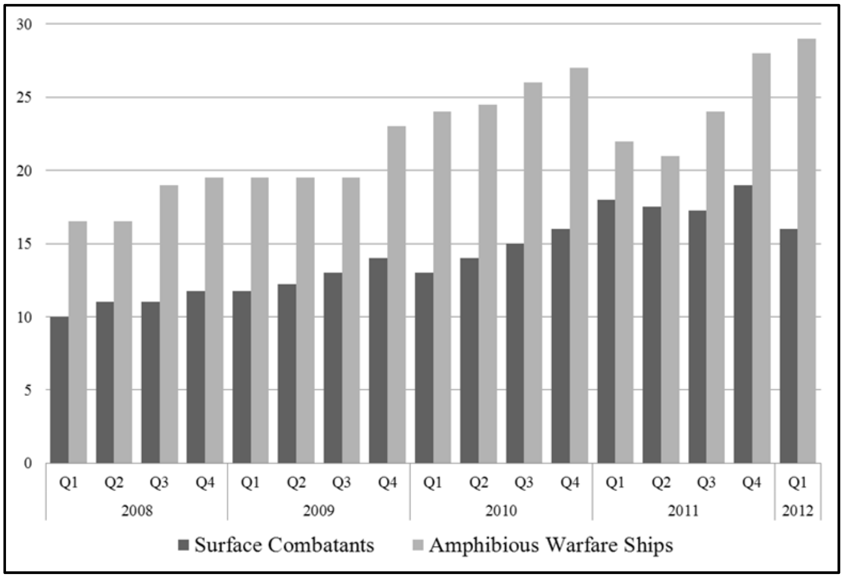

Figure 1. Average Number of Casualty Reports of Surface Combatant and Amphibious Warfare Ships by Quarter From January 2008 Through March 2012 (GAO, 2012)

For the U.S. military to remain effective as funding is reduced, efficiencies and cost-saving opportunities must be identified and implemented to ensure that the nation can sustain a competitive advantage in the 21st century. There are myriad ways that the DoD can achieve cost savings from the numerous programs in development, as well as from those that have reached maturity and are currently in the sustainment phase. In this research, we seek to identify one such avenue for the U.S. Navy that would require a minimal investment and result in maximum effectiveness.

In addition to the fact that the DoD has been mandated to reduce spending and find efficiencies wherever possible, other significant reasons justify why such research should take place. Following the events of September 11, the entire DoD saw a dramatic increase in the amount of funding appropriated for operations and maintenance (O&M; Office of Management and Budget [OMB], 2003). This O&M funding is used to pay for the day-to-day activities of our deployed or deployable forces and typically consists of the costs associated with fuel, repair parts, and maintenance. The increase in O&M funding resulted in a decrease in acquisition funding that covers the research, development, and production of the next generation of weapons systems. As the campaigns in Afghanistan and Iraq expire, O&M funding is expected to decrease and return to more traditional, peacetime levels. However, the expected decrease in O&M funding does not guarantee a subsequent increase in procurement funding. This distinction is important to note, because the findings of the present research may impact both appropriation types and, if successful, would result in a reduction of total ownership cost (TOC).

According to the Defense Acquisition University (DAU, 2012), *TOC* is defined as a concept designed to determine the true cost of the design, development, ownership, and support of DoD weapons systems. Within TOC are the acquisition costs and operations and sustainment (O&S) costs of the system, with the O&S costs accounting for a significantly larger segment. Figure 2 presents the breakdown of TOC of a weapons system with greater clarity.

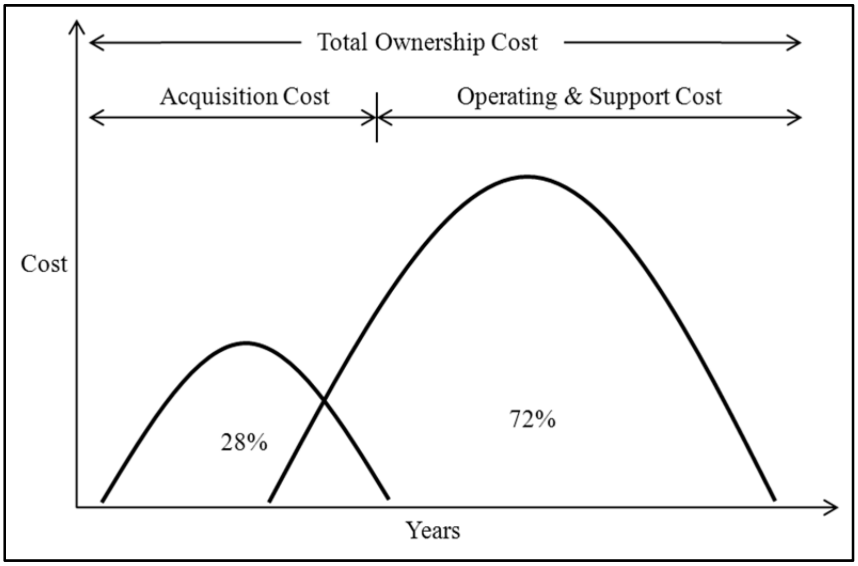

Figure 2. Total Ownership Cost Throughout the System Life Cycle (Defense Systems Management College, 1997, p. 181)

Figure 2 makes clear, and the GAO has agreed, that significantly more cost savings can be generated throughout the O&S phase as a result of more aggressive research during the procurement phase of the system life cycle (GAO, 2010). A reduction in O&S costs translates directly to a reduction in the amount of O&M funding required for agencies to operate, which further results in an overall savings by the DoD. As mentioned previously, a reduction in O&M funding would provide the opportunity to invest more in the acquisition of critical programs and potentially improve our national defense capabilities. Our research focuses on the O&S phase, because this is the phase that requires the largest amount of funding.

B. SCOPE

The scope of this project is to conduct a business case analysis (BCA) of the Continuous Integrated Logistics Support–Targeted Allowancing Technique (CILS–TAT) with the assistance of the Naval Sea Logistics Center (NSLC). According to the NSLC (2012) command description, “NSLC is a field activity of the Naval Undersea Warfare Center, and is tasked with providing integrated logistics, engineering, and information technology expertise to all facets of the Navy's worldwide logistics support structure.”

Embedded in NSLC’s integrated logistics support responsibilities are the requirements to manage the configuration of naval weapons systems within the different classes of ships and submarines, as well as to provide the appropriate allowances for spare parts to be stocked onboard. Configuration management, while closely related to the allowancing process, is beyond the scope of our research and therefore is not fully introduced here. Our research instead focuses on a subset of the allowancing process known as CILS–TAT. We discuss this technique, as well as the traditional allowancing process, in much greater detail in subsequent chapters and provide a better understanding of the variables considered when NSLC is determining allowances.

Our current motivation behind evaluating the effectiveness of the CILS–TAT is the suspension of the program since 2009, when the U.S. Navy began its transition to an enterprise resource planning (ERP) framework. We expect that by the time this research is published, the U.S. Navy’s allowancing process systems will have fully transitioned into the ERP framework; therefore, the time for a possible re-implementation of the CILS–TAT is quickly approaching. Based on our findings, we hope to demonstrate the level of effectiveness achieved as a result of using the CILS–TAT and provide recommendations concerning the use of the program in the future.

The CILS–TAT can be used onboard any U.S. Navy platform. To further narrow the scope of our project, we focused on 18 ships from the U.S. Navy’s Ballistic Missile Defense (BMD) Fleet. Five Ticonderoga-class guided missile cruisers (CGs) and 13 Arleigh Burke–class guided missile destroyers (DDGs) make up our sample. Critical to the U.S. National Security Strategy, the mission of the BMD Fleet is to detect, track, and intercept ballistic missiles of all ranges and types (Missile Defense Agency, n.d.). The principal reason for our selection of these ships is not only the importance of the BMD mission but also the commonality of systems contained within the Ticonderoga and Arleigh Burke classes. With the Arleigh Burke class still in production, the results of this research will provide the longest period of applicability and support the largest class of ships in the naval inventory.

C. PROBLEM DESCRIPTION

The task of minimizing costs while maximizing effectiveness is not one that can easily be achieved and, in some cases, may not be realistic. The goal of this project, however, is to do just that through an aggressive spare-part allowancing model that will improve the effectiveness of the U.S. Navy surface fleet through a reduction in O&S costs. The project analysis covers two distinct time periods to capture the true value of the CILS–TAT and then uses forecasting models to determine the future viability of the program. The first period covers the years 2003–2009. During this time, 18 CILS–TAT reviews were conducted and 48 months of operational data were available per ship. During the second period, from 2009 to 2011, no CILS–TATs were conducted, and no other allowancing maintenance was done. Based on the data available for analysis during these periods, we attempted to forecast the long-term effectiveness of the CILS–TAT.

Unlike land-based forces, where the addition of another warehouse to store repair parts is not a major concern, on a U.S. Navy ship, there is a finite amount of space to store repair parts. In a perfect world, a ship could carry a replacement part for every installed component in the event that a repair is required. Because that is not feasible, a great deal of consideration must be given to determine the right mix of parts that make up the ship’s onboard allowance list. A shipboard allowance list for maintenance parts is the larger list from which spare items are selected, or not selected, for onboard allowances.

In the past, one problem with such lists has been assuring maximum value received for dollars spent on spare items. Such value may be received only by making sure that spare items are ordered through some type of a combinatorial optimization process (Harrahy, Powell, & Lutz, 1968). According to the GAO (2003), the U.S. Navy’s spare-parts supply problems can delay the completion of needed maintenance and repair jobs on deployed ships and can affect their operations and mission readiness. In the same 2003 GAO report, covering two carrier strike groups over six deployments, 58% of the 50,000 maintenance work requests were delayed because the appropriate parts were not located on the ships. It can be deduced from these studies that getting the right mix of parts onboard a ship is a costly, complex, and critical task with far-reaching implications. The processes involved in allowancing have evolved over time. We cover two such processes in subsequent chapters.

Over the course of several decades, initiatives have been implemented to either improve the business practices associated with allowancing or reduce slow-moving and unnecessary inventory (K. R. Bitner, personal communication, November 5, 2012). Allowances can be reduced for a number of reasons ranging from obsolescence to a lack of demand from the system. When an allowance is reduced due to a lack of demand, greater risk is incurred in the event of an equipment casualty. The severity of a casualty can range from an insignificant impact to the loss of a critical system and failure to complete a primary mission. These circumstances obviously cover a wide spectrum but hopefully provide some insight into the factors that must be considered at the component level when determining allowances.

One proposal to help the U.S. Navy more efficiently use its appropriated funds has been to spend less in the procurement of spare-parts allowances onboard ships. The problem with reducing the number of parts onboard is that when a system fails and the parts are not onboard, logistics support is required—whether the part is coming from the other side of the globe or from a warehouse a few miles away. In addition to the required logistics support, the system requiring the part is either non-operational or degraded while awaiting repairs. The costs of the part not being onboard can be measured quantitatively in monetary terms and more abstractly by a decrease in the ship's capabilities.

The monetary costs of providing material support to an operational vessel are the most simple to compute and typically involve determining the cost of the part required, the location of the vessel requiring it, and the urgency of the need for the item. Transportation costs are reasonably easy to obtain and can be forecasted for a variety of scenarios using simulations. The more difficult cost to capture is the significance of losing a mission-critical system for an extended period as a result of not having the parts in the right place at the right time.

D. RESEARCH OBJECTIVES

The objectives for our research include the following:

1. Conduct a BCA of the CILS–TAT process using historical data.
2. Measure the costs associated with performing a CILS–TAT.
3. Provide recommendations to NSLC concerning possible improvements to the existing CILS–TAT model.

E. RESEARCH QUESTIONS

We have addressed the following questions in our research:

1. How did CILS–TAT impact allowance effectiveness for our sample, and at what cost?
2. Are there correlations between allowance effectiveness rates, percentage of time free (POTF) from CASREPs, and CILS–TAT cost?
3. What was the effect of not having CILS–TAT during 2009–2011, when traditional allowancing procedures were not available?

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BACKGROUND

F. ALLOWANCING FUNDAMENTALS

When considering the austere environment within which U.S. Navy ships operate and the absolute necessity to function above readiness metrics, it is important that the U.S. Navy develop and implement a robust set of allowancing procedures to ensure that the right parts are on the shelf when equipment fails. As related to inventory management, *allowancing* can be defined as determining the correct blend of items carried onboard to ensure that the part is available to restore the equipment when failures occur. The correct quantity of items is influenced by constraints such as funding and the cost of procurement, the availability of the item, space availability onboard the ship, mean time between failures (MTBFs), and estimated lead-times for replenishment.

As mentioned previously, the entire purpose of the allowancing process is to generate the right set of parts to stock onboard the ship, thereby ensuring that the overall mission readiness levels of the vessel do not drop below prescribed metrics set forth by the U.S. Navy. To measure the effectiveness of the allowancing process, the U.S. Navy has formulated several performance metrics, such as operational availability (A_o), supply gross issue effectiveness, supply net issue effectiveness, CASREP frequency, and POTF from CASREPs.

1. Operational Availability

A_o provides a method of predicting and assessing system performance and readiness during the acquisition process and then becomes the performance benchmark during initial operational capability (IOC), deployment, and operations/maintenance cycles (Chief of Naval Operations [CNO], 2003). The U.S. Navy's ability to meet the highest readiness levels is principally derived by the A_o of the warfighting systems and equipment installed onboard U.S. Navy vessels.

According to Chief of Naval Operations Instruction (OPNAVINST) 3000.12A (CNO, 2003), the calculation for determining the A_o is a probability function of reliability, maintainability, and supportability components. The equation for determining A_o is written as the following: system up time divided by total time (up time + down time).

A_o is fundamentally considered as a supportability calculation of the equipment/system in terms of predicted reliability (R), called *mean time between failure* (MTBF); predicted maintainability (M), in terms of mean time to repair (MTTR); and designed supportability, called mean logistics delay time (MLDT; CNO, 2003). Inherent availability (A_i), an alternative metric, does not include a consideration of support functions related to re-supply transportation and repair. Once A_i is determined, one is ready to add in the supportability portion, or MLDT, to calculate A_o (CNO, 2003). See Figure 3 for a graphical representation of A_i and A_o.

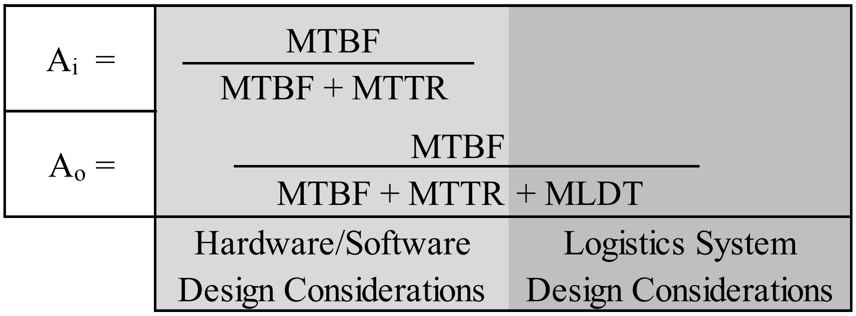


Figure 3. Logistics Impact on Operational Availability (CNO, 2003)

2. Measuring Allowancing Effectiveness

In order to effectively measure the allowancing packages that the U.S. Navy is developing and sending to the fleet, the U.S. Navy has constructed several calculations to interpret the demand signal against the assets onboard. The metrics are assembled by segregating the demand into different pools or supply source codes based on the stock posture of the requirement. Figure 4 represents the various codes.

CODE	DEFINITION
A	Allowance List Material issued from storeroom stock
C	Non-Allowance List Material (SIM) issued from storeroom stock
D	Allowance List Material Not In Stock (NIS) when requested
F	Non-Allowance List Material (SIM) Not In Stock (NIS) when requested
G	Not Carried (NC) repair parts which are not listed on an APL in the ship's COS file
J	Not Carried (NC) repair parts which are listed on an APL, but does not compute for an allowance

Figure 4. U.S. Navy Allowance Supply Source Codes (Naval Supply Systems Command [NAVSUP], 1997)

The calculation used in evaluating allowance performance is the allowance effectiveness metric, which is represented by the following equation: $(A + C + D + F)/(A + C + D + F + G + J)$. The allowance effectiveness calculation allows stakeholders to determine the strength of the allowanced items, as well as the non-allowance material selective item maintenance (SIM) against demand (NAVSUP, 1997).

3. Supply Issue Effectiveness Rates

In an effort to measure the overall issue effectiveness of the allowancing packages throughout the training cycle and into deployment, the U.S. Navy has developed a set of inventory issue effectiveness rates to judge the ability of the inventory to meet the demands placed against that inventory. There are two metrics that are used to determine the success of the allowancing package, the first being the supply gross issue effectiveness rate. Supply gross issue effectiveness measures the number of requirements, commonly called requisitions, issued against the total number of requirements. Supply gross issue effectiveness is computed by dividing the number of requisitions issued by the total number of requisitions: $(A + C)/(A + C + D + F + G + J)$.

The aforementioned performance measurement allows the managers of the allowancing package to quantitatively judge whether or not they have the correct variety and quantity of parts on the ship. The calculation provides a percentage value for every demand that was issued from the storeroom. In other words, it reveals how many parts were not onboard that should have been onboard given the current demand. The output from this calculation would provide an allowancing package stakeholder with a sense of how many parts or line items must be added to the allowancing package to meet issue effectiveness goals.

The second metric that the U.S. Navy uses is the supply net issue effectiveness rate. This measurement tool is calculated by dividing the total number of issued requisitions by the total number of requisitions minus the number of requisitions not carried (NC) onboard: $(A + C)/(A + C + D + F)$. This more focused rate allows the stakeholders to obtain a sense of how the variety and quantity of the parts included in the allowancing package are reacting to the current demand signal. For the purpose of allowancing package development, the use of the supply gross issue effectiveness rate would prove to be more useful because stakeholders desire to know on average how well the allowancing package supported the demand as a whole.

4. Casualty Reporting

A measure of effectiveness central to our project involves tracking the number and severity of CASREPs for each of the 18 ships in the sample. A CASREP is a report made to the ship's operational chain of command concerning a significant equipment malfunction that cannot be corrected within a 48-hour period. The release of a CASREP will also alert supporting activities of the urgency to provide aid in the form of spare parts or technical assistance. The significance of each CASREP is determined by the impact of the equipment failure on the ship's mission. There are different categories of CASREPs, ranging from Category Two (C2) through Category Four (C4), with C4 being the most severe. A C4 CASREP denotes that a deficiency exists in mission-essential equipment that causes the loss of at least one primary mission. A C3 CASREP denotes that a deficiency exists in mission-essential equipment that causes a major degradation but not the loss of a primary mission. Finally, a C2 CASREP indicates that the ship has lost redundancy in one of its primary or secondary mission areas. CASREPs are required to be updated periodically by the ship until the damaged equipment is restored to a fully mission-capable state. The frequency of updates is correlated to the severity of the CASREP. The CASREP will remain an open report until all repairs are finalized (NAVSUP, 1997).

5. Percentage of Time Free From Casualty Reports

POTF is a readiness metric tracked by NAVSUP Corporate Information Systems (CIS) that records the number of days in a reporting period that a ship does not have an open C3 or C4 CASREP. This metric is a central measure of a ship's material readiness and one that we use in the analysis section of this report. A calculation of time free of casualties is

$$100 \times \frac{\sum_{i=1}^{K}\left(\frac{\left(days\ out\ of\ shipyard\ and\ free\ of \frac{C3}{C4} CASREPS\ during\ period\right)}{(Calendar\ days\ during\ period)}\right)_i}{K} \tag{1}$$

where

i = a running index for individual ships in the grouping that have been active for more than 1/5 of the calendar period, and

K = total ships in the grouping meeting the active time criteria.

G. ALLOWANCING STAKEHOLDERS

The entire allowancing process is completed by a vast array of logistics and maintenance professionals employed by the U.S. Navy and civilian partners. The requirements necessary to develop a comprehensive allowancing package deem that all influencers collaborate effectively as one cohesive team. The requirements for the allowancing package range from ship configuration data, maintenance and logistics data, and, if available, logistics support data specifically related to reliability concerns.

On the logistics side of the house, there are a couple of key players across the U.S. Navy. The first of these players—and probably the most dominant in calculating the allowances—is the NAVSUP Weapons System Support, Mechanicsburg (WSS Mech). The WSS Mech is the U.S. Navy's representative to manage the allocation of resources relating to the allowancing process. NAVSUP WSS Mech possesses the models necessary to develop allowancing packages and work with all stakeholders to ensure that the end product fits the needs of the warfighter. In addition, it is tasked with controlling the funding for initial outfitting onboard the vessels.

On the maintenance side of the house, the stakeholder most concerned with the development of the allowancing process is the Naval Sea Systems Command (NAVSEA). NAVSEA is tasked with ensuring that the ship is configured properly with the most up-to-date systems and equipment. To ensure that the configuration of all systems is correct, NAVSEA works closely with NSLC, which provides integrated logistics support. The configuration of the ship must be accurate when developing the allowancing package to facilitate superior sustainability during the entire life cycle of the ship.

When developing a product, there must be a customer. In this case, the customer is the warfighter on the waterfront: Commander, Fleet Forces Command (CFFC). CFFC is charged by the CNO to ensure that all fleet forces maintain the highest levels of operational readiness to support the nation's maritime strategy. With regard to surface ships, Commander, Naval Surface Forces (SURFOR) is the stakeholder involved in the allowancing process and subsequent reviews of that process as the ship progresses throughout its life cycle. Within SURFOR, there are maintenance and logistics components that work in concert with their counterparts involved in the process. Fundamentally, once SURFOR takes ownership of the vessel, it is ultimately responsible if the ship does not meet the mission.

The maintenance personnel at SURFOR manage the maintenance practices and configuration changes related to keeping the ship up to date. The logisticians are constantly monitoring the issue effectiveness rates to determine whether an allowancing package should be applied to increase the mission readiness.

H. FUNDING

The allowancing process requires two different classifications of funding to pay for all inventory required: initial issue provisioning and follow-on replenishment over the life cycle of the allowance being tied to that vessel. The reasoning behind using two different classifications of money is the delineation between the budget activities (BA) of Operations and Maintenance, Navy (O&M,N) and Other Procurement, Navy (OPN) within the DoD budget. The two classifications of money are controlled by separate organizations within the U.S. Navy.

The funding stream more closely tied to the allowancing process and initial provisioning is the OPN appropriation. This appropriation is designated for the procurement, production, and modernization of support equipment and materials not otherwise provided for, as well as the procurement and installation of equipment (Department of the Navy

[DoN], 2012). Because of the designation of these funds to support the initial outfitting of naval forces, all initial provisioning within an allowancing package are paid for with OPN funds.

The allocation of these funds from Congress is given to NAVSUP WSS Mech to determine the best allocation across the competing priorities within the enterprise. The funds are then designated as OPN-8 funds. The Navy Working Capital Fund (NWCF) then buys spare parts listed in the new allowancing product with OPN-8 funds following the post-material support date (MSD; CNO, 2012). Once the allowancing products are developed with the inputs from stakeholders, NAVSUP WSS Mech makes the determination to purchase the requisite spare parts to fill the allowances.

The appropriations assigned to the BA of O&M,N are designated to finance the day-to-day costs of operating naval forces, including fuel, supplies, and maintenance of ships; U.S. Navy and Marine Corps aircraft; related weapons systems; and the support establishment ashore (DoN, 2012). Consequently, any replenishment for stock that the ship might require to maintain operational readiness must be paid for with O&M,N dollars. At the force level, these funds are controlled by the type commander (TYCOM) and allocated down to the unit supply officer on a quarterly basis in the form of an operating target (OPTAR). The OPTAR will pay for all spare-part requirements and any related costs, to include transportation costs, ordering costs, and any holding costs associated with keeping the part in inventory.

I. ALLOWANCING PRODUCT MAKEUP

1. Depot-Level Repairable Versus Non–Depot-Level Repairable

The typical allowancing package is composed of a variety of different line items and quantities dependent on the type of equipment onboard the ship, the dollar value, the required endurance level, and the average MTBF. The most basic classification among the varying spare parts in the allowancing package is the designation as a depot-level repairable (DLR) item versus a non-DLR item, otherwise known as a consumable item.

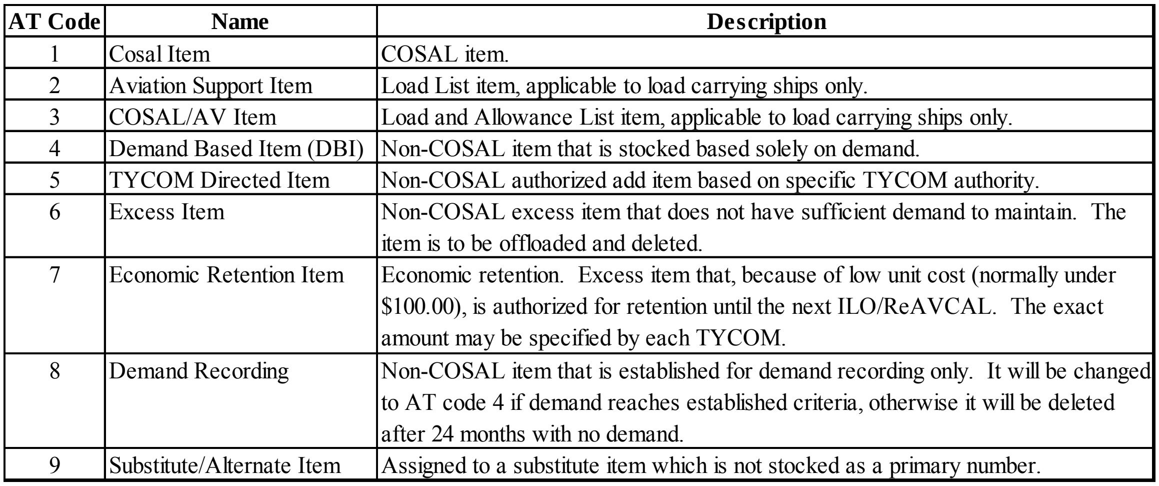
DLR items are usually the high-dollar-value components and are deemed too costly to dispose of. This classification requires that when a DLR is unserviceable, it must be sent back to the pre-determined repair facility for overhaul and subsequent clearance as ready for issue (RFI). When considering the dollar value of these items, the U.S. Navy aggressively tracks the movement and repair status of all items both on the vessels and ashore to eliminate unnecessary waste. As a rule of thumb, the allowance for a DLR in an allowancing package is incapable of being altered by the personnel onboard the ship. These allowances are to remain as they were when they were implemented. The designation of DLRs is determined by NAVSUP guidance (NAVSUP, 1997). Specific codes are assigned to segregate the DLRs by their application of use in a particular system and into manageable groupings based on their level of usage. In addition, these codes are used to designate which inventory manager will handle the day-to-day administration of that particular item.

The non-DLR items are not tracked as closely but still require a compulsory level of oversight. Consumable items are kept onboard the ship to be used as necessary; once the life of that asset has been exhausted, the item is simply discarded in accordance with published guidelines. The logistics personnel onboard the ships are given authorization to manipulate the allowance of these items as they see fit to meet future demand signals. The following is a list of the most commonly found allowance classifications for non-DLR items: 9C, 9B, 9G, 9N, and 9E (NAVSUP, 1997).

2. Allowance Type Codes

When apportioning allowances, the allowancing package will assign a classification code to the assets within the package. This will enable the logistics personnel to know by which process the asset was placed on the ship. The classification codes are broken down into nine different categories, called allowance type (AT) codes. The most common classification with regard to allowancing products is an AT1. This classification explains that the asset is mandated to be carried because of the implementation of an allowancing product. A breakdown of the other applicable AT codes and descriptions are captured in Table 1.

Table 1. Allowance Type Codes
(NAVSUP, 1997)



AT Code	Name	Description
1	Cosal Item	COSAL item.
2	Aviation Support Item	Load List item, applicable to load carrying ships only.
3	COSAL/AV Item	Load and Allowance List item, applicable to load carrying ships only.
4	Demand Based Item (DBI)	Non-COSAL item that is stocked based solely on demand.
5	TYCOM Directed Item	Non-COSAL authorized add item based on specific TYCOM authority.
6	Excess Item	Non-COSAL excess item that does not have sufficient demand to maintain. The item is to be offloaded and deleted.
7	Economic Retention Item	Economic retention. Excess item that, because of low unit cost (normally under $100.00), is authorized for retention until the next ILO/ReAVCAL. The exact amount may be specified by each TYCOM.
8	Demand Recording	Non-COSAL item that is established for demand recording only. It will be changed to AT code 4 if demand reaches established criteria, otherwise it will be deleted after 24 months with no demand.
9	Substitute/Alternate Item	Assigned to a substitute item which is not stocked as a primary number.

3. Mission Criticality Codes

The U.S. Navy's Item Mission Essentiality Coding (IMEC) system consists of a combination of military essentiality code (MEC) and mission criticality code (MCC). These codes help the allowancing product developers to apply weights to those assets that are most important to the sustainability and readiness of the ship within the allowancing model. The allowancing package contains either the MEC or MCC in Coordinated Shipboard Allowance List (COSAL) Part I, Sections A and B, depending on the ship's computation method (DoN, 2009). The possible MCCs that can be assigned to components are listed in Table 2.

Table 2. Mission Criticality Codes
(DoN, 2009)

CODE	DEFINITION
1	Failure of component/equipment causes minor mission impact.
2	Failure of component/equipment causes total loss or severe degradation of a secondary mission.
3	Failure of component/equipment causes severe degradation of a primary mission capability.
4	Failure of component/equipment causes total loss or severe degradation of mobility or primary mission (propulsion or life support).
5	The loss of this equipment results in a safety hazard to the ship or its crew.
X	Assigned to all Allowance Equipage Lists (AEL).

J. ALLOWANCING INPUT AND OUTPUT

1. Inputs

The process for developing an allowance package requires several pieces of data from varying stakeholders within the process. The information necessary to effectively determine the allowancing package ranges from configuration management data to maintenance history data located within the ship's Maintenance, Material and Management (3M) database.

The configuration management data is taken from the Configuration Data Managers Database–Open Architecture (CDMD–OA), which is managed by NSLC. CDMD–OA tracks the status and maintenance of naval equipment and their related logistics items (e.g., drawings, manuals) on ships and naval activities around the world. The status of a given piece of equipment on a ship determines what and how many spare parts will be stored on that ship for that equipment, making this tracking extremely important in terms of cost, shipboard space and weight, and the A_o of the ship (CDMD–OA, 2012). The U.S. Navy identifies the required spare parts onboard U.S. Navy vessels through the use of allowance parts lists (APLs). APLs provide support and outfitting for parts that are required for the particular maintenance action performed onboard the ship (Alvarez, 2010).

The 3M database is a central point on the ship where all data is kept related to maintenance performed. In addition, the database contains a comprehensive list of all assets that are and should be kept on the ship to perform maintenance. Along with the comprehensive list is the associated usage data for the parts. If the ship is a new construction, the usage data from similar vessels across the fleet will be used in the development of the allowancing package for the new vessel.

In addition to gathering the maintenance, demand, and configuration data from the 3M system, data must also be extracted from the ship's current stock record file (SRF). The SRF contains the financial records of the ship to gauge the impacts of the previous allowancing product against the current funding levels. This information can be very telling as to whether the previous product was effective at saving costly procurements and the inclusion of unnecessary carrying costs.

The final portion of information that must be incorporated into the allowancing package is the Weapons System File (WSF) Level C, which contains all provisioning and technical decisions.

2. Outputs

With the consideration of the aforementioned input of configuration, financial, maintenance, and demand data, the stakeholders are capable of applying this information into a sophisticated mathematical allowance model that provides the optimized allowancing package. The model can be manipulated to varying degrees, permitting different types of allowancing packages dependent on the desires of the stakeholders. In the next section, we explore several different types of allowancing packages.

Once the model produces the output, the package is socialized among the stakeholders. Once it is finalized, the allowances are generated by NAVSUP WSS Mech and funded and released to SURFOR for issuance to the ship. The final piece of the puzzle is that the ship will integrate the new product into the ship's database and drop the order requisitions to stock the shelves accordingly.

K. TYPES OF ALLOWANCING PACKAGES

1. Comprehensive Allowancing

As previously discussed, the output product from the allowancing process can be tailored to focus on a particular weapons system or set to review the entire ship's spare parts support package. The most common comprehensive allowancing package is the COSAL. The COSAL provides both technical and supply information, which makes it an integrated logistics support (ILS) document. It is a technical document to the extent that equipment/component/part nomenclatures, operating characteristics, technical manuals, and so forth, are described in APLs or allowance equipage lists (AELs; NAVSUP, 1997).

Implementation of the COSAL is typically conducted during the initial outfitting of the platform at the beginning of its life cycle. Factors determining the composition of the COSAL are the maintenance philosophy/capability, support concept, logistics response time, historical demand, and item/system population and redundancy. Because the COSAL is the primary listing for all spare parts allocated for the ship, logisticians routinely reference the COSAL in its day-to-day operations. Purportedly, the COSAL is designed to provide the warship with a sustained level of material support for 90 combat days without replenishment and is tailored to a particular ship class because each ship class has a different weapons system configuration (Axinto & Giles, 2005).

Once implemented onboard the ship, the COSAL begins to receive periodic updates to support any configuration or allowancing modifications. Because COSALs are costly to implement and very time intensive, the U.S. Navy has developed a system of implementing the incremental changes to COSALs by way of an automated shore interface (ASI). These updates are specifically tailored to a particular ship or class to ensure that the COSAL remains up to date with configuration changes or additions and deletions to the allowancing package. The periodicity of ASI updates varies depending on the timing of the changes included in the updates and the funding levels available to support those changes. The process of using ASIs is far less costly and less labor intensive on the ship and the shore facilities.

2. Targeted Allowancing

Considering the significant costs involved with developing and implementing a COSAL, the U.S. Navy has worked towards minimizing those costs by employing a targeted allowancing process. Stakeholders use this focused approach to zero in on the spare-parts requirements that would provide the greatest benefit towards increased readiness of the shipboard allowancing package. The process of targeted allowancing follows a similar path to the comprehensive review, with one exception. A filter is applied to the mathematical model that lets only certain aspects of the COSAL be reviewed based on criteria set forth by the stakeholders. Once the targeted allowancing package is produced, the implementation process is identical and the funding follows a similar stream for procurement of the assets.

L. CONTINUOUS INTEGRATED LOGISTICS SUPPORT–TARGETED ALLOWANCE TECHNIQUE (CILS–TAT)

1. Overview

One of the common targeted allowancing techniques that the U.S. Navy has adopted is the process termed the CILS–TAT. A CILS–TAT is used to focus the allowancing process to minimize the overall funding requirement, increase support for poor-performing equipment, and reduce allowance churn while providing the greatest increase to readiness for the ship. In the current fiscally constrained environment, this approach is absolutely vital to ensuring that the dollars are spent optimally.

The U.S. Navy's Maritime Allowance Working Group (MAWG) began discussing the use of the CILS–TAT in 1999 with 15 prototype ships. The concept was to develop a technique by which ship-optimized allowances were discreetly applied to update a ship's SRF, eliminating allowances with no usage and targeting systems with usage for allowance updates of either range additions or depth increases. During the prototype phase, the MAWG measured success by looking at the increase in supply effectiveness, reduction in cost, and churn of the allowances. Through evaluation of these metrics specifically, the MAWG recognized a 47% and 50% reduction in the line-item churn and cost of new allowances, respectively, during the prototype phase (Bruno, 1999). The results of the prototypes also revealed a 0.9% increase in the supply gross issue effectiveness, from 51.8% to 52.7% (Bruno, 1999).

From 1999 to 2009, the U.S. Navy adopted CILS–TAT as one of the primary methods for conducting targeted allowancing and has implemented the process on many different platforms, to include Los Angeles–class fast-attack submarines (SSNs), Arleigh Burke–class DDGs, Avenger-class mine countermeasures ships (MCMs), Oliver Hazard Perry–class frigates (FFGs), and Ticonderoga-class cruisers (CGs). The selection process for implementation of a CILS–TAT on a ship is conducted by various stakeholders included in the MAWG, to include representatives from NSLC, NAVSUP WSS Mech, NAVSEA, and the TYCOM.

2. Time Line

The time line for implementation typically follows the deployment cycles and is displayed in Figure 5. After a ship has completed two years of normal underway operations, data is collected from that period and evaluated by the MAWG to determine whether the ship is a candidate for a CILS–TAT. As the data is assessed, several key factors influence the MAWG's decision, ranging from the availability of time for implementation (i.e., maintenance availability opportunities), a recognized reduction of the supply gross issue effectiveness, a decrease in readiness levels below the fleet average, and funding availability.

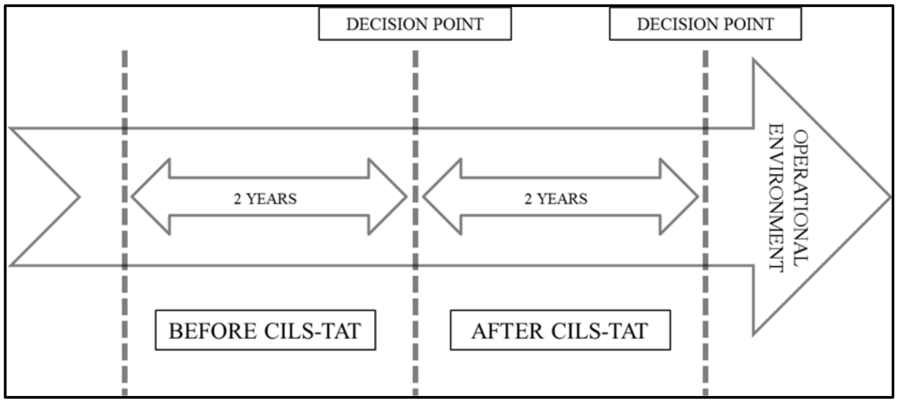


Figure 5. CILS–TAT Implementation Time Line

Once the CILS–TAT is completed and ready for implementation, the product is given to the TYCOM, who is then assigned the responsibility of working with the operational unit to implement the product into the ship's onboard databases. In an effort of continuous evaluation, at the conclusion of another two-year period, the MAWG will once again review the health of the ship and determine whether the process was profitable and whether another CILS–TAT product should be introduced.

3. Input

In order to develop the CILS–TAT, product stakeholders draw from several different systems and add a filter into the process to focus on a narrowly defined set of data. The systems used in the CILS–TAT are the same as those used to formulate a comprehensive allowancing product and include the CDMD–OA, 3M data from the ship, CASREP information, and the WSF. Once this information is compiled, it is run through an elaborate mathematical allowancing model. The final piece in the application is a filter that focuses the allowancing package to look at only a particular type of 3M data. Once the filter is applied, the output file is generated and reviewed. The CILS–TAT's filter only (a) allows new allowances to APLs that have had 3M usage, (b) provides allowance deletions or decreases for those APLs with no reported usage, or (c) provides deletions for parts that no longer support installed configurations. This filter is what makes this allowancing product a more targeted approach.

4. Output

The output provided by the model is an allowancing package that truly focuses on improving the collection of parts necessary to support the ship based on the demand that has been realized over the previous two years. Those systems that have needed a particular asset onboard, but the part that was not available would now be added to the ship's inventory, thereby improving the supply gross issue effectiveness and operational readiness. Specifically, the output file would include (a) range additions to prevent missing a future demand and (b) range and depth decreases. Those parts that historically have not been demanded or do not currently conform to the current configuration onboard would be offloaded through attrition. This more focused approach truly reduces the cost of allowancing, especially when calculating the cost of allowancing over the entire U.S. Navy fleet while providing the most efficient use of dollars to improve overall operational readiness.

5. CILS–TAT Process Flow

The actual process of a CILS–TAT begins with the collection of 24 months of operational data (see Figure 5). The historical demand data is then added to the ship's current COSAL and analyzed for allowance additions and decreases. CILS–TATs are ship specific, meaning that no two ships will experience exactly the same types or frequency of material demands. There is a degree of commonality among demands, but due to different missions performed, environmental factors experienced in the area of operation, and the overall material condition of the ship, these CILS–TATs have to be performed on an individual basis.

Once the 24 months of data is drawn down from the ship, the demands registered for scheduled and unscheduled maintenance are analyzed. A CILS–TAT will also add new allowances when a system configuration change is in process or expected to happen in the near future. Allowances will also be added to the SRF in anticipation of required maintenance for each of those new systems.

Once analysis of both the historical demand data and forecasted equipment upgrades are complete, the new allowances and the remainder of the COSAL product is sent to the ship for loading into the central database. The CILS–TAT output is then validated by comparing the total list of national item identification numbers (NIINs) recommended by the CILS–TAT against the allowances that the ship already has onboard. Any shortfalls identified during this validation become candidates for procurement. To simplify this with an example, a CILS–TAT may recommend that the ship carry 5,000 different repair parts at a cost of $2.5 million but, after validating the CILS–TAT against the ship's current onboard allowances, determines that only 300 new parts at a cost of $250,000 may be additionally required. A CILS–TAT not only recommends new allowances but also allows the ship to validate its current configuration.

Once all shortfalls are identified, requisitions are prepared for each new NIIN to be procured. The ship is not required to prioritize the new allowance requisitions because all additional allowances are considered valid by NSLC and will be further evaluated by the supply system during the requisition filling process. There are three distinct phases of further evaluation that each requisition goes through before funding is obligated. We cover these phases in the next section.

6. Requisition Screening

Once requisitions are released into the supply system as a result of a CILS–TAT, they are reviewed by the NAVSUP Outfitting Support Activity (OSA) and Outfitting Requisition Control Accounting System (ORCAS) managers. The purpose of this screening is to conduct quality checks and ensure that the correct fund codes and advice codes were applied to each requisition by the ship. These codes play an important role in determining the right type of funding applied to each of the requisitions and confirming that the obligations and expenditures eventually match for each. Requisitions flow freely through this process and are not held up for funding constraints. The main concern here is to ensure that the requisition was submitted properly by the ship.

Once the requisitions complete the quality assurance process, they then move to the Pushed Material Inventory Control System (PMICS) offices, which are a branch within NSLC. The new allowances recommended by the CILS–TAT are compared against allowances that are already being procured via other means—for example, the In-Service Engineering Activity (ISEA). A contractor may already have the responsibility to provide initial outfitting support for a particular system or group of systems onboard the ship. The screen through PMICS is done to look at all possible avenues from which this support could come and ensure that the government is not paying for the same initial allowance for the same ship twice. Requisitions can sometimes be held up in this process if the ship is entering a maintenance availability or shipyard period and material deliveries to the ship are being routed to another location.

Once a requisition clears the PMICS and NAVSUP OSA screens, requisitions are split between high and low value. (High value is any requisition with an extended value of more than $300.) During periods when defense budgets were not so tight, low-value requisitions would then immediately be funded and, if material were available, they would be sent to the ships. High-value requisitions are caught, and a re-evaluation of each allowance is conducted to ensure that the allowance is still valid before funding is applied. Because the process up to this point can take up to 45 days, it is possible that a new allowance identified by the CILS–TAT may have become obsolete due to an onboard system upgrade or a NIIN supersession. The NSLC may also cancel a requisition during this phase if the re-evaluation determines that the part in question no longer computes for an allowance or that the part has already been provided by the NSLC or the ISEA.

If a requisition is cancelled in error, the ship is required to contact the NSLC or the item manager directly to have the requisition reinstated. At the time of this report, all requisitions, both high and low value, generated as a result of a CILS–TAT are initially given a status code of "NM" by NSLC, although only high-value requisitions are re-evaluated. The NM status code signifies that the requisitions are being delayed by NSLC until funding becomes available.

7. Prioritization of Requisitions

Once funding becomes available for these new allowances, it is applied and material can start moving to the ship. NSLC does not determine which requisitions are funded or which CILS–TATs are funded first. There may be CILS–TAT requisitions for more than one ship that are awaiting funding; therefore, a determination has to be made concerning which CILS–TATs are funded first. As previously stated, the determination of priorities at this level is done by recommendations from the TYCOM. The TYCOM typically sets its priorities based on which ship is set to deploy next and the relative importance of the mission that it is set to carry out. CILS–TAT requisitions are funded at this point on an all-or-nothing basis, meaning that if funds are available for an entire CILS–TAT output for a particular ship, they are released. Otherwise, requisitions continue to hold with an NM status until additional funds are available. No prioritization exists for the types (or criticality) of a particular part over another, and as a consequence, allowances that have little impact on overall system readiness (as determined by the MCC) may be funded ahead of those that could cripple a primary mission area.

M. NAVY ENTERPRISE RESOURCE PLANNING

1. Overview

In an effort to improve the functionally and compatibility of such a wide conglomerate of information systems across the U.S. Navy enterprise, senior leaders endeavored to find an information software package that could help the U.S Navy streamline the process of logistics information sharing. They were able to work with commercial vendors to develop a system that mirrors the civilian equivalent of ERP. The Navy ERP program uses a product from SAP Corporation, the largest provider of ERP solutions in the world.

Navy ERP is the DoN financial system of record, meaning that it provides reliable information for naval leadership to keep the fleet moving forward. Navy ERP streamlines the

U.S. Navy's business operations, namely financial and supply chain management (U.S. Navy ERP, 2013). In 2010, Navy ERP Release 1.1 (Single Supply Solution) went live on March 17 at NAVSUP, enhancing the ability for U.S. Navy supply chain managers to effectively and efficiently provide Sailors and ships with the items that they need every day (NAVSUP, 2010).

2. Impact on the CILS–TAT

Due to the roll-out of Navy ERP in 2010, all inventory management programs were placed in a phasing plan to gradually implement the system and mitigate any adverse effects that might occur by rushing through the implementation process. The highest priority was given to the requirements that the fleet needed on a day-to-day basis, thereby relegating all re-allowancing processes to a lower priority until the system had been proven. This measure was taken to ensure that no high-priority requirements were missed during the migration period. The measure led to the suspension of all CILS–TATs in 2009 until further notice.

The Navy ERP system contains several improved capabilities that will significantly impact the effect of the CILS–TAT in the future. The integrated processes within Navy ERP use a single set of data, automatically disseminate information from one entry to all parts of the process where it is required, and make the entire end-to-end information stream visible to managers with responsibility over the processes (U.S. Navy ERP, 2013). There are upgraded supply chain and financial management capabilities that provide for better asset visibility across the enterprise as well as better reporting of the financial impacts of CILS–TAT implementation. The improved supply chain suite also aids in acquiring the parts to fill the newly added allowances.

As of 2013, Navy ERP has proven to be a significant success across the U.S. Navy, and senior leadership within the logistics community is once again ready to discuss the return of the CILS–TAT. If CILS–TAT is proven to be a wise investment and re-implemented, it should benefit greatly from the increased functionality recognized through the use of Navy ERP.

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II. METHODOLGY

A. INTRODUCTION

Included in the following chapter is a brief overview of the methodologies or models used in conducting the BCA regarding the effectiveness of CILS–TAT. The reasoning behind examining the following models was threefold. First, we utilized the cost-benefit analysis (CBA) to attach a dollar amount necessary to achieve a certain level of readiness. Further, a CBA allowed us to determine the cost and benefits to be weighed against a performance metric defined by the stakeholder. Next, we developed a regression model to evaluate the effectiveness of CILS–TAT from the before and after periods. The regression model was further refined through the use of cluster analysis, which enabled the grouping of data in an attempt to find commonality experienced by varying sets of ships. Finally, we include in this chapter an overview of the knapsack model. This information is contained within this chapter for use in making improvements to the current CILS–TAT framework. The aforementioned methods provide a comprehensive set of tools for developing a thorough BCA.

B. BUSINESS CASE ANALYSIS

1. Background

In business and throughout the DoD, the use of BCA has gained popularity through the leadership of the Office of the Secretary of Defense (OSD) to support strategy decisions regarding program implementation. A BCA provides a best-value analysis that considers not only cost but also other quantifiable and non-quantifiable factors supporting an investment decision (DAU, 2013). Depending on the type of BCA, it may be used throughout the life cycle of the project. Specifically, the BCA should be used in further decisions to sustain or enhance the solution and to refine estimation of benefits and costs for future projects in the organization (DAU, 2013). The BCA can be thought of as an expanded CBA with the intent of determining a best-value solution. The BCA process goes beyond cost/benefit or traditional economic analyses by documenting how each alternative fulfills the strategic objectives of the program and the resulting impact on stakeholders (DAU, 2013).

Within the BCA, a CBA is used as a method to aid decision-makers in quantifying differences between projects. It provides a comparative assessment of all benefits anticipated and the costs incurred in various iterations. CBAs thereby allow decision-makers to pick the optimal solution for the allocation of scarce resources.

When conducting a CBA, three frames of reference can be used to approach the analysis: ex ante, ex post, and in medias res (Boardman, 1996, p. 3). These different reference frames define the time at which the analysis is completed. In ex ante analysis, a CBA is conducted prior to the start of a project. The advantage of ex ante analysis is that it facilitates the decision-maker in ensuring better decisions about the allocation of resources; however, it does not provide the most complete understanding of the actual benefits or cost assumed—there is a high degree of uncertainty. An in medias res analysis is completed as the project progresses. Although this method provides a reduction of uncertainty, it reduces the ability of the decision-maker to have full control of the proper allocation of scarce resources. If a project has been completed, an ex post CBA can be conducted. This method does not provide a decision-maker with the ability to allocate resources because they have already been expensed, but it is the most accurate method to understand the actual impacts of benefits and costs. For most companies, ex post analysis is not an option because of the large monetary investment in conducting a CBA. In general, most companies or government agencies rely on ex ante analysis with an understanding that there is an added degree of risk due to inherent uncertainties. Looking further into the CBA process, the framework for the analysis consists of nine steps (Boardman, 1996, pp. 6–24). The following is a breakdown of each step:

2. The Steps of a Cost-Benefit Analysis

The following steps describe a typical CBA:

1. *Decide whose benefits and costs count.* In this step, the analysts must choose the scope of the analysis and determine the target group. Specifically, the analysts must decide whether they are looking from the perspective of a guardian. This decision becomes integral in later steps because it will define how costs or benefits are viewed—a benefit to a guardian may be a cost to a spender. In general, guardians ignore nonfinancial social benefits. For social benefits in the federal government, it is assumed that the analysis is

being completed from the spender's (society's) perspective vice the guardian's (federal government's) perspective (OMB, 1992).

2. *Select the portfolio of alternative projects.* This step allows the analysts to bound the project being analyzed. For simplicity, only one project is analyzed at a time—in theory, there are infinite numbers of alternatives. This step mitigates uncertainty associated with complicated relationships among parameters being manipulated. As the number of possible values increases among alternative projects, the overall alternatives increase exponentially. As Boardman (1996) observed, "If there were n dimensions, each with k possible values, there would be kn alternatives … there would be 27 mutually exclusive alternatives. Neither decision makers nor analysts can cognitively handle comparison among such a large number of alternatives" (p. 13). Often, external constraints further restrict the project from reaching the optimal output levels. The analysts must be cognizant of these factors and what limitations are being imposed.

3. *Catalog potential (physical) impacts, and select measurement indicators.* Within this step, the analysts define variables, both tangible and intangible, that are being considered and quantify their impact to the overall project. Chosen variables must ensure that there is a cause-and-effect relationship between a tangible outcome and a society. When defining variables, analysts must explicitly state all assumptions, especially if assumptions are made about future benefits or costs (OMB, 1992). Once the list is collected, the variables are aggregated as either a benefit or a cost.

4. *Predict quantitative impacts over the life of the project.* This step takes each variable impact and projects its value and changes over the life of the project. In some instances, the projections are taken past the life of a project if the project is anticipated to have a continued impact on alternate projects following termination. This section looks to correlate the impact of a variable to a tangible value—for example, lives saved per year or part reduction per year. If existing projects are available, historical data can be used as a baseline to extrapolate the impact of possible changes.

5. *Monetize (attach a dollar value to) all impacts.* The goal of this step is to associate a monetary amount to all impacts in terms of the dollar amount saved or lost for each variable. This goal ensures a common set of units for comparing one variable to

another. The monetary amount associated with an impact is often valued based on a willingness to pay (OMB, 1992). This relationship can be extrapolated, for a well-defined product, from market prices. Variables such as parts reduction or labor reduction will be monetized based on the market price for labor or the price of each part reduced.

6. *Discount for time to find present values.* If a project is expected to have benefits or costs realized over the course of the project's life (years), these future values must be aggregated in their present value (PV) for comparison. The PV of a future cost or benefit can be calculated using the PV equation (see Figure 6).

$$\boxed{\text{Present Value} = \frac{\text{Future Value of Benefit or Cost}}{(1+d)^t}}$$

Figure 6. Present Value Equation
(Brealey, Myers, & Allen, 2011, p. 104)

In Figure 6, *d* represents the opportunity cost of capital, and *t* represents the number of years in the future that the benefit or cost is realized (Brealey et al., 2011, p. 104). The opportunity cost of capital represents the expected return not realized because of a project investment compared to financial securities (Brealey et al., 2011, pp. G–11).

7. *Sum: Add up the benefits and costs.* Using the PV of each variable, the analysts sum up all benefits and costs to calculate the net present value (NPV) of each alternative (see Figure 7).

$$\boxed{\text{Net Present Value} = \sum \text{PV of Benefits} - \sum \text{PV of Costs}}$$

Figure 7. Net Present Value Equation
(Brealey et al., 2011, p. 104)

8. *Perform sensitivity analysis.* A sensitivity analysis allows the analysts to capture the impact of uncertainty for each variable within a project. This analysis will identify to a decision-maker what variables can absorb higher degrees of uncertainty with marginal impacts to the outcome. It is very rare that the impact of a variable or its valuation per unit impact is known completely. A sensitivity analysis can be completed by either

manually adjusting variables to see their impact to the output or by conducting a model analysis (Ragsdale, 2008, p. 136).

9. Recommend the alternative with the largest NPV. When choosing between alternatives, the decision-maker should choose the project or alternative with the highest NPV. If the decision is between all negative NPVs, the project or alternative with the lowest negative value should be chosen. After the analysis, there may be an instance where doing the status quo will result in a higher NPV—sometimes doing nothing different is a better option.

C. KNAPSACK PROBLEM

1. Introduction

Integer and combinatorial optimization deals with the problems of maximizing or minimizing a function of many variables subject to (a) inequality and equality constraints and (b) integrality restrictions on some or all of the variables. Because of the robustness of the general model, a remarkably rich variety of problems can be represented by discrete optimization models (Nemhauser & Wolsey, 1988).

The knapsack problem (KP) is founded in the scope of integer and combinatorial optimization. Suppose that a hitchhiker has to fill up his knapsack by selecting from among various possible objects those which will give him maximum comfort. This very rudimentary question formulates the basis of the KP. According to Martello and Toth (1990), the KP can be mathematically formulated by numbering the objects from 1 to n and introducing a vector of binary variables x_j $(j = 1, \dots, n)$ with the following assignments:

$$x_j = \begin{cases} 1 & if\ object\ j\ is\ selected; \\ 0 & otherwise. \end{cases} \tag{2}$$

Then, if p_j is a measure of the comfort given by object j, w_j, its size, and c (the size of the knapsack), our problem will be to select, from among all binary vectors x satisfying the constraint

$$\sum_{j=1}^{n} w_j x_j \leq c, \tag{3}$$

the one which maximizes the objective function

$$\sum_{j=1}^{n} p_j x_j. \tag{4}$$

The KP has attracted and been intensively studied by both theorists and practitioners. Nemhauser and Wolsey (1988) espoused that an important and widespread area of application concerns the management and efficient use of scarce resources to increase productivity. These applications include operational problems such as the distribution of goods, production scheduling, and machine sequencing. They also include planning problems such as capital budgeting, facility location, and portfolio analysis.

For the purposes of this research, we address a capital budgeting model with the problem of selecting among various allowancing possibilities so as to maximize the total operational readiness without exceeding the available funds. According to Christofides, Mingozzi, Sandi, and Toth (1979), this model can be directly expressed as a zero-one (0-1) KP (each allowance possibility is either accepted or rejected).

2. Zero-One Knapsack Problem

The 0-1 KP is the most important KP and one of the most intensively studied discrete programming problems. According to Martello and Toth (1990), the 0-1, or binary, KP is given a set of n items and the knapsack, with

$$p_j = profit\ of\ item\ j,$$

$$w_j = weight\ of\ item\ j,$$

$$c = capacity\ of\ the\ knapsack.$$

Select a subset of the items so as to

$$\text{maximize} \qquad z = \sum_{j=1}^{n} p_j x_j \tag{5}$$

$$\text{subject to} \qquad \sum_{j=1}^{n} w_j x_j \leq c \tag{6}$$

$$x_j = 0 \text{ or } 1 \qquad j \in N = \{1, \dots, n\},$$

where

$$x_j = \begin{cases} 1 & \text{if item } j \text{ is selected;} \\ 0 & \text{otherwise.} \end{cases} \tag{7}$$

The reason for such an interest basically derives from three facts: (a) the 0-1 KP can be viewed as the simplest integer linear programming problem, (b) it appears as a subproblem in many more complex problems, and (c) it may represent a great many practical situations (Martello & Toth, 1990).

3. Bounded and Unbounded Knapsack Problem

One common variant of the 0-1 KP model is that each item can be chosen multiple times. The bounded knapsack problem (BKP) specifies that for each item j, an upper bound b_j (which may be a positive integer, or infinity) is on the number of times that item j can be selected (Martello & Toth, 1990). The BKP equation, as defined by Martello and Toth (1990), asserts to

$$\text{maximize} \qquad z = \sum_{j=1}^{n} p_j x_j \tag{8}$$

$$\text{subject to} \qquad \sum_{j=1}^{n} w_j x_j \le c, \tag{9}$$

$$0 \le x_j \le b_j \text{ and integer}, j \in N = \{1, \ldots, n\}.$$

The BKP is a generalization of the 0-1 KP, in which $b_j = 1$ for all $j \in N$. We assume, without loss of generality, that

$$p_j, w_j, b_j \text{ and } c \text{ are positive integers},$$

$$\sum_{j=1}^{n} b_j w_j > c, \tag{10}$$

$$b_j w_j \le c \text{ for } j \in N. \tag{11}$$

The unbounded knapsack problem (UKP), sometimes referred to as the integer KP, does not put any upper bounds on the number of times that an item may be selected (Christofides et al., 1979). This type of scenario might be applicable to the allowancing product in that the allowancing model determines that multiple assets of the same line item are necessary to support the demand signal of the ship. According to Martello and Toth (1990), the model seeks to

$$\text{maximize} \qquad z = \sum_{j=1}^{n} p_j x_j \tag{12}$$

$$\text{subject to} \qquad \sum_{j=1}^{n} w_j x_j \le c, \tag{13}$$

$$x_j \geq 0 \; and \; integer, \qquad j \in n = \{1, \ldots, n\}.$$

Through the use of combinatorial optimization, any possible revision of the current CILS–TAT model would be streamlined to ensure the greatest yield for the financial investment. The application of the KP model to this project is vitally necessary to maximize the effectiveness of the allowance products developed for U.S. Navy ships.

D. REGRESSION ANALYSIS

1. Overview

Taken from a very broad vantage point, regression analysis can be understood as a statistical tool for the estimation of relationships between variables. It includes many techniques for modeling and analyzing several variables when the focus is on the specific relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps explain how the typical value of the dependent variable changes when any one of the independent variables is varied while the other independent variables are held fixed (Lind & Mason, 1993). Regression analysis can have varying uses, ranging from prediction (to include the forecasting of time-series data), inference, hypothesis testing, and modeling of causal relationships (Anderson, Sweeney, & Williams, 2000).

Linear regression was the first type of regression analysis to be studied rigorously and to be used extensively in practical applications. According to Anderson et al. (2000), the equation includes the effects or regression coefficients (β), a dependent variable (y), independent variables (x), and the error term or noise (ε). A regression model relates the dependent variable y to a function of x and β, written $y = f(x, \beta)$. The regression analysis model can have a single independent variable or multiple independent variables, as seen in Figure 8.

$$\boxed{y = \beta_0 + \beta_1 \mathrm{x} + \varepsilon}$$

Figure 8. Linear Regression Analysis Equation (Lind & Mason, 1993)

With the development of a regression analysis, the researcher must develop a set of assumptions regarding the probability distribution of the errors that must hold in order for the model to be effective. Statistical tests are then made on the basis of these assumptions (Lind & Mason, 1993).

It is worth mentioning here a couple of key assumptions that must be considered when evaluating the output from the model. The first assumption that must be addressed is the presence of *multicollinearity*, which is defined as the problem where changes in two variables are nevertheless highly correlated—to the point that it is difficult to separate their effects on the dependent variable (Sykes, 1993). The other assumption that must be addressed is the presence of normality. The evaluation of normality is done by calculating the random error in the relationship between the independent variables and the dependent variable in a regression model; the random error should be normally distributed.

Once the regression model is developed, the researcher must assess the statistical significance of the estimated relationship to determine the strength of the relationship predicted by the data against the true relationship. Along with determining the statistical significance, the investigator must determine the goodness of fit for the model by evaluating the R^2 value. The R^2 value is a number between 0 and 1 that describes how well a regression fits a data set. Once the model is developed, assumptions have been validated, and the statistical significance and goodness of fit has been proven, the model is ready to be used for various applications (Anderson et al., 2000).

2. Linear Regression

When developing a simple linear regression, the researcher must determine which variables of interest must be taken from the data set to satisfy the question posed by the hypotheses. This data will then be graphically depicted using a scatter plot diagram. The resulting display will give the researcher the ability to easily determine the general correlation between the two variables when the other covariates are held fixed.

The regression is further defined through the use of the least squares method to fit a line to the distribution. We call the estimate of the line's intercept b_0 and that of the line's slope b_1. The estimated or predicted value of y is denoted as $\hat{y}$. Within the scatter plot, the hypothesized relationship thus implies that somewhere on the diagram may be found a line with the equation $\hat{y} = b_0 + b_1 x$. In the least squares method, we minimize the sum of squared differences between y and $\hat{y}$. Then we define a residual for observation i to be $e_i = y_i - \hat{y}_i$ and minimize the sum of squared errors, $\sum_{i=1}^{n} e_i^2$ (Anderson et al., 2000).

The same fundamental equation can also be applied when multiple independent variables are introduced. The technique is called multiple regression, and it allows additional factors to enter the analysis separately so that the effect of each can be estimated. The technique is valuable for quantifying the impact of various simultaneous influences upon a single independent variable (Sykes, 1993). Furthermore, because of omitted variables bias with simple regression, multiple regression is often essential, even when the researcher is only interested in the effects of one of the independent variables (Sykes, 1993). The general form of the model is $y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p + \varepsilon$, and the estimated relationship is $\hat{y} = b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_p x_p$. We use the least squares method to find the values of b_0, b_1… b_p that minimizes the sum of the squared differences between $y_i - \hat{y}_i$ (Lind & Mason, 1993).

3. Assumptions

As with any model, there are fundamental assumptions that must be understood before the researcher can proceed with the interpretation of the results. There are six important assumptions centered on regression analysis.

1. Relationship possesses linearity.
2. Error terms (ε) are normally distributed.
3. At every x value, the error terms have constant variance (homoscedasticity).
4. The error terms are independent of each other.
5. There is a lack of multicollinearity.

For the regression to possess linearity, the mean of the response variable is a linear combination of the parameters (regression coefficients) and the predictor variables. Because the predictor variables are treated as fixed values, linearity is really only a restriction on the parameters (Noether, 1971). In order to check for model linearity and constant variance, a scatter plot would be used. This is done by plotting the residuals against the predicted values. The researcher would hope to see a plot that reveals no patterns; in other words, he or she wants the plot to have a lot of randomly distributed points. If the error terms have different variances, the researcher would see the spread in the residuals changing as a function of the predicted value (Anderson et al., 2000).

To test the assumption that error terms are normally distributed, the researcher must evaluate the residuals. This process is conducted by constructing a histogram of the residuals. If the distribution looks bell-shaped, the researcher can feel comfortable that the error terms are close to normally distributed (Anderson et al., 2000).

The final assumption in linear regression is that the independent variables are truly independent of each other. The violation of this assumption is referred to as *multicollinearity*. If the researcher is interested only in prediction, then multicollinearity may not represent a large problem. If the researcher is trying to explain the relationships between dependent and independent variables, it does cause problems (Lind & Mason, 1993).

The main problem is that the standard error of the regression coefficients is highly inflated; hence, the estimated regression coefficients have large sampling variability. Estimated regression coefficients tend to vary widely from one sample to the next when the independent variables are highly correlated. Another problem is the interpretation of the estimated coefficients. When the explanatory variables are correlated, the researcher cannot change one variable without the correlated variable(s) changing at the same time.

There are two ways of identifying multicollinearity within the model, and the approach varies depending on preference. The researcher can either look for the effects of the correlation or focus on the causes. One example of looking for effects might be identifying large changes in the estimated regression coefficients when a variable is added or deleted. An example of looking for causes would be to recognize large correlation coefficients between independent variables in the correlation matrix (Neter, Wasserman, & Kutner, 1990).

4. Statistical Inference and Goodness of Fit

The process of determining the statistical inference of the model is done by looking at the goodness of fit of the model and whether or not the overall relationship is significant. In other words, is the dependent variable related to any of the independent variables? Variables are evaluated by testing a hypothesis of H_0 and H_a. The hypothesis is tested by comparing the amount of variation explained by the independent variables to the amount of variation left unexplained. The unexplained variance is the residual mean square. The explained portion is referred to as the regression mean square, and the F statistic is the ratio of explained to unexplained variance (Anderson et al., 2000).

All parameters were analyzed using the Welch Two-Sample *t*-test. This test method assumes unequal variance between data sets and that the two data sets are not paired. Under the assumption of unequal variances, the denominator of the *t*-test is not a function of the pooled variance, as would be the case in the Student's *t*-test (Keller, 2009). Equations 14 and 15 give the equation for the Welch t-statistic.

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}} \tag{14}$$

$$v = \frac{\left(\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}\right)^2}{\frac{S_1^4}{N_1^2(N_1 - 1)} + \frac{S_2^4}{N_2^2(N_2 - 1)}} \tag{15}$$

This test was completed using the *t*-test function in the stats package of R Studio software. Each data set was evaluated using three different hypotheses tests:

$$\text{Two Sided} \begin{cases} \mathrm{H}_0 : \mu_{Before} - \mu_{After} = 0 \\ \mathrm{H}_1 : \mu_{Before} - \mu_{After} \neq 0 \end{cases} \tag{16}$$

$$\text{Less} \begin{cases} \mathrm{H}_0 : \mu_{Before} - \mu_{After} = 0 \\ \mathrm{H}_1 : \mu_{Before} - \mu_{After} < 0 \end{cases} \tag{17}$$

$$\text{Greater} \begin{cases} \mathrm{H}_0 : \mu_{Before} - \mu_{After} = 0 \\ \mathrm{H}_1 : \mu_{Before} - \mu_{After} > 0 \end{cases} \tag{18}$$

Using these three tests ensures that any movement, positive or negative, in the data set means is fully captured in the analysis. In each case, a 95% confidence interval (Type I error < 0.05) was used as a baseline metric to establish statistically significant changes in the data sets.

E. CLUSTER ANALYSIS

1. Overview

Cluster analysis is a subset of data analysis tools called *data mining*. This analysis seeks, by grouping information, to find the interrelationships across various parameters or variables to understand the structure of data sets. Cluster analysis places data of similar values together to create a series of *N* homogeneous groupings (Ye, 2003). For the purposes of this project, in an effort to understand why certain ships experienced a statistically significant change in allowance effectiveness, cluster analysis is used to find the relationship among various source codes and allowance effectiveness. For example, for the ships that achieved a statistically significant change in allowance effectiveness, was it the respective change in source code A or source code G that caused the overall change in allowance effectiveness? What are the differentiating factors among the ships? Cluster analysis will show the thread among parameters that causes a ship to see statistically significant change in allowance effectiveness.

2. K-means Algorithm

K-means falls under the partitional method of cluster analysis. In this analysis, data is split into user-defined *K* clusters. The correct number of clusters is a subjective value, depending on constraints within the application or oftentimes found by iterating through various possibilities to find the best match (Ye, 2003). The overall goal is to find a *K* value that partitions the data into rational groupings with minimum overlap among clusters and no empty clusters.

The k-means algorithm uses a five-step process, seen in Figure 9, to identify the location and size of the clusters. In the first step, *K* number of cluster seed points are identified from the data set and represent an initial estimate of the location of the center of the clusters (initial centroids).

Basic K-means algorithm

```
Select K points as initial centroids.
repeat
    From K cluster by assigning each point to its closest centroid.
    Recompute the centroid of each cluster.
until Centroids do not change
```

Figure 9. Cluster Analysis—The Basic K-means Algorithm (Ye, 2003)

Once the location of the clusters has been identified, each of the data points is then associated with a respective cluster based on its proximity to the cluster centers. Fundamentally, the proximity calculation is an optimization problem whose objective function is to minimize the sum of the squared error (SSE), Equation 19, based on the Euclidian distance of each point to the cluster center (Ye, 2003).

$$\text{minimize: } SSE = \sum_{i=1}^{K} \sum_{x \in C_i} dist(c_i, x) \tag{19}$$

Turning to geometry, the Euclidian distance represents nothing more than the shortest distance between two points. In n-dimensional space, this distance is equal to Equation 20, where c_i and x_i represent the center point of the cluster and x represents a point in the data set:

$$\text{dist}(c_i, x_i) = \sqrt{\sum_{j=1}^{n} (c_j - x_j)^2} \tag{20}$$

Once the respective values have been assigned to one of the clusters, a new centroid is calculated based on the mean of the values within the cluster. This process is repeated until there is no change in the location of the centroids.

The results of the K-means analysis are a series *K* of centroid points for each cluster along with standard deviations of the ellipses representing a specified confidence interval. All cluster analyses in this project were completed using the k-means function in R software and the k-means cluster analysis function in JMP statistical discovery software from SAS using a Type I error of less than 0.05.

F. CONCLUSION

In this chapter, we outlined the various analytical approaches taken to analyze our data set in the context of a BCA. In reviewing this chapter, the reader should have confidence in the level of analysis and research undertaken. The content should also expand the reader's knowledge of the techniques used. Evaluating the impacts of CILS–TAT on individual ships' performance is a multivariate problem requiring multiple approaches. The data mining methods discussed provide a methodical approach to analyzing the numerous variables that have a potential impact on ship performance and, where possible, isolate CILS–TAT effects. These techniques are widely accepted as relevant approaches when conducting a BCA, and we felt that the inclusion of each was both appropriate and relevant to the research questions. Each of the models selected provides a different angle from which the data can be evaluated, and the use of multiple approaches ensures accuracy and reliability of the BCA.

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III. DATA ANALYSIS

A. DATA RETRIEVAL

The data used during the course of this project was provided entirely by NSLC. The project required a significant amount of historical data for each of the 18 ships we analyzed and included a summary of all CASREPs submitted from 2003 to 2011, in-port and underway steaming hours, 3M registered demand data from 2003 to 2011 covering more than 500,000 material requests, monthly percentages that ships were free from Category 3 and Category 4 CASREPs, and supply effectiveness rates.

NSLC also provided a detailed report for each of the 18 CILS–TATs conducted during our period of analysis. These reports contained the number of items recommended to be carried as allowances, the cost of each item identified, and the mission criticality code.

As we received data, we grouped and normalized it to verify continuity of information and determine whether gaps existed in the analysis window. Of the most critical data elements, the one with the largest amount of missing data was the CASREP summary information. The project accounts for a total of 864 months of operational data from the 18 ships we surveyed. From those 864 months, there were 42 months in which the CASREP data was either missing or incomplete and could not be provided by NSLC. Because these 42 months account for exactly 4.86% of our total sample, the amount of data provided was deemed sufficient for further analysis.

Due to the large amount of supporting data available, in our analysis, we were able to control for a number of variables that would otherwise bring the relevancy of our conclusions into question. One variable that we were unable to account for, however, was the amount of funding provided to the ships for traditional comprehensive allowancing. Because funding provided in this format is assumed to vary from ship to ship, the robustness of a ship's allowance product will impact both its supply effectiveness rates and its incidence of CASREPs.

For the purposes of this project, the ships and specific time periods we analyzed are listed in Table 3. The ships represent both the Atlantic and Pacific fleets and are the current members of the U.S. Navy's BMD fleet.

Table 3. List of Ships and CILS–TAT Periods Analyzed

Name	UIC	Date Range
MONTEREY CG 61	21450	11/1/2003 - 11/30/2007
SHILOH CG 67	21657	10/1/2004 - 10/31/2008
LAKE ERIE CG 70	21827	2/1/2005 - 2/28/2009
VELLA GULF CG 72	21829	7/1/2003 - 7/31/2007
PORT ROYAL CG 73	21830	9/1/2003 - 9/30/2007
JOHN PAUL JONES DDG 53	21313	8/1/2004 - 8/31/2008
STOUT DDG 55	21685	12/1/2004 - 12/31/2008
JOHN S MCCAIN DDG 56	21686	5/1/2005 - 5/31/2009
RUSSELL DDG 59	21821	6/1/2003 - 6/30/2007
PAUL HAMILTON DDG 60	21822	10/1/2004 - 10/31/2008
RAMAGE DDG 61	21823	7/1/2003 - 7/31/2007
FITZGERALD DDG 62	21824	6/1/2004 - 6/30/2008
BENFOLD DDG 65	21940	10/1/2004 - 10/31/2008
THE SULLIVANS DDG 68	21942	11/1/2003 - 11/30/2007
MILIUS DDG 69	21943	3/1/2005 - 3/31/2009
HOPPER DDG 70	21944	11/1/2003 - 11/30/2007
DECATUR DDG 73	21947	8/1/2003 - 8/31/2007
HIGGINS DDG 76	21950	5/1/2003 - 5/31/2007

B. CILS–TAT ANALYSIS WINDOWS

Throughout the analysis, all ships were analyzed individually. The overall data set covers periods from December 2003 to January 2011. It is worth noting that for the remainder of this analysis, a period represents a month of time unless otherwise specified. For parameters that are sampled at frequencies greater then monthly, the data has been averaged or summed as necessary to ensure consistent analysis periods.

For the various ships, CILS–TAT was implemented at different times during the periods from June 2003 to May 2005. When analyzing the individual ships' parameters, we broke up the data sets between the 24 periods before the implementation of CILS–TAT and the 24 periods after. In total, the data set covers 48 periods. Table 4 identifies the applicable date ranges for the CILS–TAT data set windows. The Before column in Table 4 indicates the month and year that starts the 24 months before CILS–TAT; and similarly, the End column indicates the final month and year of the 24 months following. The date of CILS–

TAT implantation is indicated by the Entered column. When grouping individual ships before and after CILS–TAT, respective periods (0–48) are combined accordingly, ensuring consistency in period-to-period analysis.

Table 4. CILS–TAT Analysis Windows

Ship Name	Before	Entered	End
USS Monterey	Nov/2003	Nov/2003	Nov/2007
USS Shiloh	Oct/2004	Oct/2004	Oct/2008
USS Lake Erie	Feb/2005	Feb/2005	Feb/2009
USS Vella Gulf	Jul/2003	Jul/2003	Jul/2007
USS Port Royal	Sep/2003	Sep/2003	Sep/2007
USS John Paul Jones	Aug/2004	Aug/2004	Aug/2008
USS Stout	Dec/2004	Dec/2004	Dec/2008
USS John S McCain	May/2005	May/2005	May/2009
USS Russell	Jun/2003	Jun/2003	Jun/2007
USS Paul Hamilton	Oct/2004	Oct/2004	Oct/2008
USS Ramage	Jul/2003	Jul/2003	Jul/2007
USS Fitzgerald	Jun/2004	Jun/2004	Jun/2008
USS Benfold	Oct/2004	Oct/2004	Oct/2008
USS The Sullivans	Nov/2003	Nov/2003	Nov/2007
USS Milius	Mar/2005	Mar/2005	Mar/2009
USS Hopper	Nov/2003	Nov/2003	Nov/2007
USS Decatur	Aug/2003	Aug/2003	Aug/2007
USS Higgins	May/2003	May/2003	May/2007

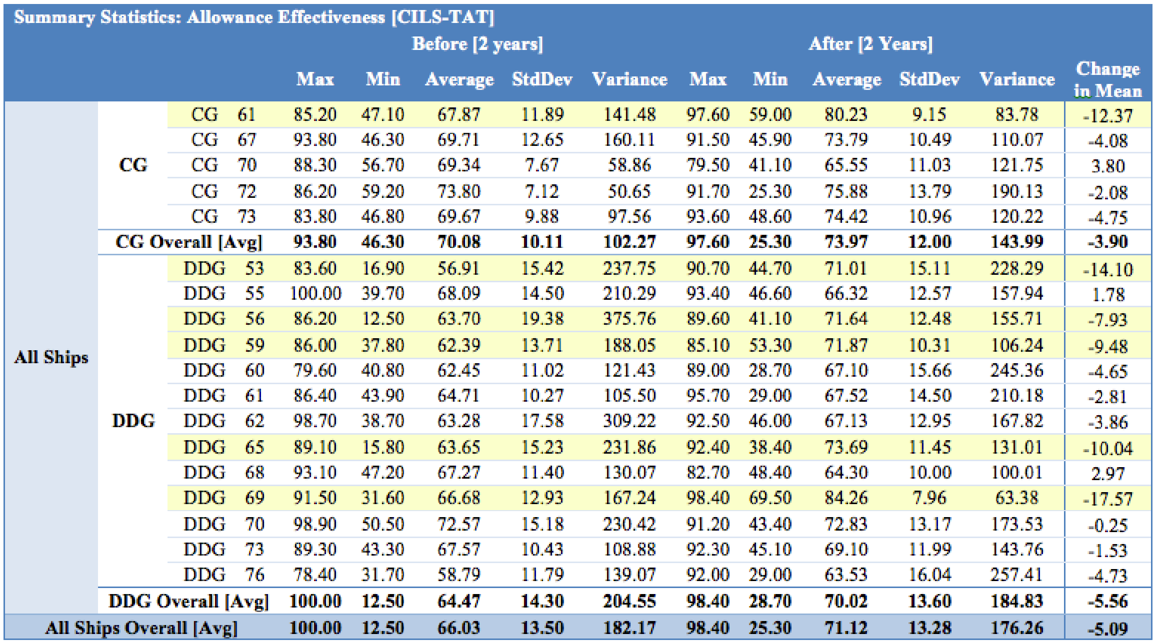
C. MODEL OUTPUT AND ANALYSIS

1. Allowance Effectiveness Results

In the analysis of CILS–TAT's impact on allowance effectiveness, we start by looking at the descriptive statistics for the before and after data sets. Throughout this evaluation, the expected result is that the mean of the before data set is less than the mean of the after data set. This is consistent with Hypothesis 2 (Equation 17) noted in the Methodology chapter under the Regression Analysis section. Looking at Table 5, which outlines baseline statistics for the before and after data sets, the entire before data set has an average allowance effectiveness of 66.03%, with values ranging from 100% to 12.50%. Between the CG and DDG groups, the average allowance effectiveness is 70.08% and 64.47%, respectively. Although these values appear to be dissimilar, they are well within one standard deviation of each other and the overall average, thereby making them statistically similar. For the purposes of comparison, the data shared between the two classes of ships are similar, from an allowance effectiveness perspective.

For the after data, the overall averages range from 25.30% to 98.40%, with an average of 71.12%. Similarly, CG and DDG groups average 73.97% and 70.02%, respectively. The absolute change in means range from -17.57% to -0.25%. Overall, the average change in means for the data sets was -5.09. Categorically, CGs experienced an average change of -3.90, compared to an average change of -5.56 experienced by DDGs. To ensure consistency in the Welch Two-Sample *t*-test, the change in mean—as calculated in Table 5—is the difference between the mean of the before data set minus the mean of the after data set. Therefore, a negative number in the Change in Mean column from Table 5 equates to an increase in allowance effectiveness from the before period to the after period.

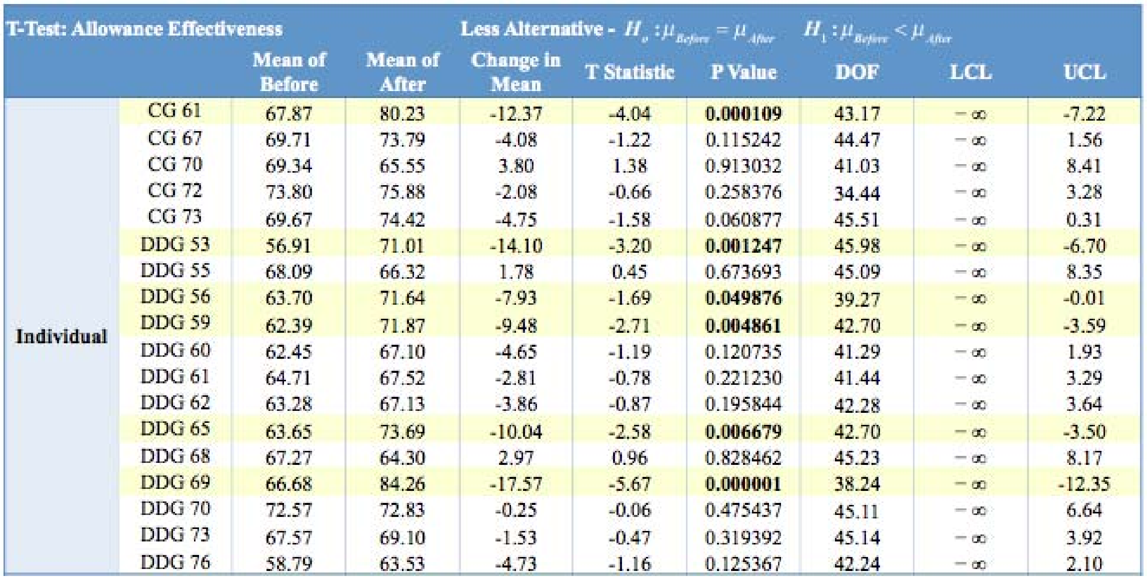
Table 5. Summary of Changes in Means due to CILS–TAT



Summary Statistics: Allowance Effectiveness [CILS-TAT]			Before [2 years]					After [2 Years]					
			Max	Min	Average	StdDev	Variance	Max	Min	Average	StdDev	Variance	Change in Mean
All Ships	CG	CG 61	85.20	47.10	67.87	11.89	141.48	97.60	59.00	80.23	9.15	83.78	-12.37
		CG 67	93.80	46.30	69.71	12.65	160.11	91.50	45.90	73.79	10.49	110.07	-4.08
		CG 70	88.30	56.70	69.34	7.67	58.86	79.50	41.10	65.55	11.03	121.75	3.80
		CG 72	86.20	59.20	73.80	7.12	50.65	91.70	25.30	75.88	13.79	190.13	-2.08
		CG 73	83.80	46.80	69.67	9.88	97.56	93.60	48.60	74.42	10.96	120.22	-4.75
	CG Overall [Avg]		**93.80**	**46.30**	**70.08**	**10.11**	**102.27**	**97.60**	**25.30**	**73.97**	**12.00**	**143.99**	**-3.90**
	DDG	DDG 53	83.60	16.90	56.91	15.42	237.75	90.70	44.70	71.01	15.11	228.29	-14.10
		DDG 55	100.00	39.70	68.09	14.50	210.29	93.40	46.60	66.32	12.57	157.94	1.78
		DDG 56	86.20	12.50	63.70	19.38	375.76	89.60	41.10	71.64	12.48	155.71	-7.93
		DDG 59	86.00	37.80	62.39	13.71	188.05	85.10	53.30	71.87	10.31	106.24	-9.48
		DDG 60	79.60	40.80	62.45	11.02	121.43	89.00	28.70	67.10	15.66	245.36	-4.65
		DDG 61	86.40	43.90	64.71	10.27	105.50	95.70	29.00	67.52	14.50	210.18	-2.81
		DDG 62	98.70	38.70	63.28	17.58	309.22	92.50	46.00	67.13	12.95	167.82	-3.86
		DDG 65	89.10	15.80	63.65	15.23	231.86	92.40	38.40	73.69	11.45	131.01	-10.04
		DDG 68	93.10	47.20	67.27	11.40	130.07	82.70	48.40	64.30	10.00	100.01	2.97
		DDG 69	91.50	31.60	66.68	12.93	167.24	98.40	69.50	84.26	7.96	63.38	-17.57
		DDG 70	98.90	50.50	72.57	15.18	230.42	91.20	43.40	72.83	13.17	173.53	-0.25
		DDG 73	89.30	43.30	67.57	10.43	108.88	92.30	45.10	69.10	11.99	143.76	-1.53
		DDG 76	78.40	31.70	58.79	11.79	139.07	92.00	29.00	63.53	16.04	257.41	-4.73
	DDG Overall [Avg]		**100.00**	**12.50**	**64.47**	**14.30**	**204.55**	**98.40**	**28.70**	**70.02**	**13.60**	**184.83**	**-5.56**
All Ships Overall [Avg]			**100.00**	**12.50**	**66.03**	**13.50**	**182.17**	**98.40**	**25.30**	**71.12**	**13.28**	**176.26**	**-5.09**

Although all 18 ships experienced a change in the means of their data sets, only six ships, highlighted in yellow, had a change based on the Welch Two-Sample *t*-test, which was statistically significant. For the remaining ships that did not meet the threshold for a Type I error of less than 0.05, there was not enough evidence to prove that the variance in the data sets and the respective changes in means was not purely based on chance. The intent of this analysis is to show that for six of the ships in the sample, CILS–TAT was directly responsible for the change in effectiveness. The results of the Welch Two-Sample *t*-test are summarized in Table 6.

Table 6. Summary of Allowance Effectiveness and the Welch Two-Sided t-Test



T-Test: Allowance Effectiveness				Less Alternative - $H_o : \mu_{Before} = \mu_{After}$		$H_1 : \mu_{Before} < \mu_{After}$			
		Mean of Before	**Mean of After**	**Change in Mean**	**T Statistic**	**P Value**	**DOF**	**LCL**	**UCL**
Individual	CG 61	67.87	80.23	-12.37	-4.04	**0.000109**	43.17	$-\infty$	-7.22
	CG 67	69.71	73.79	-4.08	-1.22	0.115242	44.47	$-\infty$	1.56
	CG 70	69.34	65.55	3.80	1.38	0.913032	41.03	$-\infty$	8.41
	CG 72	73.80	75.88	-2.08	-0.66	0.258376	34.44	$-\infty$	3.28
	CG 73	69.67	74.42	-4.75	-1.58	0.060877	45.51	$-\infty$	0.31
	DDG 53	56.91	71.01	-14.10	-3.20	**0.001247**	45.98	$-\infty$	-6.70
	DDG 55	68.09	66.32	1.78	0.45	0.673693	45.09	$-\infty$	8.35
	DDG 56	63.70	71.64	-7.93	-1.69	**0.049876**	39.27	$-\infty$	-0.01
	DDG 59	62.39	71.87	-9.48	-2.71	**0.004861**	42.70	$-\infty$	-3.59
	DDG 60	62.45	67.10	-4.65	-1.19	0.120735	41.29	$-\infty$	1.93
	DDG 61	64.71	67.52	-2.81	-0.78	0.221230	41.44	$-\infty$	3.29
	DDG 62	63.28	67.13	-3.86	-0.87	0.195844	42.28	$-\infty$	3.64
	DDG 65	63.65	73.69	-10.04	-2.58	**0.006679**	42.70	$-\infty$	-3.50
	DDG 68	67.27	64.30	2.97	0.96	0.828462	45.23	$-\infty$	8.17
	DDG 69	66.68	84.26	-17.57	-5.67	**0.000001**	38.24	$-\infty$	-12.35
	DDG 70	72.57	72.83	-0.25	-0.06	0.475437	45.11	$-\infty$	6.64
	DDG 73	67.57	69.10	-1.53	-0.47	0.319392	45.14	$-\infty$	3.92
	DDG 76	58.79	63.53	-4.73	-1.16	0.125367	42.24	$-\infty$	2.10

The primary driver that differentiated statistically significant ships from those that were not statistically significant was a large change in the means of the data sets coupled with a decrease in the variance and standard deviation of the data from the before period to the after period. Figure 10, in the top graph, shows a boxplot for each ship's allowance effectiveness before (blue) and after (red) CILS–TAT. For each ship, the dot in the middle is the mean effectiveness, and the block represents the range of +/- one standard deviation from the mean. Finally, the whiskers show the difference between the maximum and minimum allowance effectiveness. The blue line between the two data sets represents the change, direction and magnitude, of the before and after data. Similarly, plotted in the bottom section of Figure 10 are the standard deviations before and after for each ship. This graph both identifies the change in standard deviation for an individual ship and shows these standard deviations in the context of the overall sample population.

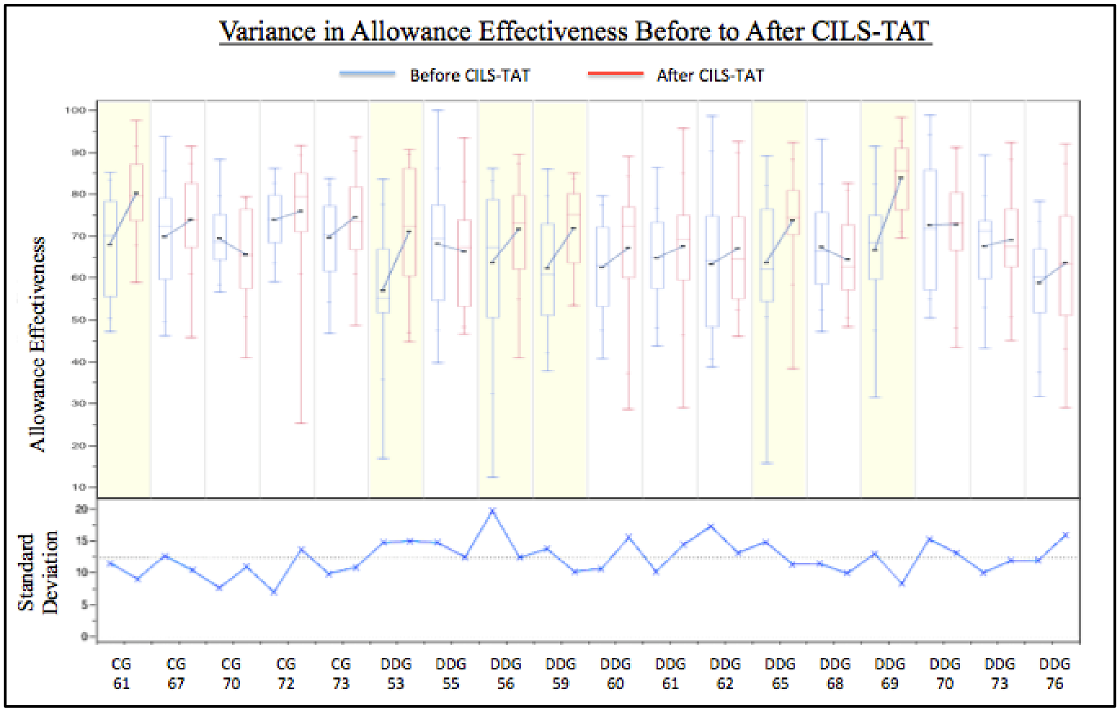


Figure 10. Variance in Allowance Effectiveness Before and After CILS–TAT

For five out of the six ships, this is the exact relationship observed: The allowance effectiveness increased in all ships where the change was statistically significant. However, for DDG 53, the standard deviation of the data sets changed only marginally. For this ship, it was the -14.10% change in allowance effectiveness that was well above the upper control limit of -6.70 that allowed this value to be statistically significant. The key is that the ships that experienced a statistically significant change saw less variance in allowance effectiveness following the implementation of CILS–TAT. The reduction in variance from before to after indicates that CILS–TAT enabled the ships to more tightly and accurately control allowance effectiveness. Similarly, increased control in variance resulted in a significant increase in the allowance effectiveness values post CILS–TAT—the ships were able to maintain a higher value of allowance effectiveness. From a manager's perspective, we can conclude that because of CILS–TAT implementation, we noticed an improved level of allowance effectiveness as well as a more consistent percentage from before to after.

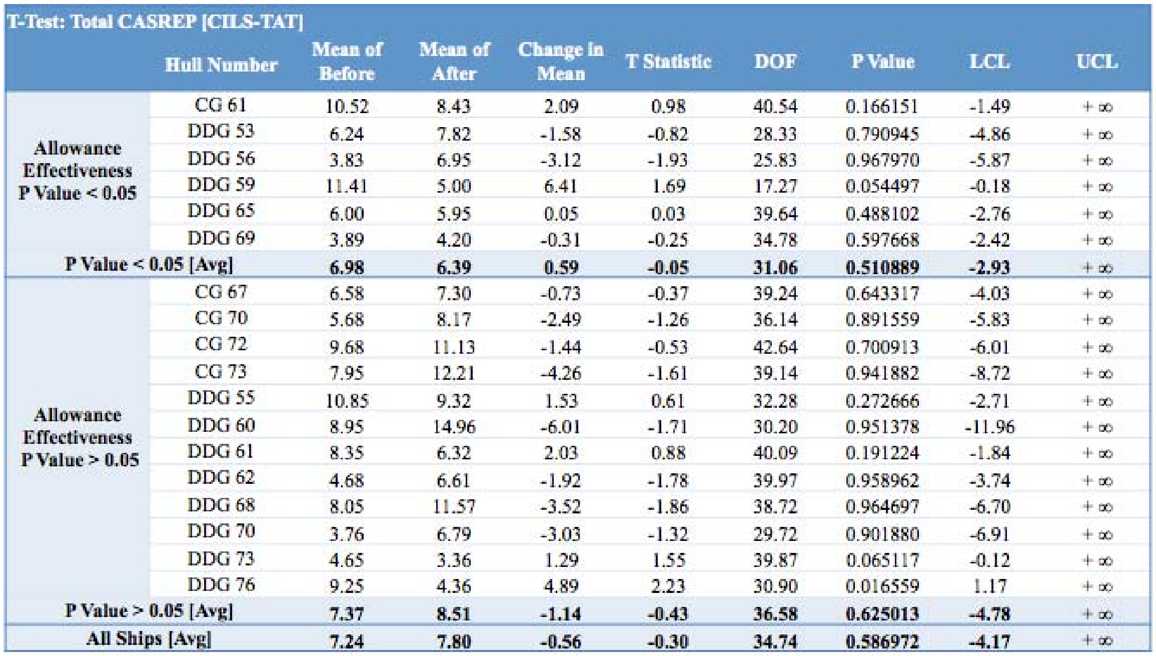
Given the final results of the before and after data, CILS–TAT had a direct and positive impact on allowance effectiveness for six out of 18 ships. Of the 12 remaining ships, nine saw a positive change in allowance effectiveness, although this change is not statistically significant and thus cannot be attributed to CILS–TAT.

2. Casualty Report Frequency and Percentage of Time Free Results

The CASREP data used represents the daily count for Categories 2, 3, and 4. For review, CASREPs reflect broken or inoperable equipment onboard U.S. Navy ships. In order to aggregate the data, the CASREPs were totaled over the monthly period to be consistent with the periodicity of allowance effectiveness data. However, for the purposes of CASREP frequency analysis, the various categories of CASREPs were summed together with C3 and C4 CASREPs, representing less than 20% of all CASREPs.

Table 7 shows that seven out of the 18 ships resulted in a positive change in mean (before minus after). Of these seven ships, only two of the ships experienced a change with a Type I error less than 0.05. None of the ships that experienced a statistically significant change in allowance effectiveness saw a similar result for CASREPs. Overall, the average change in total CASREPs was -0.5.

Table 7. *t*-Test Results for Total Casualty Reports

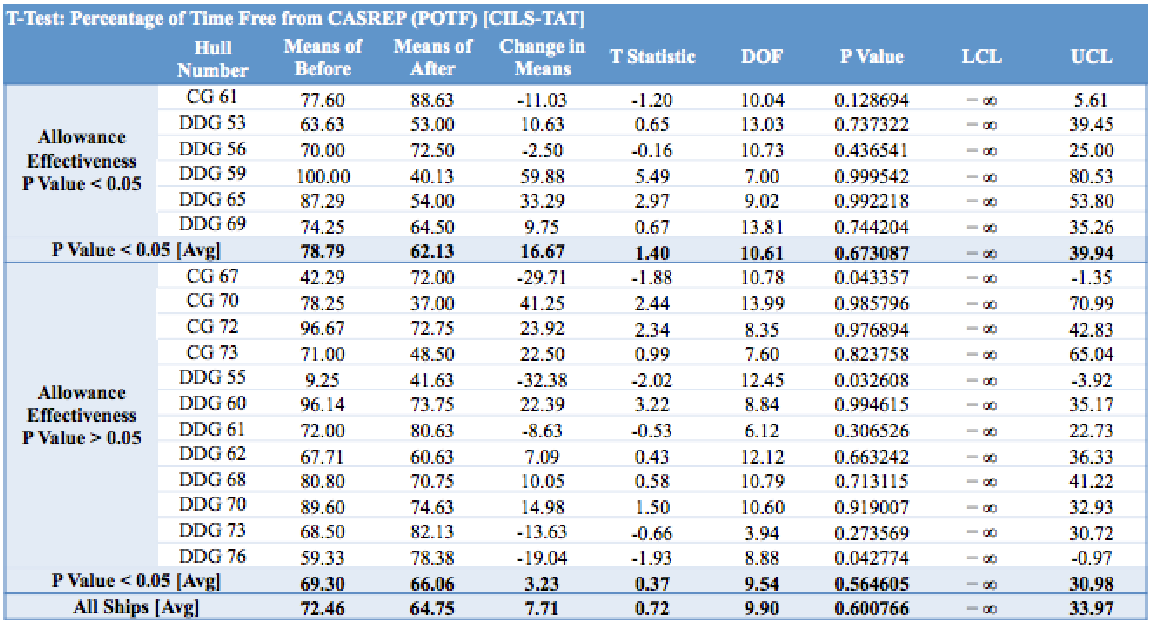


T-Test: Total CASREP [CILS-TAT]

	Hull Number	Mean of Before	Mean of After	Change in Mean	T Statistic	DOF	P Value	LCL	UCL
Allowance Effectiveness P Value < 0.05	CG 61	10.52	8.43	2.09	0.98	40.54	0.166151	-1.49	+ ∞
	DDG 53	6.24	7.82	-1.58	-0.82	28.33	0.790945	-4.86	+ ∞
	DDG 56	3.83	6.95	-3.12	-1.93	25.83	0.967970	-5.87	+ ∞
	DDG 59	11.41	5.00	6.41	1.69	17.27	0.054497	-0.18	+ ∞
	DDG 65	6.00	5.95	0.05	0.03	39.64	0.488102	-2.76	+ ∞
	DDG 69	3.89	4.20	-0.31	-0.25	34.78	0.597668	-2.42	+ ∞
P Value < 0.05 [Avg]		**6.98**	**6.39**	**0.59**	**-0.05**	**31.06**	**0.510889**	**-2.93**	+ ∞
Allowance Effectiveness P Value > 0.05	CG 67	6.58	7.30	-0.73	-0.37	39.24	0.643317	-4.03	+ ∞
	CG 70	5.68	8.17	-2.49	-1.26	36.14	0.891559	-5.83	+ ∞
	CG 72	9.68	11.13	-1.44	-0.53	42.64	0.700913	-6.01	+ ∞
	CG 73	7.95	12.21	-4.26	-1.61	39.14	0.941882	-8.72	+ ∞
	DDG 55	10.85	9.32	1.53	0.61	32.28	0.272666	-2.71	+ ∞
	DDG 60	8.95	14.96	-6.01	-1.71	30.20	0.951378	-11.96	+ ∞
	DDG 61	8.35	6.32	2.03	0.88	40.09	0.191224	-1.84	+ ∞
	DDG 62	4.68	6.61	-1.92	-1.78	39.97	0.958962	-3.74	+ ∞
	DDG 68	8.05	11.57	-3.52	-1.86	38.72	0.964697	-6.70	+ ∞
	DDG 70	3.76	6.79	-3.03	-1.32	29.72	0.901880	-6.91	+ ∞
	DDG 73	4.65	3.36	1.29	1.55	39.87	0.065117	-0.12	+ ∞
	DDG 76	9.25	4.36	4.89	2.23	30.90	0.016559	1.17	+ ∞
P Value > 0.05 [Avg]		**7.37**	**8.51**	**-1.14**	**-0.43**	**36.58**	**0.625013**	**-4.78**	+ ∞
All Ships [Avg]		**7.24**	**7.80**	**-0.56**	**-0.30**	**34.74**	**0.586972**	**-4.17**	+ ∞

The POTF metric, which is calculated as a quarterly percentage, represents the amount of time a ship operates without a Category 3 or 4 CASREP. Of the 18 ships evaluated, seven had a negative change in POTF. Table 8 shows that the mean of the after data is greater than the mean of the before data with a maximum change of -29.71. Although these ships experienced a change in POTF, only three of the ships were determined to be statistically significant. It is important to note, however, that POTF is reported on a quarterly basis, and for the 48 months analyzed, there are only 16 data points, which is considered a small sample for analysis.

Table 8. *t*-Test Results for Percentage of Time Free From Casualty Report



T-Test: Percentage of Time Free from CASREP (POTF) [CILS-TAT]

	Hull Number	Means of Before	Means of After	Change in Means	T Statistic	DOF	P Value	LCL	UCL
Allowance Effectiveness P Value < 0.05	CG 61	77.60	88.63	-11.03	-1.20	10.04	0.128694	−∞	5.61
	DDG 53	63.63	53.00	10.63	0.65	13.03	0.737322	−∞	39.45
	DDG 56	70.00	72.50	-2.50	-0.16	10.73	0.436541	−∞	25.00
	DDG 59	100.00	40.13	59.88	5.49	7.00	0.999542	−∞	80.53
	DDG 65	87.29	54.00	33.29	2.97	9.02	0.992218	−∞	53.80
	DDG 69	74.25	64.50	9.75	0.67	13.81	0.744204	−∞	35.26
P Value < 0.05 [Avg]		**78.79**	**62.13**	**16.67**	**1.40**	**10.61**	**0.673087**	−∞	**39.94**
Allowance Effectiveness P Value > 0.05	CG 67	42.29	72.00	-29.71	-1.88	10.78	0.043357	−∞	-1.35
	CG 70	78.25	37.00	41.25	2.44	13.99	0.985796	−∞	70.99
	CG 72	96.67	72.75	23.92	2.34	8.35	0.976894	−∞	42.83
	CG 73	71.00	48.50	22.50	0.99	7.60	0.823758	−∞	65.04
	DDG 55	9.25	41.63	-32.38	-2.02	12.45	0.032608	−∞	-3.92
	DDG 60	96.14	73.75	22.39	3.22	8.84	0.994615	−∞	35.17
	DDG 61	72.00	80.63	-8.63	-0.53	6.12	0.306526	−∞	22.73
	DDG 62	67.71	60.63	7.09	0.43	12.12	0.663242	−∞	36.33
	DDG 68	80.80	70.75	10.05	0.58	10.79	0.713115	−∞	41.22
	DDG 70	89.60	74.63	14.98	1.50	10.60	0.919007	−∞	32.93
	DDG 73	68.50	82.13	-13.63	-0.66	3.94	0.273569	−∞	30.72
	DDG 76	59.33	78.38	-19.04	-1.93	8.88	0.042774	−∞	-0.97
P Value < 0.05 [Avg]		**69.30**	**66.06**	**3.23**	**0.37**	**9.54**	**0.564605**	−∞	**30.98**
All Ships [Avg]		**72.46**	**64.75**	**7.71**	**0.72**	**9.90**	**0.600766**	−∞	**33.97**

Overall, based on the minimal changes in CASREP frequency and the lack of a statistically significant change of POTF, CILS–TAT appears to have had a negligible impact on the number of CASREPs experienced and the amount of time CASREPs are open. Additionally, ships that saw an increase in allowance effectiveness as a result of CILS–TAT did not see a reduction in CASREP frequency or marked improvement in POTF. The inclusive statistical relationship could be explained by an assumption that the processing of CASREPs onboard ships is often riddled with variable subjectivity introduced by the controllers of the process.

3. Impact of CILS–TAT Spending

To measure the impact of the dollars spent on CILS–TAT, and the respective changes in allowance effectiveness, we turn to the amount of money obligated. Table 9 shows a breakdown of the actual dollar amounts obligated in the year that CILS–TAT was implemented. These values have been adjusted to constant fiscal year (FY) 2003 (base year) dollars using the OPN inflation category found in the 2012 Joint Inflation Calculator. FY2003 was chosen as the base year in conjunction with the beginning of the first CILS–TAT analysis periods.

Table 9. CILS–TAT Obligation Amounts

Hull Number	Year Obligated	Inflation Factor	Actual Obligated Value	Actual Obligated Value ($FY2003)
CG 61	2005	0.9537	$234,668.92	$223,801.14
CG 67	2006	0.9250	$161,646.56	$149,525.24
CG 70	2007	0.9007	$184,329.58	$166,024.67
CG 72	2005	0.9537	$229,774.69	$219,133.56
CG 73	2005	0.9537	$292,576.74	$279,027.18
DDG 53	2006	0.9250	$837.01	$774.25
DDG 55	2006	0.9250	$751.57	$695.21
DDG 56	2007	0.9007	$92,066.71	$82,924.00
DDG 59	2005	0.9537	$201,782.00	$192,437.25
DDG 60	2006	0.9250	$119,360.84	$110,410.38
DDG 61	2005	0.9537	$182,834.45	$174,367.18
DDG 62	2006	0.9250	$318,133.93	$294,278.16
DDG 65	2006	0.9250	$227,216.30	$210,178.13
DDG 68	2005	0.9537	$62,657.90	$59,756.14
DDG 69	2007	0.9007	$86,102.12	$77,551.72
DDG 70	2005	0.9537	$159,333.84	$151,954.91
DDG 73	2005	0.9537	$148,749.17	$141,860.43
DDG 76	2005	0.9537	$229,568.54	$218,936.96
		Total	**$2,932,390.87**	**$2,753,636.52**

For purposes of comparison, Figure 11 brings together the allowance effectiveness *t*-test results and the dollar amounts obligated after CILS–TAT. FY2003 obligated values were plotted against the observed change in allowance effectiveness means and the respective *t*-test p-value. Ships that were identified as statistically significant are annotated by red circles.

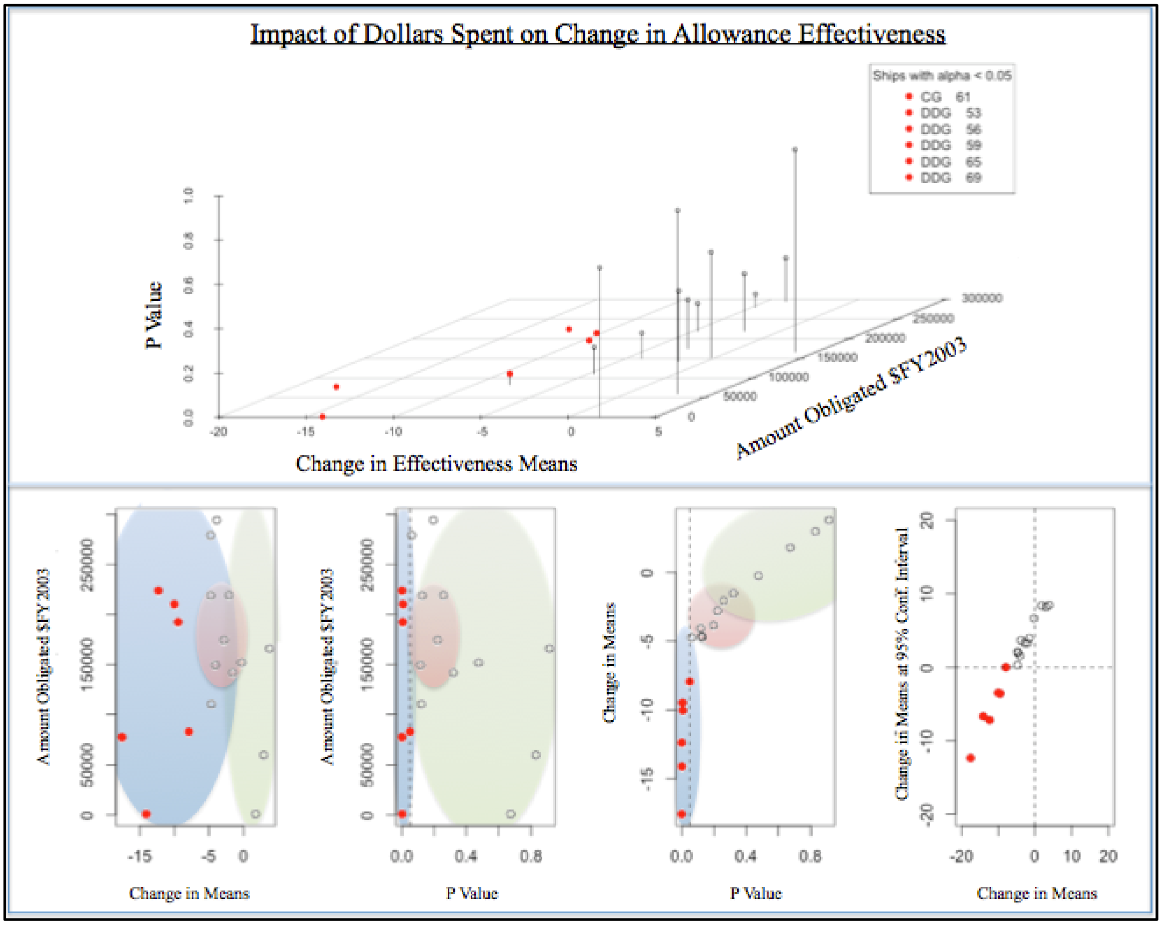


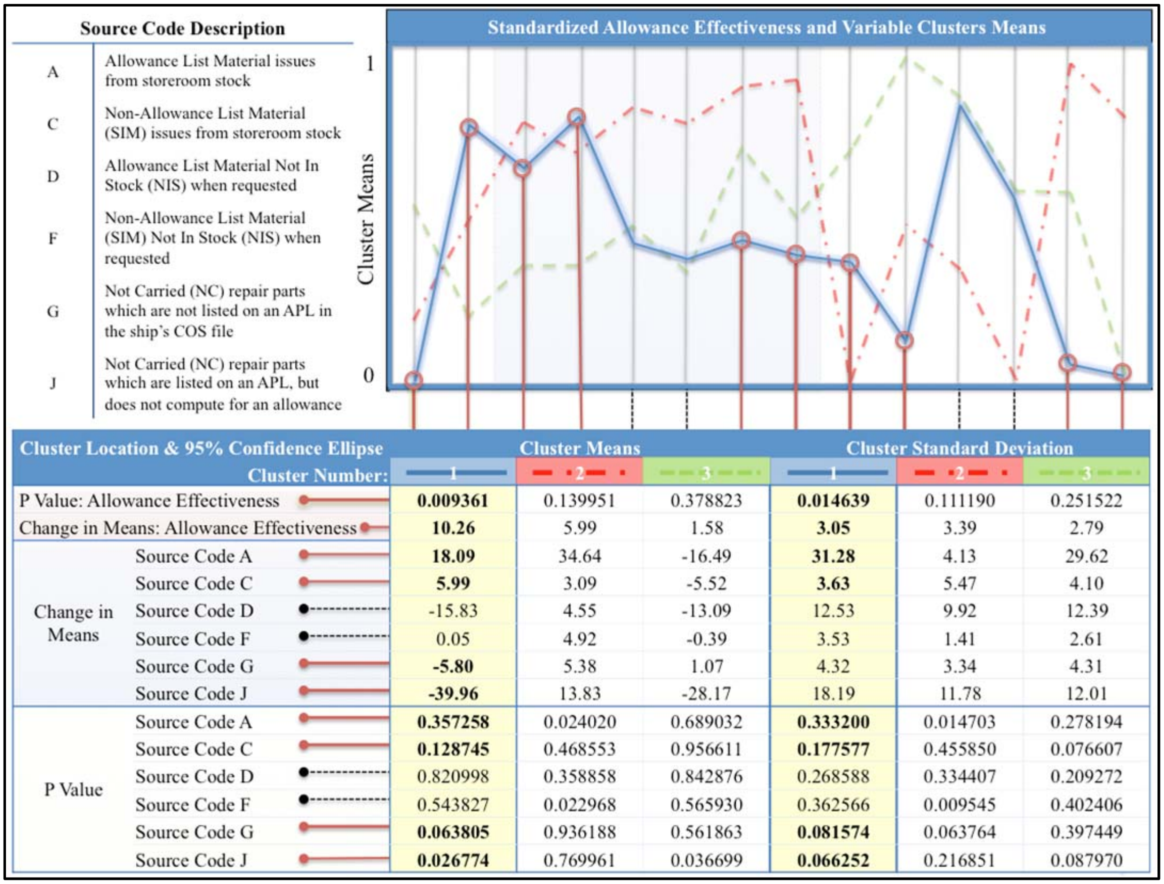
Figure 11. Explaining the Relationship Between Amounts Obligated and the Significance of the Change in Allowance Effectiveness for Each Ship

The top graph in Figure 11 shows how the three variables interact. The bottom charts are two-dimensional projections of the various variables from the top chart. Starting with the amount obligated versus the change in means, while a strong relationship between these two does not appear to exist, using cluster analysis and the k-means function in R Statistics software, the ships were grouped into three clusters with similar characteristics. Fifteen parameters were used as variables in the cluster analysis, including obligated amount, p-values, and changes in means for the various source codes. These variables were used in an effort to find those parameters that differentiate the ships that experienced a statistically significant difference in means and those that did not. A grouping of three clusters was used because it naturally split the *t*-test p-values into three levels of Type I errors, with one group centered at approximately 0.05.

Based on this analysis, Cluster 1 (blue ellipse) encompasses all ships with a Type I error approximately less than 0.05. Cluster 1 is centered on a p-value of 0.03, a change in means of -10.11%, and an obligated amount of $147,138. Within this cluster, the ships can be split again into two groups based on the amount that was obligated. In the first set (bottom left), DDG 53 and DDG 69 achieved a significant change in means with an obligated amount almost half of the other statistically significant ships—less than $100,000. Included in this grouping, DDG 56 did not see as large of a change in means for a similar amount obligated, but the change was enough to be statistically significant.

In the second grouping in the first cluster (top left) are CG 61, DDG 59, and DDG 65, with amounts obligated ranging from $174,000 to $210,000. They achieved a smaller change in the means of allowance effectiveness, with an average change of -10.63%. The other two clusters of ships, Cluster 2 (red ellipse) and Cluster 3 (green ellipse), encompass the remaining ships whose change in allowance effectiveness was not below the p-value threshold of less than 0.5. The important takeaway from this analysis is that the amount of money obligated appears to be independent of a change in allowance effectiveness. This is true in terms of both magnitude of the change and its statistical significance. For roughly the same amount obligated, Clusters 1 (blue ellipse) and 2 (red ellipse) achieved vastly different changes in means and statistical significance.

We also used cluster analysis to examine individual source codes. There are two for Cluster 1, source codes A and C, for which almost all ships experienced a significant change. Figure 12 shows the relative magnitude of the change in means and their statistical significance for the three clusters. The values in Figure 12 have been normalized to allow for better comparison between variables with dissimilar scales. It is important to note that in terms of source codes (see Figure 4) A, C, D, and F, the expected change in means is negative, and for source codes G and J, the expected change is positive. This indicates that for the first four source codes of A, C, D, and F, the lower the value for change in means, the better; and for the final two source codes of G and J, the larger the value, the better. For the ships that are statistically significant, Cluster 1, it is clear that these ships experienced the largest changes in four out of six source codes; however, only source codes A and C experienced Type I errors less than 0.05.



Source Code Description	
A	Allowance List Material issues from storeroom stock
C	Non-Allowance List Material (SIM) issues from storeroom stock
D	Allowance List Material Not In Stock (NIS) when requested
F	Non-Allowance List Material (SIM) Not In Stock (NIS) when requested
G	Not Carried (NC) repair parts which are not listed on an APL in the ship's COS file
J	Not Carried (NC) repair parts which are listed on an APL, but does not compute for an allowance

Cluster Location & 95% Confidence Ellipse		Cluster Means			Cluster Standard Deviation		
	Cluster Number:	1	2	3	1	2	3
P Value: Allowance Effectiveness		**0.009361**	0.139951	0.378823	**0.014639**	0.111190	0.251522
Change in Means: Allowance Effectiveness		**10.26**	5.99	1.58	**3.05**	3.39	2.79
Change in Means	Source Code A	**18.09**	34.64	-16.49	**31.28**	4.13	29.62
	Source Code C	**5.99**	3.09	-5.52	**3.63**	5.47	4.10
	Source Code D	-15.83	4.55	-13.09	12.53	9.92	12.39
	Source Code F	0.05	4.92	-0.39	3.53	1.41	2.61
	Source Code G	**-5.80**	5.38	1.07	4.32	3.34	4.31
	Source Code J	**-39.96**	13.83	-28.17	18.19	11.78	12.01
P Value	Source Code A	**0.357258**	0.024020	0.689032	**0.333200**	0.014703	0.278194
	Source Code C	**0.128745**	0.468553	0.956611	**0.177577**	0.455850	0.076607
	Source Code D	0.820998	0.358858	0.842876	0.268588	0.334407	0.209272
	Source Code F	0.543827	0.022968	0.565930	0.362566	0.009545	0.402406
	Source Code G	**0.063805**	0.936188	0.561863	**0.081574**	0.063764	0.397449
	Source Code J	**0.026774**	0.769961	0.036699	**0.066252**	0.216851	0.087970

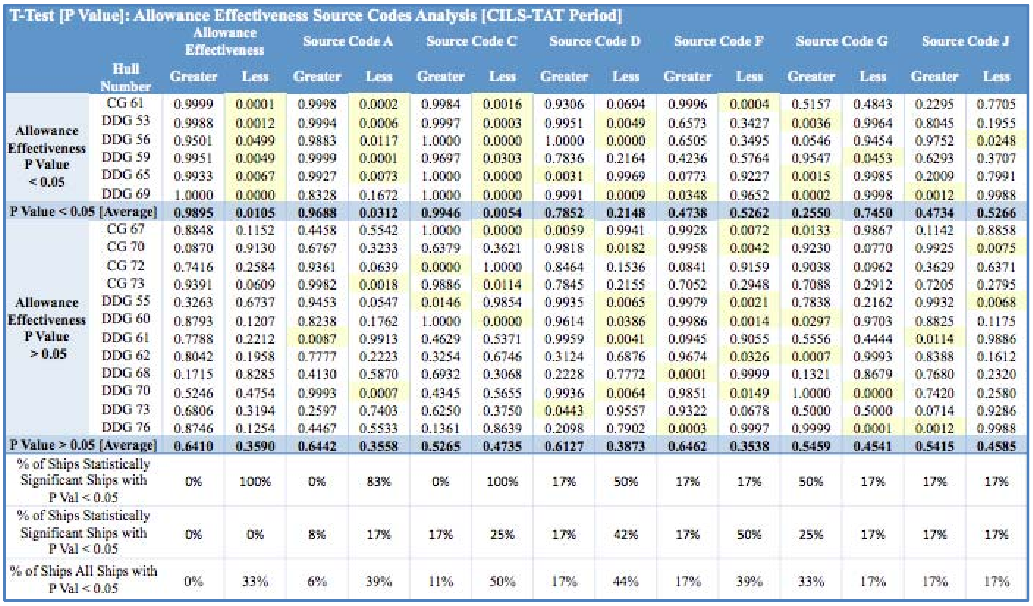
Figure 12. Source Codes That Drive Allowance Effectiveness to Be Statistically Significant Using Cluster Analysis

Table 10, which shows the results of t-test analysis for the various source codes in conjunction with Figure 13 in terms of its change, shows that source code C had the lowest p-value both individually and when averaged across the six statistically significant ships. However, in terms of numerical magnitude and the parameters' relative ability to change the allowance effectiveness equation, the primary parameter of concern is source code A. This can be seen in the ellipse for change in source code A, which is centered on -57.73, while the ellipse for source code C is centered on -12.18. In summary, we found that source code A had a greater ability to impact the change in allowance effectiveness than any other source code

In keeping with this theme, overall changes in source code G are not statistically significant within a 95% confidence interval. This can be explained by looking at the *t*-test results for source code G. Looking at the p-values for the greater-than and less-than hypothesis, there does not appear to be a clear direction among all of the six ships with statistically significant change nor among all ships for the change in source code G; out of all of the ships, 33% were statistically significant with a greater-than hypothesis and 17% with a less-than hypothesis. In terms of source code J, the ships in Cluster 1 fell between the other clusters. Similarly, this is explained by the ambiguous direction of the change in means among all ships; for the greater-than hypothesis, 17% of the ships experienced a Type I error less than 0.05, and likewise, under the less-than hypothesis, 17% of the ships experienced a Type I error less than 0.05. Essentially, the results of the G and J source codes are not consistent and not statistically significant. The data is split unevenly in directionality. Early on, CILS‒TAT affected A and C but did not affect the G and J source codes. According to the framework of source codes, one would expect some correlation between A/C and G/J. As stated previously, the data analysis does not reveal any correlation between the four source codes of A, C, G, and J.

These changes are consistent with the expected results of CILS‒TAT implementation because the technique is designed to increase the frequency of source codes A and C. If demands received in the after period are identical to demands received in the before period, then one would expect the occurrence of source codes A and C to increase while G and J decreased in a perfectly inverse relationship. In reality, however, there are other factors that influence the frequency of G and J that cannot be completely mitigated by CILS‒TAT (e.g., poor configuration management practices). This proves that, independent of the amount of money obligated, in those ships that achieved a statistically significant change in allowance effectiveness, CILS‒TAT was able to accurately target source codes A and C. This implies that the true measure of CILS‒TAT's impact on allowance effectiveness can be quantified simply by focusing analysis on changes in source codes A and C.

Table 10. Analysis of Source Codes for Allowance Effectiveness Calculation



T-Test [P Value]: Allowance Effectiveness Source Codes Analysis [CILS-TAT Period]

		Allowance Effectiveness		Source Code A		Source Code C		Source Code D		Source Code F		Source Code G		Source Code J	
	Hull Number	Greater	Less	Greater	Less	Greater	Less	Greater	Less	Greater	Less	Greater	Less	Greater	Less
Allowance Effectiveness P Value < 0.05	CG 61	0.9999	0.0001	0.9998	0.0002	0.9984	0.0016	0.9306	0.0694	0.9996	0.0004	0.5157	0.4843	0.2295	0.7705
	DDG 53	0.9988	0.0012	0.9994	0.0006	0.9997	0.0003	0.9951	0.0049	0.6573	0.3427	0.0036	0.9964	0.8045	0.1955
	DDG 56	0.9501	0.0499	0.9883	0.0117	1.0000	0.0000	1.0000	0.0000	0.6505	0.3495	0.0546	0.9454	0.9752	0.0248
	DDG 59	0.9951	0.0049	0.9999	0.0001	0.9697	0.0303	0.7836	0.2164	0.4236	0.5764	0.9547	0.0453	0.6293	0.3707
	DDG 65	0.9933	0.0067	0.9927	0.0073	1.0000	0.0000	0.0031	0.9969	0.0773	0.9227	0.0015	0.9985	0.2009	0.7991
	DDG 69	1.0000	0.0000	0.8328	0.1672	1.0000	0.0000	0.9991	0.0009	0.0348	0.9652	0.0002	0.9998	0.0012	0.9988
P Value < 0.05 [Average]		**0.9895**	**0.0105**	**0.9688**	**0.0312**	**0.9946**	**0.0054**	**0.7852**	**0.2148**	**0.4738**	**0.5262**	**0.2550**	**0.7450**	**0.4734**	**0.5266**
Allowance Effectiveness P Value > 0.05	CG 67	0.8848	0.1152	0.4458	0.5542	1.0000	0.0000	0.0059	0.9941	0.9928	0.0072	0.0133	0.9867	0.1142	0.8858
	CG 70	0.0870	0.9130	0.6767	0.3233	0.6379	0.3621	0.9818	0.0182	0.9958	0.0042	0.9230	0.0770	0.9925	0.0075
	CG 72	0.7416	0.2584	0.9361	0.0639	0.0000	1.0000	0.8464	0.1536	0.0841	0.9159	0.9038	0.0962	0.3629	0.6371
	CG 73	0.9391	0.0609	0.9982	0.0018	0.9886	0.0114	0.7845	0.2155	0.7052	0.2948	0.7088	0.2912	0.7205	0.2795
	DDG 55	0.3263	0.6737	0.9453	0.0547	0.0146	0.9854	0.9935	0.0065	0.9979	0.0021	0.7838	0.2162	0.9932	0.0068
	DDG 60	0.8793	0.1207	0.8238	0.1762	1.0000	0.0000	0.9614	0.0386	0.9986	0.0014	0.0297	0.9703	0.8825	0.1175
	DDG 61	0.7788	0.2212	0.0087	0.9913	0.4629	0.5371	0.9959	0.0041	0.0945	0.9055	0.5556	0.4444	0.0114	0.9886
	DDG 62	0.8042	0.1958	0.7777	0.2223	0.3254	0.6746	0.3124	0.6876	0.9674	0.0326	0.0007	0.9993	0.8388	0.1612
	DDG 68	0.1715	0.8285	0.4130	0.5870	0.6932	0.3068	0.2228	0.7772	0.0001	0.9999	0.1321	0.8679	0.7680	0.2320
	DDG 70	0.5246	0.4754	0.9993	0.0007	0.4345	0.5655	0.9936	0.0064	0.9851	0.0149	1.0000	0.0000	0.7420	0.2580
	DDG 73	0.6806	0.3194	0.2597	0.7403	0.6250	0.3750	0.0443	0.9557	0.9322	0.0678	0.5000	0.5000	0.0714	0.9286
	DDG 76	0.8746	0.1254	0.4467	0.5533	0.1361	0.8639	0.2098	0.7902	0.0003	0.9997	0.9999	0.0001	0.0012	0.9988
P Value > 0.05 [Average]		**0.6410**	**0.3590**	**0.6442**	**0.3558**	**0.5265**	**0.4735**	**0.6127**	**0.3873**	**0.6462**	**0.3538**	**0.5459**	**0.4541**	**0.5415**	**0.4585**
% of Ships Statistically Significant Ships with P Val < 0.05		0%	100%	0%	83%	0%	100%	17%	50%	17%	17%	50%	17%	17%	17%
% of Ships Statistically Significant Ships with P Val < 0.05		0%	0%	8%	17%	17%	25%	17%	42%	17%	50%	25%	17%	17%	17%
% of Ships All Ships with P Val < 0.05		0%	33%	6%	39%	11%	50%	17%	44%	17%	39%	33%	17%	17%	17%

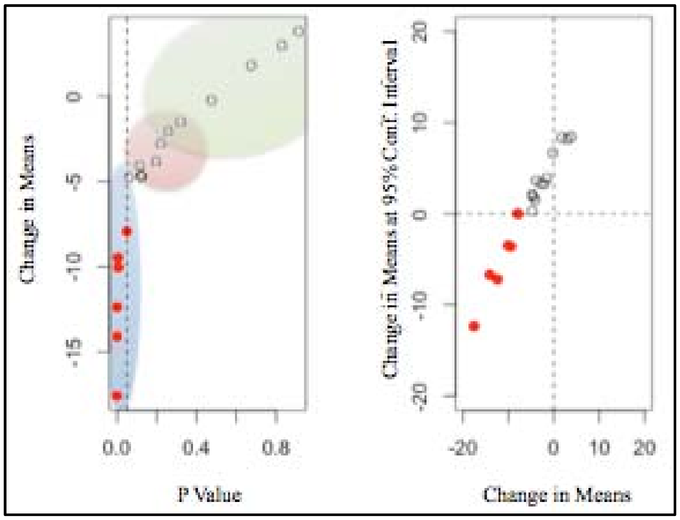


Figure 13. Statistical Significance of Change in Allowance Effectiveness (Before to After CILS–TAT)

The graphs in Figure 13 depict the relationship between the observed changes in data set means and their statistical significance relative to the p-value and the 95% upper confidence level (UCL). The UCL would be defined in this case as a type of interval estimate of a population parameter and is used to indicate the reliability of an estimate.

These two graphs show that of the data sets, which did not show statistical significance, there are some ships (Cluster 2) relatively close to achieving statistical significance. Relating Figure 13 back to Table 10, if the confidence interval was increased to

99%, the number of statistically significant ships decreases to five (one CG and four DDGs). However, in order to increase the number of statistically significant ships to 90% of all ships (~16 ships), the confidence interval must be changed to 30%, which is well outside of acceptable limits. Again, statistically significant means that at a 95% confidence interval (Type I error < 0.05), there is enough evidence, based on the change in means and the variance in the two data sets, to say that there was a change. Note that there are three ships—CG 70, DDG 55, and DDG 68—that experienced a positive change in means, which is opposite to the expected output. Herein, this shows that while there are some ships on the cusp of achieving statistical significance, only marginal losses or gains are made by increasing or decreasing the confidence interval—the ships that achieved statistical significance were well inside the 95% confidence interval.

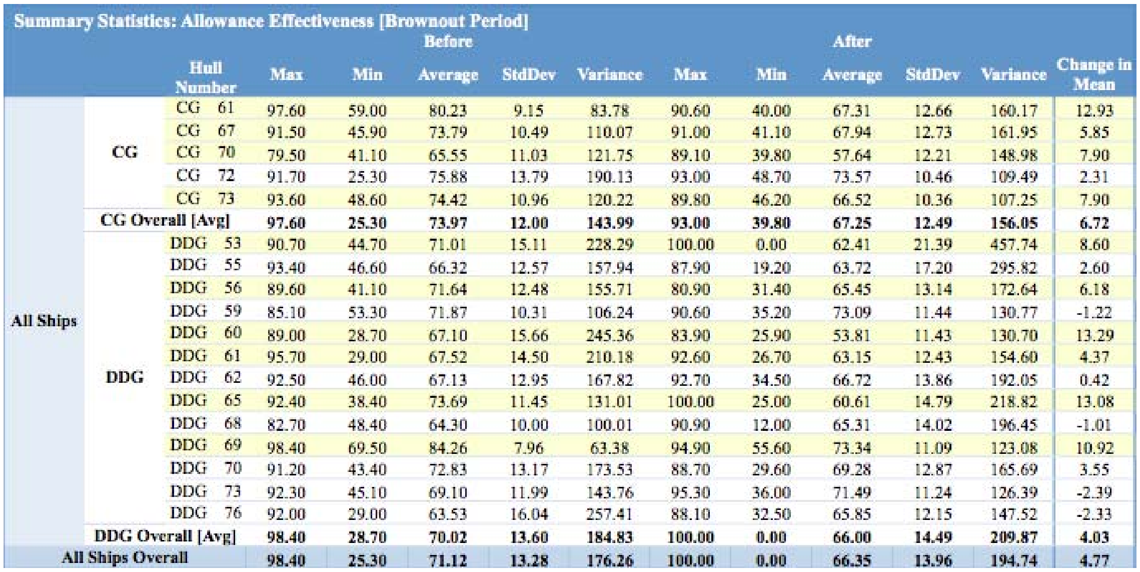
In conclusion, during the periods when CILS–TAT was implemented, there were six ships that experienced a significant enough change in allowance effectiveness to result in a Type I error less than 0.05. Although the amounts obligated for each ship varied significantly, there appears to be no relationship between the amount obligated and the resulting change in allowance effectiveness. This result is consistent for both ships that experienced a statistically significant change and those that did not. In terms of the parameters used to calculate allowance effectiveness, CILS–TAT predominately impacted source codes A and C with some change to codes G and J, however, not in a statistically significant manner.

4. Brownout Period Analysis

Data analyzed during the brownout period covers December 2009 to January 2011. In order to maintain uniformity of CILS–TAT effectiveness for those ships whose 24-month window continued past December 2009, their brownout analysis window is adjusted. For example, USS *John S McCain*'s brownout period started as of June 2009, because the 24 months following CILS–TAT implementation did not complete until June 2009. This ensures that all ships' data are given the full 24-month window following CILS–TAT implementation.

During the brownout period, there was a considerable decrease in allowance effectiveness across the board. Looking at the two data sets within the before data, the reported allowance effectiveness ranges from a minimum of 25.30% to a maximum of 98.40% with an overall average of 71.12% and a standard deviation of 13.28%. In terms of ships grouped by class, there is not an appreciable difference in the before data sets. Among the after data sets, allowance effectiveness ranges from a minimum of 0.00% to a maximum of 100.00% with an overall average of 66.35% and a standard deviation of 13.96. Table 11 summarizes the changes in the means data sets from before to after. To be consistent for comparison purposes with the change in means calculated in the Welch Two-Sided *t*-test, the change in means calculation is based on the before data set mean minus the after data set mean.

Table 11. Summary of Allowance Effectiveness (Before to After Brownout Period)

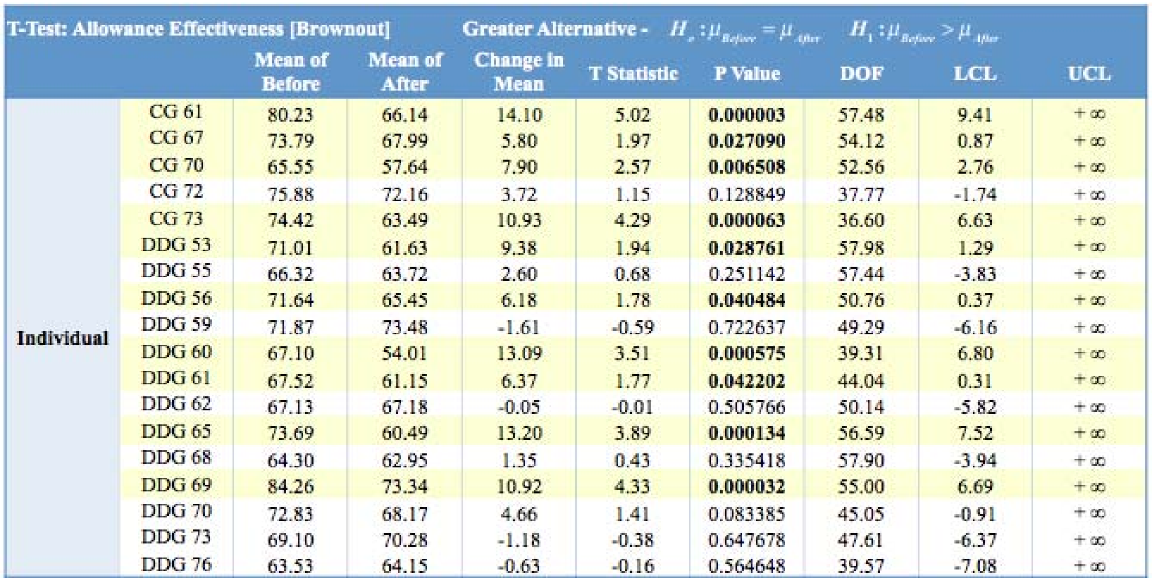


Summary Statistics: Allowance Effectiveness [Brownout Period]			Before					After					
		Hull Number	Max	Min	Average	StdDev	Variance	Max	Min	Average	StdDev	Variance	Change in Mean
All Ships	CG	CG 61	97.60	59.00	80.23	9.15	83.78	90.60	40.00	67.31	12.66	160.17	12.93
		CG 67	91.50	45.90	73.79	10.49	110.07	91.00	41.10	67.94	12.73	161.95	5.85
		CG 70	79.50	41.10	65.55	11.03	121.75	89.10	39.80	57.64	12.21	148.98	7.90
		CG 72	91.70	25.30	75.88	13.79	190.13	93.00	48.70	73.57	10.46	109.49	2.31
		CG 73	93.60	48.60	74.42	10.96	120.22	89.80	46.20	66.52	10.36	107.25	7.90
	CG Overall [Avg]		**97.60**	**25.30**	**73.97**	**12.00**	**143.99**	**93.00**	**39.80**	**67.25**	**12.49**	**156.05**	**6.72**
	DDG	DDG 53	90.70	44.70	71.01	15.11	228.29	100.00	0.00	62.41	21.39	457.74	8.60
		DDG 55	93.40	46.60	66.32	12.57	157.94	87.90	19.20	63.72	17.20	295.82	2.60
		DDG 56	89.60	41.10	71.64	12.48	155.71	80.90	31.40	65.45	13.14	172.64	6.18
		DDG 59	85.10	53.30	71.87	10.31	106.24	90.60	35.20	73.09	11.44	130.77	-1.22
		DDG 60	89.00	28.70	67.10	15.66	245.36	83.90	25.90	53.81	11.43	130.70	13.29
		DDG 61	95.70	29.00	67.52	14.50	210.18	92.60	26.70	63.15	12.43	154.60	4.37
		DDG 62	92.50	46.00	67.13	12.95	167.82	92.70	34.50	66.72	13.86	192.05	0.42
		DDG 65	92.40	38.40	73.69	11.45	131.01	100.00	25.00	60.61	14.79	218.82	13.08
		DDG 68	82.70	48.40	64.30	10.00	100.01	90.90	12.00	65.31	14.02	196.45	-1.01
		DDG 69	98.40	69.50	84.26	7.96	63.38	94.90	55.60	73.34	11.09	123.08	10.92
		DDG 70	91.20	43.40	72.83	13.17	173.53	88.70	29.60	69.28	12.87	165.69	3.55
		DDG 73	92.30	45.10	69.10	11.99	143.76	95.30	36.00	71.49	11.24	126.39	-2.39
		DDG 76	92.00	29.00	63.53	16.04	257.41	88.10	32.50	65.85	12.15	147.52	-2.33
	DDG Overall [Avg]		**98.40**	**28.70**	**70.02**	**13.60**	**184.83**	**100.00**	**0.00**	**66.00**	**14.49**	**209.87**	**4.03**
All Ships Overall			**98.40**	**25.30**	**71.12**	**13.28**	**176.26**	**100.00**	**0.00**	**66.35**	**13.96**	**194.74**	**4.77**

In terms of statistical significance for the brownout period, the expected result was that the mean of the before data set would be greater than the mean of the after data set. Based on this expected movement, the greater hypothesis was used as the base for analyzing the brownout period. Again using the Welch Two-Sided *t*-test, 10 ships (four CGs and six DDGs) saw a statistically significant change in the means of the before and after data sets. On average, all of the ships experienced a change of 4.77. When grouped together, CGs and DDGs experienced an average change of 6.72 and 4.03, respectively, in the data sets.

In stark contrast to the change experienced during the CILS–TAT period, during the brownout period, at a confidence interval of 99% (Type 1 error < 0.01), there is enough evidence to prove that six ships experienced the expected change in allowance effectiveness. There are, however, four ships that experienced a small, negative change in mean, resulting in very low statistical significance. For the brownout period, in order to capture 90% of the ships (~16 ships) being statistically significant, the confidence interval would need to shift to 60%. Table 12 summarizes the *t*-test results.

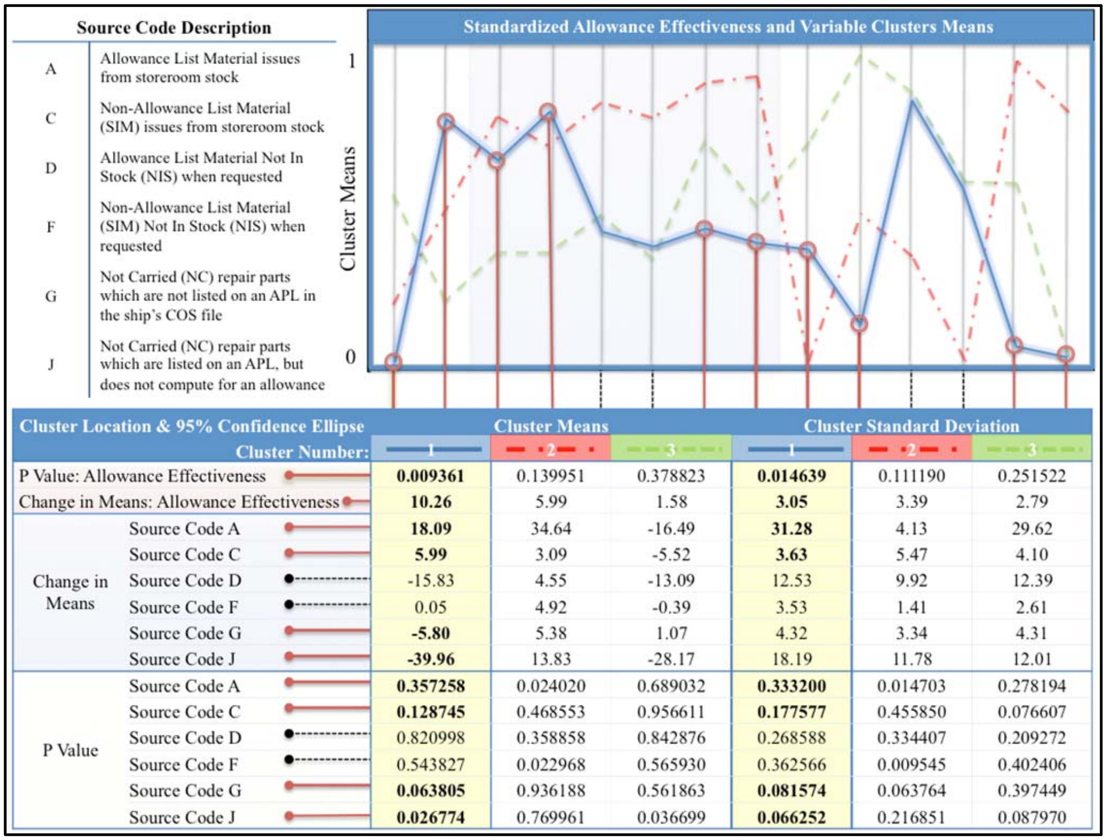
Table 12. *t*-Test Summary of Allowance Effectiveness



T-Test: Allowance Effectiveness [Brownout] **Greater Alternative -** $H_o: \mu_{Before} = \mu_{After}$ $H_1: \mu_{Before} > \mu_{After}$

		Mean of Before	Mean of After	Change in Mean	T Statistic	P Value	DOF	LCL	UCL
Individual	CG 61	80.23	66.14	14.10	5.02	**0.000003**	57.48	9.41	+∞
	CG 67	73.79	67.99	5.80	1.97	**0.027090**	54.12	0.87	+∞
	CG 70	65.55	57.64	7.90	2.57	**0.006508**	52.56	2.76	+∞
	CG 72	75.88	72.16	3.72	1.15	0.128849	37.77	-1.74	+∞
	CG 73	74.42	63.49	10.93	4.29	**0.000063**	36.60	6.63	+∞
	DDG 53	71.01	61.63	9.38	1.94	**0.028761**	57.98	1.29	+∞
	DDG 55	66.32	63.72	2.60	0.68	0.251142	57.44	-3.83	+∞
	DDG 56	71.64	65.45	6.18	1.78	**0.040484**	50.76	0.37	+∞
	DDG 59	71.87	73.48	-1.61	-0.59	0.722637	49.29	-6.16	+∞
	DDG 60	67.10	54.01	13.09	3.51	**0.000575**	39.31	6.80	+∞
	DDG 61	67.52	61.15	6.37	1.77	**0.042202**	44.04	0.31	+∞
	DDG 62	67.13	67.18	-0.05	-0.01	0.505766	50.14	-5.82	+∞
	DDG 65	73.69	60.49	13.20	3.89	**0.000134**	56.59	7.52	+∞
	DDG 68	64.30	62.95	1.35	0.43	0.335418	57.90	-3.94	+∞
	DDG 69	84.26	73.34	10.92	4.33	**0.000032**	55.00	6.69	+∞
	DDG 70	72.83	68.17	4.66	1.41	0.083385	45.05	-0.91	+∞
	DDG 73	69.10	70.28	-1.18	-0.38	0.647678	47.61	-6.37	+∞
	DDG 76	63.53	64.15	-0.63	-0.16	0.564648	39.57	-7.08	+∞

Cluster analysis was again used to discover the reason that these 10 ships experienced a statistically significant change. Figure 14 shows that during the brownout period, ships in Cluster 1, similar to the CILS–TAT period results, had the largest changes in source codes A, C, G, and J. However, during the brownout period, source codes G and J—versus codes A and C—had a Type I error less than 0.05. Looking at the magnitude of the change in means among the source codes, we see that it is clear that source code J dominated the movement of allowance effectiveness. For comparison, source code J's ellipse was centered on a change in means of -1.31 during the CILS–TAT period and on -39.96 during the brownout period; source code A's ellipse was centered on -57.73 during the CILS–TAT period and on 18.90 in the brownout period. During the brownout period, both the magnitude and statistical significance flipped. Looking at the parallel coordinate plot at the top of the figure, we note that during the brownout period, the higher the value, the better for the change in means of source codes A, C, D, and F; and the smaller the number, the better for the change in means of source codes G and J. Based on this analysis, it is clear that the change in source code J is the reason that the 10 ships experienced a statistically significant change in allowance effectiveness.

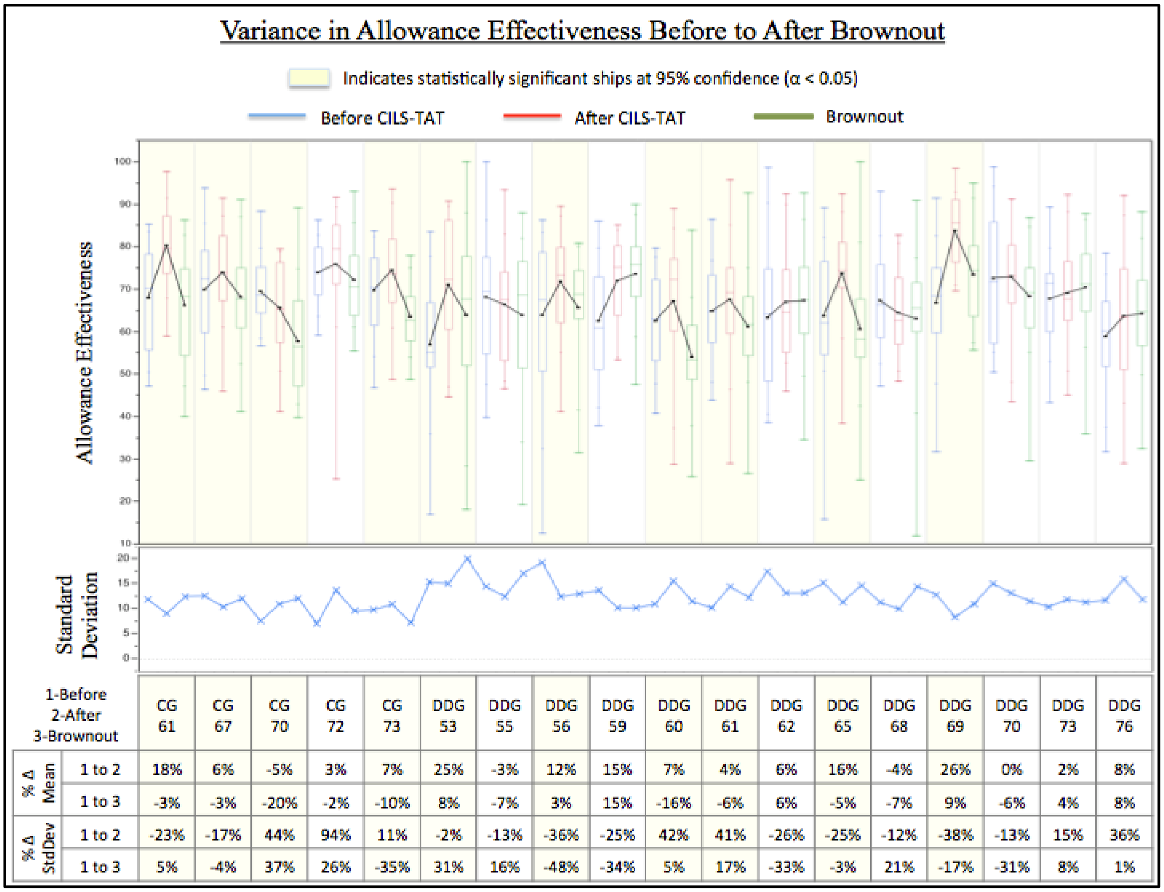


Source Code Description	
A	Allowance List Material issues from storeroom stock
C	Non-Allowance List Material (SIM) issues from storeroom stock
D	Allowance List Material Not In Stock (NIS) when requested
F	Non-Allowance List Material (SIM) Not In Stock (NIS) when requested
G	Not Carried (NC) repair parts which are not listed on an APL in the ship's COS file
J	Not Carried (NC) repair parts which are listed on an APL, but does not compute for an allowance

Cluster Location & 95% Confidence Ellipse		Cluster Means			Cluster Standard Deviation		
	Cluster Number:	1	2	3	1	2	3
P Value: Allowance Effectiveness		**0.009361**	0.139951	0.378823	**0.014639**	0.111190	0.251522
Change in Means: Allowance Effectiveness		**10.26**	5.99	1.58	**3.05**	3.39	2.79
Change in Means	Source Code A	**18.09**	34.64	-16.49	**31.28**	4.13	29.62
	Source Code C	**5.99**	3.09	-5.52	**3.63**	5.47	4.10
	Source Code D	-15.83	4.55	-13.09	12.53	9.92	12.39
	Source Code F	0.05	4.92	-0.39	3.53	1.41	2.61
	Source Code G	**-5.80**	5.38	1.07	4.32	3.34	4.31
	Source Code J	**-39.96**	13.83	-28.17	18.19	11.78	12.01
P Value	Source Code A	**0.357258**	0.024020	0.689032	**0.333200**	0.014703	0.278194
	Source Code C	**0.128745**	0.468553	0.956611	**0.177577**	0.455850	0.076607
	Source Code D	0.820998	0.358858	0.842876	0.268588	0.334407	0.209272
	Source Code F	0.543827	0.022968	0.565930	0.362566	0.009545	0.402406
	Source Code G	**0.063805**	0.936188	0.561863	**0.081574**	0.063764	0.397449
	Source Code J	**0.026774**	0.769961	0.036699	**0.066252**	0.216851	0.087970

Figure 14. Impact of Source Codes on Allowance Effectiveness Using Cluster Analysis

In conclusion, it is clear that the brownout period caused an impact on a larger number of ships when compared to the CILS–TAT period. However, looking at the bigger picture and Figure 15, which shows allowance effectiveness and the standard deviation for the three different periods, it is clear that the brownout period resulted in many of the ships returning to their pre–CILS–TAT means and standard deviations.



1-Before 2-After 3-Brownout		CG 61	CG 67	CG 70	CG 72	CG 73	DDG 53	DDG 55	DDG 56	DDG 59	DDG 60	DDG 61	DDG 62	DDG 65	DDG 68	DDG 69	DDG 70	DDG 73	DDG 76
% Δ Mean	1 to 2	18%	6%	-5%	3%	7%	25%	-3%	12%	15%	7%	4%	6%	16%	-4%	26%	0%	2%	8%
	1 to 3	-3%	-3%	-20%	-2%	-10%	8%	-7%	3%	15%	-16%	-6%	6%	-5%	-7%	9%	-6%	4%	8%
% Δ StdDev	1 to 2	-23%	-17%	44%	94%	11%	-2%	-13%	-36%	-25%	42%	41%	-26%	-25%	-12%	-38%	-13%	15%	36%
	1 to 3	5%	-4%	37%	26%	-35%	31%	16%	-48%	-34%	5%	17%	-33%	-3%	21%	-17%	-31%	8%	1%

Figure 15. During the Brownout Period, Many Ships Return to Before CILS–TAT Levels

In summary, five ships were statistically significant during both the CILS–TAT period and the brownout period. Of those five ships, three ended up with allowance effectiveness means that were higher than their pre–CILS–TAT levels, indicating a lasting effect of the implementation. Six ships were not significant during the CILS–TAT analysis but returned to within 10% of their pre–CILS–TAT mean during the brownout phase. This change is not directly related to CILS–TAT, although it is a variable to consider. The remaining seven ships did not see a significant change in mean in either of the analysis windows.

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IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

In summary, the goal of this research was to conduct a BCA of CILS–TAT to determine its historical effectiveness against allowancing metrics. The analysis examined the before and after periods to determine whether the benefits were substantial enough to restart the program following the implementation of the Navy's ERP. The research identified three specific questions used in guiding the process. In the following paragraphs, we summarize our findings.

First, we asked the question of how did CILS–TAT impact allowance effectiveness for our sample and at what cost? The findings suggested that CILS–TAT had a direct and positive impact on allowance effectiveness for six out of 18 ships. Of the 12 remaining ships, nine saw a positive change in allowance effectiveness, although this change is not statistically significant and thus cannot be attributed to CILS–TAT. Based on these findings, CILS–TAT does achieve the ends for which it is designed. Regardless of whether the U.S. Navy re-implements this program or some other targeted allowancing technique, we have found that there is a need throughout the fleet for this model.

Second, we explored the question of whether there are correlations between allowance effectiveness rates, POTF from CASREPs, and CILS–TAT cost. Our research concluded that there was, in fact, no direct correlation between the effectiveness of CILS–TAT and these three variables. Of the ships that were statistically significant, their performance as related to allowance effectiveness and POTF could not be linked directly to the amount of funds obligated.

Last, we sought to answer the question of the effect of not having CILS–TAT during 2009–2011, when traditional allowancing procedures were not available. The research demonstrated that in the absence of targeted allowancing techniques, ships that received CILS–TAT were able to maintain allowance effectiveness rates within 10% of their pre–CILS–TAT averages for up to 24 months following implementation. These results are most encouraging because they display the longer term impact of CILS–TAT, as well as provide an expected shelf life for each iteration of the process.

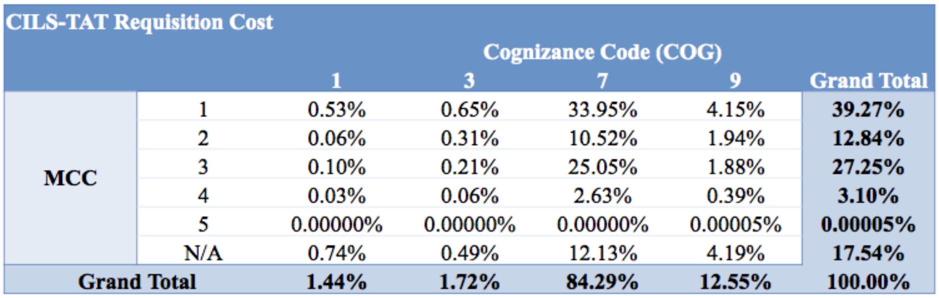
Upon concluding our research, we determined that CILS–TAT did directly contribute to the improved allowance effectiveness of ships within the BMD fleet. Ships in the sample that saw increases in allowance effectiveness were able to maintain those higher levels of performance for up to two years in both the presence and absence of traditional allowance maintenance processes. Although CILS–TAT did not improve allowance effectiveness to the same extent on every ship, the fact that it did improve one third of our sample cannot be ignored, and we recommend that the Navy continue to utilize this program to improve allowance effectiveness in the future.

1. Recommendations for Change

How can the effectiveness of a CILS–TAT product be measured? This depends on the priority of the decision-maker as to whether CILS–TAT should be used to primarily improve allowance effectiveness with a second order effect of reducing the number of CASREPs or whether the program should first reduce CASREP frequency and then focus on allowance effectiveness if resources exist. We believe that the system could be tailored in either direction.

CILS–TAT seeks to improve allowance effectiveness first with no consideration given to the priority of critical systems. Allowances added as a result of CILS–TAT are funded on an all-or-nothing basis, and when funding is constrained, use of a knapsack model would aid in optimizing dollars spent. For example, funding could be applied to all 9X Cognizance Code (COG) items with MCCs 2, 3, or 4 first because this family of COGs accounts for 34.76% of all CASREPs recorded and only 3.02% of total CASREP cost. Additionally, MCCs 2, 3, and 4 accounted for 75.17% of all CASREPs during the analysis window. If more priority were given to these MCCs, the same effect on overall system readiness could be realized at half of the cost. Over the time period analyzed, CILS–TAT requisitions were funded at the rates shown in Table 13.

Table 13. Breakdown of CILS–TAT Requisition Cost (2003–2009)

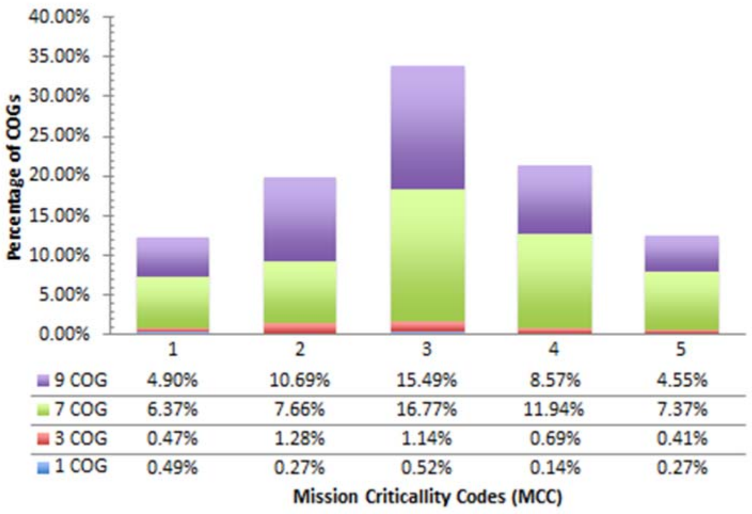


CILS-TAT Requisition Cost

		Cognizance Code (COG)				
		1	3	7	9	Grand Total
MCC	1	0.53%	0.65%	33.95%	4.15%	**39.27%**
	2	0.06%	0.31%	10.52%	1.94%	**12.84%**
	3	0.10%	0.21%	25.05%	1.88%	**27.25%**
	4	0.03%	0.06%	2.63%	0.39%	**3.10%**
	5	0.00000%	0.00000%	0.00000%	0.00005%	**0.00005%**
	N/A	0.74%	0.49%	12.13%	4.19%	**17.54%**
Grand Total		**1.44%**	**1.72%**	**84.29%**	**12.55%**	**100.00%**

As shown in Table 13, nearly 40% of all funding applied as a result of CILS–TAT is used for NIINs with MCC 1 (failure results in minor mission impact). By using a nearly identical amount of funding across MCCs 2, 3, and 4, a much larger impact could be realized on the ship's ability to perform its mission.

Figures 16 and 17 clearly demonstrate the effect of making a change in funding priorities by using MCCs as a factor. Results are based on the analysis of 13,956 CASREPs submitted by sample ships during the analysis window.



	1	2	3	4	5
9 COG	4.90%	10.69%	15.49%	8.57%	4.55%
7 COG	6.37%	7.66%	16.77%	11.94%	7.37%
3 COG	0.47%	1.28%	1.14%	0.69%	0.41%
1 COG	0.49%	0.27%	0.52%	0.14%	0.27%

Figure 16. Breakdown of Casualty Report Frequency

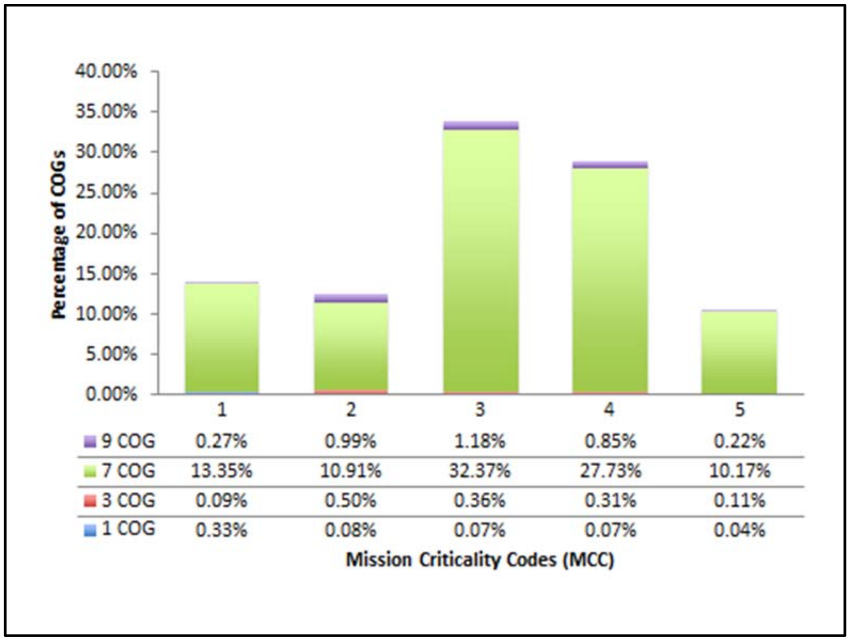


Figure 17. Breakdown of Casualty Report Cost

2. Potential Obstacles

The primary obstacle to changing the implementation of CILS–TAT would be in making the shift away from allowance effectiveness as a primary measure to an approach focused more on critical systems. In a perfect world, all systems would operate as required at all times, but in reality, certain systems will experience difficulty and operate in a degraded capacity. For this reason, it is important that we focus more closely on critical systems both during the initial allowance provisioning process and during times when allowances are being maintained. By shifting to an MCC-based allocation model, we would be moving away from some of the more traditional supply effectiveness metrics. Because this change would be both cultural and procedural in nature, it makes implementation the most difficult.

This change would result in a decrease in allowance effectiveness but an increase in the ability of a ship to carry out mission tasking. In an era where the DoD is expected to operate at prior years' levels with fewer resources, perhaps this cultural change is necessary.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

During the course of our research, we identified some areas where our research could be improved or additional questions that could be answered through the use of a larger sample size, as well as a more diverse set of platforms selected. An additional improvement to this research would be to select a control group, or in this case, a control ship. This ship would be evaluated over the same time period; however, it would not receive a CILS–TAT. Its performance could then be compared against several other ships of the same class or mission area to determine the long-term benefits of the program at the unit level.

There are other variables that could also contribute to the supply effectiveness of a ship that were not evaluated here. Particularly, if supply gross and net effectiveness are to be evaluated, then operational funding has to be considered as well. Improved operational funding levels will increase the opportunity for a ship to replenish its stock and thereby reduce the number of not-in-stock (NIS) demands. Our research evaluated the NC rate for each ship and was therefore independent of periodic OPTAR funding grants.

A study should be conducted comparing the allowance maintenance done through traditional processes as well as through CILS–TAT. We were unable to gain access to this data, but we hypothesize that those ships in our study that did not see a significant statistical change attributed directly to CILS–TAT may have been a result of increased traditional allowance products (e.g., more allowance adds through ASIs). The results of this new study would provide a more accurate understanding as to the precise impact of CILS–TAT.

Lastly, in order to grasp CILS–TAT's impact on CASREP frequency, additional analysis could be conducted on NIINs added as a result of CILS–TAT. Because the allowances added to a ship following a CILS–TAT are derived from previously NC demands, a percentage of those demands were recorded as CASREPs. Analysis could be conducted to determine the demand frequency of previous CASREP NIINs that are added to the ship's stock and subsequently avoid a new CASREP.

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