IMPROVING THE METHODOLOGY TO ESTIMATE JOINT LOGISTICS OVER-THE-SHORE OPERATIONAL THROUGHPUT AND DURATION

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

DOCTOR OF PHILOSOPHY

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ABSTRACT

Joint Logistics Over-the-Shore (JLOTS) is the method the United States (US) Army and Navy use to discharge cargo from large seafaring vessels onto a bare beach when an enemy force has denied access to a deep-water port or the ports have been damaged by natural disasters, terrorist actions, sabotaged by military forces, etc. The last large scale, published analytic study on JLOTS was conducted in 1993 during the Ocean Venture 93 exercise at Camp Lejeune, NC; since that time, nearly the entire US Army inventory of wheeled vehicles have been replaced and tracked systems have increased in size and weight with the additions of reactive armor tiles and urban survival kits. The current estimation method for determining how long a JLOTS operation will take relies on the median duration values in order to determine total operational length.

This research shows that the JLOTS activity duration medians published in current military doctrine are no longer representative of the current inventory of US Army vehicles. New planning factors are defined based on JLOTS subject matter expert opinions as well as a new method of JLOTS duration estimation is described through the use of discrete-event simulation. The results of the proposed duration estimation method were compared to both the existing methodology using both the published planning factors and the new planning factors defined through subject matter expert opinion. In both comparisons the current estimation method was found to consistently overestimate operational throughput while underestimating duration since it fails to capture the queuing actions that occur in a resource constrained environment such as JLOTS.

It is the recommendation of this research that a time and motion study be conducted on JLOTS operations in order to more accurately define the probability distributions associated with JLOTS activities. These distributions would replace the triangular distributions defined by subject matter experts in this research in order to generate a more accurate estimate of JLOTS duration and throughput. More accurate estimates for JLOTS operations will enable cost savings by providing maritime transportation providers with greater fidelity on scheduling while reducing the time these ships are vulnerable to enemy actions.

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DEDICATION

For my girls who will probably never read this.

For my parents who always believed in me despite thinking I might never finish my undergrad (thanks – it was a great five and a half years).

And for my amazing wife who has supported me on this journey for the past 15 years, I could never have achieved this without you babe.

Whatever it takes.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

LIST OF ABBREVIATIONS

A&M ....Approach and Moor.

ABCT ....Armored Brigade Combat Team.

AMP ....Analysis of Mobility Platform.

BCT..Brigade Combat Team.

C&C ....Castoff and Clear.

CJLOTS ....Combined Joint Logistics Over-the-Shore.

ELCAS ....Elevated Causeway System.

HADR..Humanitarian Assistance Disaster Relief.

HMMWV..High Mobility Multipurpose Wheeled Vehicle.

HWV..Heavy Wheeled Vehicle.

IBCT..Infantry Brigade Combat Team.

ICODES...Integrated Computerized Deployment System.

INLS ....Improved Navy Lighterage System.

JLOTS ....Joint Logistics Over-the-Shore.

JOTE ....Joint Estimator.

JP...Joint Publication.

LARC-V...Lighterage Amphibious Resupply Cargo-5 Ton.

LCAC ....Lighterage, Cargo, Air Cushion.

LCM ....Landing Craft, Mechanized.

LCU...Landing Craft, Utility.

LOTS ....Logistics Over-the-Shore.

LSV ....Logistics Support Vessel.

LWV ....Light Wheeled Vehicle.

MCS...Modular Causeway System.

MSV-Light ....Maneuver Support Vessel-Light.

MTOE...Modification Table of Organizational Equipment.

PORTSIM..Port Simulation Model.

RRDF ....Roll-on/Roll-off Discharge Facility.

RTCH...Rough Terrain Container Handler.

SBCT ....Stryker Brigade Combat Team.

TARGET...Transportation Analysis Report Generator.

US ....United States.

LIST OF EQUATIONS

LIST OF APPENDIX TABLES

Table Page

LIST OF APPENDIX FIGURES

CHAPTER 1. INTRODUCTION

"Plans based on average assumptions are wrong on average."

--Sam L. Savage, 2009

Logistics Over-the-Shore (LOTS) operations are amphibious military practices that involve personnel and equipment from a single branch of the Armed Forces of the United States. The purpose of a LOTS operation is transporting follow-on combat and support units from large oceangoing vessels in places where adequate port facilities are not available, after the coastal region designated for LOTS operations has been secured through amphibious assault, airborne landing, ground forces originating from another location, or any combination thereof (Joint Staff, 2012). When two or more branches of the Armed Forces of the United States coordinate LOTS operations together under the auspices of a joint task force organization, then the operation is referred to as a Joint Logistics Over-the-Shore (JLOTS) operation. If the Armed Forces of allied nations are involved in JLOTS operations, then the operation is termed a Combined Joint Logistics Over-the-Shore (CJLOTS) operation (Joint Staff, 2012). Currently the United States of America is the only country known to possess the ability to conduct JLOTS without the assistance or support of another allied country's personnel and/or equipment (Expeditionary Strike Group Three, 2013).

The introduction chapter is organized as follows: the need for the study, a statement of the problem the study addresses, the contributions the research makes to the field, and a summation of military service JLOTS resources that familiarizes the reader with the myriad of capabilities each of the services possesses. In addition, this chapter also details the organization that the remaining chapters follow.

1.1. The Need for the Study

The research described by this study is applicable to a number of study areas, each detailed in its own section.

1.1.1. The Changing Inventory of United States Army Vehicles

The most recent study conducted on JLOTS operations throughput analysis occurred in 1993 during Operation Ocean Venture 93 at Camp Lejeune, North Carolina (Joint Staff, 2012). During the intervening 26 years, the United States (US) Army's inventory of wheeled vehicles has been completely replaced. The Family of Medium Tactical Vehicles has supplanted the 5-ton trucks of the Vietnam and Cold War eras (Oshkosh Defense, 2017). The High Mobility Multipurpose Wheeled Vehicle (HMMWV) that first saw combat in the Gulf War is in the process of being retired to make way for the new Joint Light Tactical Vehicle (OshKosh Defense, 2017). The Army's primary armored vehicle systems, the Abrams tank and Bradley Infantry Fighting Vehicle, have not been retired; however, improvements in their armor plating and armament systems have only made them more oversized and heavier (Ensign-Bickford Aerospace & Defense Company, 2017). In the 2000s, the Army fielded a new type of medium armored wheeled vehicle: the Stryker (General Dynamics Land Systems, 2017).

1.1.2. Switch to Expeditionary Operations from a Forward Deployed Mindset

Since the end of the Cold War, the US Army has redeployed most of the conventional forces previously forward deployed at locations throughout the world. During the height of the Cold War, half of the Army's active-duty combat units were forward deployed to locations around the world (predominately in Europe and Korea) (Lust, 2017). At present, only 20% are permanently stationed outside the continental United States (four of the six in either Alaska or Hawai'I, with the remaining two in Europe) (U.S. Army Force Management Support Agency, 2017). While this shift reduces the costs associated with maintaining military strength on a daily basis, the units must travel a greater distance to arrive at their destination when called upon to deploy.

1.1.3. Raising Awareness of the Critical Role JLOTS Operations Possesses during Military Deployments

During the last 16 years the United States Department of Defense has been almost exclusively focused on combating counterinsurgencies with Operation Enduring Freedom (Afghanistan), Operation Iraqi Freedom (later Operation New Dawn), and Operation Inherent Resolve (Iraq and Syria) (Combined Joint Task Force – Operation Inherent Resolve, 2017). Throughout this time, distinctly military niche skill sets like JLOTS have atrophied. The United States military has not conducted a large-scale amphibious assault since the Inchon landings of Operation Chromite during the Korean War (Bartlett, 1983).

1.1.4. Use of JLOTS Equipment During Disaster Relief Operations

The amount and scale of natural disasters has increased over the past 60 years due primarily to the urbanization of the world's population coupled with changes in the climate (Leaning & Guha-Sapir, 2013). When a deep-water port is damaged by a disaster, such as the 2010 Haiti earthquake, the harm is compounded as relief supplies have little or no way of reaching the populations that desperately require them (Bono & Gutierrez, 2011). JLOTS can be leveraged to replace a damaged port until it can resume normal operations or augment an undamaged port where the throughput demand exceeds capacity (Joint Staff, 2012).

1.2. Problem Statement

JLOTS are characterized by a plethora of external factors that influence operations on a minute-by-minute basis. Tidal fluctuations, wind and weather effects on sea state conditions, and equipment operational readiness rates are only some of the variables. Given the inherent complexity of the aforementioned variables, especially when considering the interaction effects between when they occur in concert, it is misrepresentative to attempt to distill JLOTS tasks into a single measure of central tendency like a median. Attempting to determine the duration or throughput of a JLOTS operation using the current methodology set forth in Joint Publication 4-01.6 (Joint Staff, 2012) or the Joint Over the Shore Transportation Estimator developed by the Logistics Management Institute (Thede, Staats, Crowder, & Fortenberry, 1995) underestimates duration while overestimating throughput due to reliance on measures of central tendency (Savage, 2009).

Without a more accurate method to approximate duration and throughput, the underestimations derived from the current approaches would cause a domino effect as subsequent vessels arrive to download and must wait until the current ship is complete. During an expeditionary combat operations scenario, that wait time places the equipment and supplies at increased risk of destruction by enemy forces. In a humanitarian assistance disaster relief (HADR) setting, the much-needed food and basic sundry items would sit idle off the coast. In both situations the time those vessels wait for unloading accrues charges to the government or relief organization that chartered the ships.

1.2.1. Research Questions

This research deconstructs the problem of determining a better solution to estimating JLOTS operations throughput and duration into the following four questions.

1.2.1.1. Research Question One

Do the median times for JLOTS activities recorded during the Ocean Venture 93 exercise and published in military doctrine still represent the present-day equipment of the US Army? If the median times are no longer representative of present-day equipment, then what value is representative and can that value be defined as a probability distribution for use in a discrete-event simulation?

1.2.1.2. Research Question Two

Are the parameters for the proposed probability distribution valid for the JLOTS activity they are intended to describe?

1.2.1.3. Research Question Three

Is the calculated duration for the baseline (control) method that uses the currently published median values similar to the revised baseline (experimental) method that substitutes subject matter expert derived average values for the medians? Is the calculated duration for the baseline (control) method that uses the currently published median values statistically similar to the expected value of the discrete-event simulation (experimental) method that leverages probability distributions defined by subject matter experts? Is the calculated duration for the revised baseline (experimental) method that substitutes subject matter expert derived average values for the medians statistically similar to the expected value of the discrete-event simulation (experimental) method that leverages probability distributions defined by subject matter experts?

1.2.1.4. Research Question Four

How do the different sets of lighterage compare to each other from a fiscal perspective?

1.3. Research Contributions

This research contributes to the current literature as well as the JLOTS field in the following areas: more accurate estimates for JLOTS operational throughput and duration in both contingency and disaster relief operations, improved decision maker fidelity for scheduling follow-on vessels for discharge through JLOTS, and development of a model that can simulate the fielding of new JLOTS equipment or the retirement of older systems.

1.3.1. More Accurate Estimates for JLOTS Operational Throughput and Duration

This research shows that the previous methods for estimating JLOTS operational throughput and duration consistently overestimate the throughput while underestimating the time. By providing decision makers with more realistic estimates, actions can be taken to properly safeguard the exposed forces, equipment, and supplies from enemy interaction during JLOTS operations. Furthermore, planners from the units receiving the equipment from the vessels are able to more precisely plan for when the combat forces could be expected to conduct operations (US Army War College, 2016).

1.3.2. Fidelity for Scheduling Follow-On Vessels for Discharge

This research shows that by more accurately estimating the timeframe discharge operations take, the costs associated with demurrage fees for other vessels awaiting download via JLOTS Operations. Military officers and Department of Defense civilian employees are charged with safeguarding the taxpayer's dollars by the Defense Contingency Contracting Handbook (Defense Procurement and Acquisition Policy, Contingency Contracting, 2015); by having vessels await discharge for lengthy amounts of time could be seen as a waste of government funds. In disaster relief scenarios, the cost for vessels awaiting download could have been spent on additional relief supplies.

1.3.3. Simulate the Fielding of New JLOTS Equipment or the Retirement of Older Systems

This research develops a model that can be used by military acquisitions personnel to simulate the replacement of aging JLOTS equipment with newer designs. Additionally, the model may be used to simulate the effect of removing a specific type of equipment from the JLOTS inventory without replacement to create analysis for budgetary decisions.

1.4. How this Research is Organized

This research is organized in the following manner: Chapter 1 defines JLOTS operations and presents an overview of the problem and contributions the research makes. Chapter 2 reviews the literature associated with JLOTS operations. Chapter 3 describes the methodologies used in the gathering of data, the design and implementation of the models used for analysis, as well as the statistical methods and analytical tools employed by this research. Chapter 4 discusses the results of the models. Analysis of those results are presented in Chapter 5, along with conclusions and recommendations for additional research.

CHAPTER 2. LITERATURE REVIEW

This chapter defines the key terminology required to properly comprehend JLOTS operations, outlines the limitations of the research, and provides an overview of previous literature on JLOTS. Figure 1 depicts an idealized JLOTS operation, with the region enclosed by the black dashed lines representing the aspects of JLOTS operations this research is focused upon.

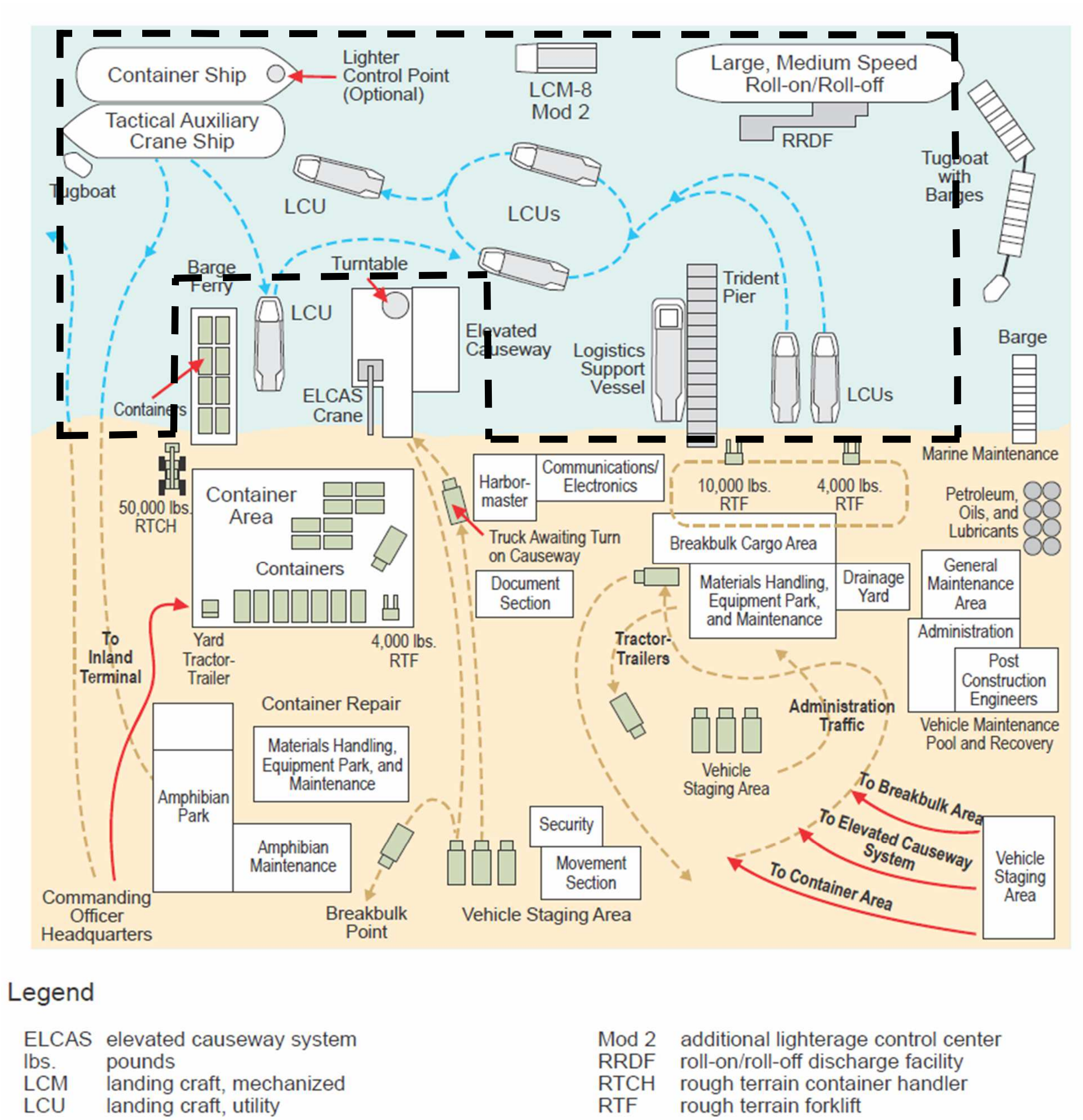

Figure 1. Typical Joint Logistics Over-the-Shore Operational Area. (Joint Staff, 2012)

2.1. Key Terminology

The following terms are used throughout the research; they differ significantly from their colloquial use. To avoid reader misconceptions, they are defined below in a context specific to JLOTS.

2.1.1. Amphibian

The term amphibian refers to military vehicles that can traverse both land and water surfaces for relatively short distances while transporting personnel or cargo from a ship to the shore or vice versa (Joint Staff, 2012). For long sea voyages, vehicles of this type are hoisted aboard larger vessels or stored in a well deck for transport and deployed near the JLOTS site. These vehicles can be floating watercraft that move through the water via propellers, but also have wheels or treads which allow them to beach themselves and continue on land without assistance from other vehicles. An example still in current use by the United States Navy is the Lighter, Amphibious Resupply, Cargo, 5 ton (LARC-V) (United States Navy, 2017). The term can also apply to air cushion vehicles (hovercraft) that move with large wind fans that inflate the cushion as well as providing forward momentum; Landing Craft Air Cushion (LCAC) is a current illustration of this type of vehicle in present use by the US Navy (United States Navy, 2017).

2.1.2. Barge

Barges used in JLOTS Operations refer to large, unpowered, flat-bottomed, cargo vessels (Department of the Army, 2015). Tugboats, landing craft, or contacted civilian vessels must maneuver barges while they are transported from their point of origin to destination or during JLOTS operations. Due to a barge’s short freeboard height, they can only be safely operated in protected harbors, inland waterway systems, or times of calm ocean conditions.

2.1.3. Break Bulk

Break bulk is a type of cargo which, due to its size or composition, cannot be stored inside of a standardized shipping container and must be individually loaded and unloaded during JLOTS operations using material handling equipment. This drawback means that break bulk cargo is inefficient when compared to containerized cargo or rolling stock. Examples of break bulk cargo include barrels, drums, boxes, and bags (Pierre & Stewart, 2010).

2.1.4. Causeway

Some beach locations have too shallow a gradient to allow non-amphibious vessels the ability to approach the beach close enough to lower their bow ramps without flooding the cargo decks with seawater. In those scenarios a causeway system can be installed to allow the vessels the ability to operate without fear of running aground. Causeway systems are modular in nature and can configure in various lengths with three different purposes: causeway ferry, causeway pier, or roll-on/roll-off discharge facility (RRDF).

In a causeway ferry configuration, a powered causeway section attaches to multiple (typically zero to three) unpowered sections in a linear fashion, ending in a beach section. This beach end facilitates discharge of wheeled or tracked vehicles under their own power on to a bare beach or the use of material handling equipment to remove break bulk or containerized cargo from the ferry's deck. In a causeway pier configuration, unpowered modular causeway sections assemble to create a floating wharf with a beach end that is "stabbed" into the bare beach, and with the sea end having interfaces that allow for cargo ships or JLOTS vehicles to dock and discharge cargo. The pier can be as long as 1,500 feet depending on the gradient of the coastal area.

The roll-on/roll-off discharge facility is assembled from unpowered causeway pieces and is lashed to a commercial deep-draft roll-on/roll-off vessel anchored in deep water. Rolling stock drive under their own power down the vessel's ramps to the RRDF, where they move on to JLOTS watercraft for transport to the bare beach or the causeway pier (Department of the Army, 2003). Currently, the US Army uses the Modular Causeway System, or MCS (Department of the Army, 2003). The US Navy operates the Elevated Causeway System, or ELCAS. While this system can install on an unimproved beach, the setup can take weeks and requires significant heavy construction vehicle support to build (Groff, 1992). The Navy also possesses the Improved Navy Lighterage System (INLS) that is similar to the Army's MCS with its own pier, RRDF, and powered ferries (Naval Facilities Engineering Command, 2017). The primary differences between the Army's MCS and the Navy's INLS are the size of their individual components, and that the INLS has a "rhino horn" attachment that can be installed on the sea ramps of its RRDF and causeway pier configurations. The MCS's individual sections can be folded upon themselves to be moved as a 20-foot container equivalent via line-haul truck, railcar, or container ship. The INLS must be shipped on an ocean vessel due to each section measuring 80 feet long, 24 feet wide, and 8 feet high (Joint Staff, 2012).

2.1.5. Discharge Lighter

Discharge lighters, also referred to as beach discharge lighters, are seaworthy cargo vessels possessing the ability to load five to thirty vehicles from a deep-draft vessel using the RRDF or load-on/load-off methods. Then they approach an unimproved bare beach “splash zone” where the wheeled or tracked vehicles offload under their own power or allow material handling equipment access to remove break bulk or containerized cargo (Joint Staff, 2012). Currently, the discharge lighters the US Army uses are the Landing Craft, Utility-2000 series (LCUs) and Logistics Support Vessels (LSVs) (United States Army Transportation Corps, 2008). The US Navy uses Landing Craft, Utility-1600 series (United States Navy, 2017). During the 1960s, the US Army and Navy experimented with a Beach Discharge Lighter ship named the *Lieutenant Colonel John U. D. Page*. The ship was designed to act as a causeway by beaching itself, then allowing a roll-on/roll-off vessel to lash itself to the *Page’s* stern, which allowed rolling stock to pass through the cargo deck and onto the beach (United States Army, 1960). This concept was revisited by the Logistics Management Institute in their report *Joint Logistics Over the Shore – An Assessment of Capabilities*, in the form of recommending research and development of a similar ship design to the *Page*, calling it a Landing Ship Quay/Causeway. At present, no action has been taken by the US Army or US Navy (Thede, Staats, Crowder, & Fortenberry, 1995).

2.1.6. Landing Craft

Landing craft are small, seaworthy vessels that can transport one or two wheeled or tracked vehicles that are loaded through load-on/load-off or roll-on/roll-off methods. They, like amphibians, are stored aboard larger vessels for long-distance transport. While much smaller in scale than the discharge lighter, landing craft possess the same characteristics as the discharge lighter (Joint Staff, 2012). The US Army uses Landing Craft, Mechanized (LCM) 8 series originally fielded in 1959 (United States Army Transportation Corps, 2008). The US Navy uses LCM 8 and LCM 6 series vessels (United States Navy, 2017). Currently, the US Army is developing a replacement for the aging LCM fleet: the Maneuver Support Vessel (Light) (MSV-Light) (Program Executive Office Combat Support and Combat Service Support, 2017).

2.1.7. Lighterage

Lighterage is the collective term referring to the different types of cargo carrying systems operating as ship-to-shore connecters during a JLOTS operation. This definition includes the previously defined types of amphibians, barges, causeways, causeway ferries, discharge lighters, and landing craft used during a JLOTS operation (Joint Staff, 2012).

2.1.8. Rolling Stock

Rolling stock is a collective term referring to wheeled or tracked self-propelled ground vehicles that are driven on and off large roll-on/roll-off cargo ships via ramps. This type of cargo requires no special equipment to move it to a stowage location aboard a vessel, increasing the rate at which it can upload or download compared to containerized or break bulk cargo. Furthermore, any rolling stock with the capacity to carry cargo can have break bulk or containerized cargo loaded on prior to shipment to increase transport efficiencies for upload and download operations. Cargo stored in this manner is a secondary load (Department of the Army, 2015).

2.1.9. Rough Terrain Container Handler

A rough terrain container handler (RTCH) is a piece of specialized material handling equipment designed to lift and transport containerized cargo in a field environment. During JLOTS operations, RTCHs are used to load and unload all types of lighterage. Currently, the US Army operates the RT-240 Kalmar RTCH, which is capable of lifting containers from their narrow end (unlike older model RTCHs, which could only approach and lift containers from their long side) and can operate on unimproved beaches and in up to five feet of water (Kalmar RT Center LLC, 2017).

2.1.10. Sea State

Weather effects have a tremendous impact on JLOTS operations, as the dangers inherent with the operation of multiple vessels operating in close proximity to one another for the purposes of docking and cargo transfer are compounded during periods of increased wind speed and wave height (Joint Staff, 2012). The Pierson-Moskowitz Sea Spectrum is a succinct method of classifying the wind and wave interactions to determine their effects on JLOTS operations. The scale starts at 0, which describes fairly calm seas. The scale increments up to 9, which represents significant wave actions of 70 to 100 feet in height with winds approaching hurricane strength (Pierson & Moscowitz, 1964). No reduction in JLOTS throughput operations are expected during sea state 0 or 1 conditions; however, a significant reduction of throughput can be expected while operating in sea state 2, and operations are typically halted during sea state 3 conditions and higher (Joint Staff, 2012).

2.3. Limitations

2.3.1. Cargo Preparation and Beach Clearance Rates

It has previously been identified that the bottleneck in a JLOTS operation occurs with the lighterage moving cargo from ship to shore (Joint Logistics Over-the-Shore III Test Directorate, 1994). This assumption holds while the ship platoons on the deep-draft cargo vessels preparing rolling stock or containerized cargo for loading on aboard lighterage as well as the customer unit receiving the equipment on the beach have enough personnel to meet or exceed the rate lighterage is transferring cargo. This research contends it remains a valid assumption and those rates will not be a part of the model.

2.3.2. Liquid Cargo Discharge Operations

The delivery of large amounts of fuel supplies during JLOTS operations is accomplished by an Offshore Bulk Fuel System; this system consists of a tanker and large-diameter submersible hoses that connect to the US Army's Inland Petroleum Distribution System (Joint Staff, 2012). After the systems are installed, the transfer of fuel from tanker to shore can be expected to occur at continuous rates while in operation, so throughput would be a function of rate multiplied by time and not modeled by a simulation.

2.3.3. Enemy Force Interactions

With any military undertaking, the possibility exists that a belligerent force could attempt to use kinetic operations to destroy personnel and equipment as well as deny friendly forces access to key terrain such as coastal areas conducive to JLOTS operations (US Army War College, 2016). Such interactions are incredibly complex and attempting to simulate them would overshadow the main purpose of the JLOTS simulation.

2.3.4. Size of Forces

The personnel and equipment density of a deploying force can vary depending upon their assigned mission; however, the basic combat organization is the Brigade Combat Team (BCT) (Department of the Army, 2016). This research limits the size of the simulated forces to a single BCT. The types of BCTs are:

Armored Brigade Combat Team (ABCT), Infantry Brigade Combat Team (IBCT), and Stryker Brigade Combat Team (SBCT).

2.4. Previously Published Work

Due to the very specialized equipment involved in JLOTS operations, the fact that the United States is the only country to possess the equipment and personnel to conduct a JLOTS operation without assistance from other countries (Expeditionary Strike Group Three, 2013), and that no commercial analog exists for JLOTS undertakings, it is no surprise that the literature on this subject is fairly sparse. However, a small amount of scholarly reports exist as well as current military doctrine that comprise the bulk of the previously published work on JLOTS operations.

2.4.1. Current Military Doctrine

The Joint Publications (JP) series of manuals serves as the overarching doctrinal guide for all the Armed Forces of the United States; several exist that mention the use of JLOTS operations to achieve operational goals. *JP 3-0 Joint Operations* mentions JLOTS tangentially in the sections discussing foreign humanitarian aid and the defense support of civil authorities of the Crisis Response and Limited Contingency Operations chapter (Joint Staff, 2017). *JP 3-02 Amphibious Operations* discusses JLOTS in that after an amphibious force has secured a beach, JLOTS operations can proceed to provide resupply and support to the combat units; however, it stops short of providing more specific guidance (Joint Staff, 2014). *JP 3-35 Deployment and Redeployment Operations* provides a more detailed description of JLOTS as well as listing some tools that are available to assist with planning the deployment and redeployment of military forces, specifically the Port Simulation Model (PORTSIM) that could “calculate the impact of JLOTS” (Joint Staff, 2013). *JP 4-09 Distribution Operations* discusses JLOTS operations in greater detail than the previously mentioned manuals; however, it refrains from providing a methodology for the estimation of throughput or duration aside from mentioning the same tool cited by JP 3-35 (Joint Staff, 2013).

Joint Publication 4-01.6 Joint Logistics Over-the-Shore is the seminal reference for JLOTS operations. It provides details on the roles and responsibilities of units conducting a JLOTS operation, planning considerations preceding execution, and the execution proper. Where this publication stands apart from the rest is that it provides the reader with the planning factors that allow an estimate for throughput and operational duration to be calculated. However, the planning factors printed are average values based on Joint Logistics Over-the-Shore Test II & III data conducted in 1985 and 1993 respectively; not only is the data published nearly 25 years old but all of the planning factors are only median values (Joint Staff, 2012).

The US Army, Marine Corps, and Navy each possess a myriad of published material on the various aspects tangential to JLOTS operations. The preponderance of these publications are technical manuals for each specific type of equipment the services use. They contain operator's guides with tactics, techniques, and procedures; a list of preventative maintenance checks and services; as well as parts listings and additional equipment. An example is the US Army's *Modular Causeway System Technical Manual,* which includes all of the previously mentioned sections (Department of the Army, 2003). In addition, there are also manuals pertaining to how the individual service's units function as a part of the JLOTS operation. Examples of this include *Army Techniques Publication 4-15 Army Watercraft Operations* (Department of the Army, 2015), *Navy Warfare Publication 3-02.12 Employment of Landing Craft, Air Cushion (LCAC)* (Department of the Navy, 1997), and *Marine Corps Warfare Publication 4-11.3 Transportation Operations* (Department of the Navy, 2001).

2.4.2. Technical Reports

Two significant JLOTS operational tests were conducted aptly named JLOTS II and JLOTS III Throughput Tests (no reference to the JLOTS I Throughput Test has been found but it must have transpired between 1957 and 1984 as prior to 1957 JLOTS was referred to as Supply Over-the-Beach (Killblane, 2016)).

JLOTS II Throughput Test occurred at Fort Story, Virginia, in September and October 1984. One of the test's objectives was to assess the capability for sustained container, break bulk, rolling stock, and liquid fuel throughput operations. To this end, the observers were concerned with the average cycle time that lighterage took to ferry cargo from the anchored deep-draft cargo ship to the beach (Joint Logistics Over-the-Shore II Test Directorate, 1985). *Joint Publication 4-01.6 Joint Logistics Over-the-Shore* references the sustained rates for container and rolling stock discharge (Joint Staff, 2012).

JLOTS III occurred at Camp Lejeune, North Carolina, in July of 1993. This test's objectives, while similar to those of JLOTS II, differed significantly in that the observers were concerned with determining the average times that the intermediate activities constituting a trip take. These intermediate activities include the approach and mooring to the RRDF, beach, or MCS; aggregate load and unload times for all cargo taken aboard; casting off and clearing of the RRDF, beach, or MCS; and travel times between the RRDF and beach or MCS in 1- to 5-mile discrete increments (Joint Logistics Over-the-Shore III Test Directorate, 1994). *Joint Publication 4-01.6 Joint Logistics Over-the-Shore* references the average times for all the aforementioned intermediate transport activities for use as discharge planning factors (Joint Staff, 2012).

2.4.3. Simulations and Models

The Joint Over the Shore Transportation Estimator (JOTE) model is a deterministic linear programming model that attempts to minimize the shortfall between the required cargo to be discharged onto a bare beach and the capacity of the lighterage to accomplish that task. The selection of shortfall minimization rather than duration minimization is due to the initial studies conducted with JOTE that were looking into the feasibility of long-term sustainment of combat operations or humanitarian aid/disaster relief operations leveraging only JLOTS assets. JOTE was developed using Microsoft Excel and Visual Basic. The average values it uses for determining duration and associated throughput are those published in *JP 4-01.6 Joint Logistics Over-the-Shore*. JOTE accepts user-defined parameters for the distance from cargo ships to the beach, amounts of lighterage available by specific type, number of discharge lanes and the types of cargo each can accept, as well as the tonnage of cargo to be transported ashore (Thede, Staats, Crowder, & Fortenberry, 1995).

Port Simulation Model (PORTSIM) was a discrete-event simulation designed to depict the flow of various types of cargo into and out of existing deep-water ports. The model was multi-modal in nature, as it would accept cargo arrivals in the form of military convoys, commercial trucks, railcars, watercraft, and air transport (both of cargo and helicopters arriving to be cargo themselves). After unloading, the cargo would be segregated by type (rolling stock, containers, pallets, outsize, and so on), and then queued for stowage aboard a large cargo ship (Howard, Bragen, Burke, Jr., & Love, 2004). The Transportation Engineering Agency, the organization that had oversight of the PORTSIM software, was contacted, it was discovered that PORTSIM was retired for seaport analysis in 2014. The Analysis of Mobility Platform (AMP) Port Analysis Tool replaced PORTSIM with similar functionality (Callan, 2017).

AMP is a suite of models containing quick-look analysis tools for airports and seaports, as well as airport and seaport simulation tools. Due to its inclusion of both airports and seaports, AMP provides optimal distribution node selection from a global perspective. While AMP possesses the ability to estimate JLOTS throughput, its analysis is rudimentary in nature as the variables that limit JLOTS operations (amount and type of lighterage, expected sea states, distance from ship to shore, and so on) are not taken into account in determining the estimate (Transportation Engineering Agency, 2017).

CHAPTER 3. METHODOLOGY

This chapter describes the data sources, models, and experimental methods this research uses to attempt to provide finer resolution to JLOTS operational throughput and duration estimates. The first section covers the data sources used in this research, and in the cases where data was gathered in the field, discusses the procedures used to capture that data. The second section discusses the three models employed by this research and how they were developed. The final section details the methodology used to answer the research questions for the results presented in Chapter 4.

3.1. Data Sources

This section details the different sources for the data used in this research and describes the methodology used to collect that data for the first time.

3.1.1. Equipment Set Lists for the Brigade Combat Teams

The equipment set lists for the three different types of Brigade Combat Teams (Armored, Infantry and Stryker) are a combination of data from separate data sources.

3.1.1.1. Rolling Stock Quantities

The rolling stock quantities are derived from the fiscal year 2018 versions of the BCT's approved Modification Table of Organization and Equipment (MTOE), these raw quantities are characterized into the following categories to streamline the modeling processes: container, light wheeled vehicle (three axles or less), light wheeled vehicle with trailer, heavy wheeled vehicle (four axles or more), heavy wheeled vehicle with trailer, and tracked vehicle. These MTOEs were retrieved from the US Army Force Management Support Agency database accessed through their website (US Army Force Management Support Agency, 2017). Specifically, the MTOEs for the 4th Infantry Division's three BCTs were used as each represents one of the three types of BCTs: 1st Brigade – Stryker, 2nd Brigade – Infantry, and 3rd Brigade – Armored (Department of the Army, 2017). The totals for each rolling stock cargo type by BCT appear in Table 1. Brigade Combat Team Rolling Stock by Category.

Table 1. Brigade Combat Team Rolling Stock by Category.

Rolling Stock Category	Armored	Infantry	Stryker
Tracked Vehicle	445	6	6
Light Wheeled Vehicle	275	313	182
Light Wheeled Vehicle w/Trailer	331	471	437
Heavy Wheeled Vehicle	7	57	341
Heavy Wheeled Vehicle w/Trailer	213	107	151

3.1.1.2. Container Quantities

The amount of containerized cargo for each type of BCT has been estimated using an amalgamation of methods because containerized cargo is based on two separate components: the organizational equipment that is not rolling stock and the amount of personal gear that each soldier deploying with the BCT brings. The number of containers loaded with organization equipment is estimated using the Integrated Computerized Deployment System's (ICODES) Transportation Analysis Report Generator (TARGET) module, which is developed and maintained by the Surface Deployment and Distribution Command's Transportation Engineering Agency (Surface Deployment and Distribution Command, 2018). The ICODES-TARGET module receives an organizational equipment list as an input, then uses predefined values for the weight and cube space of the organizational equipment to provide an estimated number of 20-foot containers as an output. The number of containers needed to transport personal soldier gear is estimated at a rate of one container required per 50 soldiers rounded up to the next integer. The mathematical formulation of this estimate is depicted in Equation 1 (Anderson, 2018). The total number of 20-foot containers required for each type of BCT appears in Table 2. Brigade Combat Team Containers by Cargo Type. The 500 containers for the humanitarian assistance disaster relief scenario was determined arbitrarily because the amount of relief supplies delivered by container ships during a relief effort varies depending on the circumstances of the event and availability of supplies.

$$Number\ of\ Containers\ Required = \left\lceil \frac{Number\ of\ Soldiers\ in\ Unit}{50} \right\rceil \qquad \text{(Eq. 1)}$$

Table 2. Brigade Combat Team Containers by Cargo Type.

Container Cargo Type	Armored	Infantry	Stryker
Organizational	75	85	87
Personal Gear	98	103	107
Total	173	188	194

3.1.2. Measures of Central Tendency for Baseline Model

The measures of central tendency utilized by the baseline (control) model are published in the *Joint Publication 4-01.6 Joint Logistics Over-the-Shore* Appendix B Planning Factors. These planning factors represent median values for observed JLOTS operations during JLOTS exercises that occurred in 1985 and 1993. These exercises made use of over a hundred observers that had prior training on how to properly collect work and motion data relative to JLOTS operations (Joint Logistics Over-the-Shore II Test Directorate, 1985; Joint Logistics Over-the-Shore III Test Directorate, 1994). Multiple attempts to obtain the raw observational data for these exercises were made, but it was not located.

3.1.3. Probability Distributions and Measures of Central Tendency for Discrete-Event Simulation (Experimental) and Revised Baseline (Experimental) Model

This research collects new data for both the discrete-event simulation and the revised baseline (experimental) model. This data was collected via in-person interviews with service members of both the US Army and US Navy whose primary military occupational specialty has first-hand experience with the onload and offload of cargo via lighterage. In the US Army, these service members are the Watercraft Operators who sail causeway ferries, LCM-8s, and serve as crew aboard LCUs and LSVs, or they are the Marine Deck Warrant Officers that serve as the vesselmasters on LCU-2000s and LSVs. In the Navy, these service members are the craftmasters for LCACs, LCM-6s, and LCU-1600s. During the interview, the service members were asked for their expert opinions based on first-hand experiences during training exercises as well as JLOTS operations for the most likely, best-case, and worst-case times for specific, repetitive activities conducted during JLOTS operations. The JLOTS subject matter expert interview tool that was developed for this research and used to collect this data appears in Appendix A of this research. The short list of the activities that the subject matter experts were asked about includes: the loading and unloading of each of the six categories of cargo defined in section 3.1.1.1 Rolling Stock Quantities; cast off and clearing times for a beach splash zone, a causeway pier, or an RRDF; and approach and mooring times to a splash zone, a causeway pier, or an RRDF. If an interviewee had no experience performing JLOTS operations with a certain type of lighterage, the interviewer skipped all questions pertaining to that vessel type rather than have the interviewee guess at possible values.

3.1.4. Sample Data Points Collected During an Actual JLOTS Operation

Sample data points were recorded during a JLOTS exercise that occurred in Pohang, South Korea, in April 2017. The sample data points were collected by a single researcher for each of the observed activities aboard all the different types of lighterage participating in the exercise. Each sample point observation included the name of the activity, the type of lighterage, the observed duration of the activity, the dominant sea state during the activity, and, if applicable, the cargo category with specific model types for rolling stock. Only a subset of the lighterage JLOTS activity combinations were observed during this data gathering as only LCU-2000s, and US Navy causeway ferries were present with a US Navy RRDF and US Army causeway pier, and no tracked vehicles or containers were downloaded.

3.1.5. Lighterage Operating Costs

The lighterage operating costs were collected from numerous sources. The manpower costs were determined using the current yearly fully burdened cost of the US Army and US Navy personnel assigned to each type of lighterage, which appears in the Army Military-Civilian Cost System database (US Army Financial Management & Comptroller, 2018). The operations and sustainment costs for each type of US Army lighterage were derived from historical data during the time period from 2002 to 2017 stored in the Operating and Support Management Information System (Office of the Deputy Assistant Secretary of the Army for Cost and Economics, 2018). The operations and sustainment costs for each type of US Navy lighterage were provided directly by the US Navy's Program Executive Office Ships, Amphibious Warfare Program Office (Rivers, 2018).

3.2. Model Development

This section describes the three models this research utilizes along with the inputs and outputs for each. The first is the baseline (control) model that represents the current method used by military planners to estimate the throughput and duration of a JLOTS exercise. The second model (experimental) is a revision of the baseline model that uses updated values gathered from subject matter experts. The final model (experimental) is a discrete-event simulation that leverages probability distributions to emulate a JLOTS operation in repetition to draw insights into the expected throughput and duration.

3.2.1. Baseline (Control) Model

The baseline (control) model is deterministic in nature and models the process described by Joint Publication 4-01.6 Joint Logistics Over-the-Shore Appendix B Planning Factors to estimate the duration of a JLOTS operation as a non-linear discrete optimization program (Joint Staff, 2012). The model was developed using Excel and leverages Excel's Solver to perform the optimization due to the small number of variables in the problem. The mathematical formulation of this non-linear optimization program is defined in Appendix B of this research.

3.2.1.1. Constant Values

All of the constant values used by the model are either taken directly or derived from tables printed in *Joint Publication 4-01.6 Joint Logistics Over-the-Shore* Appendix B Planning Factors or from the researcher' first-hand observations (Joint Staff, 2012). These values are referred to as constants because they are not expected to vary from JLOTS operation to JLOTS operation. In the matrixes that follow, a number of columns or rows are empty of values; this is due to these technologies not being present during the JLOTS II and III Throughput Tests but have been left in the model to facilitate their inclusion in future iterations of the model.

3.2.1.1.1. Approach and Moor Matrix

The approach and moor matrix details the average amount of time in minutes for the type of lighterage appearing in the column heading to approach and moor to the RRDF, causeway, beach, or Expeditionary Transfer Dock listed in the row. This data appears in Figure B-8 of *Joint Publication 4-01.6 Joint Logistics Over-the-Shore* (Joint Staff, 2012).

Approach and Moor						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
Army RRDF	34	9	9		6	
Navy RRDF w/o Rhino Horn	34	9	9		6	
Navy RRDF w/ Rhino Horn						
Army Causeway	10	12	13		12	
Navy Causeway w/o Rhino Horn	10	12	13		12	
Navy Causeway w/ Rhino Horn						
Beach	5				1	
Expeditionary Transfer Dock						

Figure 2. Approach and Moor Matrix with Times Shown in Minutes.

3.2.1.1.2. Castoff and Clear Matrix

The castoff and clear matrix details the average amount of time, in minutes, it takes for the type of lighterage appearing in the column heading to castoff and clear from the RRDF, causeway, beach, or Expeditionary Transfer Dock listed in the row. This data appears in Figure B-8 of *Joint Publication 4-01.6 Joint Logistics Over-the-Shore* (Joint Staff, 2012).

Castoff and Clear						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
Army RRDF	23	4	7		3	
Navy RRDF	23	4	7		3	
Army Causeway	3	7	7		6	
Navy Causeway w/o Rhino Horn	3	7	7		6	
Navy Causeway w/ Rhino Horn						
Beach	4				2	
Expeditionary Transfer Dock						

Figure 3. Castoff and Clear Matrix with Times Shown in Minutes.

3.2.1.1.3. Loading Times Matrix

The loading times matrix details the average amount of time in minutes it takes for the type of lighterage appearing in the column heading to be loaded with a single type of equipment listed in the row. This data was derived by dividing the total average time it takes to load the entire vessel with that type of equipment, Figures B-9 and B-10 of *Joint Publication 4-01.6 Joint Logistics Over-the-Shore*, by the amount of each equipment that can be loaded on that type of vessel, Figure B-2 of Joint Publication 4-01.6 Joint Logistics Over-the-Shore (Joint Staff, 2012).

Loading Times						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
20 ft Containers	10.58333	7.428571	5.4		7.5	
Light Wheeled Vehicle	6.125	7.153846	7		6.5	
LWV w/ Trailer	6.125	7.153846	7		6.5	
Heavy Wheeled Vehicle	6.125	7.153846	7		6.5	
HWV w/ Trailer	6.125	7.153846	7		6.5	
Tracked Vehicles	7	6.8	6.125		6.5	

Figure 4. Loading Times Matrix with Times Shown in Minutes.

3.2.1.1.4. Unloading Times Matrix

The unloading times matrix details the average amount of time in minutes it takes for the type of lighterage appearing in the column heading to unload a single type of equipment listed in the row. This data was derived by dividing the total average time it takes to unload the entire vessel with that type of equipment, Figures B-9 and B-10 of *Joint Publication 4-01.6 Joint Logistics Over-the-Shore*, by the amount of each equipment that can be loaded on that type of vessel, Figure B-2 of *Joint Publication 4-01.6 Joint Logistics Over-the-Shore* (Joint Staff, 2012).

Unloading Times						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
20 ft Containers	5	9	9		2	
Light Wheeled Vehicle	1.75	2.307692	1.86		2	
LWV w/ Trailer	1.75	2.307692	1.86		2	
Heavy Wheeled Vehicle	1.75	2.307692	1.86		2	
HWV w/ Trailer	1.75	2.307692	1.86		2	
Tracked Vehicles	3	2.4	2.416667		1	

Figure 5. Unloading Times Matrix with Times Shown in Minutes.

3.2.1.1.5. Max Load Matrix

The max load matrix details the maximum amount of a specific cargo type listed in the row for each type of lighterage appearing in the column heading. This data appears in Figure B-2 of *Joint*

Publication 4-01.6 Joint Logistics Over-the-Shore and first-hand observations of the researchers (Joint Staff, 2012).

Max Load						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
20 ft Containers	24	24	50	14	4	6
Light Wheeled Vehicle	16	13	50	16	4	6
LWV w/ Trailer	8	7	25	8	2	3
Heavy Wheeled Vehicle	8	7	25	8	2	3
HWV w/ Trailer	4	3	12	4	1	1
Tracked Vehicles	3	5	24	3	2	1

Figure 6. Max Load Matrix.

3.2.1.1.6. Load Portion Matrix

The load portion matrix details the proportion of deck space a single unit of a specific cargo type listed in the row occupies each type of lighterage appearing in the column heading. This data was derived by calculating the reciprocal value for a single piece of cargo using the values show in Figure 6 Max Load Matrix.

Load Portion						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
20 ft Containers	0.041666667	0.041667	0.02	0.071429	0.25	0.166667
Light Wheeled Vehicle	0.0625	0.076923	0.02	0.0625	0.25	0.166667
LWV w/ Trailer	0.125	0.142857	0.04	0.125	0.5	0.333333
Heavy Wheeled Vehicle	0.125	0.142857	0.04	0.125	0.5	0.333333
HWV w/ Trailer	0.25	0.333333	0.083333	0.25	1	1
Tracked Vehicles	0.333333333	0.2	0.041667	0.333333	0.5	1

Figure 7. Load Portion Matrix.

3.2.1.1.7. Travel Times Matrix

The travel times matrix details the average amount of time in minutes each type of lighterage appearing in the column heading takes to traverse the number of nautical miles listed in the row. This data was derived from lighterage operational characteristics appearing in Figure D-2 of *Joint Publication 4-01.6 Joint Logistics Over-the-Shore* (Joint Staff, 2012).

Travel Times						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
1 Mile	7.448364215	5.213855	4.344879	5.213855	4.344879	1.303464
2 Mile	14.89672843	10.42771	8.689758	10.42771	8.689758	2.606927
3 Mile	22.34509265	15.64156	13.03464	15.64156	13.03464	3.910391
4 Mile	29.79345686	20.85542	17.37952	20.85542	17.37952	5.213855
5 Mile	37.24182108	26.06927	21.7244	26.06927	21.7244	6.517319

Figure 8. Travel Times Matrix with Times Shown in Minutes.

3.2.1.1.8. Sea State Operational Degradation Vector

The sea state operational degradation vector details the decrease in throughput to be expected when the sea state increases to 2 or above during a JLOTS operation. These factors were derived from *Joint Publication 4-01.6 Joint Logistics Over-the-Shore* and represent a scalar divisor to adjust the expected time due to sea state conditions (Joint Staff, 2012).

Sea State Operational Degradation	
0-1	1
2	0.4
3 +	0

Figure 9. Sea State Operational Degradation Vector.

3.2.1.2. User Defined Values

The user defined values are entered into the model by JLOTS planners and are meant to reflect the conditions and resources for a specific JLOTS operation. Therefore, these values are expected to change from run to run of the modelling tool to reflect different scenarios requiring analysis.

3.2.1.2.1. Lighterage Available Vector

The lighterage available vector represents the number of each specific type of lighterage that are available to support the JLOTS operation.

	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
Lighterage Available	3	3	0	0	3	0

Figure 10. Lighterage Available Vector.

3.2.1.2.2. Loads to be Placed Ashore Vector

The loads to be placed ashore vector represents the number of each specific type of cargo that need to be transported from the deep-draft vessel to the beach via lighterage during the JLOTS operation.

Loads to be Placed Ashore	
20 ft Containers	150
Light Wheeled Vehicle	275
LWV w/ Trailer	331
Heavy Wheeled Vehicle	7
HWV w/ Trailer	213
Tracked Vehicles	445

Figure 11. Loads to be Placed Ashore Vector.

3.2.1.2.3. Discharge Points Vector

The discharge points vector represents the number of lighterage that load or unload at the RRDF or causeway pier at any given time during the JLOTS operation. This number varies depending on the configuration of the RRDF or causeway pier when they are assembled preceding discharge operations. The typical configurations for both the RRDF and causeway pier only allow for two lighterage to moor at any given time.

	RRDF	Causeway
Discharge Points	2	2

Figure 12. Discharge Points Vector.

3.2.1.2.4. Expected Sea State Vector

The expected sea state vector represents the steady state values for the portion of the JLOTS operation that the sea state will be at: 0-1, 2, and 3 or greater. This vector’s values must sum to one to calculate correctly.

Expected Sea State (Steady State Values)				
	0-1	2	3 +	Sum
Portion	0.7	0.2	0.1	1
	must sum to 1			

Figure 13. Expected Sea State Vector.

3.2.1.2.5. Single Round-Trip Time Matrix

The single round-trip time matrix represents the amount of time, in minutes, each type of lighterage takes to make a single round-trip, consisting of approaching and mooring to the RRDF, casting off and clearing the RRDF, travelling from the RRDF to causeway, approaching and mooring to the causeway, casting off and clearing from the causeway, and the returning to the RRDF. The single round-trip time does not include the amount of time required to load and unload any equipment. The values in this matrix reference the values in the approach and moor, castoff and clear, and travel time matrixes. These values are collected in this single matrix to reflect the specific set of conditions that this iteration of the model is analyzing.

Travel Times						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
Approach and Moor	34	9	9	0	6	0
Castoff and Clear	23	4	7	0	3	0
One Way Travel Time	7.448364215	5.213855	4.3448791	5.213855	4.3448791	1.3034637
Approach and Moor	10	12	13	0	12	0
Castoff and Clear	3	7	7	0	6	0
One Way Travel Time	7.448364215	5.213855	4.3448791	5.213855	4.3448791	1.3034637

Figure 14. Single Round-Trip Travel Time Matrix with Times Shown in Minutes.

3.2.1.3. Changing Variables and Constraints

The changing variables are those that Excel's Solver iterates to determine the optimal value for the non-linear program's objective function. The constraint vectors ensure that the solution discharges the equipment and only uses available lighterage.

3.2.1.3.1. Load Configuration Matrix

The load configuration matrix represents how many of each type of equipment that needs to be placed ashore from the deep draft vessel to the beach will be placed on each different type of available lighterage. These values have been constrained to be only integer values since dividing a 20-foot container in half to fit on two different lighters is not a feasible solution.

Load Configuration						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
20 ft Containers	16	27	0	0	107	0
Light Wheeled Vehicle	1	1	0	0	273	0
LWV w/ Trailer	155	176	0	0	0	0
Heavy Wheeled Vehicle	2	4	0	0	1	0
HWV w/ Trailer	186	27	0	0	0	0
Tracked Vehicles	11	321	0	0	113	0

Figure 15. Load Configuration Matrix.

3.2.1.3.2. Total Load Validation Constraint Vectors

The total load validation constraint vectors ensure that every piece of equipment that needs to be placed ashore is assigned to lighterage for transport. The left column is a sum of its row on the adjoining load configuration matrix, while the right column is set equal to the respective values in the loads to be placed ashore vector.

Load Configuration									
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC	Totals		Validation
20 ft Containers	16	27	0	0	107	0	150	=	150
Light Wheeled Vehicle	1	1	0	0	273	0	275	=	275
LWV w/ Trailer	155	176	0	0	0	0	331	=	331
Heavy Wheeled Vehicle	2	4	0	0	1	0	7	=	7
HWV w/ Trailer	186	27	0	0	0	0	213	=	213
Tracked Vehicles	11	321	0	0	113	0	445	=	445

Figure 16. Load Configuration Matrix with Total Load Validation Constraint Vectors.

3.2.1.3.3. Lighterage Available Constraint Vectors

The lighterage available constraint vectors ensure that no pieces of equipment are assigned to lighterage that is not available during this JLOTS operation. The top row is a sum of its column on the adjoining load configuration matrix, while the bottom row is set to multiply the respective values in the lighterage available vector by 10,000. These bottom-row values ensure the solutions used by Solver account for “less-than” constraints.

Load Configuration						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
20 ft Containers	16	27	0	0	107	0
Light Wheeled Vehicle	1	1	0	0	273	0
LWV w/ Trailer	155	176	0	0	0	0
Heavy Wheeled Vehicle	2	4	0	0	1	0
HWV w/ Trailer	186	27	0	0	0	0
Tracked Vehicles	11	321	0	0	113	0
	371	556	0	0	494	0
	<=	<=	<=	<=	<=	<=
	30000	30000	0	0	30000	0

Figure 17. Load Configuration Matrix with Lighterage Available Constraint Vectors.

3.2.1.4. Calculation Matrixes, Vectors, and Objective Function

The calculation matrixes and vectors feed into the objective function of the program to determine the optimal configuration of equipment across the lighterage in the least amount of time.

3.2.1.4.1. Trips Required Vector

The trips required vector represents how many round-trips each type of lighterage needs to make during the JLOTS operation in order to transport the number of loads it has been assigned by the load configuration matrix. The vector is equivalent to the sum of the products of each lighterage's column on the load configuration matrix and the load portion matrix.

	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
Trips Required	71	101	0	0	152	0

Figure 18. Trips Required Vector.

3.2.1.4.2. Total Single-Round Trip Time Vector

The total single round-trip time vector represents the sum of the column in the adjoining single round-trip time matrix for each type of lighterage.

Travel Times						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
Approach and Moor	34	9	9	0	6	0
Castoff and Clear	23	4	7	0	3	0
One Way Travel Time	7.448364215	5.213855	4.3448791	5.213855	4.3448791	1.3034637
Approach and Moor	10	12	13	0	12	0
Castoff and Clear	3	7	7	0	6	0
One Way Travel Time	7.448364215	5.213855	4.3448791	5.213855	4.3448791	1.3034637
Total	84.89672843	42.42771	44.689758	10.42771	35.689758	2.6069275

Figure 19. Single Round-Trip Travel Time Matrix with Total Single Round-Trip Time Vector with Times Shown in Minutes.

3.2.1.4.3. Total Average Times Matrix

The total average times matrix represents a number of calculations. The loading times row is the aggregation of the amount of time needed to load every trip of the specific type of lighter with the different types of equipment and is equal to the sum of the products of each lighterage's column on the load configuration matrix and the loading times matrix. The unloading times row is the same as the loading times row, except it uses the unloading times matrix instead of the loading times matrix. The total travel times row is the product of each lighterage's value in the number of trips required vector and total single trip travel time vector. The total time by lighterage is the sum of all aggregated loading and unloading times plus the total travel time. The total time row divides the result of the total time by lighterage row by the lighter available vector since the lighterage should be operating in parallel during the JLOTS operation.

Total Average Times						
	Causeway Ferry	LCU-2000	LSV	INLS Ferry	LCU-1600	LCAC
Loading Times	2353.33328	3871.3714	0	0	3318	0
Unloading Times	715	1493.3999	0	0	875	0
Total Travel Times	6027.667719	4285.1987	0	0	5424.8433	0
Total Time by Lighterage	9096.000999	9649.97	0	0	9617.8433	0
Total Time	**3032.000333**	**3216.657**	**0**	**0**	**3205.948**	**0**

Figure 20. Total Average Times Matrix with Times Shown in Minutes.

3.2.1.4.4. Logical Checks Vectors

The logical checks vectors represent the significant drawback of this method of estimation. Because the lighterage are assumed to be operating in parallel with one another during the JLOTS operation, the deterministic calculations do not take into account the queuing occurs because a finite number of lighters can load and unload at a given time. The top vector represents the sum product of the load configuration matrix and the loading and unloading times matrixes. The bottom vector is the proportion of time of the JLOTS operation that the cranes, RRDF, and causeway pier respectively would be utilized; a value greater than or equal to one signifies an issue with the load configuration. These vectors are not explicitly described by *Joint Publication 4-01.6 Joint Logistics Over-the-Shore*, but were added by the researcher in order to determine the feasibility of the estimate the model provided.

	Container Load	RO/RO Load	RO/RO Unload
Logical Checks	1172.404697	4185.149984	1541.699968
	0.364479276	1.301086939	0.479286453

Figure 21. Logical Check Vectors.

3.2.1.4.5. Objective Function with and without Sea State Calculations Vectors

The objective function seeks to minimize the maximum value appearing in the total time row of the total average times matrix (Figure 20). The reason it is the maximum value of the row and not the sum of it is that the lighterage is assumed to be working in parallel during the JLOTS operation. In Figure 22, the top vector shows the minimum time without the sea state factors applied to the time required. It also displays the time in the more appropriate units of hours and days (assuming a 20-hour workday to facilitate lighterage maintenance and sustainment operations) rather than minutes. The bottom vector is the same minimum time in minutes, hours, and workdays with the scalar delays (Figure 9) due to the expected sea state.

Total Mission Time	3216.656674	Minutes	
without Sea State	53.61094456	Hours	
Calculations	2.680547228	Days (20 hour workdays)	
Total Mission Time	4567.652477	Minutes	
with Sea State	76.12754128	Hours	
Calculations	3.806377064	Days (20 hour workdays)	

Figure 22. Objective Function with and without Sea State Calculation Vectors with Times Shown in Minutes, Hours, and Days.

3.2.2. Revised Baseline (Experimental) Model

The revised baseline (experimental) model remains deterministic in nature like the baseline (control) model with the same required inputs and outputs. The fundamental difference between the two models is the measures of central tendency used to calculate the point estimate have been adjusted to reflect the interview results as described in section 3.1.3 Probability Distributions and Measures of Central Tendency for Discrete-Event Simulation and Revised Baseline (Experimental) Model. All mathematical relationships and calculations of the revised baseline (experimental) model are identical to the baseline (control) model that are defined in section 3.2.1 Baseline (Control) Model. Like the baseline (control) model, the revised baseline (experimental) model uses Solver to optimize the non-linear program it defines. The mathematical formulation of this non-linear optimization program is defined in Appendix B of this research.

3.2.3. Discrete-Event Simulation (Experimental) Model

The third model is stochastic because instead of relying upon a point measure of central tendency as a prime component of the model, a probability distribution is used in its place. These distributions might more accurately reflect the inherent variability of real-world operations. The variables for this model remain the same as the previous models; however, instead of using a single point of central tendency for the duration of an activity, it is represented by a triangular distribution based on the expert opinions of JLOTS subject matter experts and collected as explained in section 3.1.3 Probability Distributions and Measures of Central Tendency for Discrete-Event Simulation (Experimental) and Revised

Baseline (Experimental) Model. The output is a point estimate for the expected duration of operation with a confidence interval for the likelihood of where the true duration should occur. Due to using discrete-event simulation, this model uses Rockwell Automation's Arena software version 14.7 to depict the JLOTS operation.

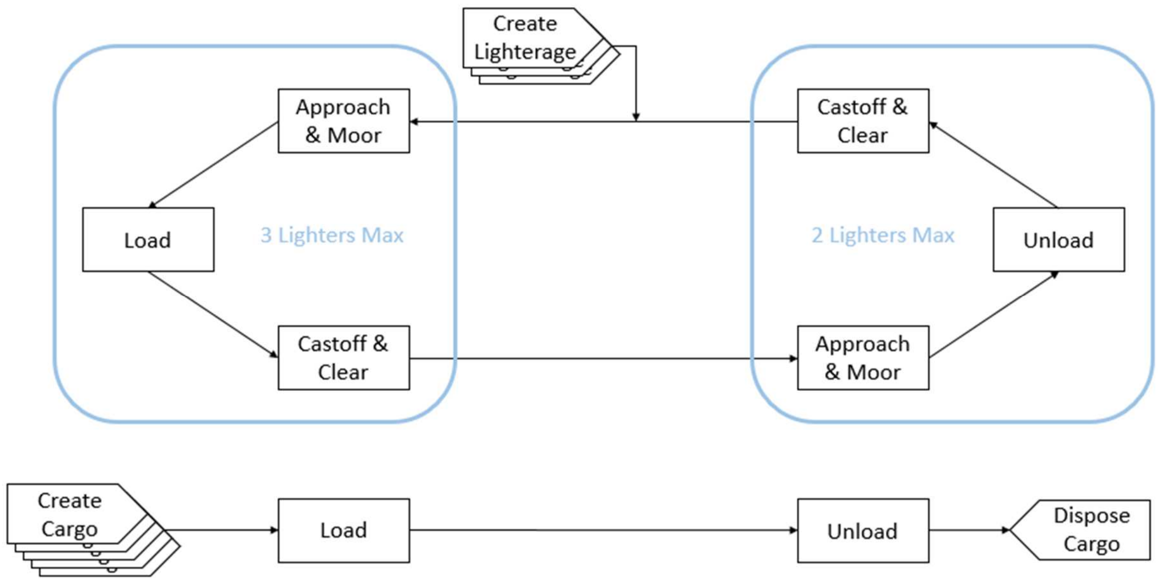

Figure 23. High-level Graphical Depiction of Lighterage and Cargo Segments.

To achieve the level of fidelity required to model JLOTS operations the discrete-event simulation was built in three distinct but interconnected segments: the lighterage segment, the cargo segment, and the shutoff segment. Figure 23 shows a high-level graphical depiction of the how the lighterage and cargo segments are modeled. The following sections describe each of the discrete-event simulation's segments in detail.

3.2.3.1. Required Inputs for the Model

Prior to running the discrete-event simulation, the correct variables must be entered. The number of each of the four types of lighterage that are available for this iteration (causeway ferries, LCU-2000 series, LSVs, and LCU-1600 series), the type of RRDF that is attached to the ship being discharged (Army or Navy version), the type of causeway pier that allows the lighters to interface with the bare beach (Army or Navy version), and the quantity for each category of cargo (containers, light wheeled vehicles, light wheeled vehicle with trailer, heavy wheeled vehicle, heavy wheeled vehicle with trailer, tracked vehicle). The values used for each iteration appear in Appendix C Table of Variable Values by Iteration and the cargo quantities appear in Table 1 Brigade Combat Team Rolling Stock by Category and Table 2 Brigade Combat Team Containers by Cargo Type in sections 3.1.1.1 and 3.1.1.2, respectively.

3.2.3.2. Lighterage Segment

The lighterage segment models the movement of the lighterage as it travels throughout the JLOTS operation by approaching and mooring to the RRDF, loading cargo, casting off and clearing from the RRDF, travelling to the causeway pier, approaching and mooring to the causeway pier, unloading cargo, casting off and clearing the causeway pier, and then travelling back to the RRDF to pick up another load. The lighterage segment groups these linked activities into smaller portions representing lighterage creation, loading at the RRDF, and unloading at the causeway pier. The specific actions that are simulated during each of these smaller portions are described in the sections that follow.

3.2.3.1.1. Lighterage Creation Portion

In this portion of the model, the lighterage entities are initialized by create processes. While different iterations of the model do not always use all four of the different types of lighterage, the model creates them in order to reduce the amount of changes that must be made to the overarching structure of the model between iterations. However, the Arena software identifies an error when a create process is directed to create zero entities. This error was circumvented by always creating a finite amount of each lighterage type, and then disposing of the excess lighters not called for in the current iteration. To model the variability representing the order the lighterage arrives at the start of the operation, the lighterage entities are created at a random, very short, time interval of an average of one second following an exponential distribution. These very short, random differences in creation time create a different order that the lighters arrive to the RRDF's loading queue in each iteration.

After the lighterage entity is created, it moves to an assignment process where its attributes are initialized. The lighter number attribute uniquely identifies the lighter amongst the other lighters of its same type. This value is initialized to zero. The trip number attribute uniquely identifies what trip the lighter is currently on. This value is initialized to zero. The current open load attribute is the amount of cargo space on the lighter's deck that can be loaded with rolling stock or containers. This value is initialized to one, representing an empty deck. The lighter type attribute identifies the type of lighter that this specific entity represents. The value that is initialized depends on which type of lighter it is: one stands for a causeway ferry, two for an LCU-2000 series vessel, three for an LSV, and four for an LCU-1600 series vessel.

The lighterage entity moves to another assignment node that increments its lighterage number attribute. The first lighterage of that type will be lighter number one, the second two, and so on. Next the lighterage entity enters a decide process that looks at the lighterage entity's lighterage number; if that lighter number is greater than the amount of that lighterage type that is supposed to be in this iteration of the model, then the entity is sent to a disposal node and is removed from the model. If the lighterage number is less than the amount specified by the variables for this iteration, then the entity is allowed to proceed to the RRDF queue for loading cargo.

3.2.3.1.2. Loading at the RRDF Portion

This section describes the activities that lighterage entities pass through to receive their cargo prior to traveling to the causeway pier to unload. The first three lighterage entities to arrive at the approach and moor to the RRDF process are able to seize a berth on the RRDF: one at the container loading area to the side of the vessel two receive containers via cranes, and two on the RRDF itself to receive rolling stock. Any additional lighterage that attempts to approach the RRDF will enter a first in, first out queue until one of the three lighters currently at the RRDF completes the castoff and clear process. The amount of time that each lighterage takes to complete the approach and moor activity is represented by the triangular distribution for the specific lighterage type and RRDF type. Upon completing the approach and moor process, the entity is directed to an empty berth for either container loading or roll-on loading operations.

If the lighterage is directed to the container loading berth, then it receives a new attribute identifying it as carrying container cargo and the global container trip number variable is incremented by one. Next, the two-dimensional global variable container current load matrix is updated with the entity's lighterage type and that its deck is currently devoid of cargo. The entity signals the cargo segment of the model that it is prepared to receive containers from the cranes and awaits the return signal that it has been loaded to capacity or that the last container has been loaded aboard. After the loaded signal is received, the lighterage entity conducts the castoff and clear process described by the triangular distribution for the specific lighterage type and RRDF type. The lighterage entity then travels the distance from the RRDF to the causeway pier in accordance with Figure 8 Travel Times Matrix in section 3.2.1.1.7.

If the lighterage is directed to one of the two roll-on cargo berths, then it immediately begins the loading of rolling stock if no other lighterage is currently receiving roll-on cargo. If another lighterage is receiving roll-on cargo, then the lighterage waits until the other lighterage has completed the loading process. After the lighterage is clear to begin loading, it receives a new attribute identifying it as carrying rolling stock and the global roll-on trip number variable is incremented by one. Next, the two-dimensional global variable roll-on current load matrix is updated with the entity's lighterage type and that its deck is currently devoid of cargo. The entity signals the cargo segment of the model that it is prepared to receive rolling stock via the RRDF loading team and awaits the return signal that it has been loaded to capacity or that the last piece of rolling stock has been loaded aboard. When the cargo segment of the model signals the lighterage is loaded, the lighterage entity conducts the castoff and clear process described by the triangular distribution for the specific lighterage type and RRDF type. The lighterage entity then travels the distance from the RRDF to the causeway pier in accordance with Figure 8 Travel Times Matrix in section 3.2.1.1.7.

3.2.3.1.3. Unloading at the Causeway Pier Portion

After a lighterage entity loaded with containers reaches the causeway pier, it waits for one of the two berths to become available, and then conducts the approach and moor with a time defined by the triangular distribution for the specific lighterage type and causeway type. The lighterage entity possibly pauses again, this time for the unloading team to complete their work removing all of the cargo from the previous lighterage entity before incrementing the global container unload variable. Next, a signal is sent to the cargo segment of the model signifying that a lighterage entity is ready to be downloaded of container cargo. The lighterage entity remains until a signal is sent from the cargo segment denoting that all of the containers have been removed from the lighterage entity and that the unloading team is free to start unloading the next vessel. The lighterage entity then performs the castoff and clear activity as designated by the triangular distribution for the specific lighterage type and causeway type, and then travels back to the RRDF to receive another load of cargo.

When a lighterage entity loaded with rolling stock reaches the causeway pier, it waits for one of the two berths to become available, and then conducts the approach and moor with a time defined by the triangular distribution for the specific lighterage type and causeway type. The lighterage possibly pauses again, this time for the unloading team to complete their work removing all cargo from the previous lighterage before incrementing the global roll-on unload variable. Next, a signal is sent to the cargo segment of the model signifying that a lighterage entity is ready to be downloaded of all rolling stock. The lighterage entity remains until a signal is sent from the cargo segment denoting that all rolling stock has been removed from the lighterage and that the unloading team is free to start unloading the next vessel. The lighterage then performs the castoff and clear activity as described by the triangular distribution for the specific lighterage type and causeway type, and then travels back to the RRDF to receive another load.

3.2.3.3. Cargo Segment

The cargo segment models the order of appearance for the containers and five types of rolling stock as they are loaded and unloaded during the JLOTS operation. The cargo segment groups these linked activities into smaller portions representing cargo creation, cargo loading at the RRDF, and cargo unloading at the causeway pier. The specific actions that are simulated during each of these smaller portions are described in the sections that follow.

3.2.3.3.1. Cargo Creation Portion

In this portion of the model the cargo entities are initialized by create processes. While three-quarters of the iterations use all six of the different types of cargo, the model still creates the unused rolling stock entities during a HADR scenario consisting of only containerized cargo to reduce the amount of changes that must be made to the overarching structure of the model between iterations. However, Arena identifies an error when a create process is directed to create zero entities; this error is corrected by creating a small amount of each rolling stock cargo type and then immediately disposing of them. To depict the randomness of how the ship is loaded with rolling stock because the ship's crew is the final authority on the order cargo stowage occurs in, at the start of the operation the rolling stock entities are created on a random, very short, time interval of an average of one second following an exponential distribution. These very short, random differences in creation time create a different order that the rolling stock was stowed in for loading on to the awaiting lighterage entities upon their arrival to the RRDF in each iteration.

After a container cargo entity is created, it moves to an assignment process where its attributes are initialized. The roll-on trip number attribute identifies the cargo as being a container because it is initialized as a large integer. The container trip number attribute uniquely identifies what trip the container is loaded on. This value is initialized to zero. The cargo type attribute identifies the type of cargo that this specific entity represents. This value is initialized to six in order to represent a container.

After a container rolling stock entity is created, it moves to an assignment process where its attributes are initialized. The roll-on trip number attribute uniquely identifies what trip the piece of rolling stock is loaded on. This value is initialized to zero. The cargo type attribute identifies the type of rolling stock cargo that this specific entity represents. The value that is initialized depends on which type of rolling stock it is: one stands for a light wheeled vehicle, two for a light wheeled vehicle with trailer, three for a heavy wheeled vehicle, four for a heavy wheeled vehicle with trailer, and five for a tracked vehicle.

3.2.3.3.2. Cargo Loading at the RRDF Portion

Containers are held until the lighterage segment sends the signal indicating that a lighterage entity has berthed and is ready to receive containers. The container cargo entity is queried to determine if the load potion that the container will occupy on the lighterage entity that is receiving the cargo can in fact load the container or if it is full. If the container would overload the lighterage entity, then the lighterage segment is signaled that the vessel being loaded at the container berth is full and may castoff and clear the RRDF. The container entity that triggered the lighterage entity full signal then returns to the container cargo holding queue to await the next container lighterage entity to berth. If the container does fit onto the lighterage entity, then the global two-dimensional container current load matrix variable’s current load counter for the lighterage entity currently berthed is incremented, the global containers loaded count is incremented, the container entity’s lighterage type attribute is updated to reflect the lighterage type that it has been successfully loaded onto, and the container entity’s container trip number attribute is set equal to the global container trip number variable. Next, the global two-dimensional container current load matrix variable’s current load value is reduced by an amount equal to the portion of the deck that the container occupies during transport to the causeway pier. The entity is loaded onto the lighterage entity taking an amount of time described by the triangular distribution for the specific lighterage type and sends a signal to the container holding queue to release another container to be loaded onto the lighterage and then the container loading process repeats until the lighterage entity is full.

Pieces of rolling stock are held until the lighterage segment sends the signal indicating that a lighterage entity has berthed at the RRDF and the loading team is available to start. Rolling stock cargo entity is queried to determine if there is deck space on the lighterage entity to hold the load potion the piece of rolling stock will occupy or if the lighterage entity is full. If the piece of rolling stock would overload the lighterage entity, then the lighterage segment is signaled that the vessel being loaded at the RRDF berth is full and may castoff and clear the RRDF. The rolling stock entity that triggered the lighterage entity is full signal then returns to the rolling stock holding queue to await the next roll-on lighterage entity to berth. If the piece of rolling stock does fit onto the lighterage entity, then the global two-dimensional roll-on current load matrix variable’s current load counter for the lighterage entity currently berthed is incremented, the global roll-on loaded count is incremented, the rolling stock entity’s lighterage type attribute is updated to reflect the lighterage type that it is being loaded onto, and the rolling stock entity’s roll-on trip number attribute is set equal to the global roll-on trip number variable. Next, the global two-dimensional roll-on current load matrix variable’s current load value is reduced by an amount equal to the portion of deck space that the piece of rolling stock occupies during transport to the causeway pier. The entity is loaded onto the lighterage entity taking an amount of time described by the triangular distribution for the specific lighterage type and rolling stock type and then sends a signal to the rolling stock holding queue to release another piece of rolling stock to be loaded onto the lighterage entity, and then the rolling stock loading process repeats until the lighterage entity is full.

3.2.3.3.3. Cargo Unloading at the Causeway Pier Portion

Container entities are held at the causeway pier until the lighterage entity they were loaded onto at the RRDF arrives at the causeway pier, completes approaching and mooring to the causeway pier, and the unloading team has finished the download of the previous vessel. At that point, the signal from the lighterage segment is sent to the cargo segment for each of the containers with the container load attribute value equal to the lighterage entity being unloaded's container load number to be removed from the deck by the unloading crew. Next, the global two-dimensional container current load matrix variable's current load counter for the lighterage entity currently being unloaded is decremented to reflect the container removed from the deck, and the lighterage entity's current load counter value is checked to see if it is equal to zero. If so, then the cargo segment sends a signal to the lighterage segment that the lighterage entity being unloaded is now empty and can castoff of clear the causeway and return for another load at the RRDF. Regardless if the deck was empty of containers or not, the global total cargo unloaded variable is incremented.

Rolling stock entities are held at the causeway pier until the lighterage entity they were loaded onto at the RRDF arrives at the causeway pier, completes approaching and mooring to the causeway pier, and the unloading team has finished the download of the previous vessel. A signal from the lighterage segment is sent to the cargo segment for each piece of rolling stock that shares a roll-on load attribute value with the lighterage entity being unloaded's roll-on load number to be driven onto the causeway pier by the unloading crew. Next, the global two-dimensional roll-on current load matrix variable's current load counter for the lighterage entity currently being unloaded is decremented to reflect the piece of rolling stock has been driven off the vessel, and the lighterage entity's current load counter value is checked to see if it is equal to zero. If so, the cargo segment sends a signal to the lighterage segment that the entity being unloaded is now empty and can castoff of clear the causeway and return for another load at the RRDF. Regardless if the deck was cleared of rolling stock or not, the global total cargo unloaded variable is incremented.

After the global total cargo variable has been incremented by either the container or the roll-on portion, that value is then compared to the total pieces of cargo (both containers and rolling stock) for this specific iteration. If the total amount of cargo that has been unloaded is less than the total pieces of cargo, then the cargo entity is disposed of by the model. If the total amount of cargo unloaded is equal to the total cargo in the iteration, then the time that the JLOTS operation has taken is recorded and the entity disposed of.

3.2.3.4. Shutoff Segment

The shutoff segment exists to give the simulation a termination criterion. Three entities are created to travel this segment: one represents the last container entity being loaded onto a lighterage entity, the second represents the final rolling stock entity driving aboard a vessel, and the final one represents the termination entity.

The container shutoff entity is created at the start of the run and held until the global containers loaded value equals the number of container entities created for this iteration. When that occurs the shutoff segment sends a signal to the lighterage segment that there are no more containers to load at the RRDF and the lighterage entity should castoff and clear. The container loading area is then closed so that no more lighterage entities will approach and moor to load containers and then travel empty to the causeway pier. Next, the global variable of shutdown is checked to see if it is equal to one or zero. If the value of shutdown is zero, that means all containers were loaded before the rolling stock has completed loading, the shutdown variable is incremented by one, and the container shutoff entity disposed of. If the value of shutdown is one, then the rolling stock loading completed loading prior to the containers, the termination entity is signaled to be released, and the shutdown variable is incremented by one.

The roll-on shutoff entity is created at the start of the run and held until the global roll-on loaded value equals the number of all five types of rolling stock entities created for this iteration. When that occurs the shutoff segment sends a signal to the lighterage segment that there is no more rolling stock to load at the RRDF and the lighterage entity should castoff and clear. The roll-on part of the RRDF is then closed so that no more lighterage entities will approach and moor to load rolling stock. Next, the global variable of shutdown is checked to see if it is equal to one or zero. If the value of shutdown is zero, that means all rolling stock has been loaded prior the containers finishing loading, the shutdown variable is incremented by one, and the roll-on shutoff entity disposed of. If the value of shutdown is one, then the rolling stock completed loading prior to the containers, the termination entity is signaled to be released, and the shutdown variable is incremented by one.

The termination entity is created at the start of the iteration and is held until both the container shutoff entity and the roll-on shutoff entity signal that both cargo categories have entirely been loaded onto lighterage. Then the termination entity is held until the global total cargo loaded variable equals the sum of the quantities of all six cargo types. When that criterion is met the entity is released and disposed of to serve as a timer to measure the duration of the JLOTS operation.

3.3. Experimental Methods

This section discusses the experimental methodologies employed to investigate the current military doctrinal method and describes the approach taken to answer each of the research questions presented in section 1.2.1 of this document. Each subsection restates the research question or questions that it is focused on answering, and then describes in detail the methods, models, and/or tools used by this research to answer those questions.

3.3.1. Comparison of Published Median Values to Subject Matter Expert Opinions

The first part of Research Question One from section 1.2.1.1 is: Do the median times for JLOTS activities recorded during the Ocean Venture 93 exercise and published in military doctrine still represent the present-day equipment of the US Army? To answer this question, the mean of the triangular distribution values calculated using Equation 2 from the data collected from subject matter expert opinions as described in section 3.1.3 of this research is compared to the median values published in Appendix B of *Joint Publication 4-01.6 Joint Logistics Over-the-Shore* (Joint Staff, 2012) for each of the different JLOTS activities using Student's t-test with unequal sample sizes but equal variance using a 0.05 level of significance (Gosset, 1908). Because the Technical Report for Ocean Venture 93 does not include the precise number of observations for each JLOTS activity witnessed (Joint Logistics Over-the-Shore III Test Directorate, 1994), the researcher performed sensitivity analysis to conservatively estimate the number of observations used to determine the median value for each.

$$\bar{x}_{activity} = \frac{\bar{a}_{activity}+\bar{m}_{activity}+\bar{b}_{activity}}{3} \qquad \text{(Eq. 2)}$$

3.3.2. Theoretical Probability Distribution Definition

The second part of Research Question One from section 1.2.1.1 is: If the median times are no longer representative of present-day equipment, then what value is representative and can that value be defined as a probability distribution for use in a discrete-event simulation? To answer this question, a triangular probability distribution for each JLOTS activity/lighterage combination is calculated, as shown in equations 3, 4, and 5, by separately averaging the most likely, best-case, and worst-case times gathered through interviews with the subject matter experts as described in section 3.1.3 Probability Distributions and Measures of Central Tendency for Discrete-Event Simulation (Experimental) and Revised Baseline (Experimental) Model. The triangular distribution uses three terms to define it: *a* for the minimum value, *m* for the most likely value, and *b* for the maximum value. For this research the *a* term represents the best-case or minimum time, the *m* term the most likely case time, and the *b* term the worst-case or maximum time.

$$\bar{m}_{activity} = \frac{\sum_{i=1}^{n}(m_i)}{n} \quad \text{(Eq. 3)}$$

$$\bar{a}_{activity} = \frac{\sum_{i=1}^{n}(a_i)}{n} \quad \text{(Eq. 4)}$$

$$\bar{b}_{activity} = \frac{\sum_{i=1}^{n}(b_i)}{n} \quad \text{(Eq. 5)}$$

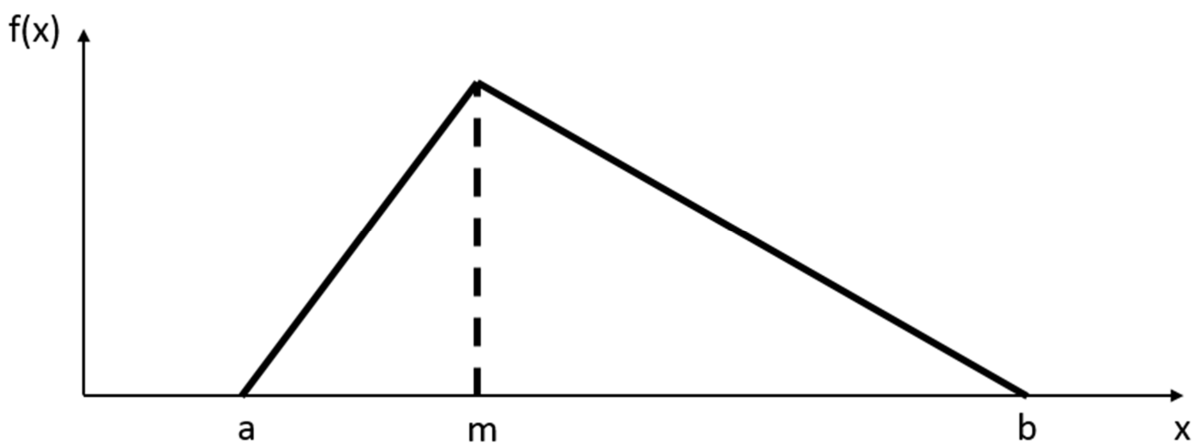

Figure 24. Generic Triangular Probability Distribution.

3.3.3. Probability Distribution Validation and Alternative Probability Distributions

Research Question Two from section 1.2.1.2 is: Are the parameters for the proposed probability distribution valid for the JLOTS activity they are intended to describe? Validation for the triangular probability distributions described in section 3.3.2 Theoretical Probability Distribution Definition was achieved through a comparison of the theoretical triangular probability distributions with that specific activity's sample data times which were observed during the JLOTS exercise that occurred in Pohang, South Korea, in April 2017. The Kolmogorov-Smirnov Test for Goodness of Fit (Massey, 1951) with a level of significance of 0.05 was employed by this research for validation of the probability distribution.

As additional analysis for this research question, the observed data collected during JLOTS observations in Pohang, South Korea were tested for goodness of fit against alternative distributions to determine if any were a better fit than the triangle distribution defined by the subject matter experts as described in section 3.3.2 Theoretical Probability Distribution Definition. The alternative probability distributions used for the goodness of fit tests, in alphabetical order, were: exponential, gamma, lognormal, normal, triangular, and Weibull distributions. The goodness of fit test for the alternative triangular distributions used in this additional analysis did not follow the parameters defined by the data collected through interviews with subject matter experts; instead the alternative triangular distribution's parameters were calculated from the observed data using Arena's Input Analyzer.

3.3.4. Model Results Comparison

The first part of Research Question Three from section 1.2.1.3 asks: Is the calculated duration for the baseline (control) method that uses the currently published median values similar to the revised baseline (experimental) method that substitutes subject matter expert derived average values for the medians? To answer this question both non-linear programs defined in sections 3.2.1 Baseline (Control) Model and 3.2.2 Revised Baseline (Experimental) Model are iterated using the input variable values in Appendix C Table of Variable Values by Iteration in this research. The point estimates calculated by each model are compared through determining the percentage change in duration from the baseline (control) model to the revised baseline (experimental) model. Any percent change greater than five percent is considered a significant difference for this research.

The second part of Research Question Three from section 1.2.1.3 asks: Is the calculated duration for the baseline (control) method that uses the currently published median values statistically similar to the expected value of the discrete-event simulation (experimental) method that leverages probability distributions defined by subject matter experts? The point estimate values calculated by the baseline (control) model from the previous part of this research question was compared to the expected value and standard deviation for the discrete-event simulation (experimental) model iterated 100 times per input variable set using Student's one-sample *t*-test (Gosset, 1908) at a level of significance of 0.05.

The final part of Research Question Three from section 1.2.1.3 asks: Is the calculated duration for the revised baseline (experimental) method that substitutes subject matter expert derived average values for the medians statistically similar to the expected value of the discrete-event simulation (experimental) method that leverages probability distributions defined by subject matter experts? The point estimate values calculated by the revised baseline (experimental) model from the first part of this research question was compared to the expected value and standard deviation for the discrete-event simulation (experimental) model iterated 100 times per input variable set using Student's one-sample t-test (Gosset, 1908) at a level of significance of 0.05.

3.3.5. Lighterage Cost Comparison

Research Question Four from section 1.2.1.4 asks: How do the different sets of lighterage compare to each other from a fiscal perspective? To compare the different lighterage sets from a cost standpoint, the estimated duration for each iteration in hours is multiplied by the sum of the quantity of each lighterage by type and the lighterage's average hourly operating cost by type determined using the data sources discussed in section 3.1.5 Lighterage Operating Costs. Equation 6 depicts the mathematical formulation for this cost calculation where t stands for the estimated duration in hours, n is the different types of lighterage represented in that iteration, q_i is the integer quantity of type i lighterage, and c_i the average hourly operating cost of type i lighterage in US dollars.

$$expected\ iteration\ cost = t * \sum_{i=1}^{n}(q_i * c_i) \qquad \text{(Eq. 6)}$$

The hourly operating cost for each lighterage type with be a sum of the hourly fully burdened cost of each servicemember assigned to the vessel, the cost of fuel for an hour of operation, and the historical cost of repair parts and services per hour of operation. The sources detailed in section 3.1.5 Lighterage Operating Costs provide adequate data on both the US Army and US Navy equipment. However, no cost database for US Navy personnel was able to be accessed so the US Navy personnel costs were surrogated with US Army personnel costs for the same rank and similar military occupational specialty.

CHAPTER 4. RESULTS

This chapter presents the results from the methods, models, and tools discussed in Chapter 3 Methodology. The first section illustrates the comparison of the published median values to subject matter expert opinions. The second section defines the theoretical probability distributions created from subject matter expert opinions collected from interviews by this research. The third section portrays the validation of the theoretical probability distributions through the employment of goodness of fit tests with observed data. The fourth section depicts the iteration results for each of the three models described in the previous chapter. The fifth section presents the comparison of the three models to one another. The final section shows the costs associated with each of the estimation methods.

4.1. Results for the Comparison of Published Median Values to Subject Matter Expert Opinions

This section presents the statistical comparison of the median values published in Joint Publication 4-01.6 Appendix B to the subject matter expert opinions for JLOTS activity duration per the methodology discussed in section 3.3.1 Comparison of Published Median Values to Subject Matter Expert Opinions. Figure 25 depicts the number of rejections and failures to reject that Student's *t*-test with unequal sample sizes but equal variance using a 0.05 level of significance when the unknown historic number of observations is increased.

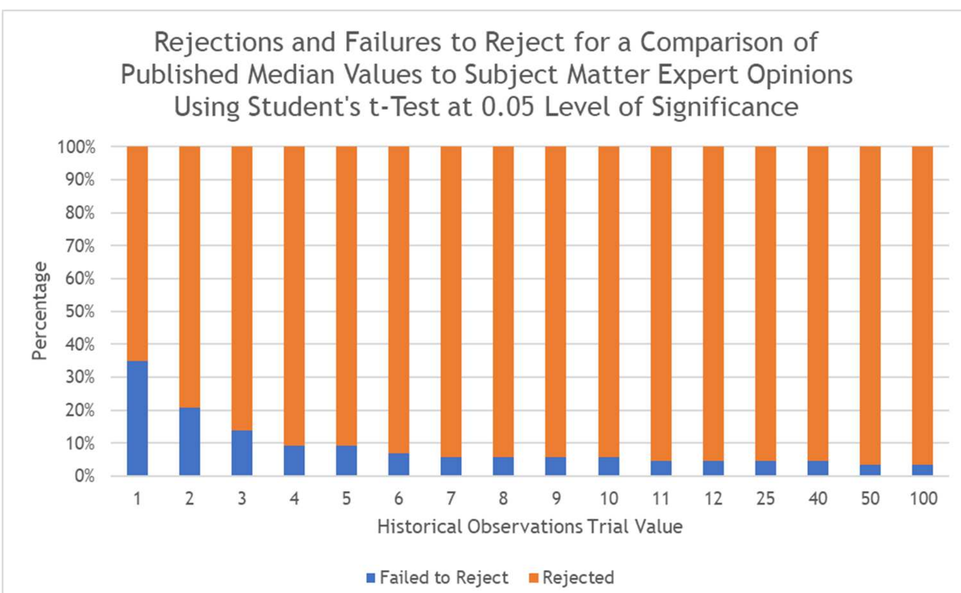

Figure 25. Rejections and Failures to Reject for a Comparison of Published Median Values to Subject Matter Expert Opinions Using Student's *t*-Test at 0.05 Level of Significance.

4.2. Theoretical Probability Distribution Definitions

This section discusses the theoretical probability distributions derived from subject matter expert opinions collected by this research as described by section 3.1.3 Probability Distributions and Measures of Central Tendency for Discrete-Event Simulation (Experimental) and Revised Baseline (Experimental) Model. The probability distributions were calculated in accordance with the methodology described in section 3.3.2 Theoretical Probability Distribution Definition. The distributions are divided into separate appendices by which type of lighterage they reflect. The numerical values that the subject matter experts provided as well as the calculated theoretical probability distribution are shown in the tables while the distributions are plotted on graphs directly below. Appendix G presents US Army causeway ferry, Appendix H the US Army Landing Craft Utility 2000 Series, Appendix I the US Army Logistics Support Vessel, and Appendix J the US Navy Landing Craft Utility 1600 series. Data was collected from JLOTS subject matter experts on the US Navy Improved Navy Lighterage System Ferry as well as the US Navy Landing Craft, Air Cushion but do not appear because the data was not used due to historical data not existing to draw comparisons to for this research.

4.3. Theoretical Probability Distribution Validation

The observed data points collected as described in section 3.1.4 Sample Data Points Collected During an Actual JLOTS Operation were compared to the theoretical probability distributions calculated per section 3.3.2 Theoretical Probability Distribution Definition through the application of a Kolmogorov-Smirnov test for goodness of fit at a 0.05 level of significance. The outcome of the test appears in Table 3 Probability Distribution Validation Goodness of Fit Test Results.

Table 3. Probability Distribution Validation Goodness of Fit Test Results.

Lighterage	Activity	Data Points	Test Statistic	Critical Value	Result
LCU-2000	A&M Navy RRDF w/ Rhino	7	0.387	0.48343	Fail to Reject
LCU-2000	Roll-On Load LWV	18	0.778	0.30936	Reject
LCU-2000	Roll-On Load LWV w/ Trailer	10	0.857	0.40925	Reject
LCU-2000	Roll-On Load HWV	23	0.957	0.2749	Reject
LCU-2000	C&C Navy RRDF	7	1	0.48342	Reject
LCU-2000	A&M Army Causeway Pier	5	0.594	0.56328	Reject
LCU-2000	Unload LWV	22	1	0.28087	Reject
LCU-2000	Unload LWV w/ Trailer	5	1	0.56328	Reject
LCU-2000	Unload HWV	22	1	0.28087	Reject
LCU-2000	C&C Army Causeway Pier	6	0.503	0.51926	Fail to Reject

4.3.1. Additional Analysis for Alternative Probability Distributions

The sample data points collected during the JLOTS operation in Pohang, South Korea were entered into Arena's Input Analyzer tool as described in section 3.3.3 Probability Distribution Validation and Additional Analysis. Each set of data was compared to the six distributions (exponential, gamma, lognormal, normal, triangular, and Weibull) through a Kolmogorov-Smirnov test for goodness of fit at a 0.05 level of significance. The histograms for the ten distributions tested appear in Appendix N Histograms of Observed Durations of JLOTS Activities. The results for each of the tests along with the associated p-value calculated for the test appears in Table 4 Additional Analysis for Alternative Probability Distribution Goodness of Fit Test Results.

Table 4. Additional Analysis for Alternative Probability Distribution Goodness of Fit Test Results.

Distribution / Lighterage and Activity	Exponential K-S Test Result	Gamma K-S Test Result	Lognormal K-S Test Result	Normal K-S Test Result	Triangular K-S Test Result	Weibull K-S Test Result
LCU-2000 A&M Navy RRDF w/ Rhino	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject
LCU-2000 Roll-On Load LWV	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject
LCU-2000 Roll-On Load LWV w/ Trailer	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject
LCU-2000 Roll-On Load HWV	.0245, Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	.0402, Reject	> .15, Fail to Reject
LCU-2000 C&C Navy RRDF	> .15, Fail to Reject	, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject
LCU-2000 A&M Army Causeway Pier	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject
LCU-2000 Unload LWV	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject
LCU-2000 Unload LWV w/ Trailer	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject
LCU-2000 Unload HWV	.0977, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject
LCU-2000 C&C Army Causeway Pier	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject	> .15, Fail to Reject

4.4. Model Iteration Results

The duration estimates from all three of the models are displayed in the following sections. The baseline (control) non-linear program results are presented first, followed by the revised baseline (experimental) non-linear program results, and lastly the discrete-event simulation (experimental) model results. The first iteration and every sixteenth iteration after the values are zero. This is due to the variables for those iterations not including any lighterage to transport cargo. The results for each model are separated into four parts by the type of cargo for ease of presentation.

4.4.1. Baseline (Control) Model Results

The non-linear program described in section 3.2.1 Baseline (Control) Model was iterated with the inputs listed in Appendix C Table of Variable Values by Iteration. Figure 26 shows the estimated duration for the 32 iterations of the baseline (control) model that have the ABCT cargo set as a variable value. Figure 27 shows the estimated duration for the 32 iterations of the baseline (control) model that have the IBCT cargo set as a variable value. Figure 28 shows the estimated duration for the 32 iterations of the baseline (control) model that have the SBCT cargo set as a variable value. Figure 29 shows the estimated duration for the 32 iterations of the baseline (control) model that have the HADR cargo set as a variable value. The exact numeric values for the results are shown in Appendix D Table of Baseline (Control) Model Results by Iteration.

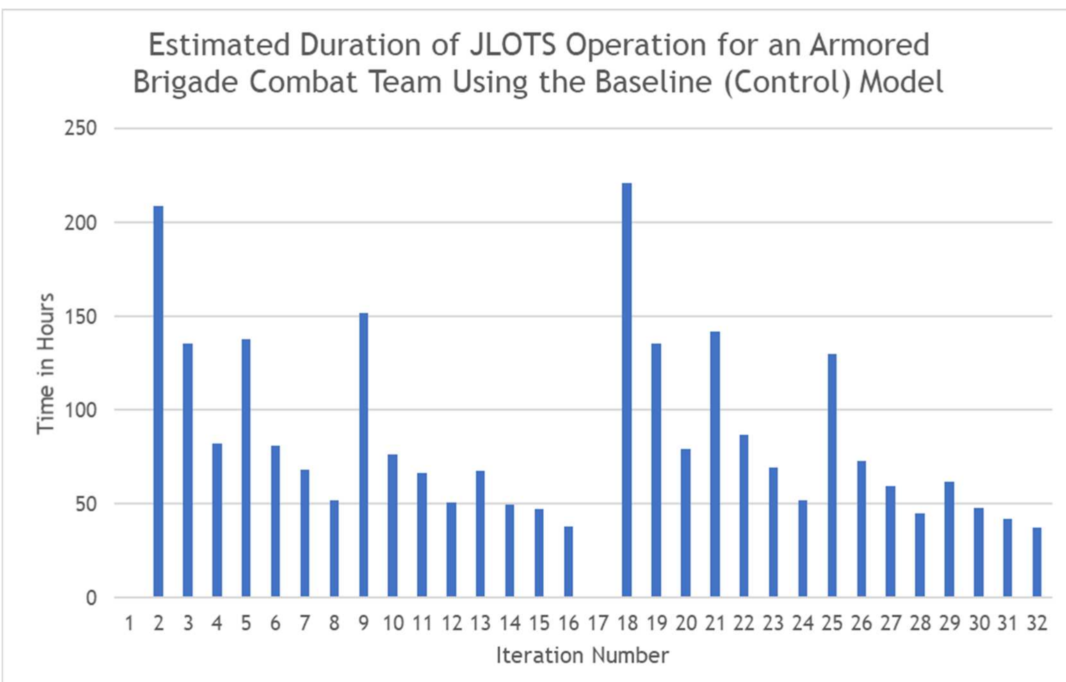

Figure 26. Estimated Duration of JLOTS Operation for an ABCT Using the Baseline (Control) Model.

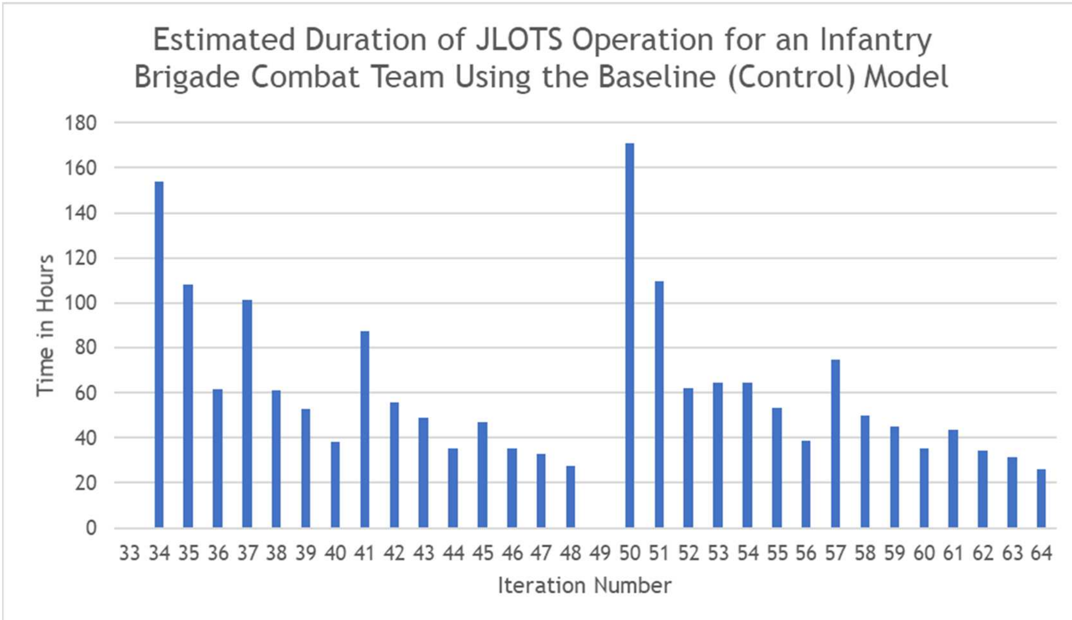

Figure 27. Estimated Duration of JLOTS Operation for an IBCT Using the Baseline (Control) Model.

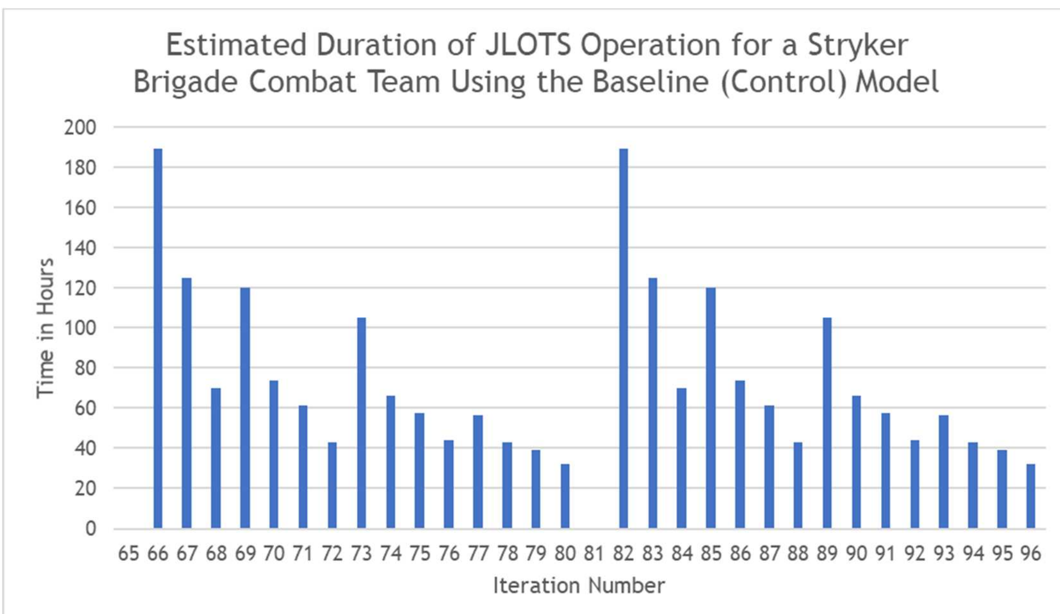

Figure 28. Estimated Duration of JLOTS Operation for a SBCT Using the Baseline (Control) Model.

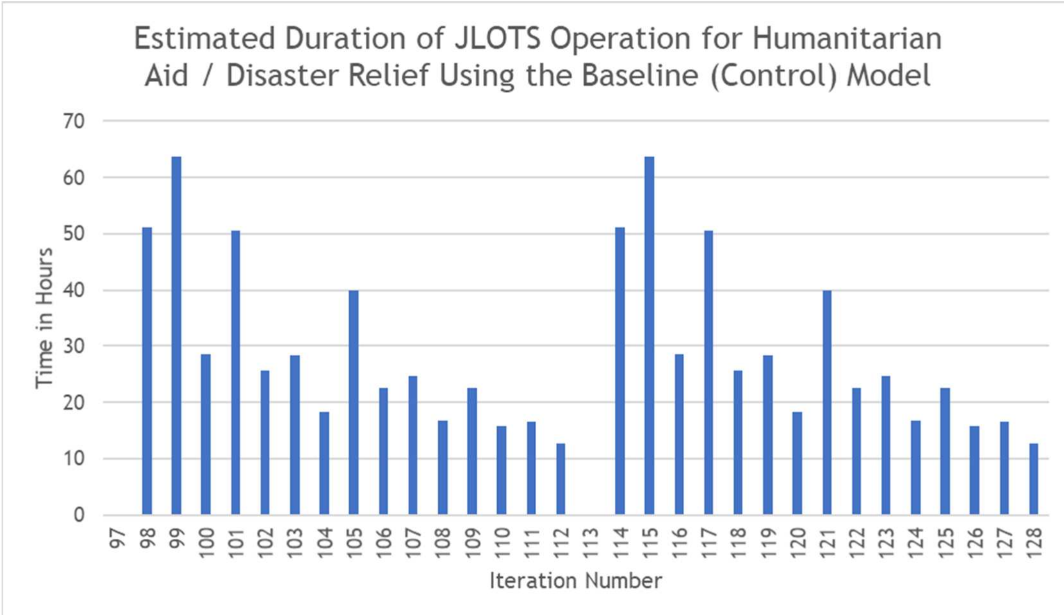

Figure 29. Estimated Duration of JLOTS Operation for HADR Using the Baseline (Control) Model.

4.4.2. Revised Baseline (Experimental) Model Results

The non-linear program described in section 3.2.2 Revised Baseline (Experimental) Model was iterated with the inputs listed in Appendix C Table of Variable Values by Iteration. Figure 30 shows the estimated duration for the 32 iterations of the revised baseline (experimental) model that have the ABCT cargo set as a variable value. Figure 31 shows the estimated duration for the 32 iterations of the revised baseline (experimental) model that have the IBCT cargo set as a variable value. Figure 32 shows the estimated duration for the 32 iterations of the revised baseline (experimental) model that have the SBCT cargo set as a variable value. Figure 33 shows the estimated duration for the 32 iterations of the revised baseline (experimental) model that have the HADR cargo set as a variable value. The exact numeric values for the results are shown in Appendix E Table of Revised Baseline (Experimental) Model Results by Iteration.

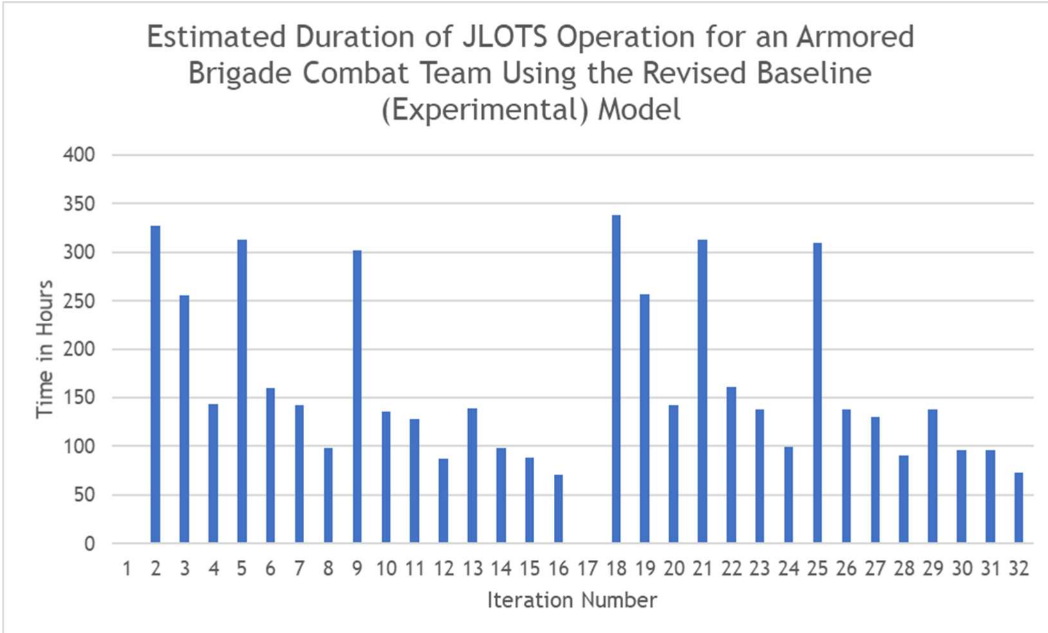

Figure 30. Estimated Duration of JLOTS Operation for an ABCT Using the Revised Baseline (Experimental) Model.

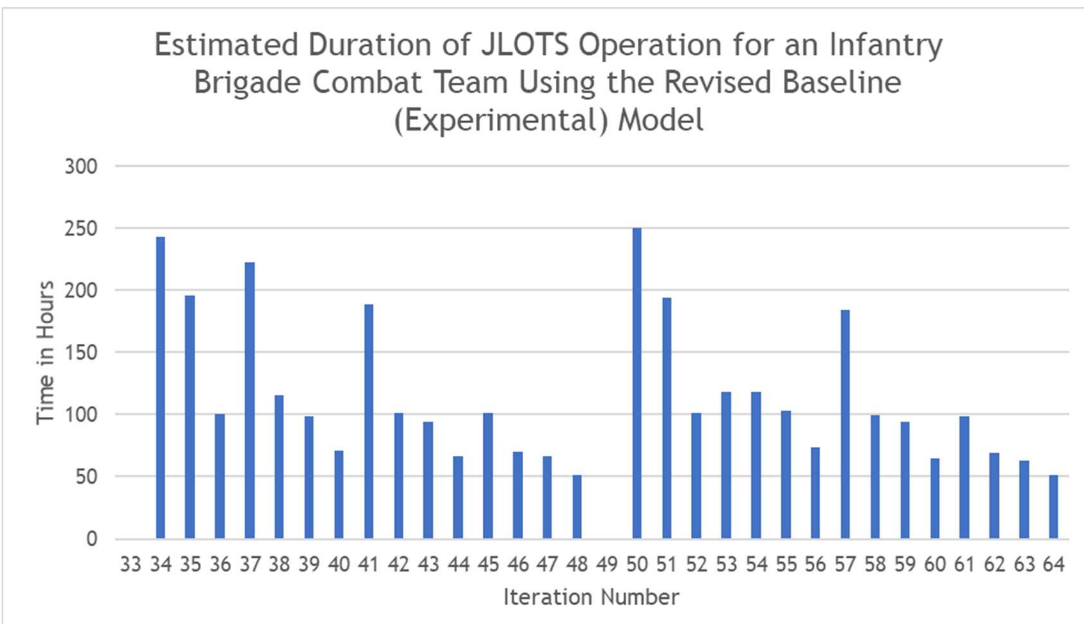

Figure 31. Estimated Duration of JLOTS Operation for an IBCT Using the Revised Baseline (Experimental) Model.

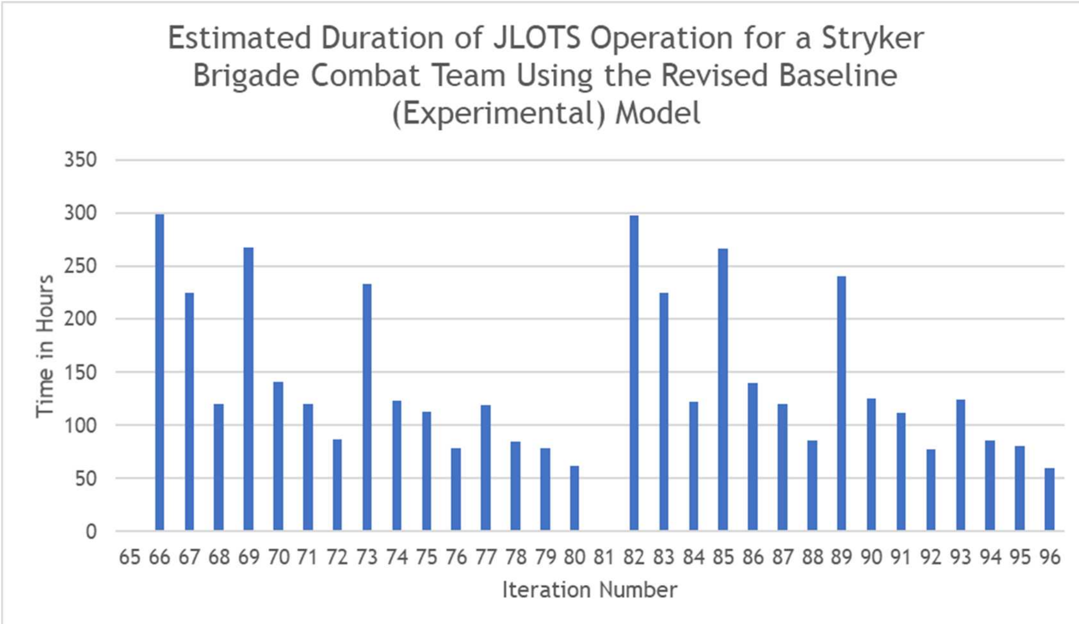

Figure 32. Estimated Duration of JLOTS Operation for a SBCT Using the Revised Baseline (Experimental) Model.

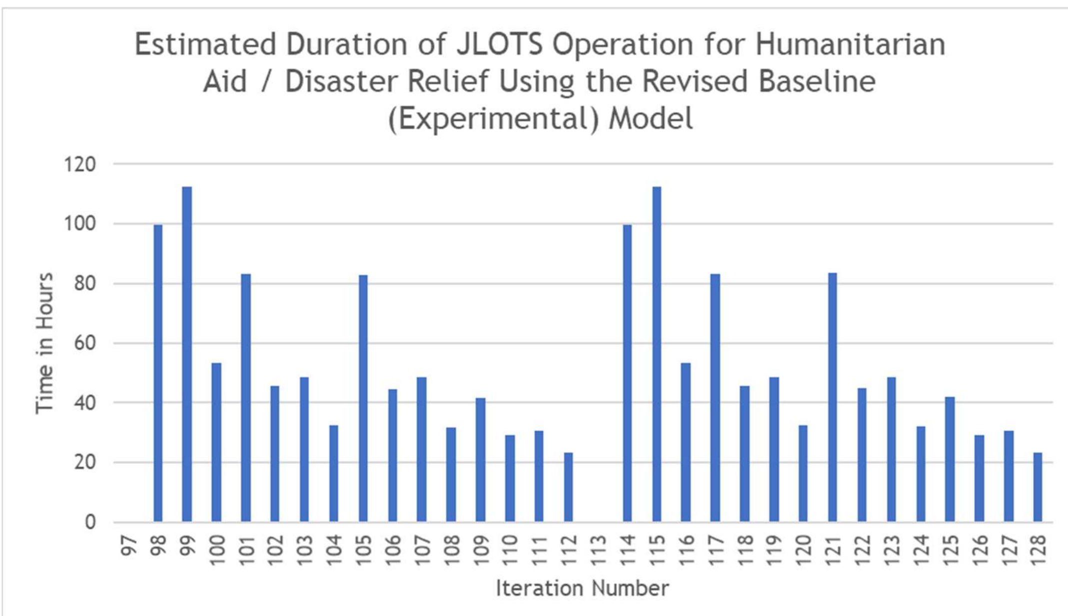

Figure 33. Estimated Duration of JLOTS Operation for HADR Using the Revised Baseline (Experimental) Model.

4.4.3. Discrete-Event Simulation (Experimental) Model Results

The discrete-event simulation described in section 3.2.3 Discrete-Event Simulation (Experimental) Model was iterated 100 times each with the inputs listed in Appendix C Table of Variable

Values by Iteration. Figure 34 shows the estimated duration for the 32 iterations of the discrete-event simulation (experimental) model that have the ABCT cargo set as a variable value. Figure 35 shows the estimated duration for the 32 iterations of the discrete-event simulation (experimental) model that have the IBCT cargo set as a variable value. Figure 36 shows the estimated duration for the 32 iterations of the discrete-event simulation (experimental) model that have the SBCT cargo set as a variable value. Figure 37 shows the estimated duration for the 32 iterations of the discrete-event simulation (experimental) model that have the HADR cargo set as a variable value. The exact numeric values for the results are shown in Appendix F Table of Discrete-Event Simulation (Experimental) Model Results by Iteration.

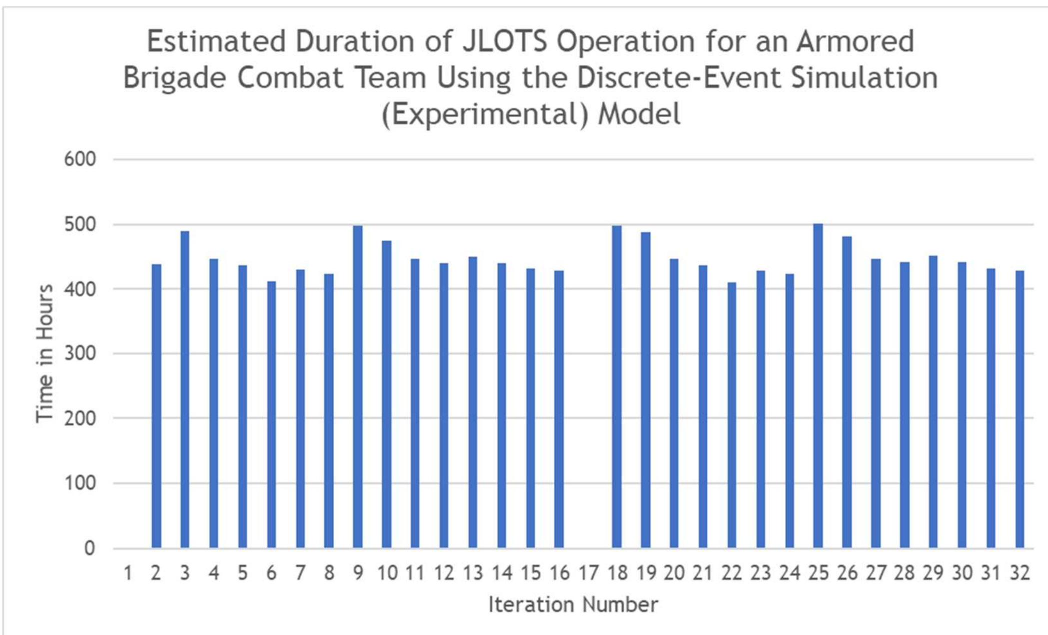

Figure 34. Estimated Duration of JLOTS Operation for an ABCT Using the Discrete-Event Simulation (Experimental) Model.

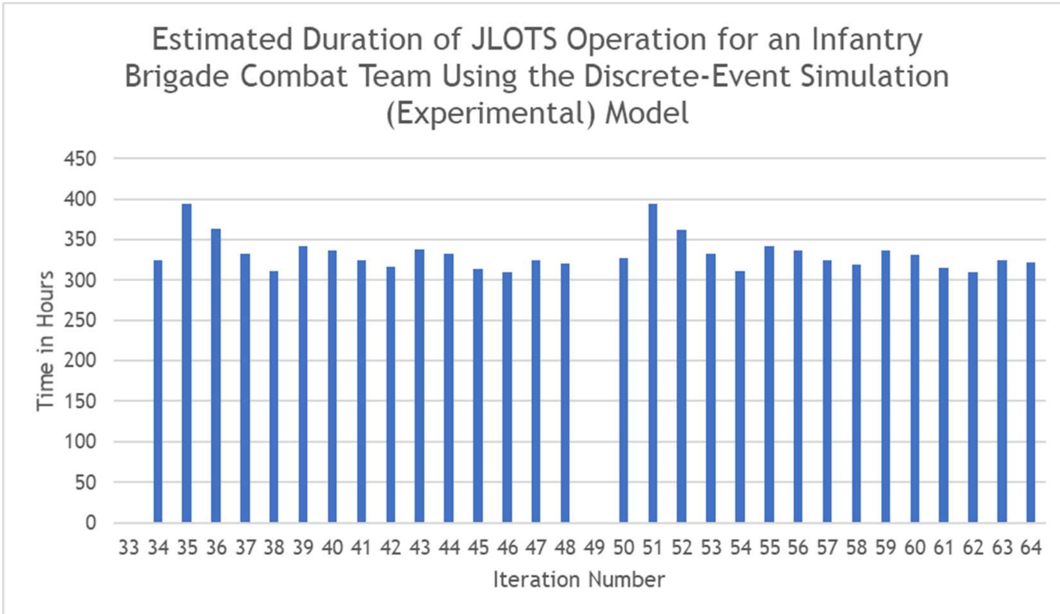

Figure 35. Estimated Duration of JLOTS Operation for an IBCT Using the Discrete-Event Simulation (Experimental) Model.

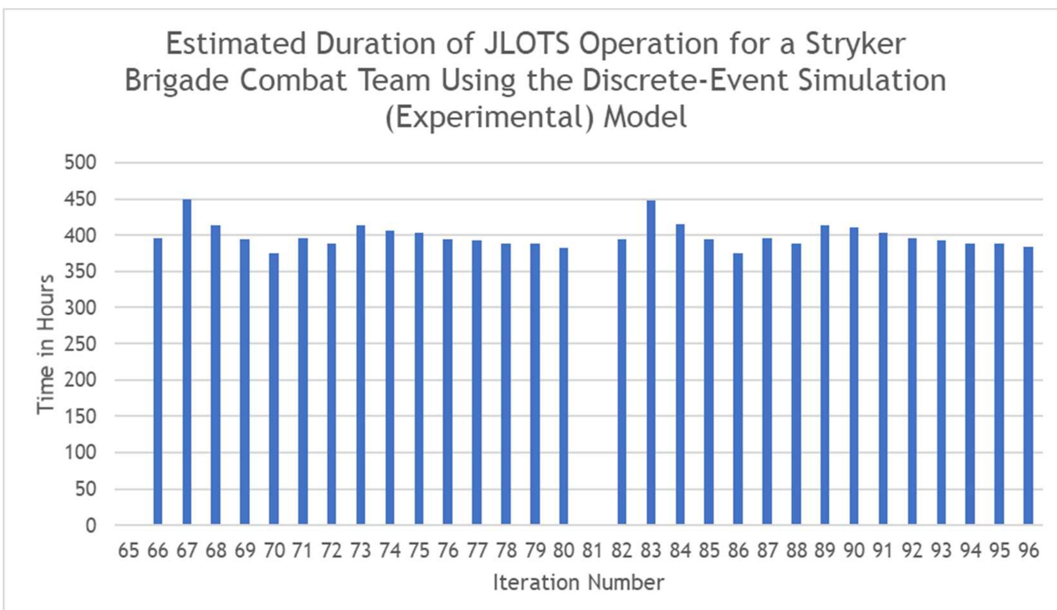

Figure 36. Estimated Duration of JLOTS Operation for a SBCT Using the Discrete-Event Simulation (Experimental) Model.

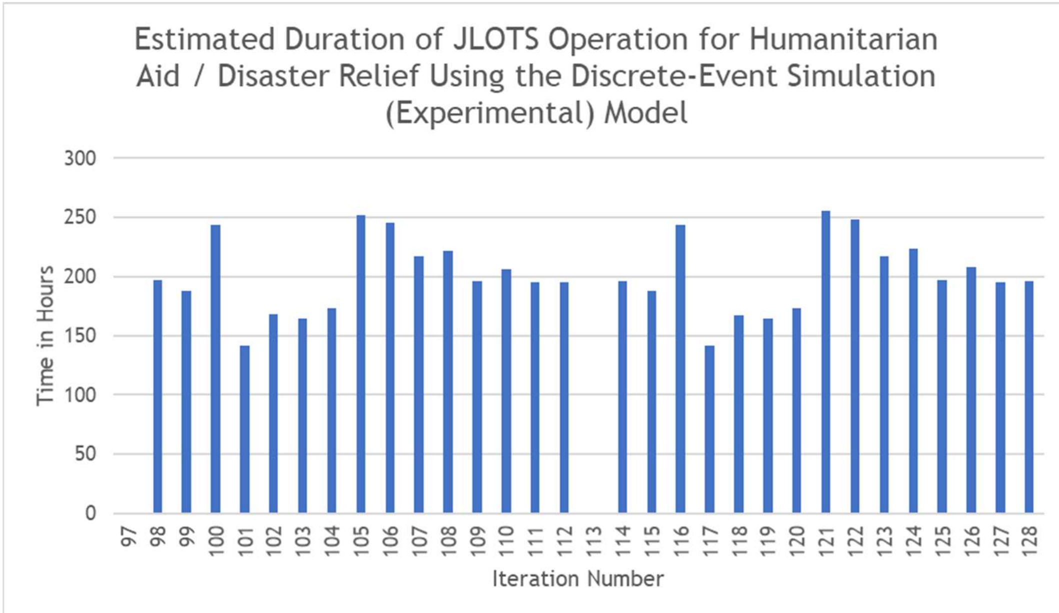

Figure 37. Estimated Duration of JLOTS Operation for a HADR Using the Discrete-Event Simulation (Experimental) Model.

4.5. Comparison of Model Duration Outputs

The comparison of duration estimates from all three of the models are displayed in the following subsections. The comparison of the baseline (control) non-linear program results and revised baseline (experimental) non-linear program results are presented first, followed by the comparison of the baseline (control) non-linear program results and discrete-event simulation (experimental) model results. Lastly the revised baseline (experimental) non-linear program results are compared to the discrete-event simulation (experimental) model results. The outcomes of each comparison are separated into four parts by the type of cargo set the JLOTS operation modeled for ease of presentation.

4.5.1. Baseline (Control) Model Results and Revised Baseline (Experimental) Model Results Comparison

This section shows comparisons of the data presented in sections 4.1.1 Baseline (Control) Model Results and 4.1.2 Revised Baseline (Experimental) Model Results, specifically Figures 25 through 32. The clustered columns in the figure represent the estimated duration (shown on the left side vertical axis) of that iteration for that model while the grey points imposed on the clustered columns denote the percent change from the baseline (control) model to the revised baseline (experimental) model (shown on the right side vertical axis). Figure 38 shows the estimated duration for the 32 iterations of the baseline (control) model and revised baseline (experimental) model that have the Armored Brigade Combat Team cargo set as a variable value. Figure 39 shows the estimated duration for the 32 iterations of the baseline (control) model and revised baseline (experimental) model that have the Infantry Brigade Combat Team cargo set as a variable value. Figure 40 shows the estimated duration for the 32 iterations of the baseline (control) model and revised baseline (experimental) model that have the Stryker Brigade Combat Team cargo set as a variable value. Figure 41 shows the estimated duration for the 32 iterations of the baseline (control) model and revised baseline (experimental) model that have the Humanitarian Assistance Disaster Relief cargo set as a variable value. The exact numeric values for the results are shown in Appendix D Table of Baseline (Control) Model Results by Iteration and Appendix E Table of Revised Baseline (Experimental) Model Results by Iteration.

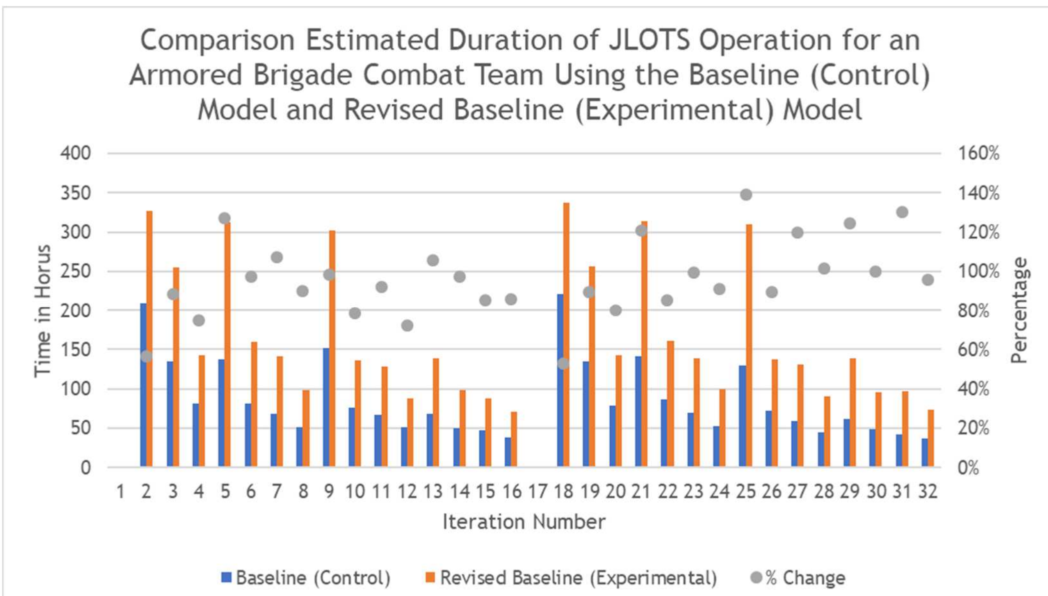

Figure 38. Comparison Estimated Duration of JLOTS Operation for an Armored Brigade Combat Team Using the Baseline (Control) Model and Revised Baseline (Experimental) Model.

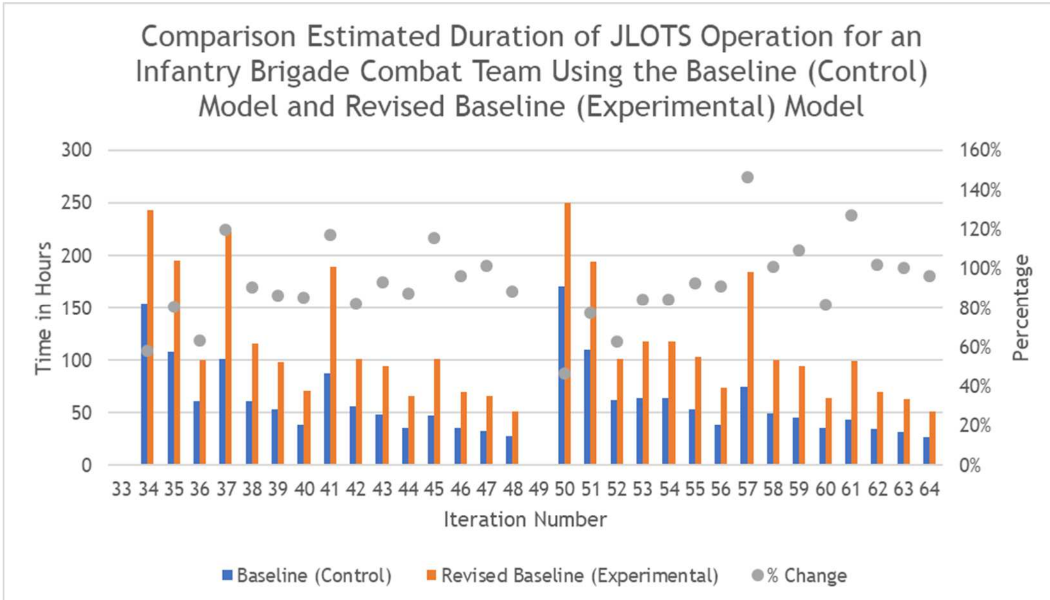

Figure 39. Comparison Estimated Duration of JLOTS Operation for an Infantry Brigade Combat Team Using the Baseline (Control) Model and Revised Baseline (Experimental) Model.

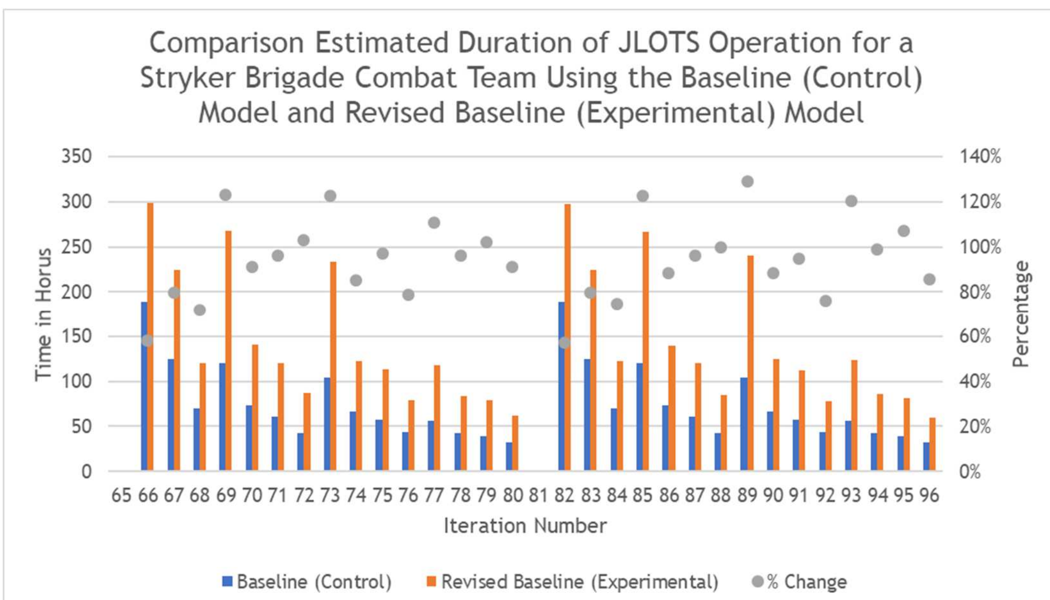

Figure 40. Comparison Estimated Durations of JLOTS Operations for a Stryker Brigade Combat Team Using the Baseline (Control) Model and Revised Baseline (Experimental) Model.

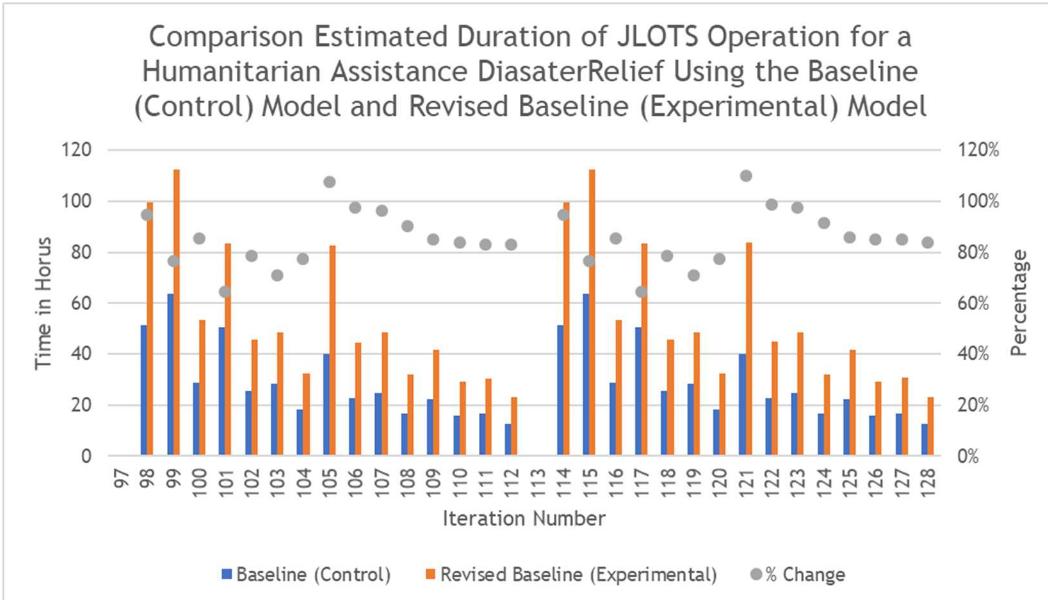

Figure 41. Comparison Estimated Durations of JLOTS Operations for a Humanitarian Assistance Disaster Relief Using the Baseline (Control) Model and Revised Baseline (Experimental) Model.

4.5.2. Baseline (Control) Model Results and Discrete-Event Simulation (Experimental) Model Results Comparison

This section shows comparisons of the data presented in sections 4.1.1 Baseline (Control) Model Results and 4.1.3 Discrete-Event Simulation (Experimental) Model Results, specifically Figures 25 through 28 and 33 through 36. The first subsection shows the percentage change from the baseline (control) model to the discrete-event simulation (experimental) model. The second subsection uses statistical analysis to determine if the duration estimated by the two models are statistically similar.

4.5.2.1. Baseline (Control) Model Results and Discrete-Event Simulation (Experimental) Model Results Comparison by Percent Change

Figure 42 shows the estimated duration for the 32 iterations of the baseline (control) model and the discrete-event simulation (experimental) model that have the ABCT cargo set as a variable value. The clustered columns in the figure represent the estimated duration (shown on the left side vertical axis) of that iteration for that model while the gray points imposed on the clustered columns denote the percent change from the baseline (control) model to the discrete-event simulation (experimental) model (shown on the right side vertical axis). Figure 43 shows the estimated duration for the 32 iterations of the baseline (control) model and discrete-event simulation (experimental) model that have the IBCT cargo set as a variable value. Figure 44 shows the estimated duration for the 32 iterations of the baseline (control) model and discrete-event simulation (experimental) model that have the SBCT cargo set as a variable value. Figure 45 shows the estimated duration for the 32 iterations of the baseline (control) model and discrete-event simulation (experimental) model that have the HADR cargo set as a variable value. The exact numeric values for the results are shown in Appendix D Table of Baseline (Control) Model Results by Iteration and Appendix F Table of Discrete-Event Simulation (Experimental) Model Results by Iteration.

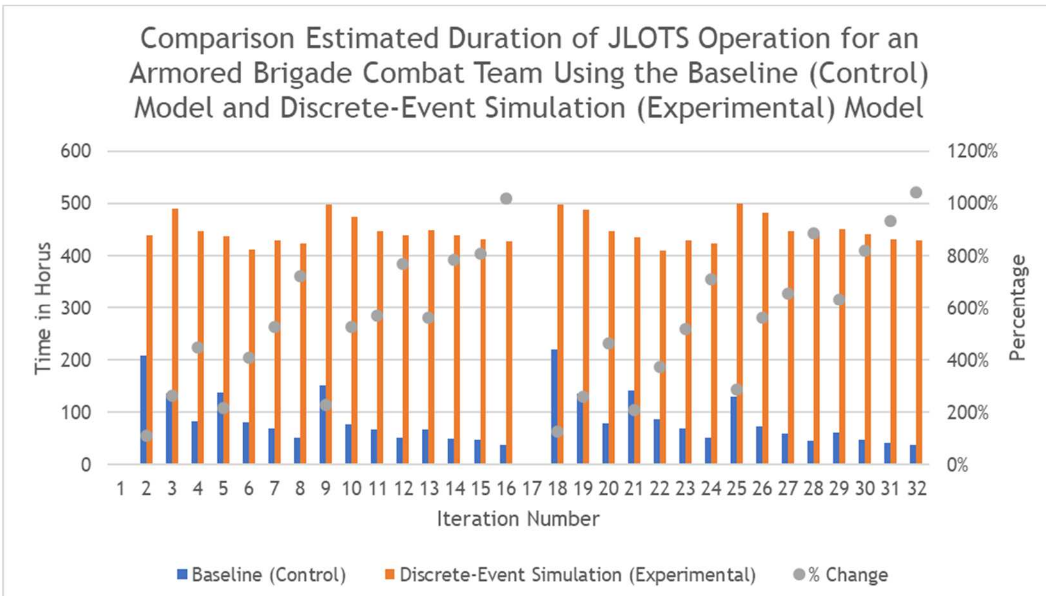

Figure 42. Comparison Estimated Duration of JLOTS Operation for an Armored Brigade Combat Team Using the Baseline (Control) Model and Discrete-Event Simulation (Experimental) Model.

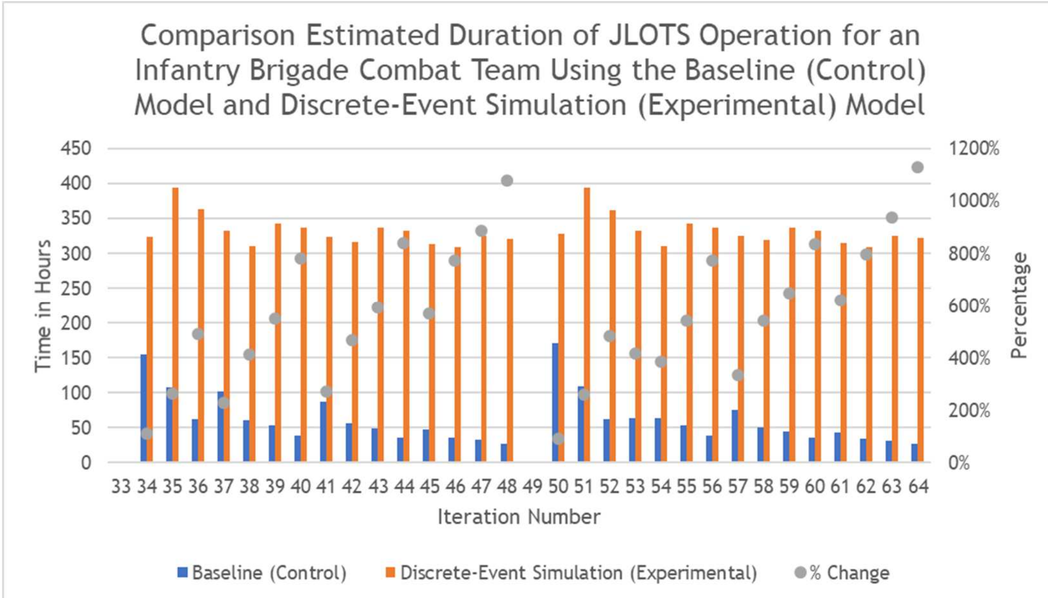

Figure 43. Comparison Estimated Duration of JLOTS Operation for an Infantry Brigade Combat Team Using the Baseline (Control) Model and Discrete-Event Simulation (Experimental) Model.

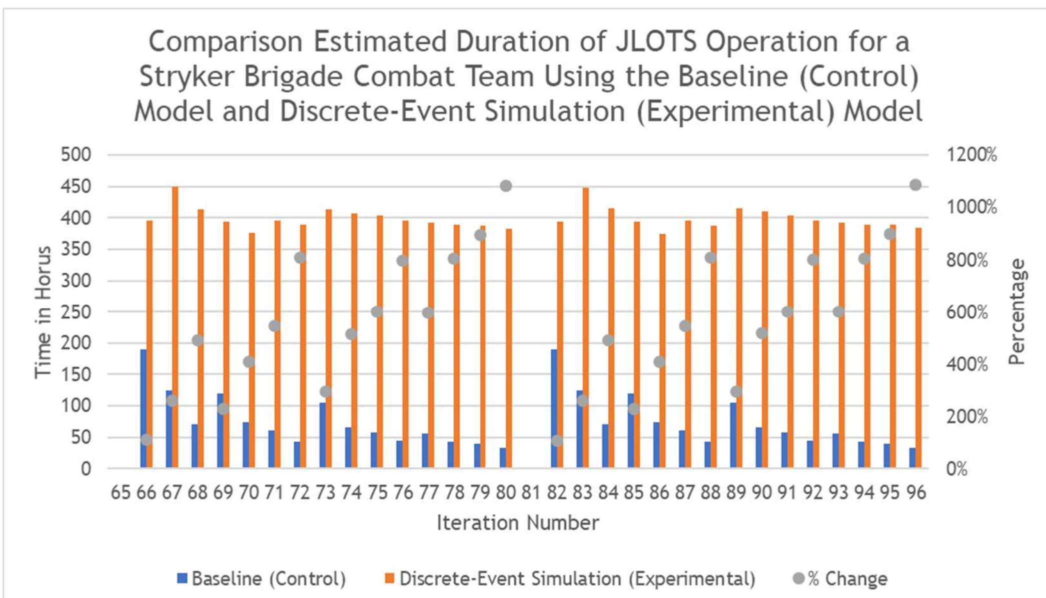

Figure 44. Comparison Estimated Durations of JLOTS Operations for a Stryker Brigade Combat Team Using the Baseline (Control) Model and Discrete-Event Simulation (Experimental) Model.

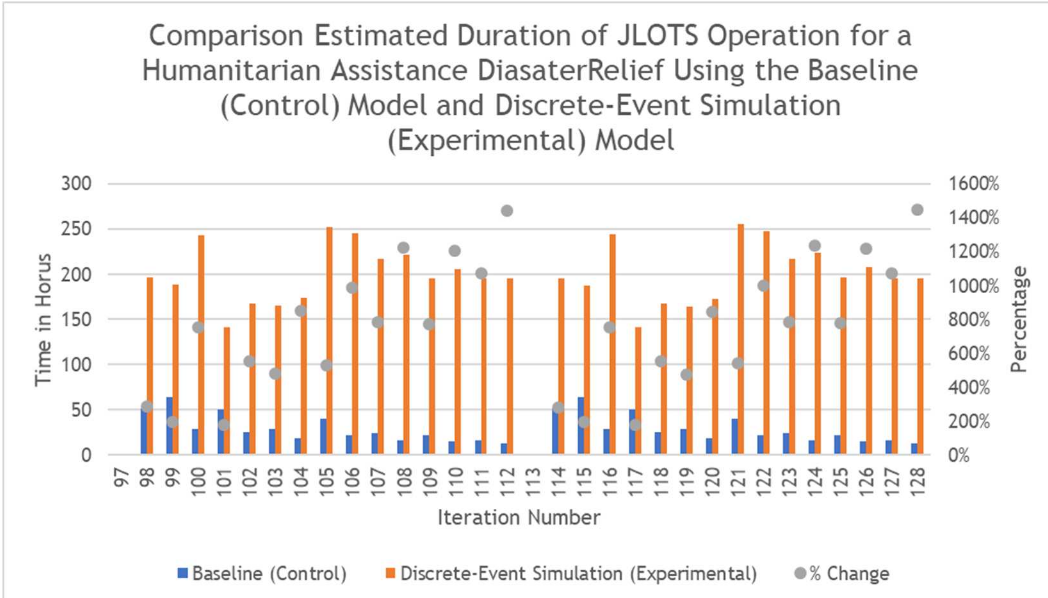

Figure 45. Comparison Estimated Durations of JLOTS Operations for a Humanitarian Assistance Disaster Relief Using the Baseline (Control) Model and Discrete-Event Simulation (Experimental) Model.

4.5.2.2. Baseline (Control) Model Results and Discrete-Event Simulation (Experimental) Model Results Comparison by Statistical Analysis

The baseline (control) model estimated duration was statistically compared to the discrete-event simulation estimated duration using Student's one sample *t*-test as discussed in section 3.3.4 Model Results Comparison. All 120 statistical tests rejected that the estimated durations were statistically similar at the 0.05 level of significance. The numerical results for this statistical analysis are in Appendix K Table of One Sample Student's *t*-Test Comparison of Discrete-Event Simulation (Experimental) Model Results to Baseline (Control) Model Results by Iteration.

4.5.3. Revised Baseline (Experimental) Model Results and Discrete-Event Simulation (Experimental) Model Results Comparison

This section shows comparisons of the data presented in sections 4.1.1 Baseline (Control) Model Results and 4.1.3 Discrete-Event Simulation (Experimental) Model Results, specifically Figures 25 through 28 and 33 through 36. The first subsection shows the percentage change from the baseline (control) model to the discrete-event simulation (experimental) model. The second subsection uses statistical analysis to determine if the durations estimated by the two models are statistically similar.

4.5.3.1. Revised Baseline (Experimental) Model Results and Discrete-Event Simulation (Experimental) Model Results Comparison by Percent Change

Figure 46 shows the estimated duration for the 32 iterations of the revised baseline (experimental) model and the discrete-event simulation (experimental) model that have the ABCT cargo set as a variable value. The clustered columns in the figure represent the estimated duration (shown on the left side vertical axis) of that iteration for that model while the gray points imposed on the clustered columns denote the percent change from the revised baseline (experimental) model to the discrete-event simulation (experimental) model (shown on the right side vertical axis). Figure 47 shows the estimated duration for the 32 iterations of the revised baseline (experimental) model and discrete-event simulation (experimental) model that have the IBCT cargo set as a variable value. Figure 48 shows the estimated duration for the 32 iterations of the revised baseline (experimental) model and discrete-event simulation (experimental) model that have the SBCT cargo set as a variable value. Figure 49 shows the estimated duration for the 32 iterations of the revised baseline (experimental) model and discrete-event simulation (experimental) model that have the HADR cargo set as a variable value. The exact numeric values for the results are shown in Appendix E Table of Revised Baseline (Experimental) Model Results by Iteration and Appendix F Table of Discrete-Event Simulation (Experimental) Model Results by Iteration.

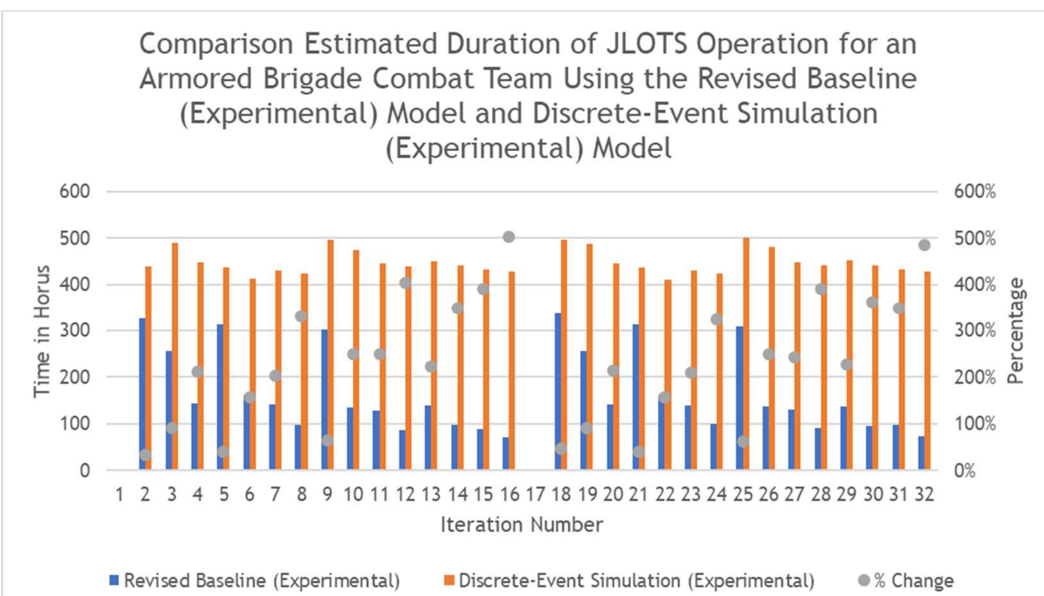

Figure 46. Comparison Estimated Duration of JLOTS Operation for an Armored Brigade Combat Team Using the Revised Baseline (Experimental) Model and Discrete-Event Simulation (Experimental) Model.

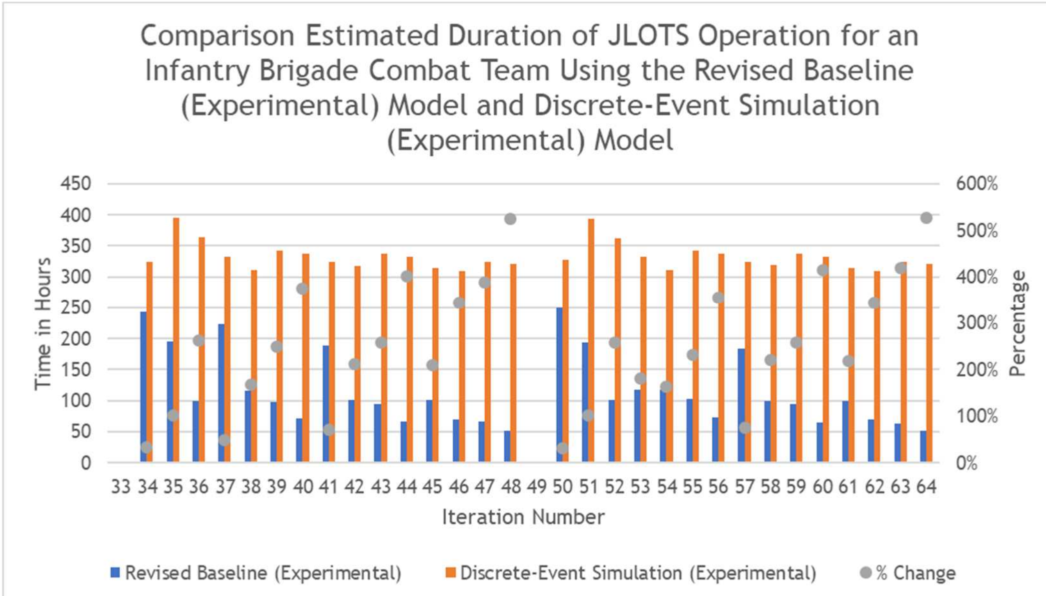

Figure 47. Comparison Estimated Duration of JLOTS Operation for an Infantry Brigade Combat Team Using the Revised Baseline (Experimental) Model and Discrete-Event Simulation (Experimental) Model.

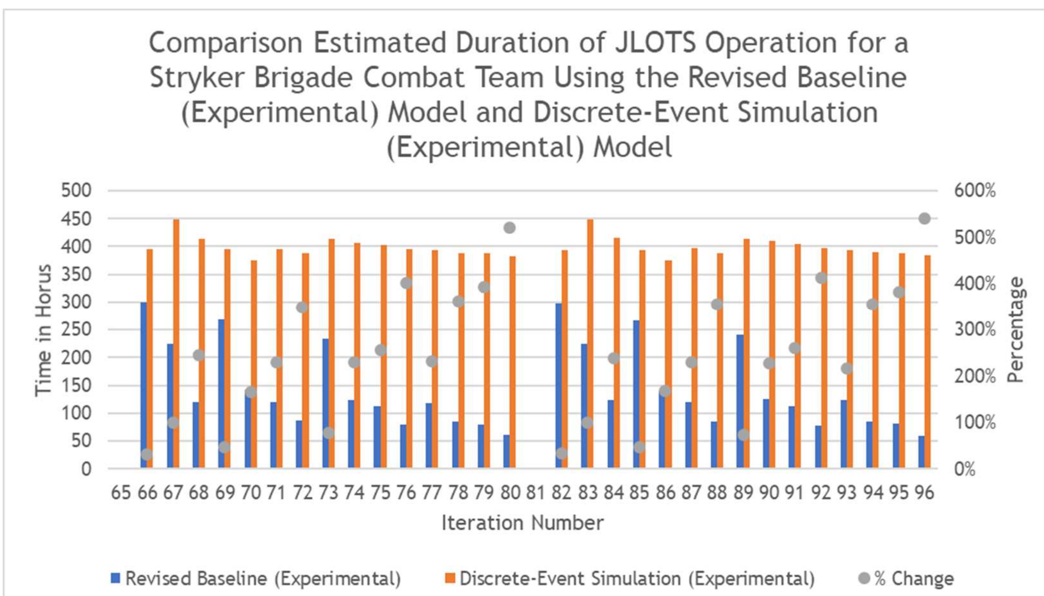

Figure 48. Comparison Estimated Durations of JLOTS Operations for a Stryker Brigade Combat Team Using the Revised Baseline (Experimental) Model and Discrete-Event Simulation (Experimental) Model.

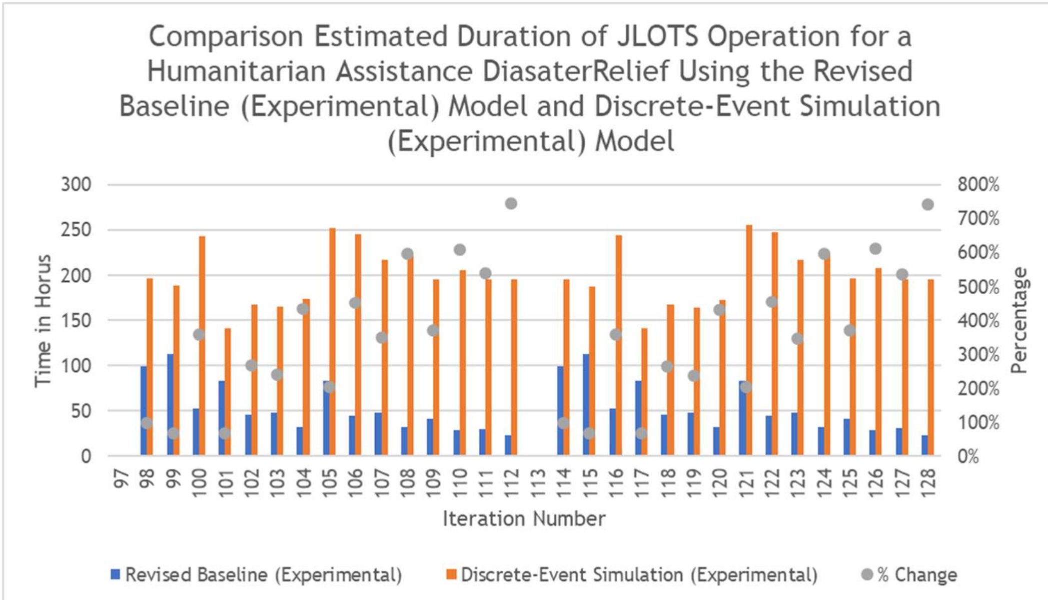

Figure 49. Comparison Estimated Durations of JLOTS Operations for a Humanitarian Assistance Disaster Relief Using the Revised Baseline (Experimental) Model and Discrete-Event Simulation (Experimental) Model.

4.5.3.2. Revised Baseline (Experimental) Model Results and Discrete-Event Simulation (Experimental) Model Results Comparison by Statistical Analysis

The baseline (control) model estimated duration was statistically compared to the discrete-event simulation estimated duration using Student's one sample *t*-test as discussed in section 3.3.4 Model Results Comparison. All 120 statistical tests rejected that the estimated durations were statistically similar at the 0.05 level of significance. The numerical results for this statistical analysis are in Appendix L Table of One Sample Student's *t*-Test Comparison of Discrete-Event Simulation (Experimental) Model Results to Revised Baseline (Experimental) Model Results by Iteration.

4.6. JLOTS Operational Cost Estimates

This section provides the results of the cost estimation methodology described by section 3.3.5 Lighterage Cost Comparison. Using the cost data sources described in section 3.1.5 Lighterage Operating Costs the hourly operating cost for each type of lighterage appears in Table 5 with the costs for personnel, fuel, and repair parts broken out. The cost estimates are in comparative graphs divided by the type of cargo variable for that iteration for ease of presentation. Figures 50, 51, 52, and 53 are the costs for each estimation method to place an Armored Brigade Combat Team, Infantry Brigade Combat Team, Stryker Brigade Combat Team, or a humanitarian assistance disaster relief supplies from ship to shore. The numerical estimates that are reflected on these graphs are in Appendix M Tables of Estimated Operating Costs by Cargo Equipment Type.

Table 5. Hourly Operating Costs of Lighterage.

US Army Causeway Ferry	US Army Landing Craft Utility 2000 Series	Logistics Support Vessel	US Navy Landing Craft Utility 1600 Series
$376.46	$654.08	$1,214.91	$712.30

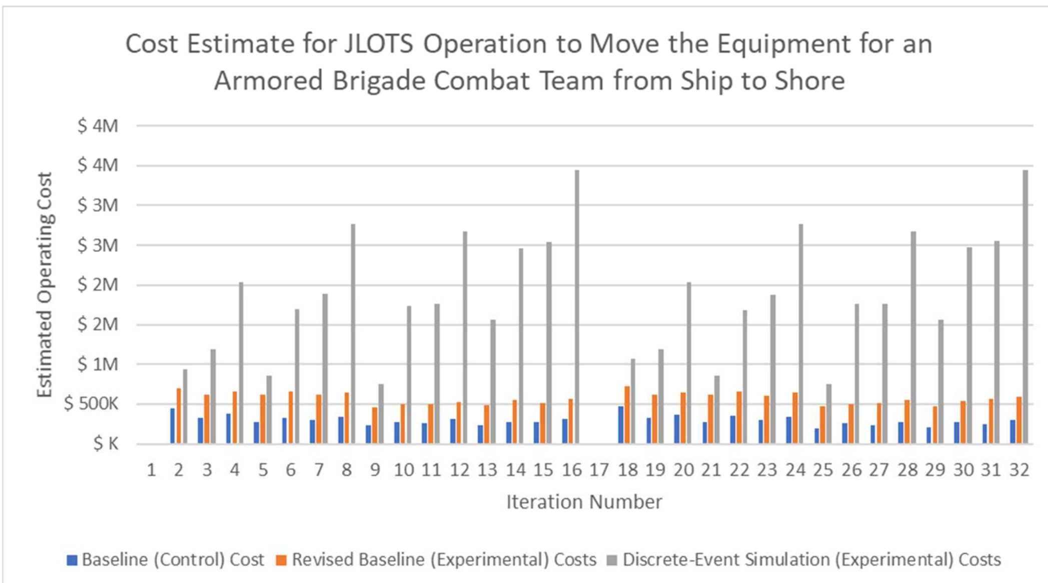

Figure 50. Cost Estimate for JLOTS Operation to Move the Equipment for an Armored Brigade Combat Team from Ship to Shore.

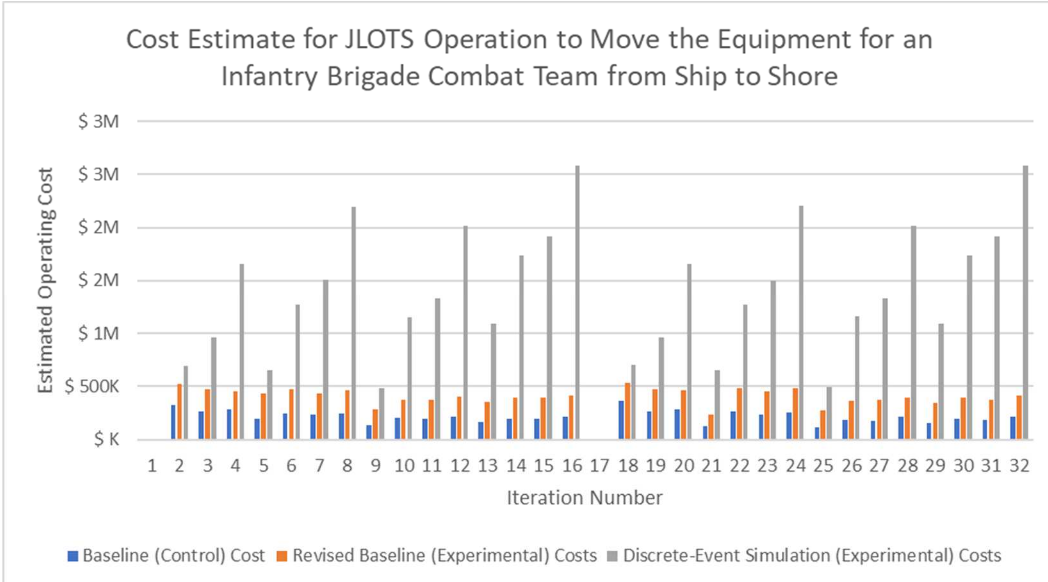

Figure 51. Cost Estimate for JLOTS Operation to Move the Equipment for an Infantry Brigade Combat Team from Ship to Shore.

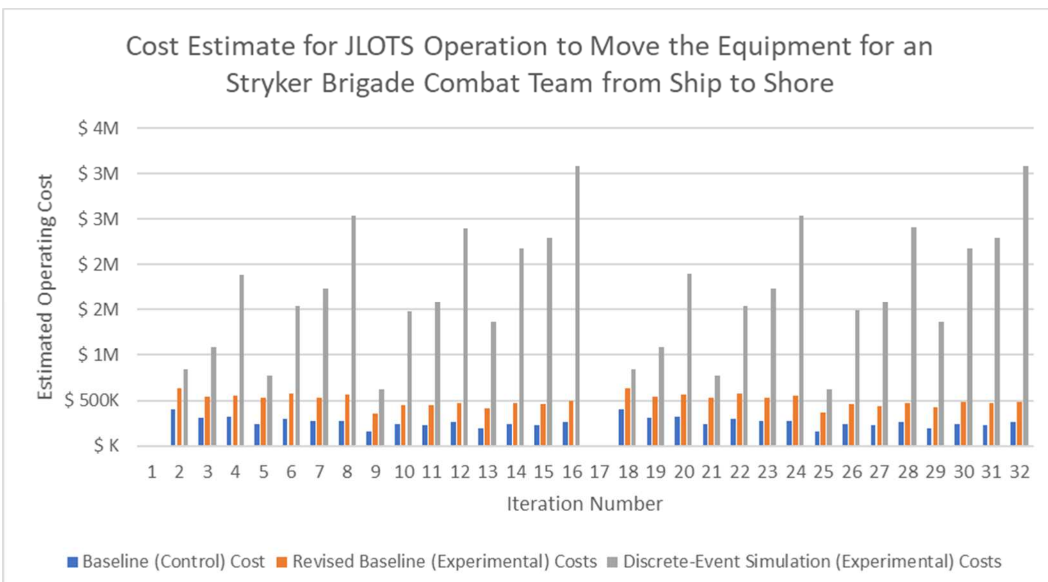

Figure 52. Cost Estimate for JLOTS Operation to Move the Equipment for a Stryker Brigade Combat Team from Ship to Shore.

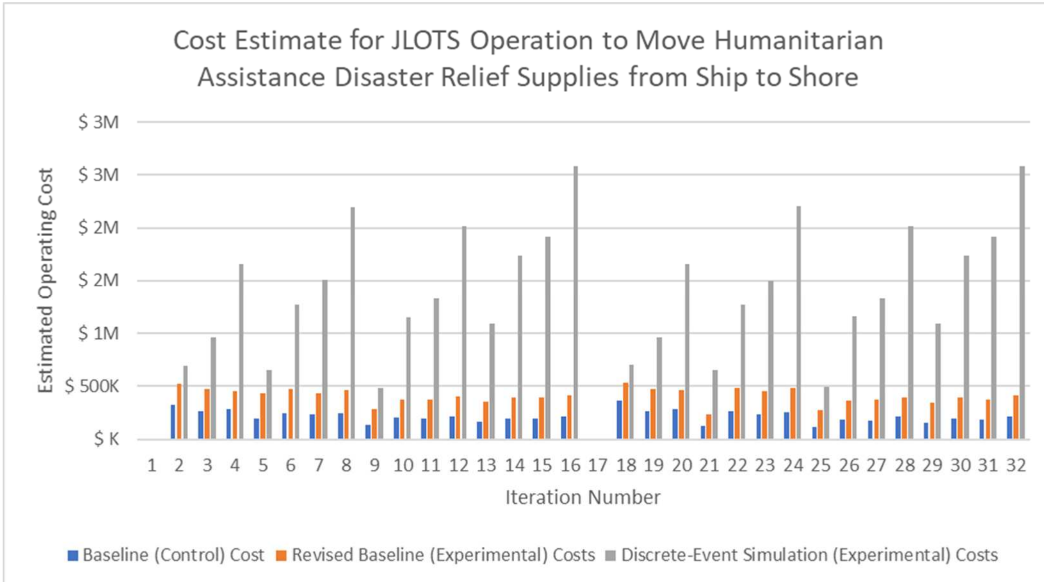

Figure 53. Cost Estimate for JLOTS Operation to Move the Equipment for a Humanitarian Assistance Disaster Relief Effort from Ship to Shore.

CHAPTER 5. DISCUSSION

This chapter presents analysis of the results depicted in Chapter 4. The first section summarizes the findings of this research. The second section discusses the conclusions drawn as a result of this research. The last section describes recommendations for future research that could lead to even greater fidelity for estimating the duration of JLOTS operations.

5.1. Research Summary

The goal of this research is to improve the methodology used to estimate throughput and duration for a JLOTS operation; while there remain areas that can be improved upon by other analytical projects, this research has shed light on assumptions that have been accepted for more than 25 years since the last exhaustive study of JLOTS took place. Interviews with JLOTS subject matter experts from different echelons of organizations from both the US Army and US Navy were used to determine that most of the planning factors that appear in published military doctrine for JLOTS are greatly underestimating the amount of time that an operation requires. Leveraging those interviews, new average values for planning factors were calculated, in addition to defining 106 probability distributions for nearly every lighterage cargo combination that could occur during a JLOTS operation. A subset of the newly determined probability distributions was statistically compared to actual observations that the researcher was able to collect at a JLOTS exercise in Pohang, South Korea in April 2017; a majority of those statistical comparisons were rejected by the test. The probability distributions were used to create the first known published discrete-event simulation of a JLOTS operation. All three of the models were run 128 times and the estimated duration compared to the other two. None of the comparisons returned values similar to each other for each iteration. Additionally, the discrete-event simulation can provide insights to senior leaders of both the US Army and US Navy that are considering the retirement of a lighterage type or the fielding of a new type of lighterage to estimate how that change effects the expected duration of a JLOTS operation.

5.2. Research Conclusions

This section is broken down into four parts, each of which represent one of the four research questions described in section 1.2.1 Research Questions.

5.2.1. Research Question One Conclusions

The first part of research question one asked: Do the median times for JLOTS activities recorded during the Ocean Venture 93 exercise and published in military doctrine still represent the present-day equipment of the US Army? Figure 25 Rejections and Failures to Reject for a Comparison of Published Median Values to Subject Matter Expert Opinions Using Student's *t*-Test at 0.05 Level of Significance in section 4.1 Results for the Comparison of Published Median Values to Subject Matter Expert Opinions shows the percentage of the 86 historical median values that were tried against the test means calculated from subject matter expert interviews. The *t*-test was preformed multiple times for each pair of means with the number of observed values for the historical mean incrementally increased to perform sensitivity analysis. This was necessary because the technical report for Ocean Venture 93 does not include the number of observations used to determine the median value published there and in current military doctrine. Even assuming the worst that only a single observation was used to determine a median value over 65%, or 56 out of 86 pairs, are rejected by the *t*-test at 0.05 level of significance. As the number of observations increases, the percentage of rejected pairs increases with 94%, or 81 out of 86 pairs, being rejected after only increasing the number of observations to seven. With an overwhelming majority of pairs being rejected by the *t*-test at a very conservative estimate of the historical quantity of observations it is the conclusion of this research that the median times for JLOTS activities recorded during the Ocean Venture 93 exercise and published in military doctrine are not representative of the present-day equipment of the US Army.

The second part of research question one asked: If the median times are no longer representative of present-day equipment what value is representative and can that value be defined as a probability distribution for use in a discrete-event simulation? As discussed in the first part of the question, the median times are no longer representative of present-day equipment of the US Army. All 106 of the theoretical triangular distributions created by this research are shown in Appendices G through J. Each appendix presents the distributions for a specific type of lighterage used in this research. Appendix G represents the US Army causeway ferry, Appendix H the US Army Landing Craft Utility 2000 Series vessel, Appendix I the US Army Logistics Support Vessel, and Appendix J the US Navy Landing Craft Utility 1600 Series vessel. These 106 distributions show that the subject matter expert opinions can be transformed into probability distributions for use in a discrete-event simulation. While they are not as representative of JLOTS activities as a time and motion study that derived a probability distribution from the data collected, these distributions can serve as a stopgap for military and humanitarian aid planners until a large scale JLOTS exercise can be orchestrated to capture the raw data required.

5.2.2. Research Question Two Conclusions

Research question two asked: Are the parameters for the proposed probability distribution valid for the JLOTS activity they are intended to describe? The results shown in Table 3 Probability Distribution Validation Goodness of Fit Test Results shows that only two of the ten activities tested failed to be rejected by the Kolmogorov-Smirnov goodness of fit test at a 0.05 level of significance. Other JLOTS activity distributions were not tested because only certain types of lighterage and cargo were being utilized during the exercise in Pohang, South Korea. Because a majority of the distributions were rejected it is the conclusion of this research that while subject matter expert opinions are an indicator that the currently published planning factors in military doctrine may not be representative of present-day equipment, actual repetitive observations of a JLOTS activity, such as a time and motion study, would better inform a probability distribution to use in discrete-event simulation models of JLOTS operations.

5.2.2.1. Additional Analysis for Alternative Probability Distributions Conclusions

As additional analysis during the course of this research, the sample data points collected during the JLOTS operation in Pohang, South Korea were entered into Arena's Input Analyzer tool as described in section 3.3.3 Probability Distribution Validation and Additional Analysis. Table 4 Additional Analysis for Alternative Probability Distribution Goodness of Fit Test Results in section 4.3.1 Additional Analysis for Alternative Probability Distributions shows that of the 60 distributions tested only two were rejected by a Kolmogorov-Smirnov test for goodness of fit at a 0.05 level of significance. Due to the observed data failing to be rejected by most of the probability distributions, it is the conclusion of this research that the sample data points collected are insufficient to determine the probability distributions that each activity should be modelled as the triangular distributions defined by the subject matter experts per section 5.2.1 Research Question One Conclusions and serves to reinforce the assertion in section 5.2.2 Research Question Two Conclusions that a time and motion study should be conducted to better inform a probability distribution to use in discrete-event simulation models of JLOTS operations.

5.2.3. Research Question Three Conclusions

The first part of research question three asked: Is the calculated duration for the baseline (control) method that uses the currently published median values return similar to the revised baseline (experimental) method that substitutes subject matter expert derived average values for the medians? Figures 38 through 41 in section 4.5.1 Baseline (Control) Model Results and Revised Baseline (Experimental) Model Results Comparison graphically compare the baseline (control) model with the revised baseline (experimental) model and show the percent change between the two from the former to the latter for each iteration. The minimum percent change between the 120 comparisons was 46.75%, the maximum was 146.31%, and the average percent was 91.91%; thus it is the conclusion of this research that the baseline (control) model's values are not similar to the revised baseline (experimental) method's values for the expected duration of a JLOTS operation given the same set of variables. This is understandable because 82 out of the 86 activities had longer expected durations from the subject matter expert opinions collected.

The second part of research question three asked: Is the calculated duration for the baseline (control) method that uses the currently published median values statistically similar to the expected value of the discrete-event simulation (experimental) method that leverages probability distributions defined by subject matter experts? Figures 42 through 45 in section 4.5.2.1 Baseline (Control) Model Results and Discrete-Event Simulation (Experimental) Model Results Comparison by Percent Change graphically compare the baseline (control) model with the revised baseline (experimental) model and show the percent change between the two from the former to the latter for each iteration. The minimum percent change between the 120 comparisons was 91.86%, the maximum was 1,448.32%, and the average percent change was 609.32%. Additionally, the baseline (control) model's estimate was compared to the output of the discrete-event simulation (experimental) model by applying Student's one sample *t*-test with all 120 of the baseline estimates being rejected by the test at the 0.05 level of significance. These results appear in Appendix K Table of One Sample Student's *t*-Test Comparison of Discrete-Event Simulation (Experimental) Model Results to Baseline (Control) Model Results by Iteration. Therefore, it is the conclusion of this research that the baseline (control) method's values are not statistically similar to the discrete-event simulation (experimental) model's values for the expected duration of a JLOTS operation given the same set of variables.

The third part of research question three asked: Is the calculated duration for the revised baseline (experimental) method that substitutes subject matter expert derived average values for the medians statistically similar to the expected value of the discrete-event simulation (experimental) method that leverages probability distributions defined by subject matter experts? Figures 46 through 49 in section 4.5.3.1 Revised Baseline (Experimental) Model Results and Discrete-Event Simulation (Experimental) Model Results Comparison by Percent Change graphically compare the baseline (control) model with the revised baseline (experimental) model and show the percent change between the two from the former to the latter for each iteration. The minimum percent change between the 120 comparisons was 30.74%, the maximum was 744.30%, and the average percent was 270.60%. Additionally, the revised baseline (experimental) model's estimate was compared to the output of the discrete-event simulation (experimental) model by applying Student's one sample *t*-test with all 120 of the baseline estimates being rejected by the test at the 0.05 level of significance. These results appear in Appendix L Table of One Sample Student's *t*-Test Comparison of Discrete-Event Simulation (Experimental) Model Results to Revised Baseline (Experimental) Model Results by Iteration. Therefore, it is the conclusion of this research that the revised baseline (experimental) method's values are not statistically similar to the discrete-event simulation (experimental) model's values for the expected duration of a JLOTS operation given the same set of variables.

5.2.4. Research Question Four Conclusions

Research question four asked: How do the different sets of lighterage compare to each other from a fiscal perspective? Table 5 Historical Hourly Operating Costs of Lighterage displays the hourly costs associated with each type of lighterage. Cost typically increases as the size of the vessel becomes larger with the exception of the costs for the Landing Craft Utility Series. The US Navy's LCU-1600 has performance engines that consume more fuel but allow it to be more maneuverable because it can be employed in amphibious assaults onto a contested beach. The US Army's LCU-2000 has less responsive but more fuel-efficient engines that reduce cost. Figures 50 through 53 in section 4.6 JLOTS Operational Cost Estimates show how the different models of determining the duration of a JLOTS operation compare from a cost perspective, comparing only the operational costs of the lighterage used in each iteration. Not captured in those costs are transport costs associated with relocating the lighterage from their point of origin to the location of the JLOTS operation, the cost of the cargo vessel being discharged, and the cost for the soldiers from the brigade combat team driving the equipment that is being unloaded. While this research shows that comparing different courses of action for a JLOTS operation could be done using cost as a discriminator, other factors such as the mission, environmental factors, time, equipment, and units available will probably be weighted more by military commanders in a real situation.

5.3. Further Research

This section discusses some specific avenues for future research to improving the methodology for estimating the duration of a JLOTS operation that the researcher revealed during this research.

5.3.1. Time and Motion Study for JLOTS Activities

The greatest improvement in the fidelity of the discrete-event simulation built for this research would be to replace the triangular distributions defined through interviews with subject matter experts with distributions fitted against data recorded during an actual JLOTS operation. This collection occurred during Ocean Venture 93 but the raw data that defined the median points published in military doctrine has been misplaced during the intervening 25 years. These distributions would increase the accuracy of the model and provide senior military leaders with greater understanding of the time required to conduct a deployment to an unimproved beach via JLOTS. While the cost for doing a time and motion study for a JLOTS operation carries a rather hefty price tag, the benefits of conducting one would be long lasting. Even if in another 25 years the US Army rolling stock inventory experiences another turnover, if the data collected is properly categorized and codified for future use, then models could be developed to provide insights into the best distribution to reflect activity times for new types of military equipment.

5.3.2. Learning Curves

During the subject matter interviews and visits to JLOTS exercises, a comment was often repeated regarding the less-than-adequate frequency of JLOTS exercises or JLOTS operations for soldiers and sailors to maintain proficiency in the skills to conduct JLOTS operations. At the beginning of every JLOTS operation there may be a learning period that occurs when the service members get accustom to their roles and functions by either doing them for the first time or relearning tactics, techniques, or procedures that have not been exercised since the last JLOTS operation. Proving this learning exists may take a number of data collection events over numerous JLOTS operations to accomplish but could lead to the application of learning curves to the JLOTS activity times as described by Wright in his seminal work on the subject (Wright, 1936).

5.3.3. Activity Duration Probability Distribution Definitions by Group Consensus

This research developed the JLOTS activity duration probability distribution by independently interviewing subject matter experts for their opinions and then taking the mathematical average to determine a generalized distribution based on all their opinions. An alternative way of defining these distributions could be to take a Delphi Method approach that allows the participants to view the opinions of other subject matter experts while not attributing the opinion to a specific person in an attempt to remove any bias that a participant might have toward another participant (Dalkey & Helmer, 1963). This could create distributions with greater fidelity at a fraction of the cost of a time in motion study.

5.3.4. Alternative Activity Duration Probability Distribution Definition

The method of defining the probability distribution for a specific JLOTS activity for this research uses the average of the best-case or worst-case times provided by the subject matter experts. This means that any extreme outlier's influence is reduced according to how many subject matter experts provided an opinion. An alternate method for defining the best-case and worst-case values for the triangular distribution would be to simply use the lowest value of any subject matter expert's opinion for the best-case time and the highest value of any subject matter expert's opinion for the worst-case time. Figure 54 shows what this method would look like if it were applied to the subject matter expert opinions for a causeway ferry to approach and moor to a US Army roll-on/roll-off discharge facility. For comparison to the current method, see Figure G1 in Appendix G.

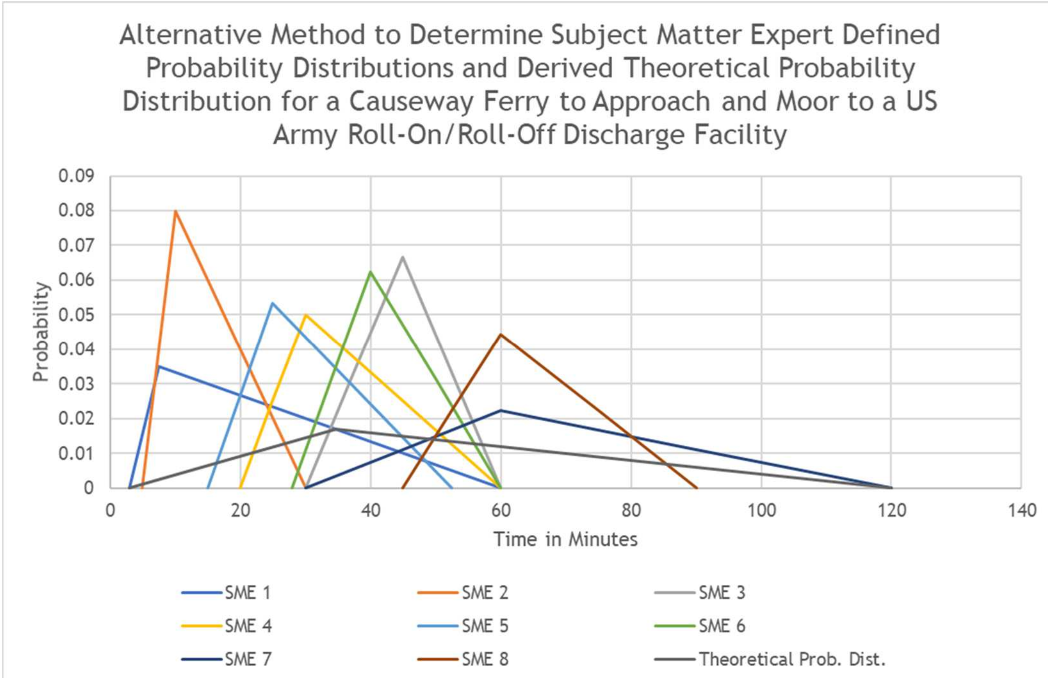

Figure 54. Alternative Method to Determine Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Causeway Ferry to Approach and Moor to a US Army Roll-On/Roll-Off Discharge Facility.

5.3.5. Reduction in Cargo Throughput Due to Maintenance Problems and Sea State Changes

The discrete-event simulation developed by this research does not model the reduction in cargo throughput that occurs either because of a lighterage becoming non-mission capable due to an unscheduled maintenance problem or during periods of increased wave actions due to weather conditions or tidal patterns. These variables can dramatically increase the time it takes to complete a JLOTS operation depending on the severity and duration of either effect. By integrating both of these effects into the discrete-event simulation the value of the duration estimate provided will increase because planners could compare two different JLOTS locations with different expected sea state conditions to provide insights to senior leaders on the pros and cons for both sites.

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APPENDIX A. JLOTS SUBJECT MATTER EXPERT INTERVIEW TOOL

Interviewer ______________________ Location ________________ Time/Date ______________

Assume sea-state 0-1 conditions for all activities and all times should be described in minutes or fractions of minutes (decimal notation preferred) except question 1 which should be answered in full year increments.

1) How many years of personal experience do you have conducting JLOTS operations as a part of your military service? _________

2) Do you have any personal experience with JLOTS operations with the **Modular Causeway System ferry**?

Yes – follow-up with questions below, No – proceed to the next question.

a) In your experience, what is the average (most likely) amount of time it takes for the **Modular Causeway System ferry** to **approach and moor** to a **US Army Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

b) In your experience, what is the average (most likely) amount of time it takes for the **Modular Causeway System ferry** to **approach and moor** to a **US Navy Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

c) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **loaded and secured** onto the **Modular Causeway System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

d) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **loaded and secured** onto the **Modular Causeway System ferry** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

e) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **loaded and secured** onto the **Modular Causeway System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

f) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be loaded and secured onto the **Modular Causeway System ferry** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

g) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **loaded and secured** onto the **Modular Causeway System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

h) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **loaded and secured** onto the **Modular Causeway System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

i) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be loaded and secured onto the **Modular Causeway System ferry** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

j) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **loaded and secured** onto the **Modular Causeway System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

k) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **loaded and secured** onto the **Modular Causeway System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

l) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be loaded and secured onto the **Modular Causeway System ferry** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

m) In your experience, what is the average (most likely) amount of time it takes for the **Modular Causeway System ferry** to **castoff and clear** from a **US Army Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

n) In your experience, what is the average (most likely) amount of time it takes for the **Modular Causeway System ferry** to **castoff and clear** from a **US Navy Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

o) In your experience, what is the average (most likely) amount of time it takes for the **Modular Causeway System ferry** to **approach and moor** to a **US Army Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

p) In your experience, what is the average (most likely) amount of time it takes for the **Modular Causeway System ferry** to **approach and moor** to an **Improved Navy Lighterage System Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

q) In your experience, what is the average (most likely) amount of time it takes for the **Modular Causeway System ferry** to **approach and anchor** at a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

r) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **unsecured and unloaded** from the **Modular Causeway System ferry** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

s) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **unsecured and unloaded** from the **Modular Causeway System ferry** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

t) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **unsecured and unloaded** from the **Modular Causeway System ferry** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

u) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **unsecured and unloaded** onto the **Modular Causeway System ferry** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

v) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **unsecured and unloaded** onto the **Modular Causeway System ferry** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

w) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **unsecured and unloaded** onto the **Modular**

Causeway System ferry during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

x) In your experience, what is the average (most likely) amount of time it takes for the **Modular Causeway System ferry** to **castoff and clear** from a **US Army Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

y) In your experience, what is the average (most likely) amount of time it takes for the **Modular Causeway System ferry** to **castoff and clear** from an **Improved Navy Lighterage System Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

z) In your experience, what is the average (most likely) amount of time it takes for the **Modular Causeway System ferry** to **castoff and clear** from a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

3) Do you have any personal experience with JLOTS operations with the **Landing Craft, Utility 2000 Series** vessel?

Yes – follow-up with questions below, No – proceed to the next question.

a) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **approach and moor** to a **US Army Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

b) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **approach and moor** to a **US Navy Roll-On/Roll-Off Discharge Facility without a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

c) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **approach and moor** to a **US Navy Roll-On/Roll-Off Discharge Facility with a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

d) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **loaded and secured** onto the **Landing Craft, Utility 2000 Series** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

e) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **loaded and secured** onto the **Landing Craft, Utility 2000 Series** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

f) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **loaded and secured** onto the **Landing Craft, Utility 2000 Series** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

g) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be loaded and secured onto the **Landing Craft, Utility 2000 Series** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

h) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **loaded and secured** onto the **Landing Craft, Utility 2000 Series** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

i) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **loaded and secured** onto the **Landing Craft, Utility 2000 Series** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

j) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be loaded and secured onto the **Landing Craft, Utility 2000 Series** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

k) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **loaded and secured** onto the **Landing Craft, Utility 2000 Series** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

l) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **loaded and secured** onto the **Landing Craft, Utility 2000 Series** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

m) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be loaded and secured onto the **Landing Craft, Utility 2000 Series** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

n) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **castoff and clear** from a **US Army Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

o) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **castoff and clear** from a **US Navy Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

p) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **approach and moor** to a **US Army Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

q) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **approach and moor** to an **Improved Navy Lighterage System Causeway Pier without a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

r) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **approach and moor** to an **Improved Navy Lighterage System Causeway Pier with a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

s) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **approach and anchor** at a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

t) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **unsecured and unloaded** from the **Landing Craft, Utility 2000 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

u) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **unsecured and unloaded** from the **Landing Craft, Utility 2000 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

v) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **unsecured and unloaded** from the **Landing Craft, Utility 2000 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

w) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **unsecured and unloaded** onto the **Landing Craft, Utility 2000 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

x) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **unsecured and unloaded** onto the **Landing Craft, Utility 2000 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

y) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **unsecured and unloaded** onto the **Landing Craft, Utility 2000 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

z) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **castoff and clear** from a **US Army Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

aa) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **castoff and clear** from an **Improved Navy Lighterage System Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

bb) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 2000 Series** to **castoff and clear** from a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

4) Do you have any personal experience with JLOTS operations with the **Logistics Support Vessel** vessel?

Yes – follow-up with questions below, No – proceed to the next question.

a) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **approach and moor** to a **US Army Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

b) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **approach and moor** to a **US Navy Roll-On/Roll-Off Discharge Facility without a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

c) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **approach and moor** to a **US Navy Roll-On/Roll-Off Discharge Facility with a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

d) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **loaded and secured** onto the **Logistics Support Vessel** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

e) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **loaded and secured** onto the **Logistics Support Vessel** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

f) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **loaded and secured** onto the **Logistics Support Vessel** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

g) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be loaded and secured onto the **Logistics Support Vessel** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

h) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **loaded and secured** onto the **Logistics Support Vessel** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

i) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **loaded and secured** onto the **Logistics Support Vessel** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

j) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be loaded and secured onto the **Logistics Support Vessel** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

k) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **loaded and secured** onto the **Logistics Support Vessel** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

l) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **loaded and secured** onto the **Logistics Support Vessel** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

m) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be loaded and secured onto the **Logistics Support Vessel** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

n) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **castoff and clear** from a **US Army Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

o) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **castoff and clear** from a **US Navy Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

p) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **approach and moor** to a **US Army Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

q) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **approach and moor** to an **Improved Navy Lighterage System Causeway Pier without a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

r) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **approach and moor** to an **Improved Navy Lighterage System Causeway Pier with a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

s) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **approach and anchor** at a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

t) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **unsecured and unloaded** from the **Logistics Support Vessel** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

u) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **unsecured and unloaded** from the **Logistics Support Vessel** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

v) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **unsecured and unloaded** from the **Logistics Support Vessel** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

w) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **unsecured and unloaded** onto the **Logistics Support Vessel** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

x) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **unsecured and unloaded** onto the **Logistics Support Vessel** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

y) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **unsecured and unloaded** onto the **Logistics Support Vessel** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

z) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **castoff and clear** from a **US Army Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

aa) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **castoff and clear** from an **Improved Navy Lighterage System Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

bb) In your experience, what is the average (most likely) amount of time it takes for the **Logistics Support Vessel** to **castoff and clear** from a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

5) Do you have any personal experience with JLOTS operations with the **Improved Navy Lighterage System ferry**?

Yes – follow-up with questions below, No – proceed to the next question.

a) In your experience, what is the average (most likely) amount of time it takes for the **Improved Navy Lighterage System ferry** to **approach and moor** to a **US Army Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

b) In your experience, what is the average (most likely) amount of time it takes for the **Improved Navy Lighterage System ferry** to **approach and moor** to a **US Navy Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

c) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **loaded and secured** onto the **Improved Navy Lighterage System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

d) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **loaded and secured** onto the **Improved Navy Lighterage System ferry** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

e) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **loaded and secured** onto the **Improved Navy Lighterage System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

f) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be loaded and secured onto the **Improved Navy Lighterage System ferry** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

g) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **loaded and secured** onto the **Improved Navy Lighterage System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

h) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **loaded and secured** onto the **Improved Navy Lighterage System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

i) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be loaded and secured onto the **Improved Navy Lighterage System ferry** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

j) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **loaded and secured** onto the **Improved Navy Lighterage System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

k) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **loaded and secured** onto the **Improved Navy Lighterage System ferry** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

l) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be loaded and secured onto the **Improved Navy Lighterage System ferry** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

m) In your experience, what is the average (most likely) amount of time it takes for the **Improved Navy Lighterage System ferry** to **castoff and clear** from a **US Army Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

n) In your experience, what is the average (most likely) amount of time it takes for the **Improved Navy Lighterage System ferry** to **castoff and clear** from a **US Navy Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

o) In your experience, what is the average (most likely) amount of time it takes for the **Improved Navy Lighterage System ferry** to **approach and moor** to a **US Army Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

p) In your experience, what is the average (most likely) amount of time it takes for the **Improved Navy Lighterage System ferry** to **approach and moor** to an **Improved Navy Lighterage System Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

q) In your experience, what is the average (most likely) amount of time it takes for the **Improved Navy Lighterage System ferry** to **approach and anchor** at a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

r) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **unsecured and unloaded** from the **Improved Navy Lighterage System ferry** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

s) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **unsecured and unloaded** from the **Improved Navy Lighterage System ferry** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

t) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **unsecured and unloaded** from the **Improved Navy Lighterage System ferry** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

u) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **unsecured and unloaded** onto the **Improved Navy Lighterage System ferry** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

v) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **unsecured and unloaded** onto the **Improved Navy Lighterage System ferry** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

w) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **unsecured and unloaded** onto the **Improved Navy Lighterage System ferry** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

x) In your experience, what is the average (most likely) amount of time it takes for the **Improved Navy Lighterage System ferry** to **castoff and clear** from a **US Army Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

y) In your experience, what is the average (most likely) amount of time it takes for the **Improved Navy Lighterage System ferry** to **castoff and clear** from an **Improved Navy Lighterage System Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

z) In your experience, what is the average (most likely) amount of time it takes for the **Improved Navy Lighterage System ferry** to **castoff and clear** from a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

6) Do you have any personal experience with JLOTS operations with the **Landing Craft, Utility 1600 Series** vessel?

Yes – follow-up with questions below, No – proceed to the next question.

a) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **approach and moor** to a **US Army Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

b) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **approach and moor** to a **US Navy Roll-On/Roll-Off Discharge Facility without a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

c) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **approach and moor** to a **US Navy Roll-On/Roll-Off Discharge Facility with a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

d) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **loaded and secured** onto the **Landing Craft, Utility 1600 Series** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

e) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **loaded and secured** onto the **Landing Craft, Utility 1600 Series** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

f) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **loaded and secured** onto the **Landing Craft, Utility 1600 Series** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

g) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be loaded and secured onto the **Landing Craft, Utility 1600 Series** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

h) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **loaded and secured** onto the **Landing Craft, Utility 1600 Series** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

i) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **loaded and secured** onto the **Landing Craft, Utility**

1600 Series during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

j) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be loaded and secured onto the **Landing Craft, Utility 1600 Series** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

k) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **loaded and secured** onto the **Landing Craft, Utility 1600 Series** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

l) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **loaded and secured** onto the **Landing Craft, Utility 1600 Series** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

m) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be loaded and secured onto the **Landing Craft, Utility 1600 Series** during **lift-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

n) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **castoff and clear** from a **US Army Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

o) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **castoff and clear** from a **US Navy Roll-On/Roll-Off Discharge Facility**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

p) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **approach and moor** to a **US Army Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

q) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **approach and moor** to an **Improved Navy Lighterage System Causeway Pier without a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

r) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **approach and moor** to an **Improved Navy Lighterage System Causeway Pier with a rhino horn connecter**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

s) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **approach and anchor** at a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

t) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **unsecured and unloaded** from the **Landing Craft, Utility 1600 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

u) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **unsecured and unloaded** from the **Landing Craft, Utility 1600 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

v) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **unsecured and unloaded** from the **Landing Craft, Utility 1600 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

w) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **unsecured and unloaded** onto the **Landing Craft, Utility 1600 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

x) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **unsecured and unloaded** onto the **Landing Craft, Utility 1600 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

y) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **unsecured and unloaded** onto the **Landing Craft, Utility 1600 Series** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

z) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **castoff and clear** from a **US Army Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

aa) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **castoff and clear** from an **Improved Navy Lighterage System Causeway Pier**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

bb) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Utility 1600 Series** to **castoff and clear** from a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

7) Do you have any personal experience with JLOTS operations with the **Landing Craft, Air Cushion** vessel?

Yes – follow-up with questions below, No – proceed to the next question.

a) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Air Cushion** to **approach and dock** on a **US Navy Mobile Landing Platform**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

b) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Air Cushion** to **approach and dock** on a **US Navy amphibious-well deck ship** (LHA, LHD, LSD, and LPD)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

c) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **loaded and secured** onto the **Landing Craft, Air Cushion** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

d) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **loaded and secured** onto the **Landing Craft, Air Cushion** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

e) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **loaded and secured** onto the **Landing Craft, Air Cushion** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

f) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **loaded and secured** onto the **Landing Craft, Air Cushion** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

g) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **loaded and secured** onto the **Landing Craft, Air Cushion** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

h) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **loaded and secured** onto the **Landing Craft, Air Cushion** during **roll-on operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

i) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Air Cushion** to **castoff and clear** from a **US Navy Mobile Landing Platform**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

j) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Air Cushion** to **castoff and clear** from a **US Navy amphibious-well deck ship** (LHA, LHD, LSD, and LPD)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

k) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Air Cushion** to **approach and land** at a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

l) In your experience, what is the average (most likely) amount of time it takes for a **container** to be **unsecured and unloaded** from the **Landing Craft, Air Cushion** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

m) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) to be **unsecured and unloaded** from the **Landing**

Craft, Air Cushion during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

n) In your experience, what is the average (most likely) amount of time it takes for a **light wheeled vehicle** (similar to a HMMWV) **with a trailer** to be **unsecured and unloaded** from the **Landing Craft, Air Cushion** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

o) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) to be **unsecured and unloaded** onto the **Landing Craft, Air Cushion** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

p) In your experience, what is the average (most likely) amount of time it takes for a **heavy wheeled vehicle** (similar to a PLS) **with a trailer** to be **unsecured and unloaded** onto the **Landing Craft, Air Cushion** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

q) In your experience, what is the average (most likely) amount of time it takes for a **tracked vehicle** (similar to an Abrams tank) to be **unsecured and unloaded** onto the **Landing Craft, Air Cushion** during **roll-off operations**? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

r) In your experience, what is the average (most likely) amount of time it takes for the **Landing Craft, Air Cushion** to **castoff and clear** from a **bare beach landing site** (splash zone)? What is the shortest (best case) time? What is the longest time (worst case)?

Average ________ Best ________ Worst ________

APPENDIX B. MATHEMATICAL FORMULATION OF NON-LINEAR PROGRAMS FOR BASELINE (CONTROL) AND REVISED BASELINE (EXPERIMENTAL) MODELS

Objective function:

$$Min: z = Max\left\{\frac{\sum_{k=1}^{6} Tt_{ik} + \sum_{j=1}^{6} Tu_{ij}L_{ij} + \sum_{j=1}^{6} Tl_{ij}L_{ij}}{A_i}\right\} \ \forall\, i$$

Subject to:

$$\sum_{j=1}^{6} L_{ij} \leq MA_i \ \forall\, i$$

$$\sum_{i=1}^{6} L_{ij} = l_j \ \forall\, j$$

$$L_{ij} \geq 0 \ and\ integer\ \forall\, i, j$$

Definitions:

i: type of lighterage being used.

j: the type of load being transported.

k: the step in the travel process.

L_{ij}: Lighterage i used to transport load j.

Tt_{ik}: Time required to complete step k for lighterage i.

Tl_{ij}: Time required to load load j on lighterage i.

Tu_{ij}: Time required to unload load j from lighterage i.

A_i: Available lighterage of type i.

l_j: Number of load i to be transported.

M: Arbitrarily large number (10,000) to ensure only available lighterage is used.

APPENDIX C. TABLE OF VARIABLE VALUES BY ITERATION

Iteration	BDE Type	RRDF Type	Causeway Pier Type	Causeway Ferries	LCU-2000	LSV	LCU-1600
1	ABCT	Army	Navy	0	0	0	0
2	ABCT	Army	Navy	0	0	0	3
3	ABCT	Army	Navy	0	0	2	0
4	ABCT	Army	Navy	0	0	2	3
5	ABCT	Army	Navy	0	3	0	0
6	ABCT	Army	Navy	0	3	0	3
7	ABCT	Army	Navy	0	3	2	0
8	ABCT	Army	Navy	0	3	2	3
9	ABCT	Army	Army	4	0	0	0
10	ABCT	Army	Army	4	0	0	3
11	ABCT	Army	Army	4	0	2	0
12	ABCT	Army	Army	4	0	2	3
13	ABCT	Army	Army	4	3	0	0
14	ABCT	Army	Army	4	3	0	3
15	ABCT	Army	Army	4	3	2	0
16	ABCT	Army	Army	4	3	2	3
17	ABCT	Navy	Navy	0	0	0	0
18	ABCT	Navy	Navy	0	0	0	3
19	ABCT	Navy	Navy	0	0	2	0
20	ABCT	Navy	Navy	0	0	2	3
21	ABCT	Navy	Navy	0	3	0	0
22	ABCT	Navy	Navy	0	3	0	3
23	ABCT	Navy	Navy	0	3	2	0
24	ABCT	Navy	Navy	0	3	2	3
25	ABCT	Navy	Army	4	0	0	0
26	ABCT	Navy	Army	4	0	0	3
27	ABCT	Navy	Army	4	0	2	0
28	ABCT	Navy	Army	4	0	2	3
29	ABCT	Navy	Army	4	3	0	0
30	ABCT	Navy	Army	4	3	0	3
31	ABCT	Navy	Army	4	3	2	0
32	ABCT	Navy	Army	4	3	2	3
33	IBCT	Army	Navy	0	0	0	0
34	IBCT	Army	Navy	0	0	0	3
35	IBCT	Army	Navy	0	0	2	0
36	IBCT	Army	Navy	0	0	2	3
37	IBCT	Army	Navy	0	3	0	0
38	IBCT	Army	Navy	0	3	0	3
39	IBCT	Army	Navy	0	3	2	0
40	IBCT	Army	Navy	0	3	2	3
41	IBCT	Army	Army	4	0	0	0

Iteration	BDE Type	RRDF Type	Causeway Pier Type	Causeway Ferries	LCU-2000	LSV	LCU-1600
42	IBCT	Army	Army	4	0	0	3
43	IBCT	Army	Army	4	0	2	0
44	IBCT	Army	Army	4	0	2	3
45	IBCT	Army	Army	4	3	0	0
46	IBCT	Army	Army	4	3	0	3
47	IBCT	Army	Army	4	3	2	0
48	IBCT	Army	Army	4	3	2	3
49	IBCT	Navy	Navy	0	0	0	0
50	IBCT	Navy	Navy	0	0	0	3
51	IBCT	Navy	Navy	0	0	2	0
52	IBCT	Navy	Navy	0	0	2	3
53	IBCT	Navy	Navy	0	3	0	0
54	IBCT	Navy	Navy	0	3	0	3
55	IBCT	Navy	Navy	0	3	2	0
56	IBCT	Navy	Navy	0	3	2	3
57	IBCT	Navy	Army	4	0	0	0
58	IBCT	Navy	Army	4	0	0	3
59	IBCT	Navy	Army	4	0	2	0
60	IBCT	Navy	Army	4	0	2	3
61	IBCT	Navy	Army	4	3	0	0
62	IBCT	Navy	Army	4	3	0	3
63	IBCT	Navy	Army	4	3	2	0
64	IBCT	Navy	Army	4	3	2	3
65	SBCT	Army	Navy	0	0	0	0
66	SBCT	Army	Navy	0	0	0	3
67	SBCT	Army	Navy	0	0	2	0
68	SBCT	Army	Navy	0	0	2	3
69	SBCT	Army	Navy	0	3	0	0
70	SBCT	Army	Navy	0	3	0	3
71	SBCT	Army	Navy	0	3	2	0
72	SBCT	Army	Navy	0	3	2	3
73	SBCT	Army	Army	4	0	0	0
74	SBCT	Army	Army	4	0	0	3
75	SBCT	Army	Army	4	0	2	0
76	SBCT	Army	Army	4	0	2	3
77	SBCT	Army	Army	4	3	0	0
78	SBCT	Army	Army	4	3	0	3
79	SBCT	Army	Army	4	3	2	0
80	SBCT	Army	Army	4	3	2	3
81	SBCT	Navy	Navy	0	0	0	0
82	SBCT	Navy	Navy	0	0	0	3
83	SBCT	Navy	Navy	0	0	2	0
84	SBCT	Navy	Navy	0	0	2	3
85	SBCT	Navy	Navy	0	3	0	0

Iteration	BDE Type	RRDF Type	Causeway Pier Type	Causeway Ferries	LCU-2000	LSV	LCU-1600
86	SBCT	Navy	Navy	0	3	0	3
87	SBCT	Navy	Navy	0	3	2	0
88	SBCT	Navy	Navy	0	3	2	3
89	SBCT	Navy	Army	4	0	0	0
90	SBCT	Navy	Army	4	0	0	3
91	SBCT	Navy	Army	4	0	2	0
92	SBCT	Navy	Army	4	0	2	3
93	SBCT	Navy	Army	4	3	0	0
94	SBCT	Navy	Army	4	3	0	3
95	SBCT	Navy	Army	4	3	2	0
96	SBCT	Navy	Army	4	3	2	3
97	HADR	Army	Navy	0	0	0	0
98	HADR	Army	Navy	0	0	0	3
99	HADR	Army	Navy	0	0	2	0
100	HADR	Army	Navy	0	0	2	3
101	HADR	Army	Navy	0	3	0	0
102	HADR	Army	Navy	0	3	0	3
103	HADR	Army	Navy	0	3	2	0
104	HADR	Army	Navy	0	3	2	3
105	HADR	Army	Army	4	0	0	0
106	HADR	Army	Army	4	0	0	3
107	HADR	Army	Army	4	0	2	0
108	HADR	Army	Army	4	0	2	3
109	HADR	Army	Army	4	3	0	0
110	HADR	Army	Army	4	3	0	3
111	HADR	Army	Army	4	3	2	0
112	HADR	Army	Army	4	3	2	3
113	HADR	Navy	Navy	0	0	0	0
114	HADR	Navy	Navy	0	0	0	3
115	HADR	Navy	Navy	0	0	2	0
116	HADR	Navy	Navy	0	0	2	3
117	HADR	Navy	Navy	0	3	0	0
118	HADR	Navy	Navy	0	3	0	3
119	HADR	Navy	Navy	0	3	2	0
120	HADR	Navy	Navy	0	3	2	3
121	HADR	Navy	Army	4	0	0	0
122	HADR	Navy	Army	4	0	0	3
123	HADR	Navy	Army	4	0	2	0
124	HADR	Navy	Army	4	0	2	3
125	HADR	Navy	Army	4	3	0	0
126	HADR	Navy	Army	4	3	0	3
127	HADR	Navy	Army	4	3	2	0
128	HADR	Navy	Army	4	3	2	3

APPENDIX D. TABLE OF BASELINE (CONTROL) MODEL RESULTS BY ITERATION

Iteration	Expected Duration (Hours)	Container Load Portion	Rolling Stock Load Portion	Unload Portion
1				
2	208.842	0.10355	0.32966	0.09748
3	135.394	0.115	0.52363	0.25658
4	81.8555	0.22014	0.85949	0.34793
5	137.815	0.15542	0.54028	0.27399
6	81.2395	0.26557	0.89798	0.32636
7	68.4233	0.26857	1.06237	0.52951
8	51.6855	0.36499	1.38787	0.62664
9	152.033	0.20071	0.44805	0.19982
10	76.0455	0.32559	0.87609	0.27796
11	66.6271	0.3076	0.99908	0.48691
12	50.617	0.41787	1.38508	0.46047
13	67.7053	0.37072	1.03131	0.49099
14	49.7883	0.45446	1.38193	0.59913
15	47.4893	0.44738	1.50047	0.73303
16	38.2708	0.57096	1.84215	0.83534
17				
18	220.792	0.09794	0.31181	0.09221
19	135.394	0.115	0.52363	0.25658
20	79.0669	0.2735	0.8971	0.28023
21	141.765	0.15109	0.52523	0.26635
22	86.7007	0.2478	0.83347	0.3636
23	69.2682	0.26285	1.04815	0.52389
24	52.175	0.3871	1.37519	0.58094
25	129.616	0.23543	0.52554	0.23438
26	72.7054	0.35256	0.91898	0.30712
27	59.2921	0.31068	1.10041	0.55617
28	44.6753	0.54036	1.50281	0.53536
29	61.5869	0.42121	1.11534	0.51859
30	47.9946	0.48551	1.4456	0.53394
31	41.891	0.51353	1.63102	0.79084
32	37.5064	0.6684	1.88661	0.8205
33				
34	154.077	0.15252	0.33538	0.12321
35	108.25	0.1563	0.51368	0.26711
36	61.3597	0.34078	0.88111	0.36989
37	101.474	0.22938	0.56029	0.31979
38	60.8496	0.38408	0.89917	0.44004
39	52.6863	0.38275	1.06796	0.58342
40	38.2154	0.5714	1.44705	0.65245
41	87.0728	0.38084	0.55973	0.25046
42	55.699	0.52432	0.89471	0.37011
43	48.7122	0.52114	1.06129	0.51644
44	35.3436	0.7754	1.47769	0.55944
45	46.8929	0.6085	1.11994	0.57079

Iteration	Expected Duration (Hours)	Container Load Portion	Rolling Stock Load Portion	Unload Portion
46	35.4781	0.73019	1.47545	0.65613
47	32.9303	0.7538	1.62344	0.83473
48	27.2703	0.87947	1.94659	0.95678
49				
50	170.744	0.13763	0.30265	0.11118
51	109.617	0.15436	0.50728	0.26378
52	62.0043	0.37844	0.87907	0.29537
53	64.2363	0.36356	0.85159	0.43038
54	64.2363	0.36356	0.85159	0.43038
55	53.4268	0.37555	1.05316	0.57534
56	38.6569	0.58887	1.43956	0.54299
57	74.7728	0.44349	0.65181	0.29166
58	49.6837	0.48954	0.99224	0.35936
59	45.0157	0.59464	1.14698	0.54734
60	35.4574	0.75202	1.45635	0.65617
61	43.5917	0.67026	1.19888	0.60146
62	34.4578	0.81123	1.51177	0.71293
63	31.2635	0.81008	1.71137	0.85983
64	26.1851	0.97205	2.02097	0.97284
65				
66	189.255	0.12813	0.3197	0.11519
67	125.101	0.13957	0.52049	0.25492
68	70.0918	0.34598	0.90854	0.29926
69	120.018	0.20013	0.55469	0.30025
70	73.886	0.32616	0.86847	0.41908
71	61.4064	0.33884	1.07263	0.55336
72	42.7276	0.56635	1.51456	0.58383
73	104.838	0.3264	0.54424	0.23308
74	66.3385	0.38492	0.87366	0.3137
75	57.488	0.39538	1.04781	0.50912
76	44.0019	0.58101	1.37698	0.60557
77	56.2259	0.52538	1.09484	0.53075
78	42.9181	0.67775	1.43442	0.62053
79	39.0002	0.65486	1.60554	0.78193
80	32.3305	0.78224	1.92324	0.90997
81				
82	189.255	0.12813	0.3197	0.11519
83	125.101	0.13957	0.52049	0.25492
84	70.0918	0.34598	0.90854	0.29926
85	120.018	0.20013	0.55469	0.30025
86	73.886	0.32616	0.86847	0.41908
87	61.4064	0.33884	1.07263	0.55336
88	42.7276	0.56635	1.51456	0.58383
89	104.838	0.3264	0.54424	0.23308
90	66.3385	0.38492	0.87366	0.3137
91	57.488	0.39538	1.04781	0.50912
92	44.0019	0.58101	1.37698	0.60557
93	56.2259	0.52538	1.09484	0.53075
94	42.9181	0.67775	1.43442	0.62053
95	39.0002	0.65486	1.60554	0.78193

Iteration	Expected Duration (Hours)	Container Load Portion	Rolling Stock Load Portion	Unload Portion
96	32.3305	0.78224	1.92324	0.90997
97				
98	51.1734	1.22134	0	0.16284
99	63.7241	0.70617	0	0.58847
100	28.6221	1.91094	0	0.74564
101	50.5848	1.22378	0	0.74133
102	25.5928	2.43037	0	0.89999
103	28.3821	1.91786	0	1.32126
104	18.3169	3.12727	0	1.48042
105	39.8937	2.21073	0	0.52222
106	22.5163	3.41481	0	0.68099
107	24.5972	2.91122	0	1.10717
108	16.7321	4.10432	0	1.25856
109	22.4903	3.40945	0	1.25091
110	15.8078	4.56957	0	1.40068
111	16.6242	4.11611	0	1.84068
112	12.6382	5.29397	0	1.98801
113				
114	51.1734	1.22134	0	0.16284
115	63.7241	0.70617	0	0.58847
116	28.6221	1.91094	0	0.74564
117	50.5848	1.22378	0	0.74133
118	25.5928	2.43037	0	0.89999
119	28.3821	1.91786	0	1.32126
120	18.3169	3.12727	0	1.48042
121	39.8937	2.21073	0	0.52222
122	22.5163	3.41481	0	0.68099
123	24.5972	2.91122	0	1.10717
124	16.7321	4.10432	0	1.25856
125	22.4903	3.40945	0	1.25091
126	15.8078	4.56957	0	1.40068
127	16.6242	4.11611	0	1.84068
128	12.6382	5.29397	0	1.98801

APPENDIX E. TABLE OF REVISED BASELINE (EXPERIMENTAL) MODEL RESULTS BY ITERATION

Iteration	Expected Duration (Hours)	Container Load Portion	Rolling Stock Load Portion	Unload Portion
1				
2	327.4063432	0.123292	0.316123	0.335864
3	255.4581046	0.180591	0.581847	0.13599
4	142.9183508	0.307168	0.887803	0.477563
5	313.2000145	0.120336	0.526244	0.490537
6	160.2968323	0.243135	0.839247	0.826826
7	141.7822597	0.325382	1.039024	0.646894
8	98.16806144	0.426455	1.395	0.96744
9	301.8094184	0.197894	0.688112	0.544312
10	135.6427153	0.37432	1.024698	1.021423
11	127.8827532	0.413586	1.246198	0.807681
12	87.18543088	0.600554	1.574991	1.173176
13	139.3921142	0.304195	1.207037	1.131837
14	98.15818587	0.435255	1.577719	1.416911
15	87.90617344	0.566229	1.76199	1.298398
16	71.08114814	0.645071	2.125924	1.597051
17				
18	337.7630098	0.119512	0.30643	0.325566
19	256.6053252	0.179783	0.579246	0.135382
20	142.4015981	0.294941	0.881732	0.457462
21	313.2078566	0.120333	0.526231	0.490524
22	160.5112114	0.242425	0.840294	0.814662
23	138.2717718	0.299402	1.121022	0.63633
24	99.58914407	0.420657	1.400918	0.951889
25	310.0055121	0.192662	0.669919	0.529921
26	137.6816065	0.367964	1.002465	1.010589
27	130.4215129	0.400715	1.233204	0.784089
28	90.08296044	0.573942	1.564214	1.107808
29	138.1280198	0.310668	1.187378	1.150447
30	95.95321025	0.517874	1.503054	1.479231
31	96.55953766	0.491468	1.774084	1.171032
32	73.36686777	0.626012	2.106278	1.526136
33				
34	243.349619	0.180262	0.299655	0.372425
35	195.5705008	0.256344	0.549819	0.147849
36	100.1189476	0.438146	0.868675	0.535501
37	222.8621054	0.183778	0.525298	0.519067
38	115.7870405	0.365624	0.809428	0.901881
39	98.18695165	0.417134	1.102863	0.665297
40	70.77849006	0.616175	1.378316	1.049302
41	188.9983302	0.343415	0.658882	0.681193
42	101.4345523	0.489353	0.906851	0.369061
43	93.95612438	0.690799	1.220311	0.773082
44	66.17091134	0.785376	1.501798	1.241669
45	101.1947259	0.518025	1.196941	1.209902

Iteration	Expected Duration (Hours)	Container Load Portion	Rolling Stock Load Portion	Unload Portion
46	69.62087927	0.722655	1.50944	1.62905
47	66.3424718	0.78042	1.751649	1.345754
48	51.43032785	0.980615	2.042379	1.752616
49				
50	250.5718413	0.175066	0.291018	0.361691
51	194.3746674	0.257921	0.553201	0.148758
52	101.0477468	0.434118	0.87918	0.523859
53	118.2551872	0.360741	0.806459	0.871203
54	118.2551872	0.360741	0.806459	0.871203
55	102.958037	0.422456	1.06138	0.655619
56	73.86537003	0.618484	1.331405	1.040482
57	184.1701548	0.352417	0.676156	0.699051
58	99.7718548	0.55183	0.966272	1.092938
59	94.17779304	0.634944	1.221558	0.830891
60	64.33774768	0.968254	1.428733	1.267396
61	99.02127135	0.570561	1.190025	1.217743
62	69.57443845	0.720469	1.502475	1.629474
63	62.66496575	0.757562	1.76126	1.401687
64	51.34842287	1.001445	2.024241	1.777761
65				
66	299.0326565	0.151377	0.338494	0.320901
67	224.7852286	0.230146	0.550874	0.141875
68	120.4237143	0.375895	0.913808	0.478524
69	267.9984332	0.157703	0.531979	0.503241
70	141.1259656	0.30902	0.863092	0.827029
71	120.3915249	0.387951	1.083394	0.652761
72	86.76127224	0.540056	1.412081	0.967363
73	233.4770575	0.286864	0.691312	0.660802
74	122.9433223	0.468315	1.067001	0.967693
75	113.1485145	0.520408	1.209381	0.801069
76	78.60068707	0.707191	1.560952	1.148715
77	118.4916974	0.436237	1.201847	1.181178
78	84.15924794	0.614312	1.581238	1.526331
79	78.82788041	0.691621	1.733509	1.302068
80	61.80068131	0.845749	2.126197	1.669944
81				
82	297.6171009	0.152097	0.340104	0.322428
83	224.7130049	0.23022	0.551051	0.14192
84	122.5532999	0.377795	0.871152	0.460503
85	267.05019	0.158263	0.533868	0.505028
86	139.315602	0.314035	0.831642	0.855727
87	120.409413	0.387893	1.088047	0.65162
88	85.34110843	0.53335	1.395623	0.966971
89	240.2885679	0.278732	0.671715	0.64207
90	125.1012732	0.474549	1.035569	0.95045
91	111.9371115	0.55903	1.185726	0.769496
92	77.48165769	0.737748	1.537072	1.138513
93	123.9271044	0.41402	1.218702	1.164349
94	85.43311043	0.608594	1.581767	1.50899
95	80.84273897	0.662176	1.734287	1.276914

Iteration	Expected Duration (Hours)	Container Load Portion	Rolling Stock Load Portion	Unload Portion
96	59.9622136	0.871541	2.08381	1.655568
97				
98	99.55308212	1.171904	0	0.467367
99	112.4602574	1.185604	0	0.333451
100	53.08082235	2.344852	0	0.79695
101	83.31459437	1.307437	0	0.707302
102	45.68606043	2.461181	0	1.166628
103	48.52179534	2.459204	0	1.026343
104	32.5135961	3.644007	0	1.498281
105	82.8025054	2.084708	0	0.767388
106	44.44229535	3.29491	0	1.250592
107	48.33302737	3.23007	0	1.088369
108	31.83594663	4.486094	0	1.587304
109	41.58879797	3.384898	0	1.472395
110	29.07205612	4.585774	0	1.952214
111	30.43277062	4.558605	0	1.804534
112	23.12695896	5.767646	0	2.288425
113				
114	99.55308212	1.171904	0	0.467367
115	112.4602574	1.185604	0	0.333451
116	53.08082235	2.344852	0	0.79695
117	83.31459437	1.307437	0	0.707302
118	45.68606043	2.461181	0	1.166628
119	48.52179534	2.459204	0	1.026343
120	32.5135961	3.644007	0	1.498281
121	83.71359915	2.06202	0	0.759036
122	44.72192502	3.269303	0	1.241251
123	48.57387868	3.210819	0	1.080828
124	32.01932721	4.457948	0	1.576587
125	41.76633514	3.36441	0	1.465694
126	29.22324662	4.55769	0	1.941798
127	30.76932721	4.503635	0	1.78141
128	23.21833094	5.740129	0	2.277954

APPENDIX F. TABLE OF DISCRETE-EVENT SIMULATION (EXPERIMENTAL)

MODEL RESULTS BY ITERATION

Iteration	Expected Duration (Hours)	Half-Width	Minimum Duration	Maximum Duration
1				
2	438.62	3.26	437.86	607.42
3	489.96	0.84	479.8	499.67
4	446.93	3.91	434.39	632.06
5	436.51	0.49	430.9	443.5
6	411.54	0.71	402.54	422.68
7	429.48	0.93	416.44	443.59
8	424.17	0.85	413.36	434.92
9	497.37	0.55	491.81	503.07
10	474.76	0.88	465.15	487.42
11	446.57	0.86	435.48	457.46
12	439.81	0.88	429.36	449.52
13	448.99	0.75	440.68	457.12
14	440.38	0.94	430.69	450.55
15	431.41	0.78	422.97	444.51
16	428.64	1	415.71	440.97
17				
18	497.37	0.55	491.81	503.07
19	488.27	0.79	476.84	497.6
20	446.33	4.03	433.64	637.86
21	436.22	0.47	431.32	443.2
22	410.9	0.65	403.54	420
23	429.12	0.79	421.14	442.85
24	423.74	0.79	417.08	434.18
25	500.74	0.55	494.04	507.08
26	481.6	0.89	469.5	489.56
27	446.92	0.83	437.77	457.57
28	440.95	0.91	431.22	452.51
29	451.21	0.86	441.77	462.89
30	442.14	1.04	427.95	453.31
31	432.37	0.8	424.38	448.75
32	428.76	0.97	418.97	443.16
33				
34	324.37	0.47	319.23	331.76
35	394.74	0.74	384.1	403.05
36	363.32	3.15	345.38	509.89
37	333.01	0.41	327.15	338.87
38	310.82	0.54	303.31	318.3
39	342.55	0.82	331.16	352
40	336.81	0.92	325.8	348.27
41	324.03	0.4	318.53	329.3
42	317.06	0.61	307.6	322.81
43	337.61	0.7	326.27	347.71
44	332.09	0.8	321.88	340.32
45	313.93	0.46	308.04	320.27

Iteration	Expected Duration (Hours)	Half-Width	Minimum Duration	Maximum Duration
46	309.16	0.67	300.37	316.08
47	324.65	0.76	315.92	334.72
48	320.99	0.84	309.19	333.2
49				
50	327.59	4.35	316.6	435.29
51	394.11	0.86	381.61	402.93
52	361.97	0.97	347.36	371.84
53	332.84	0.39	328.22	339.11
54	310.62	0.52	302.81	317.82
55	342.21	0.71	331.78	349.8
56	336.95	1.02	323.72	349.51
57	325.04	0.41	318.97	330.27
58	319.43	0.7	311.42	327.09
59	337.16	0.66	325.96	346.03
60	331.84	0.82	321.02	340.93
61	314.78	0.46	309.47	320.17
62	309.45	0.77	301.86	318.84
63	324.86	0.7	316.01	334.69
64	321.59	0.83	311.65	331.31
65				
66	395.6	0.53	389.71	403.12
67	448.85	0.95	436.28	459.24
68	414.24	4.65	396.96	575.39
69	394.58	0.48	389.12	399.7
70	375.63	0.63	368.92	385.35
71	395.9	1.17	379.61	406.93
72	388.69	0.92	377.01	398.59
73	413.65	0.56	407.26	419.57
74	406.62	0.73	398.16	417.3
75	403.18	0.74	391.69	412.26
76	395.06	0.91	385.9	406.49
77	392.61	0.55	386.28	397.97
78	388.34	0.84	376.4	398.07
79	387.89	0.94	374.42	402.5
80	382.94	0.89	371.5	394.12
81				
82	394.2	0.47	388.01	399.73
83	447.97	0.89	434.32	456.35
84	414.9	4.86	396.35	582.5
85	394.21	0.52	387.69	400.87
86	374.65	0.56	368.13	382.87
87	396.23	0.92	379.25	404.25
88	387.85	1	378.09	408.97
89	414.39	0.57	407.23	421.69
90	410.1	0.82	397.76	419.68
91	403.74	0.71	394.52	411.97
92	396.35	0.79	381.45	406.66
93	393.09	0.65	385.63	399.31
94	388.97	0.96	375.43	401.55
95	388.68	0.83	376.33	399.6

Iteration	Expected Duration (Hours)	Half-Width	Minimum Duration	Maximum Duration
96	383.79	0.85	372.12	397.46
97				
98	196.64	0.45	189.67	200.85
99	188.33	0.33	183.31	191.74
100	243.74	9.69	190.86	299.5
101	141.03	0.21	137.89	143.08
102	167.62	3.97	145.25	192.08
103	164.53	4.5	138.79	189.15
104	173.53	0.54	164.93	179.35
105	252.16	0.7	242.31	263.18
106	245.36	0.65	238.59	255.6
107	217.21	2.13	202.87	255.58
108	221.87	0.86	211.62	232.58
109	195.8	2.22	179.45	229.86
110	206.13	0.8	185.62	215.54
111	195.14	0.75	188.49	207.5
112	195.26	0.86	185.66	205.61
113				
114	195.97	0.49	189.75	202.72
115	187.77	0.35	183.57	192.5
116	243.9	9.78	189.57	298.37
117	140.88	0.21	137.9	143.24
118	166.82	3.99	146.25	191.11
119	163.91	4.46	138.15	189.04
120	173.02	0.54	164.79	178.49
121	255.16	0.63	247.13	262.69
122	247.85	0.74	239.43	258.03
123	216.75	1.99	203.61	260.19
124	223.54	0.84	214.26	235.98
125	196.74	2.13	179.12	212.7
126	208.38	0.9	187.4	226.32
127	195.56	0.75	186.47	205.25
128	195.68	0.84	185.12	207

APPENDIX G. TABLES AND FIGURES OF SUBJECT MATTER EXPERT RESPONSES AND THEORETICAL PROBABILITY DISTRIBUTIONS FOR US ARMY CAUSEWAY FERRY / JLOTS ACTIVITY COMBINATIONS

Table G1. Interview Question 2a - Subject matter expert defined probability distributions and derived theoretical probability distribution for a causeway ferry to approach and moor to a US Army roll-on/roll-off discharge facility.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	3	7.5	60
SME Opinion 2	5	10	30
SME Opinion 3	30	45	60
SME Opinion 4	20	30	60
SME Opinion 5	15	25	52.5
SME Opinion 6	28	40	60
SME Opinion 7	30	60	120
SME Opinion 8	45	60	90
Theoretical	22	34.6875	66.5625

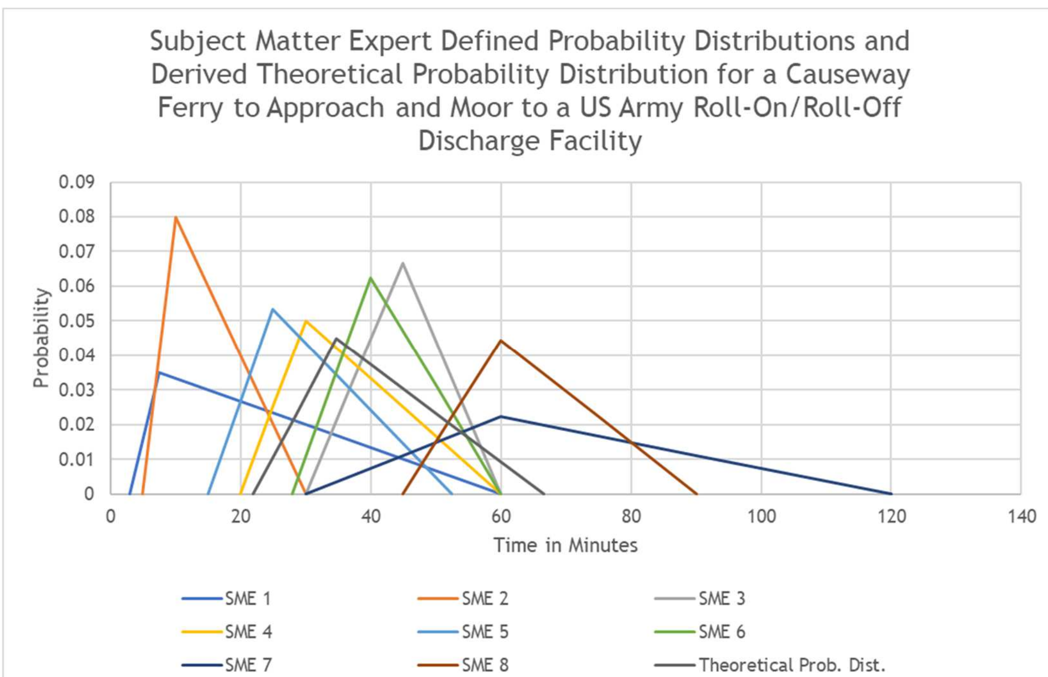

Figure G1. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Causeway Ferry to Approach and Moor to a US Army Roll-On/Roll-Off Discharge Facility.

Table G2. Interview Question 2b - Subject matter expert defined probability distributions and derived theoretical probability distribution for a causeway ferry to approach and moor to a US Navy roll-on/roll-off discharge facility.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	3	7.5	60
SME Opinion 2	5	10	30
SME Opinion 3	20	30	60
SME Opinion 4	30	40	60
SME Opinion 5	60	120	180
Theoretical	22	41.5	78

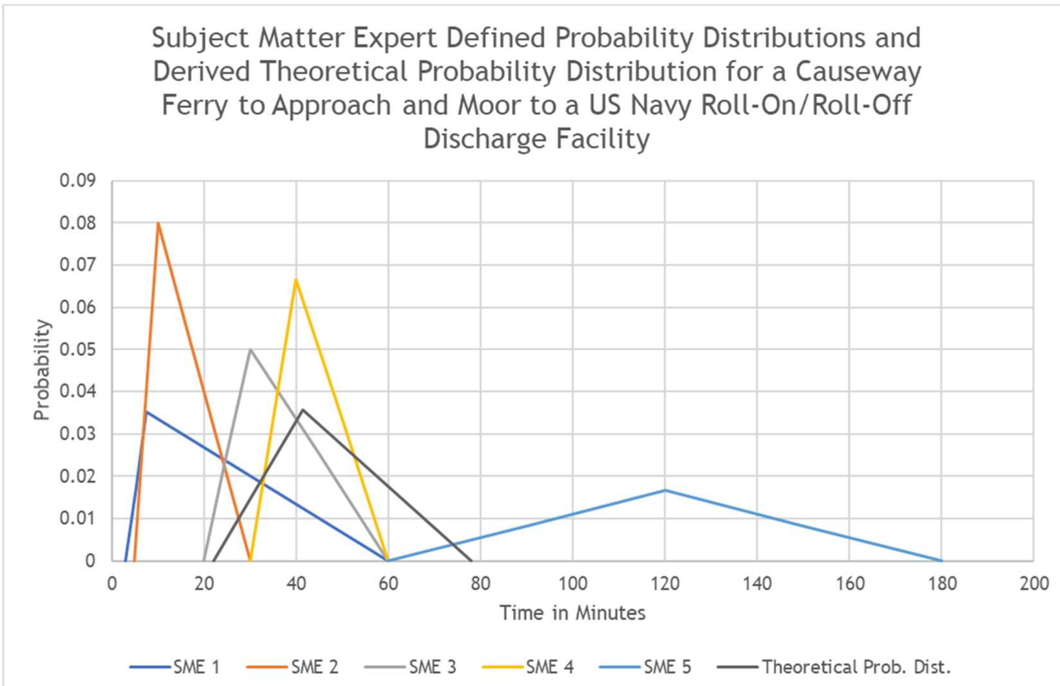

Figure G2. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Causeway Ferry to Approach and Moor to a US Navy Roll-On/Roll-Off Discharge Facility.

Table G3. Interview Question 2c - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be loaded and secured to a US Army causeway ferry during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	60
SME Opinion 2	10	20	30
SME Opinion 3	20	30	45
SME Opinion 4	15	20	60
SME Opinion 5	7	15	25
SME Opinion 6	10	20	40
SME Opinion 7	10	20	45
Theoretical	10.5	18.125	43.57142857

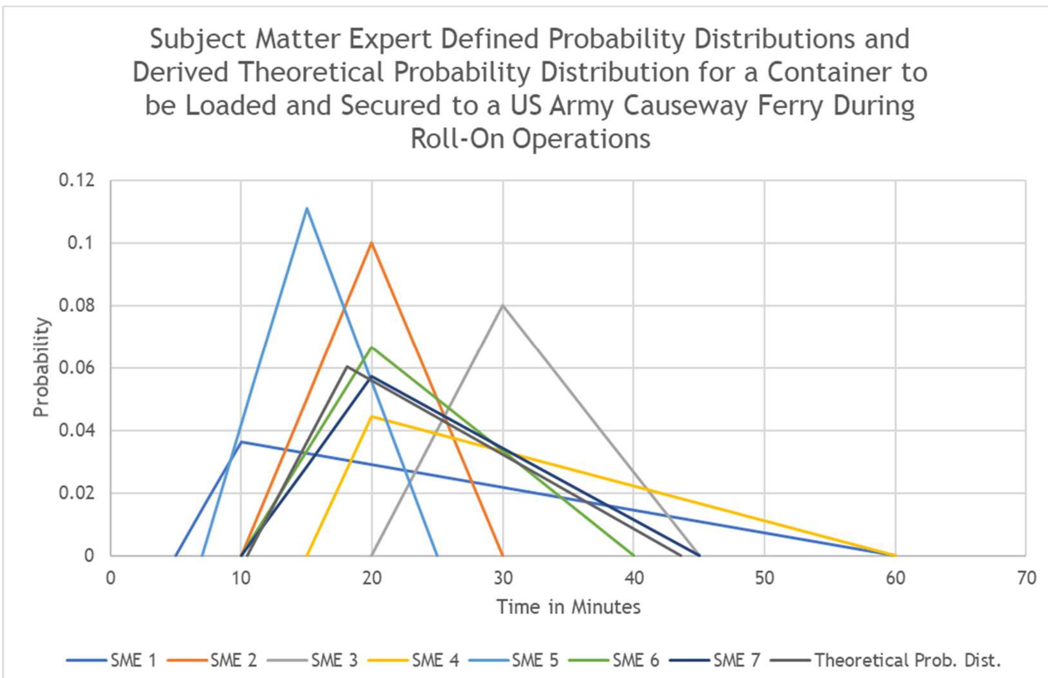

Figure G3. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Loaded and Secured to a US Army Causeway Ferry During Roll-On Operations.

Table G4. Interview Question 2d - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be loaded and secured to a US Army causeway ferry during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	60
SME Opinion 2	10	20	30
SME Opinion 3	20	30	45
SME Opinion 4	3	5	12
SME Opinion 5	15	25	60
SME Opinion 6	5	10	20
SME Opinion 7	20	45	120
Theoretical	11.14285714	20.71428571	49.57142857

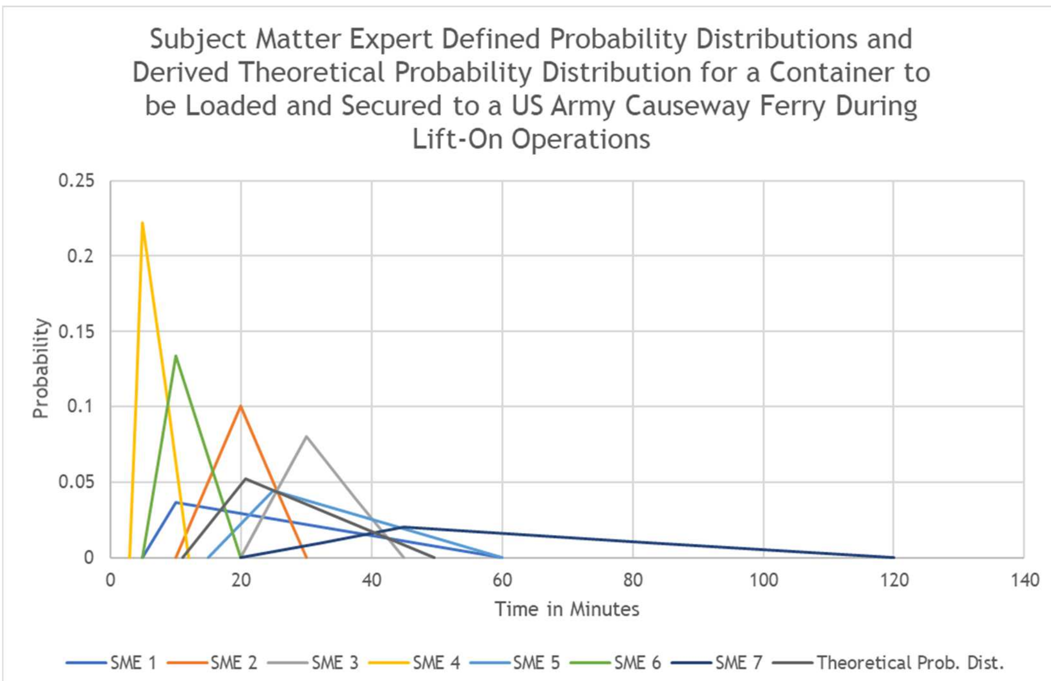

Figure G4. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Loaded and Secured to a US Army Causeway Ferry During Lift-On Operations.

Table G5. Interview Question 2e - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be loaded and secured to a US Army causeway ferry during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	0.5	2	5
SME Opinion 2	15	20	25
SME Opinion 3	5	10	20
SME Opinion 4	5	7	12
SME Opinion 5	7	17	25
SME Opinion 6	5	10	20
SME Opinion 7	10	15	30
Theoretical	6.785714286	11.57142857	19.57142857

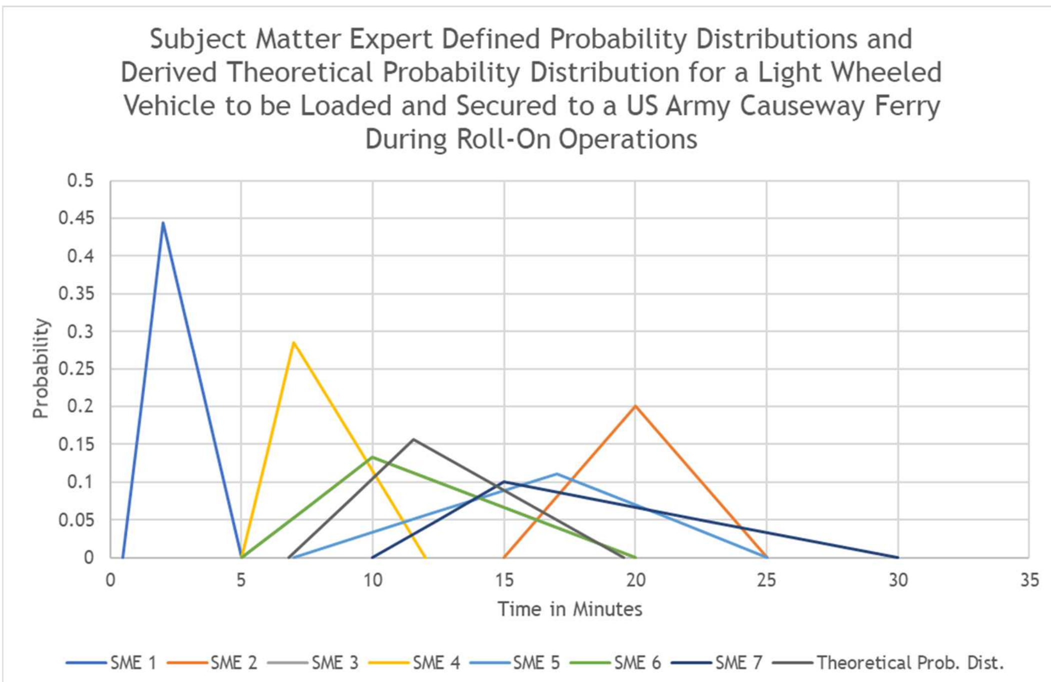

Figure G5. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Loaded and Secured to a US Army Causeway Ferry During Roll-On Operations.

Table G6. Interview Question 2f - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be loaded and secured to a US Army causeway ferry during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	1	2	5
SME Opinion 2	10	20	30
SME Opinion 3	5	10	25
SME Opinion 4	5	7	12
SME Opinion 5	15	22.5	35
SME Opinion 6	10	15	25
SME Opinion 7	7	20	60
Theoretical	7.571428571	13.78571429	27.42857143

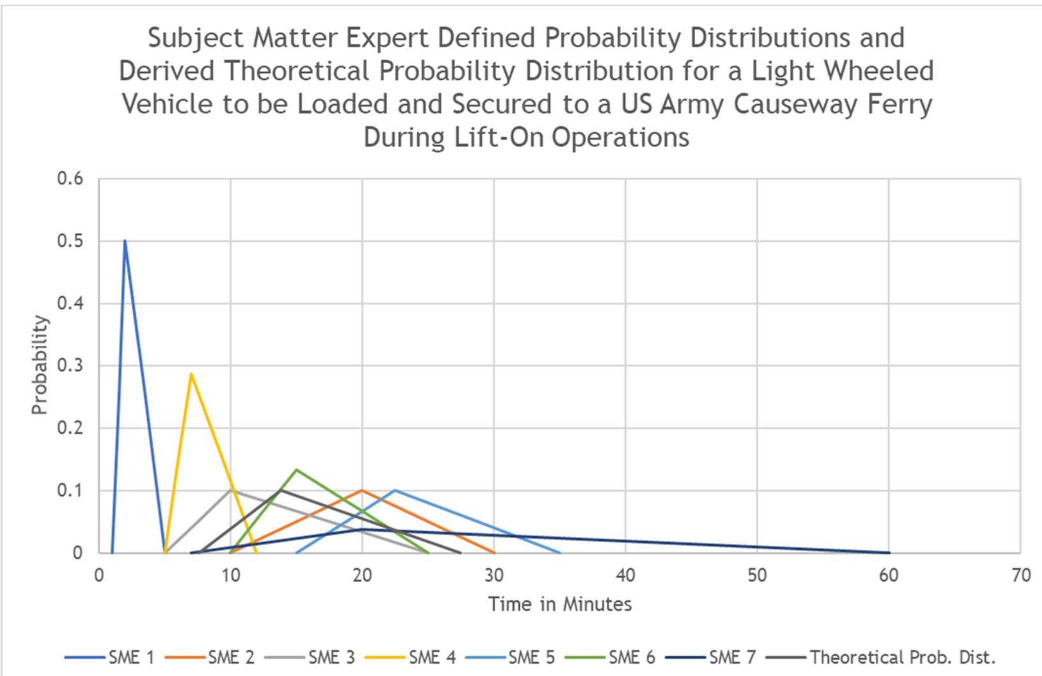

Figure G6. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Loaded and Secured to a US Army Causeway Ferry During Lift-On Operations.

Table G7. Interview Question 2g - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle with a trailer to be loaded and secured to a US Army causeway ferry during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	1	2	5
SME Opinion 2	20	25	30
SME Opinion 3	5	10	30
SME Opinion 4	6	8.5	12
SME Opinion 5	15	22.5	35
SME Opinion 6	15	20	30
SME Opinion 7	15	30	45
Theoretical	11	16.85714286	26.71428571

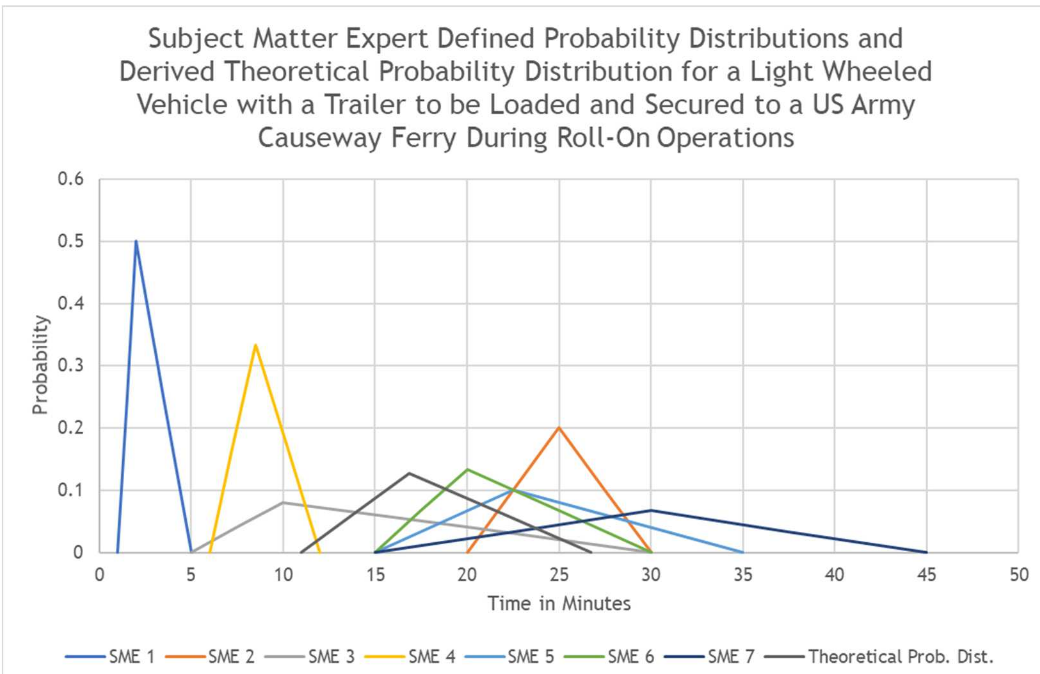

Figure G7. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle with a Trailer to be Loaded and Secured to a US Army Causeway Ferry During Roll-On Operations.

Table G8. Interview Question 2h - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be loaded and secured to a US Army causeway ferry during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	2	5	10
SME Opinion 2	30	40	45
SME Opinion 3	7	12	30
SME Opinion 4	12.5	25	35
SME Opinion 5	10	20	30
SME Opinion 6	20	30	60
Theoretical	15.66666667	19.91666667	35

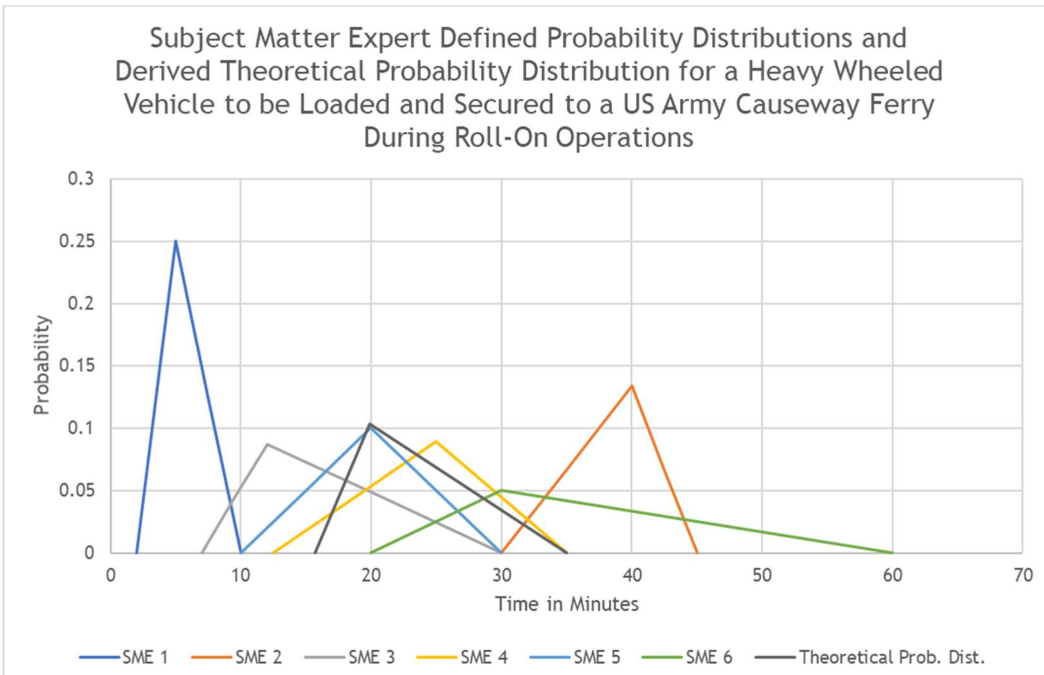

Figure G8. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Loaded and Secured to a US Army Causeway Ferry During Roll-On Operations.

Table G9. Interview Question 2i - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be loaded and secured to a US Army causeway ferry during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	20
SME Opinion 2	20	40	45
SME Opinion 3	10	15	25
SME Opinion 4	15	30	90
Theoretical	12.5	23.75	45

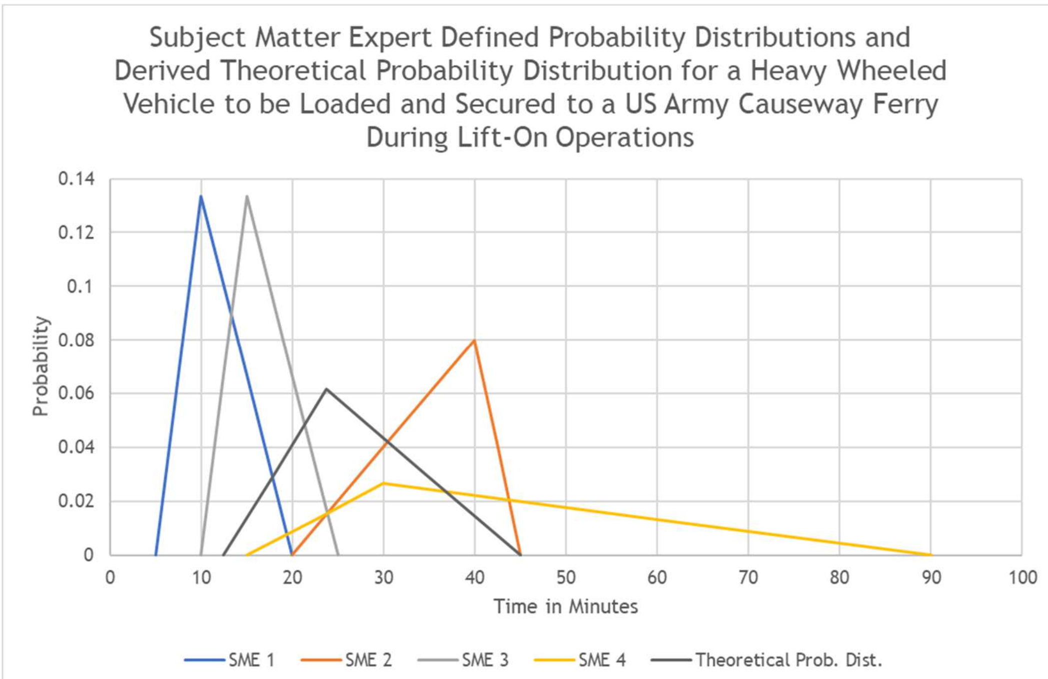

Figure G9. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Loaded and Secured to a US Army Causeway Ferry During Lift-On Operations.

Table G10. Interview Question 2j - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle with a trailer to be loaded and secured to a US Army causeway ferry during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	20
SME Opinion 2	20	25	30
SME Opinion 3	7	12	30
SME Opinion 4	15	20	35
SME Opinion 5	10	20	30
SME Opinion 6	15	30	45
Theoretical	12	19.5	31.66666667

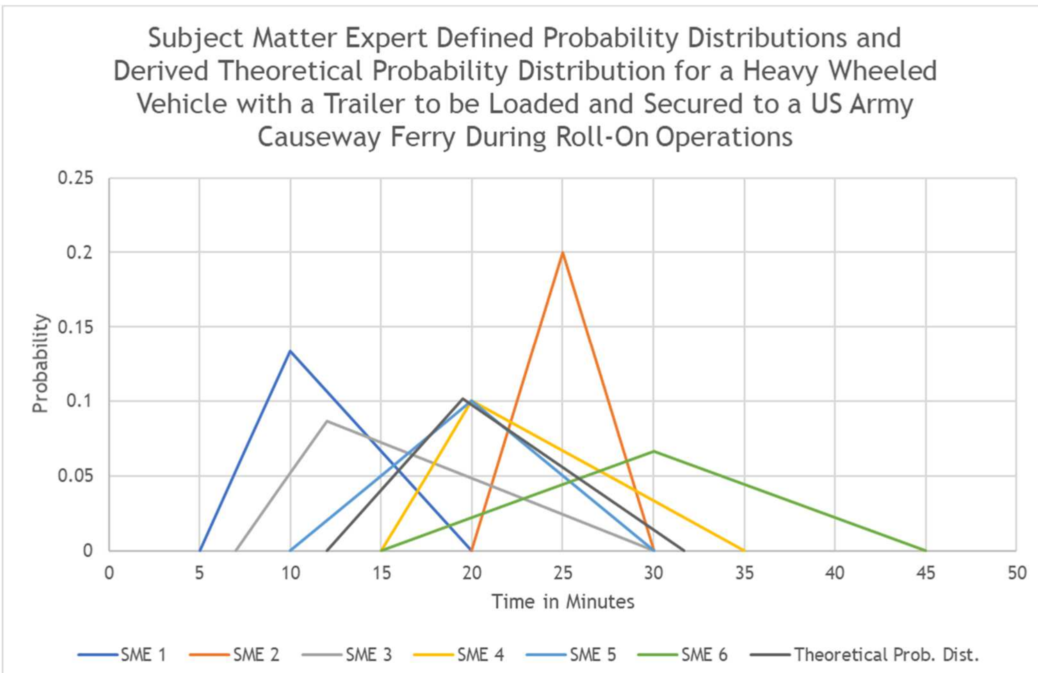

Figure G10. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle with a Trailer to be Loaded and Secured to a US Army Causeway Ferry During Roll-On Operations.

Table G11. Interview Question 2k - Subject matter expert defined probability distributions and derived theoretical probability distribution for a tracked vehicle to be loaded and secured to a US Army causeway ferry during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	25	45
SME Opinion 2	20	25	35
SME Opinion 3	15	30	45
Theoretical	16.66666667	26.66666667	41.66666667

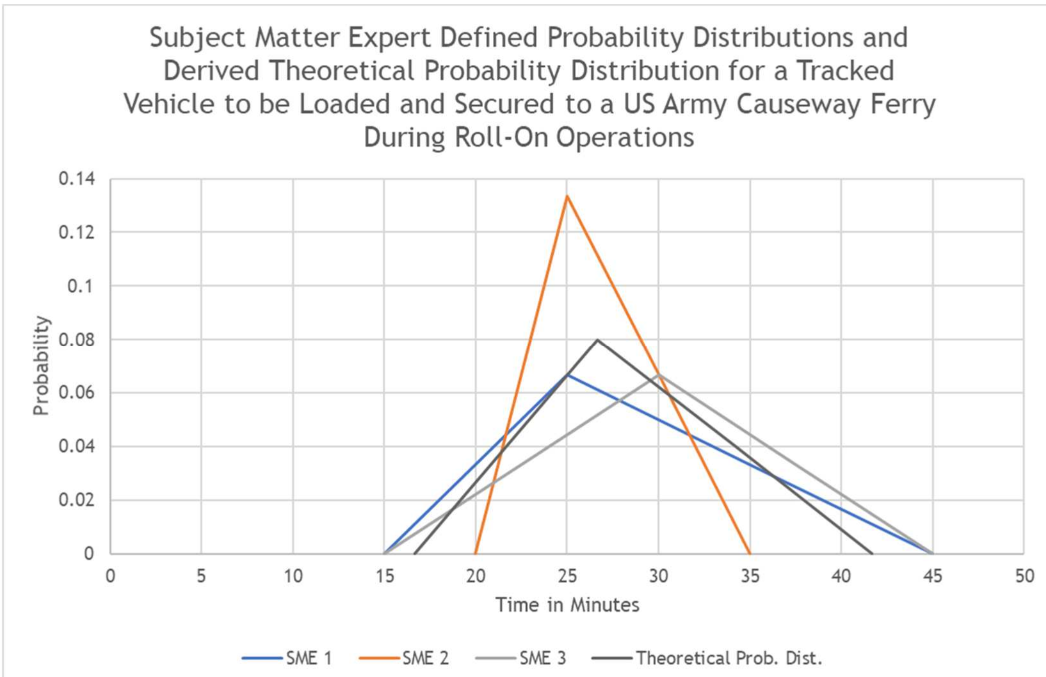

Figure G11. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Tracked Vehicle to be Loaded and Secured to a US Army Causeway Ferry During Roll-On Operations.

Table G12. Interview Question 2l - Subject matter expert defined probability distributions and derived theoretical probability distribution for a tracked vehicle to be loaded and secured to a US Army causeway ferry during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	20	30	90
Theoretical	15	22.5	60

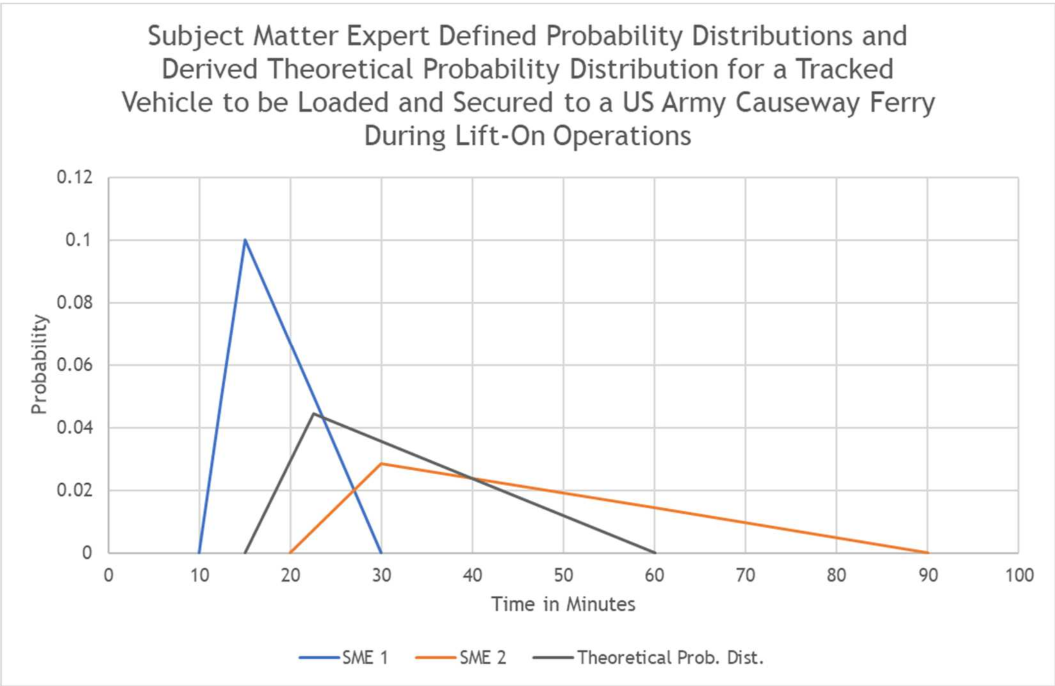

Figure G12. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Tracked Vehicle to be Loaded and Secured to a US Army Causeway Ferry During Lift-On Operations.

Table G13. Interview Question 2m - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army causeway ferry to castoff and clear a US Army roll-on/roll-off discharge facility.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	5	10	15
SME Opinion 3	4	6	20
SME Opinion 4	5	10	45
SME Opinion 5	3	5	12
SME Opinion 6	10	15	25
SME Opinion 7	10	20	30
SME Opinion 8	10	15	30
Theoretical	7.125	12	25.875

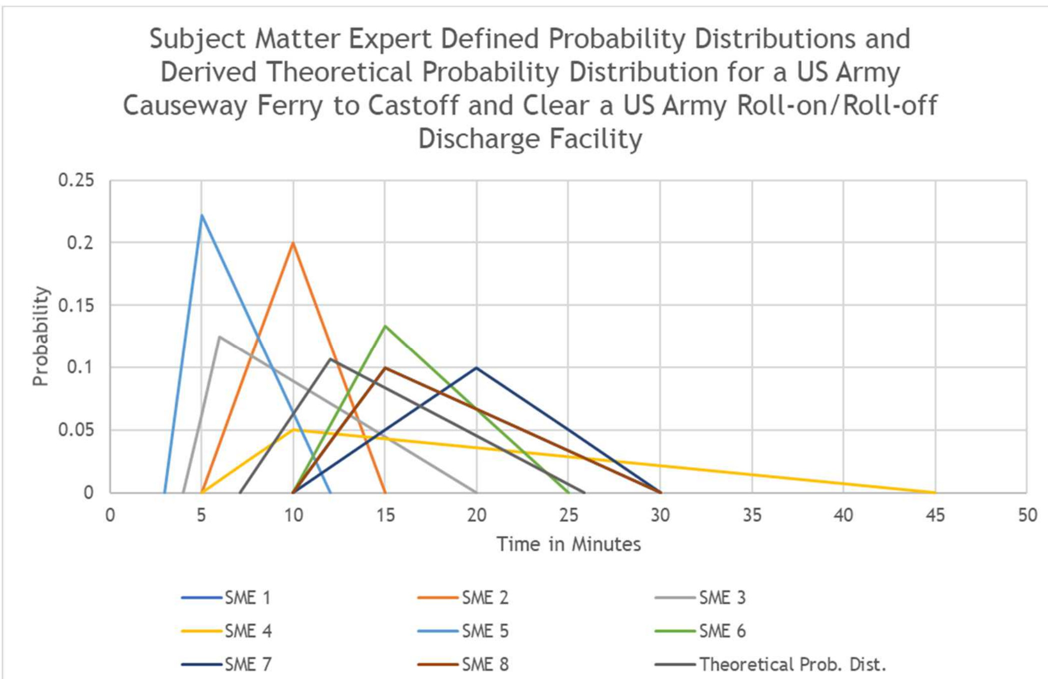

Figure G13. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Causeway Ferry to Castoff and Clear a US Army Roll-on/Roll-off Discharge Facility.

Table G14. Interview Question 2n - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army causeway ferry to castoff and clear a US Navy roll-on/roll-off discharge facility.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	4	6	20
SME Opinion 3	10	12	20
SME Opinion 4	10	15	25
SME Opinion 5	20	30	40
Theoretical	10.8	15.6	27

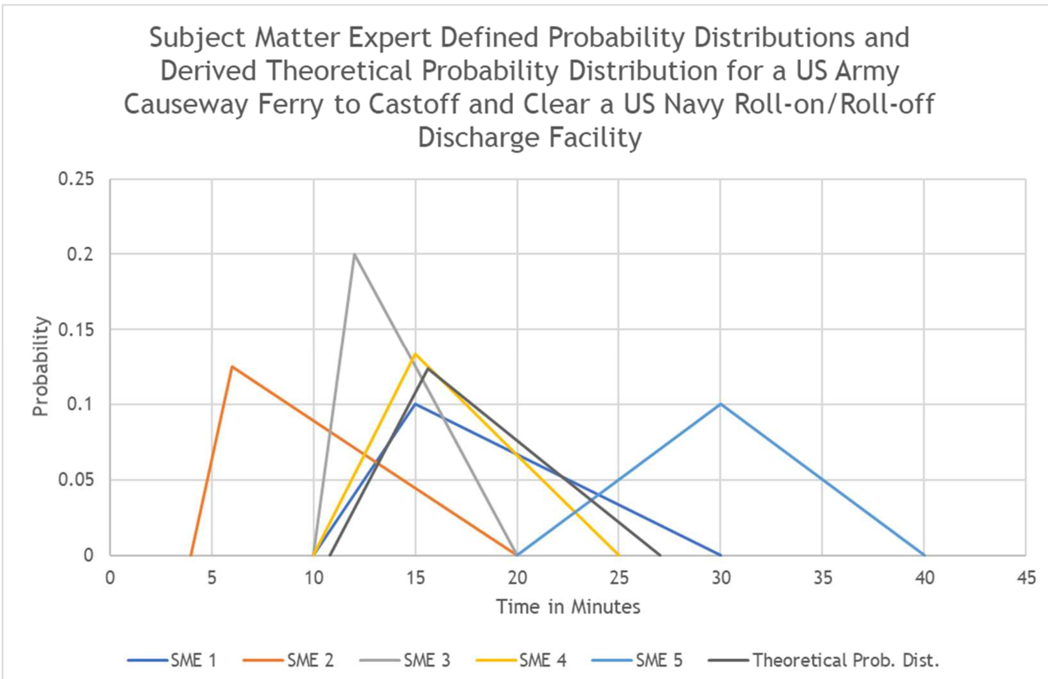

Figure G14. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Causeway Ferry to Castoff and Clear a US Navy Roll-on/Roll-off Discharge Facility.

Table G15. Interview Question 2o - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army causeway ferry to approach and moor a US Army causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	20
SME Opinion 2	10	15	20
SME Opinion 3	10	15	45
SME Opinion 4	10	15	30
SME Opinion 5	5	7.5	12
SME Opinion 6	15	20	30
SME Opinion 7	10	20	30
SME Opinion 8	30	45	90
Theoretical	11.875	18.4375	34.625

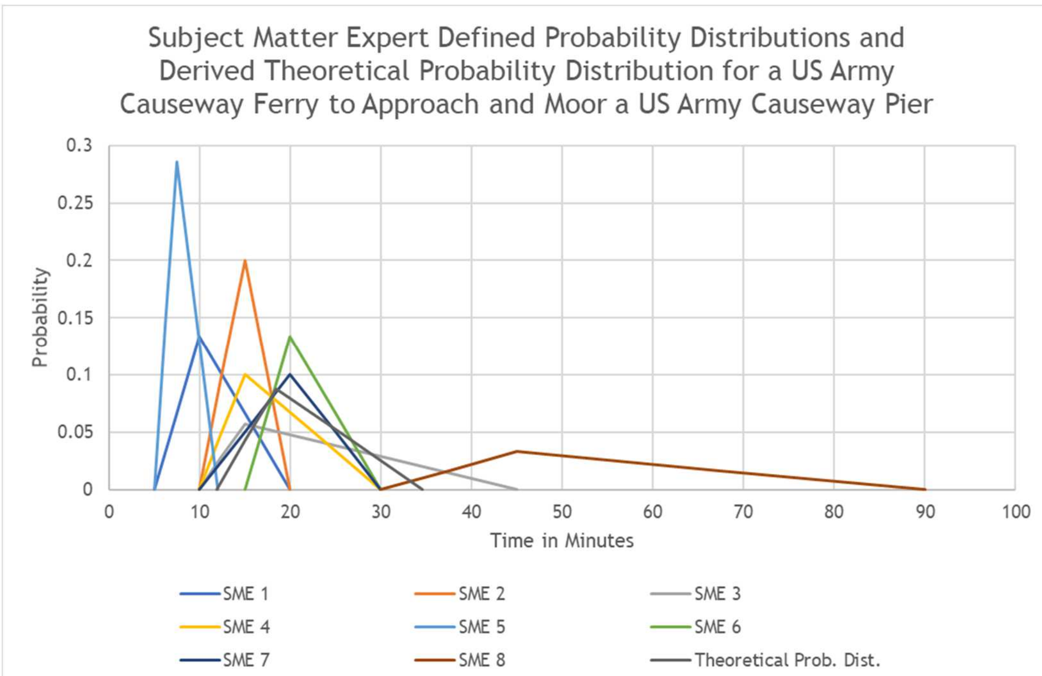

Figure G15. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Causeway Ferry to Approach and Moor a US Army Causeway Pier.

Table G16. Interview Question 2p - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army causeway ferry to approach and moor a US Navy causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	45
SME Opinion 2	15	20	30
SME Opinion 3	20	30	40
Theoretical	15	21.66666667	38.33333333

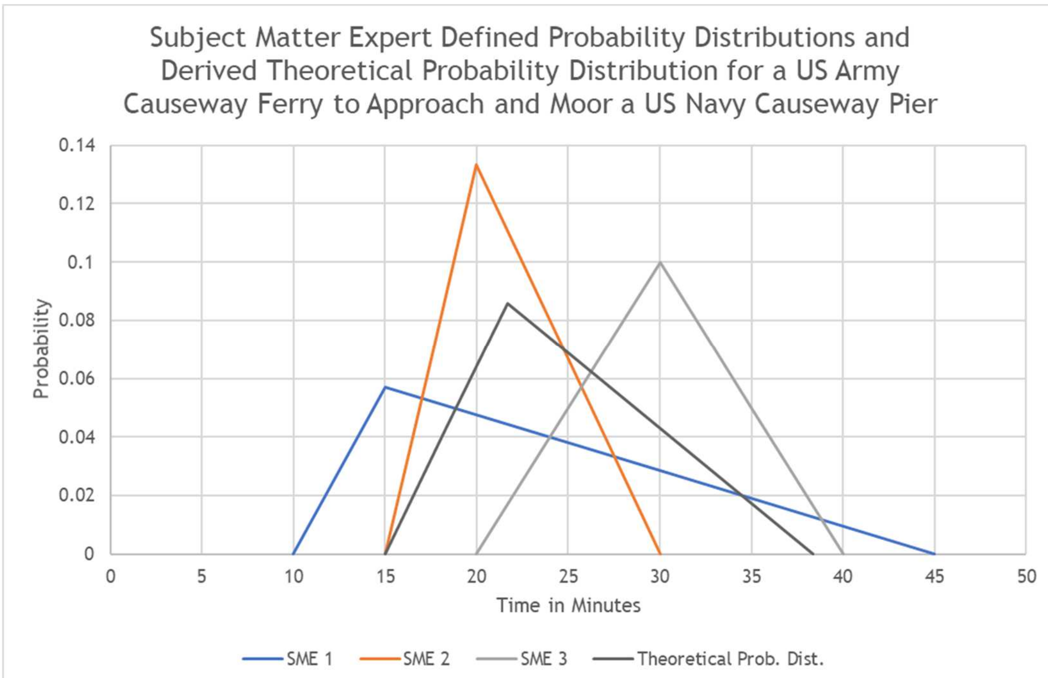

Figure G16. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Causeway Ferry to Approach and Moor a US Navy Causeway Pier.

Table G17. Interview Question 2q - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army causeway ferry to approach and moor at a bare beach landing site.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	20
SME Opinion 2	5	10	15
SME Opinion 3	20	30	60
SME Opinion 4	30	40	50
SME Opinion 5	10	20	30
SME Opinion 6	15	30	45
Theoretical	14.16666667	23.33333333	36.66666667

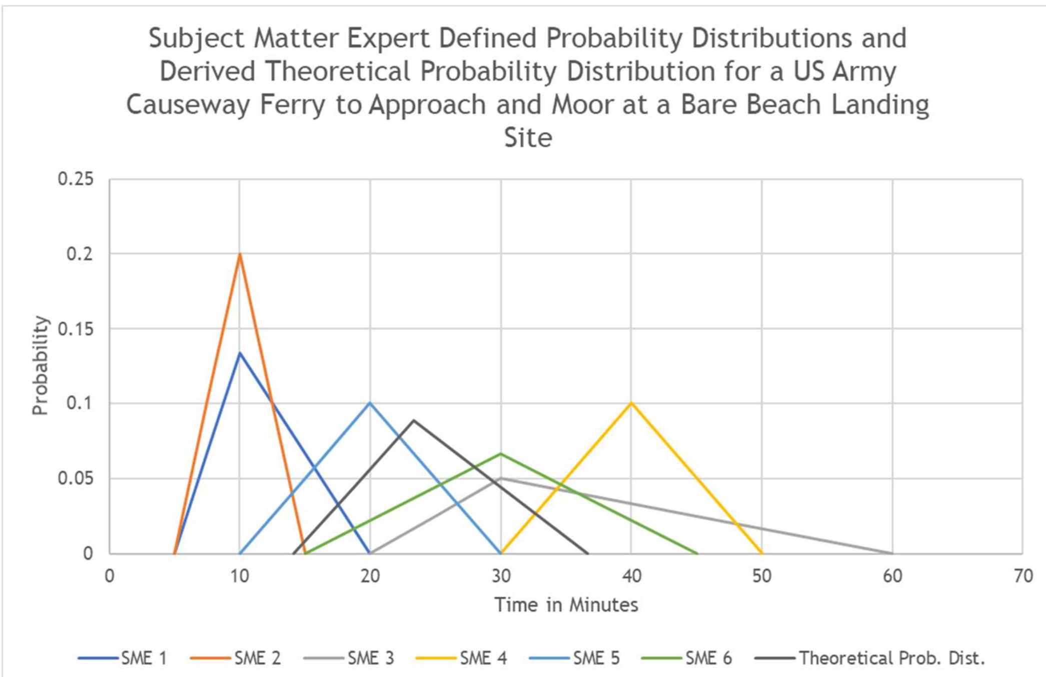

Figure G17. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Causeway Ferry to Approach and Moor at a Bare Beach Landing Site.

Table G18. Interview Question 2r - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be unsecured and unloaded from a US Army causeway ferry during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	60
SME Opinion 2	10	15	20
SME Opinion 3	5	7	20
SME Opinion 4	10	15	25
SME Opinion 5	7	10	15
SME Opinion 6	10	20	35
SME Opinion 7	10	15	20
SME Opinion 8	10	20	45
Theoretical	9	15.25	30

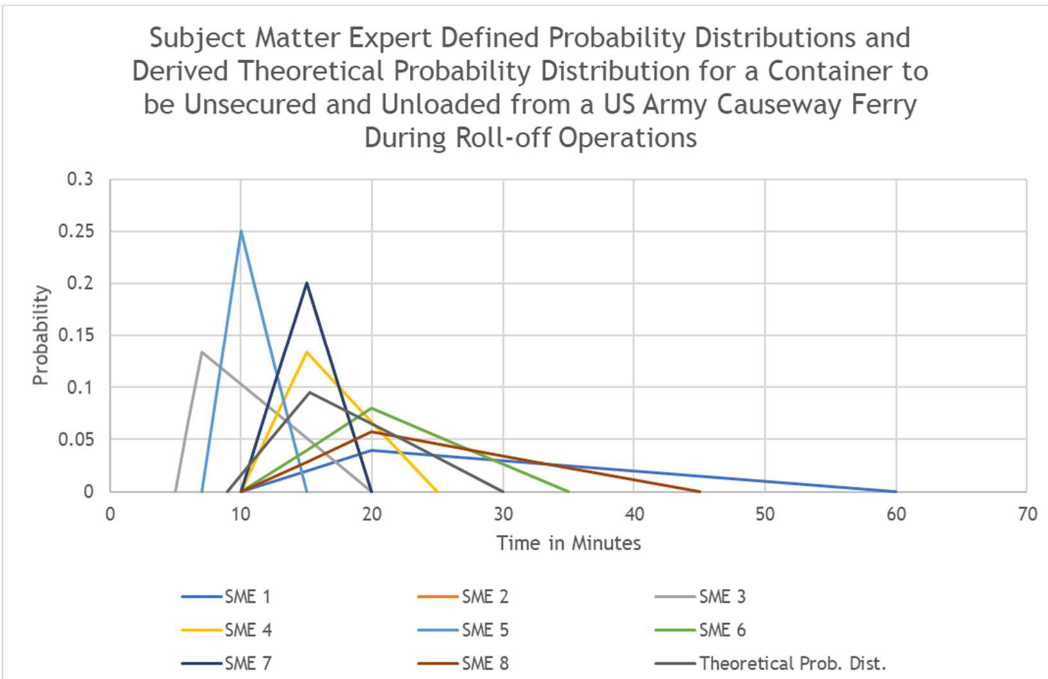

Figure G18. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Unsecured and Unloaded from a US Army Causeway Ferry During Roll-off Operations.

Table G19. Interview Question 2s - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be unsecured and unloaded from a US Army causeway ferry during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	30
SME Opinion 2	10	15	20
SME Opinion 3	5	7	20
SME Opinion 4	5	10	30
SME Opinion 5	5	7	15
SME Opinion 6	7	15	25
SME Opinion 7	5	10	20
SME Opinion 8	5	10	15
Theoretical	6.5	11.75	21.875

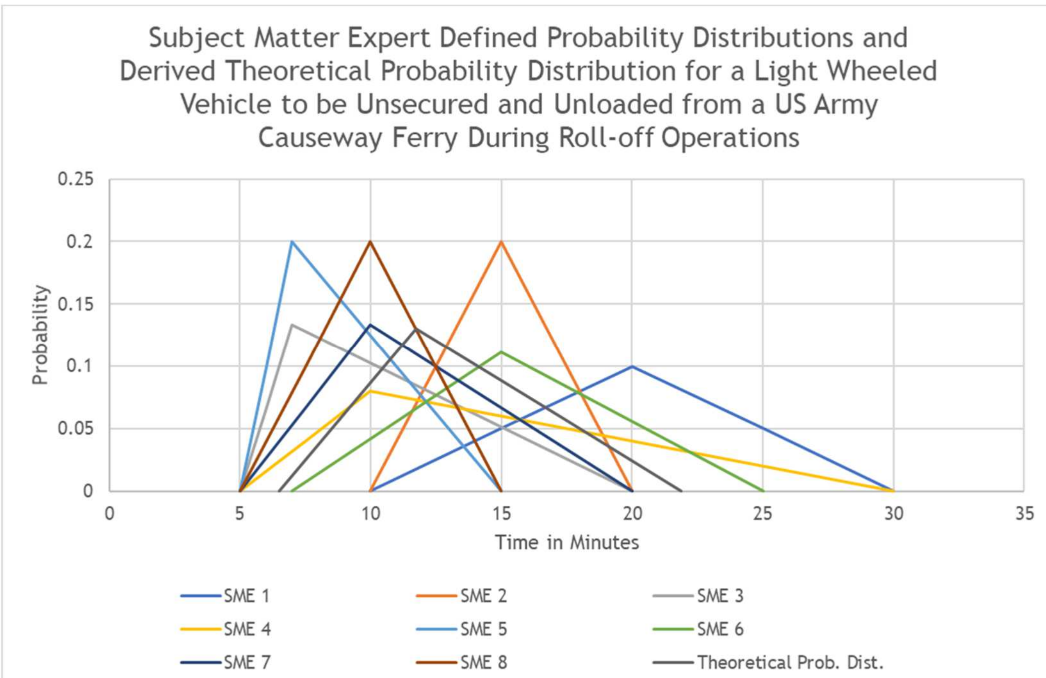

Figure G19. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Unsecured and Unloaded from a US Army Causeway Ferry During Roll-off Operations.

Table G20. Interview Question 2t - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle with a trailer to be unsecured and unloaded from a US Army causeway ferry during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	30
SME Opinion 2	10	15	20
SME Opinion 3	5	7	20
SME Opinion 4	5	6	20
SME Opinion 5	10	20	40
SME Opinion 6	10	15	25
SME Opinion 7	5	10	15
Theoretical	7.857142857	13.28571429	24.28571429

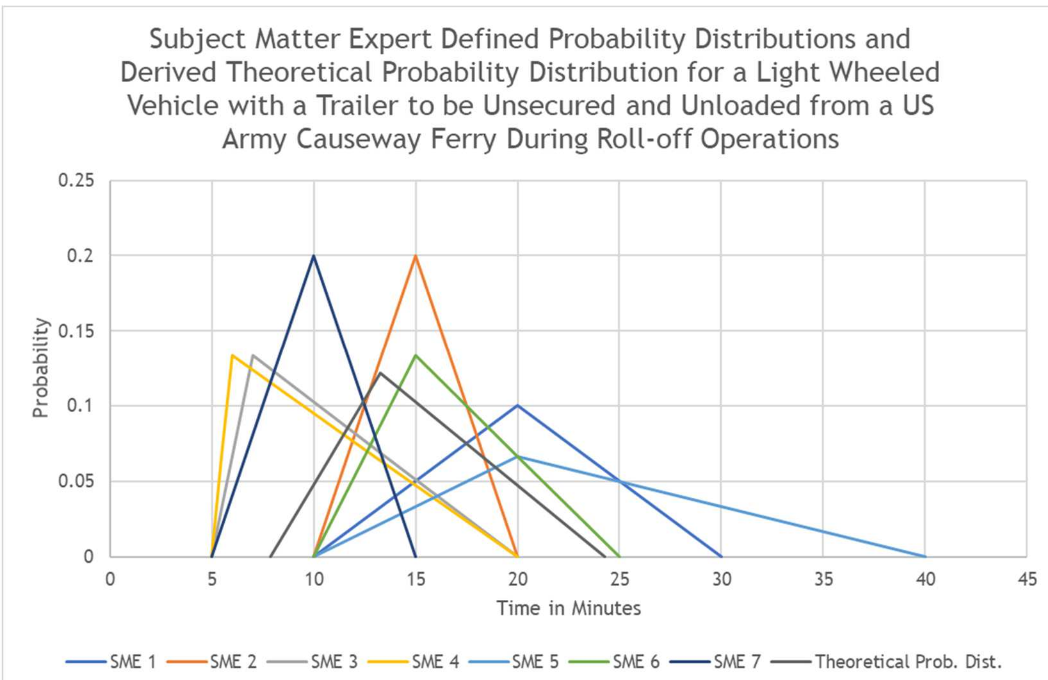

Figure G20. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle with a Trailer to be Unsecured and Unloaded from a US Army Causeway Ferry During Roll-off Operations.

Table G21. Interview Question 2u - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be unsecured and unloaded from a US Army causeway ferry during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	30
SME Opinion 2	10	15	20
SME Opinion 3	10	20	40
SME Opinion 4	5	10	20
SME Opinion 5	5	10	15
Theoretical	8	15	25

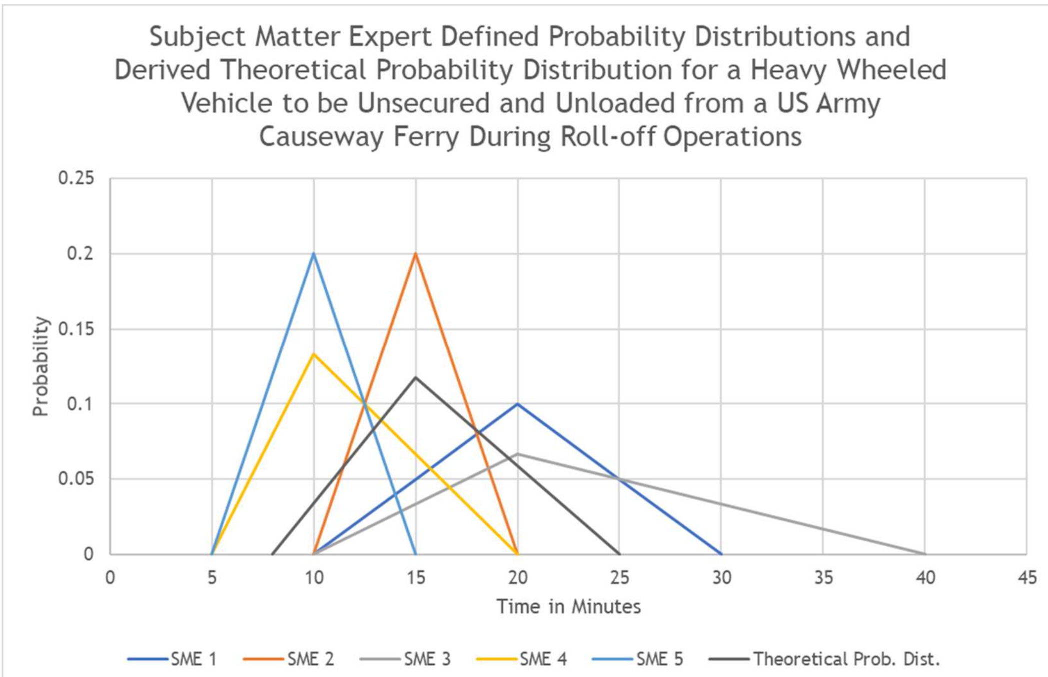

Figure G21. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Unsecured and Unloaded from a US Army Causeway Ferry During Roll-off Operations.

Table G22. Interview Question 2v - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle with a trailer to be unsecured and unloaded from a US Army causeway ferry during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	30
SME Opinion 2	10	15	20
SME Opinion 3	10	20	40
SME Opinion 4	10	15	25
SME Opinion 5	5	10	15
Theoretical	9	16	26

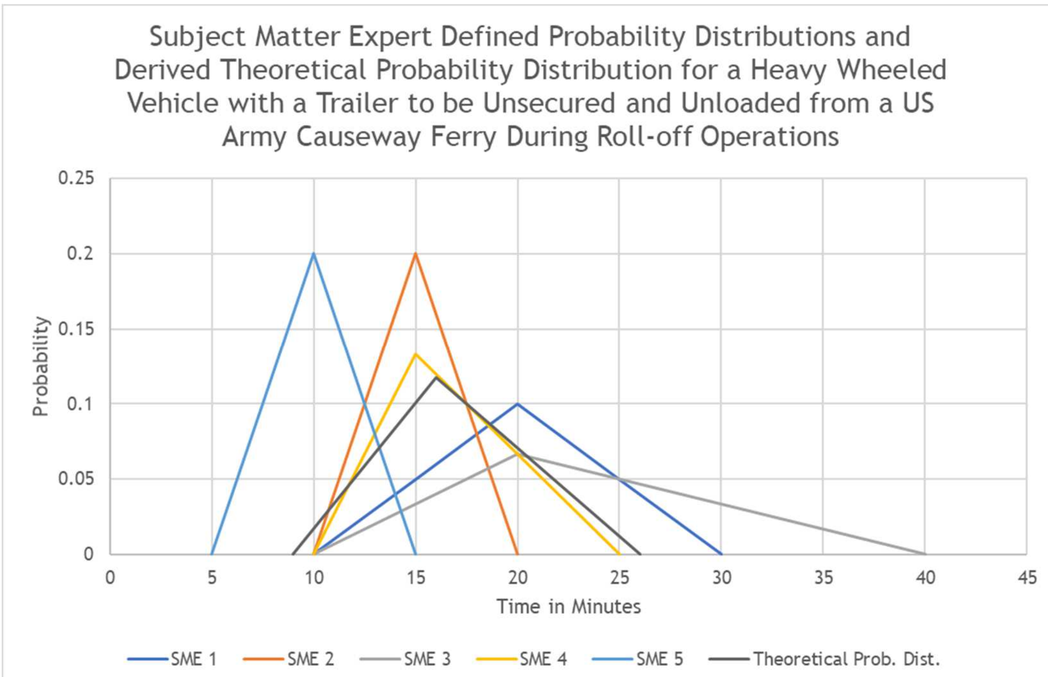

Figure G22. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle with a Trailer to be Unsecured and Unloaded from a US Army Causeway Ferry During Roll-off Operations.

Table G23. Interview Question 2w - Subject matter expert defined probability distributions and derived theoretical probability distribution for a tracked vehicle to be unsecured and unloaded from a US Army causeway ferry during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	20
SME Opinion 2	10	15	25
SME Opinion 3	5	10	15
Theoretical	8.333333333	13.33333333	20

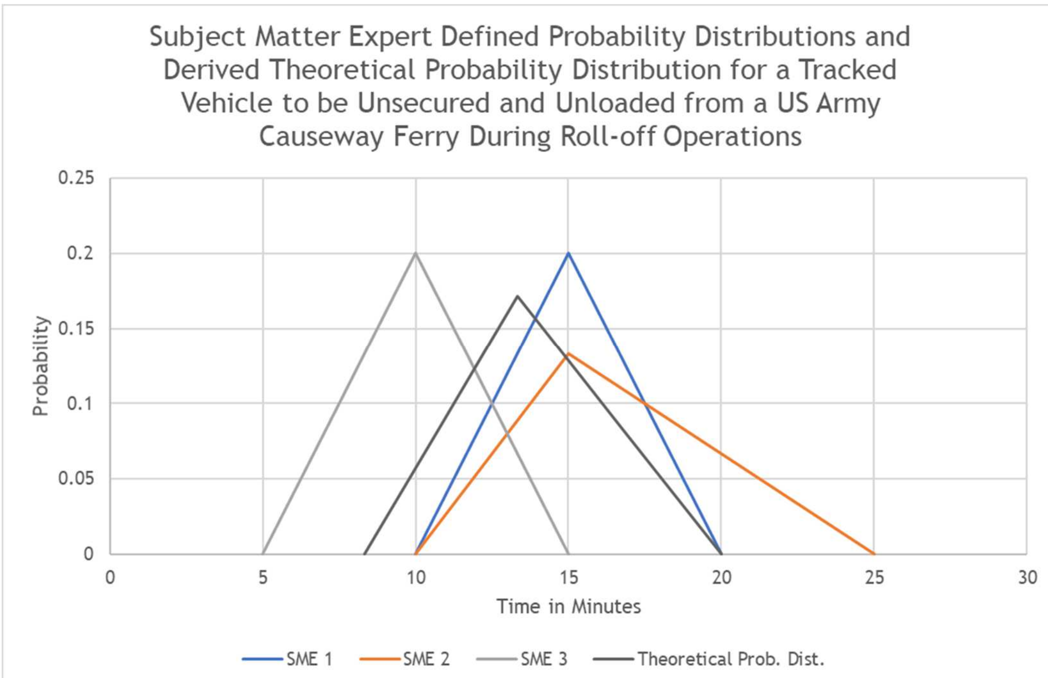

Figure G23. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Tracked Vehicle to be Unsecured and Unloaded from a US Army Causeway Ferry During Roll-off Operations.

Table G24. Interview Question 2x - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army causeway ferry to castoff and clear from a US Army causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	0.5	5	45
SME Opinion 2	5	10	20
SME Opinion 3	5	10	15
SME Opinion 4	6	10	20
SME Opinion 5	3	5	12
SME Opinion 6	10	15	20
SME Opinion 7	10	15	30
Theoretical	5.642857143	10	23.14285714

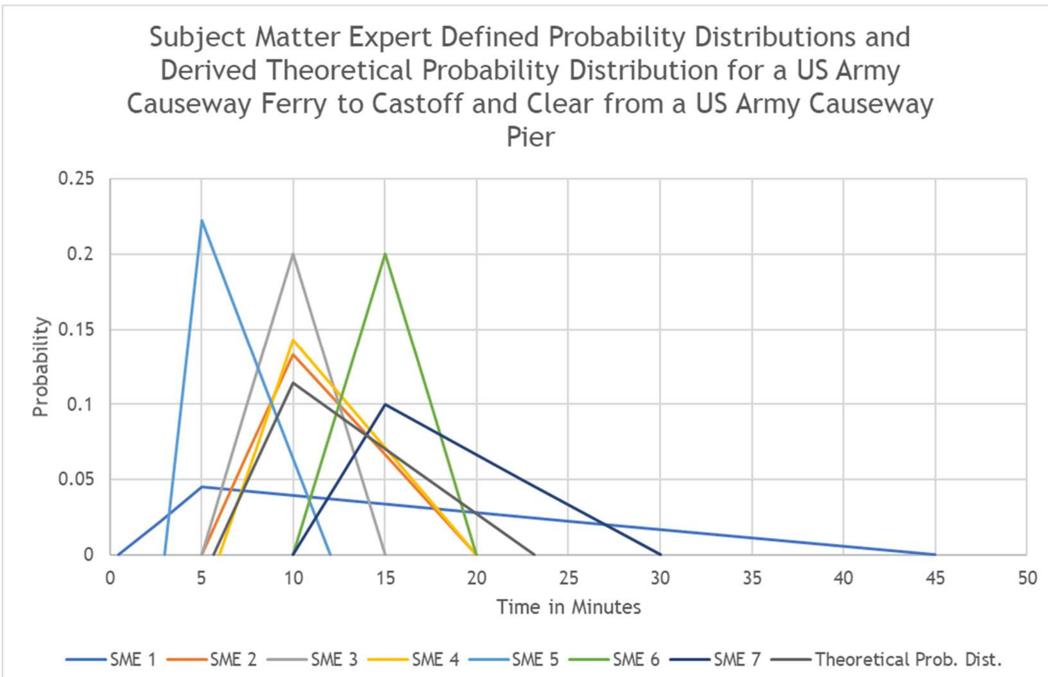

Figure G24. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Causeway Ferry to Castoff and Clear from a US Army Causeway Pier.

Table G25. Interview Question 2y - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army causeway ferry to castoff and clear from a US Navy causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	0.5	5	45
SME Opinion 2	15	20	30
Theoretical	8.333333333	13.33333333	20

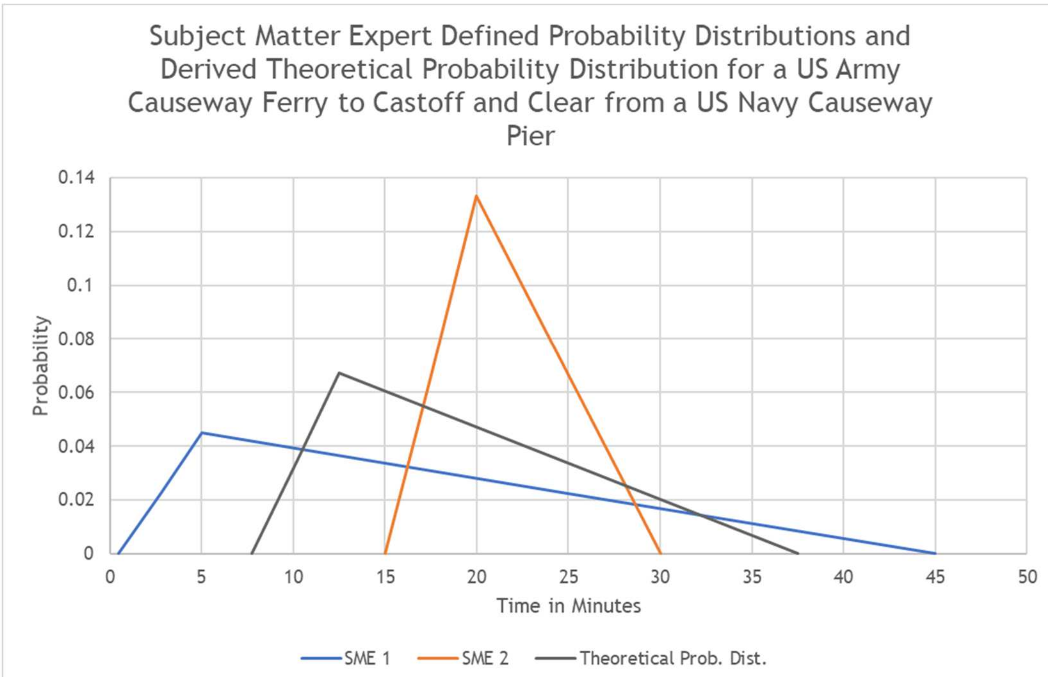

Figure G25. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Causeway Ferry to Castoff and Clear from a US Navy Causeway Pier.

Table G26. Interview Question 2z - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army causeway ferry to castoff and clear from a bare beach landing site.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	30
SME Opinion 2	10	20	20
SME Opinion 3	7	15	45
SME Opinion 4	25	30	60
SME Opinion 5	10	15	45
SME Opinion 6	5	10	25
SME Opinion 7	5	10	25
SME Opinion 8	10	20	45
Theoretical	9.611111111	16.38888889	36.875

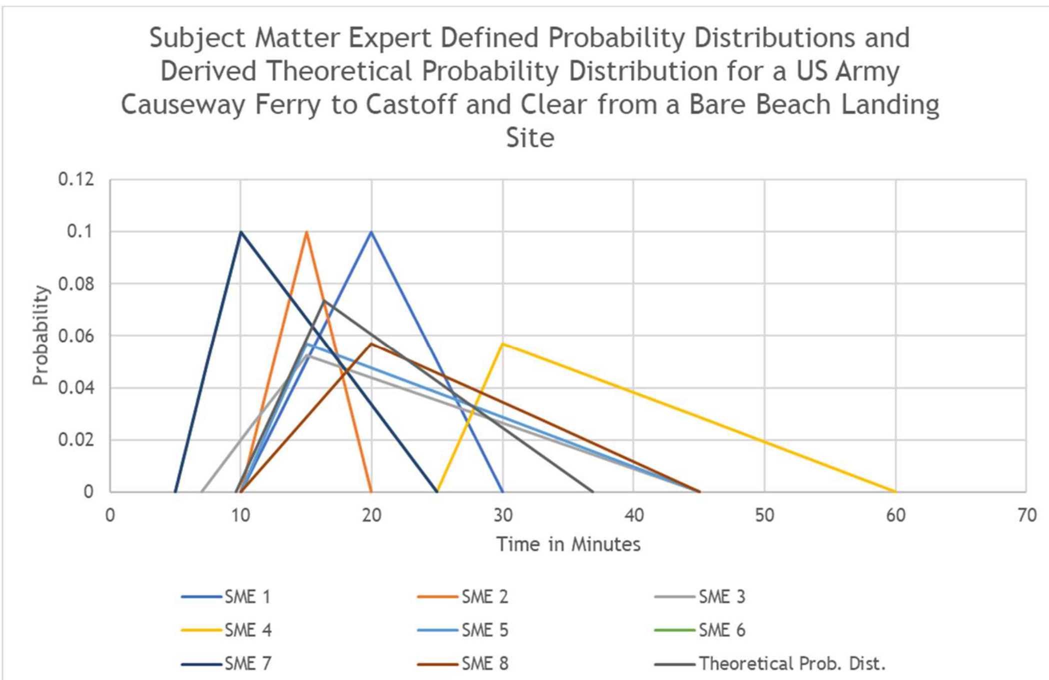

Figure G26. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Causeway Ferry to Castoff and Clear from a Bare Beach Landing Site.

APPENDIX H. TABLES AND FIGURES OF SUBJECT MATTER EXPERT RESPONSES AND THEORETICAL PROBABILITY DISTRIBUTIONS FOR US ARMY LANDING CRAFT UTILITY 2000 SERIES / JLOTS ACTIVITY COMBINATIONS

Table H1. Interview Question 3a - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to approach and moor to a US Army RRDF.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	10	30
SME Opinion 2	20	30	40
SME Opinion 3	10	15	40
SME Opinion 4	15	20	45
SME Opinion 5	10	13	20
SME Opinion 6	11.5	12	13
SME Opinion 7	12	20	30
SME Opinion 8	10	15	30
Theoretical	12.3125	16.875	31

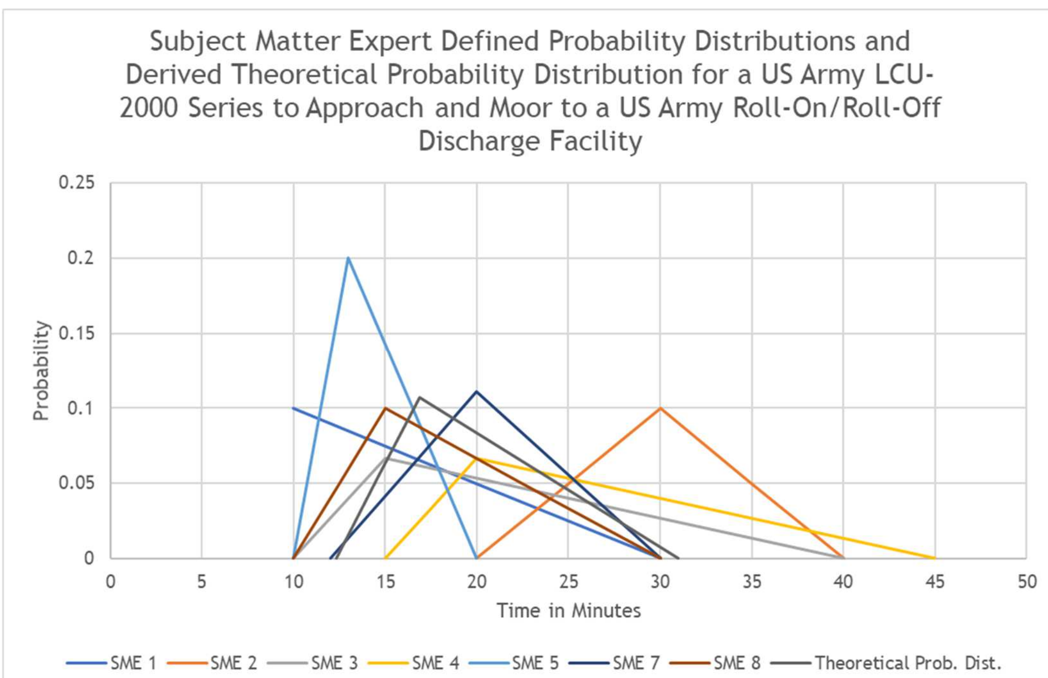

Figure H1. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Approach and Moor to a US Army RRDF.

Table H2. Interview Question 3b - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to approach and moor to a US Navy RRDF without a rhino horn connecter.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	50
SME Opinion 2	15	20	45
SME Opinion 3	10	12	15
SME Opinion 4	14	15	20
SME Opinion 5	10	15	30
SME Opinion 6	8	12	25
Theoretical	11.16666667	15.66666667	30.83333333

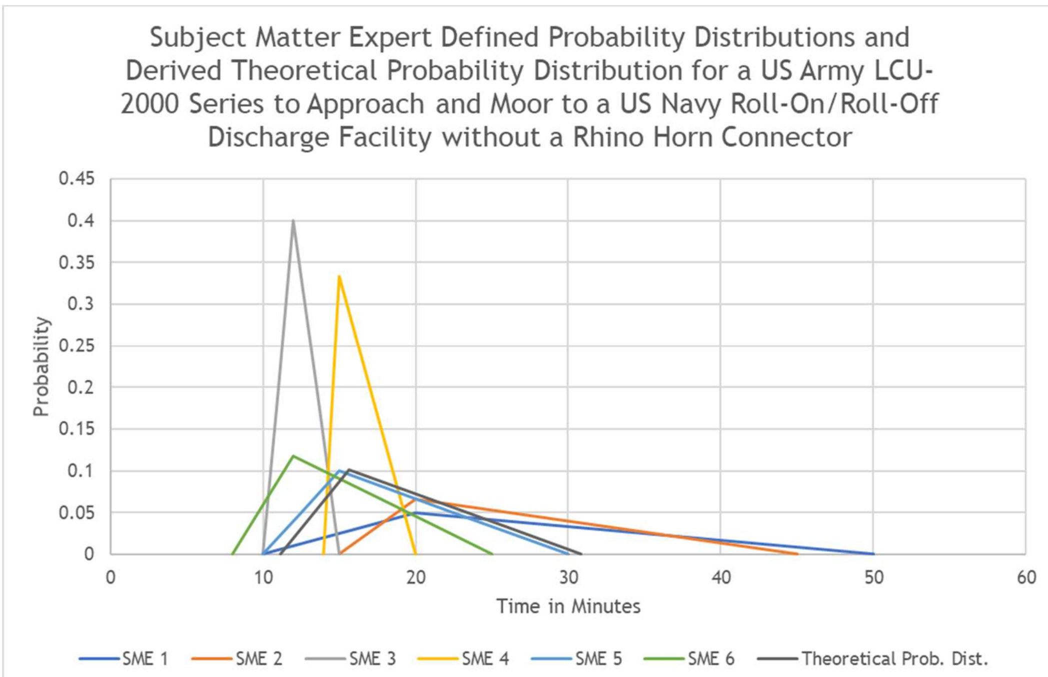

Figure H2. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Approach and Moor to a US Navy RRDF without a Rhino Horn Connector.

Table H3. Interview Question 3c - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to approach and moor to a US Navy RRDF with a rhino horn connecter.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	25	90
SME Opinion 2	20	25	60
SME Opinion 3	10	13	20
SME Opinion 4	15	16	17
SME Opinion 5	10	20	40
SME Opinion 6	10	15	30
Theoretical	14.16666667	19	42.83333333

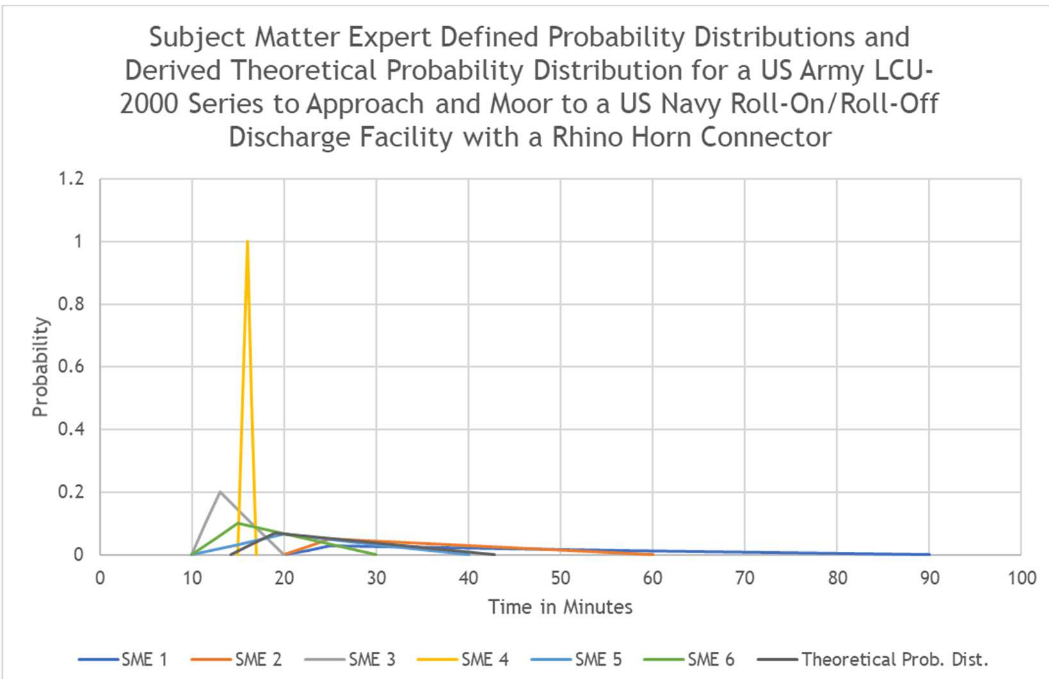

Figure H3. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Approach and Moor to a US Navy RRDF with a Rhino Horn Connector.

Table H4. Interview Question 3d - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be loaded and secured on a US Army LCU-2000 series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	12.5	20
SME Opinion 2	5	10	30
SME Opinion 3	15	20	45
SME Opinion 4	3	5	15
SME Opinion 5	7	12	20
SME Opinion 6	6	8	20
Theoretical	7.666666667	11.25	25

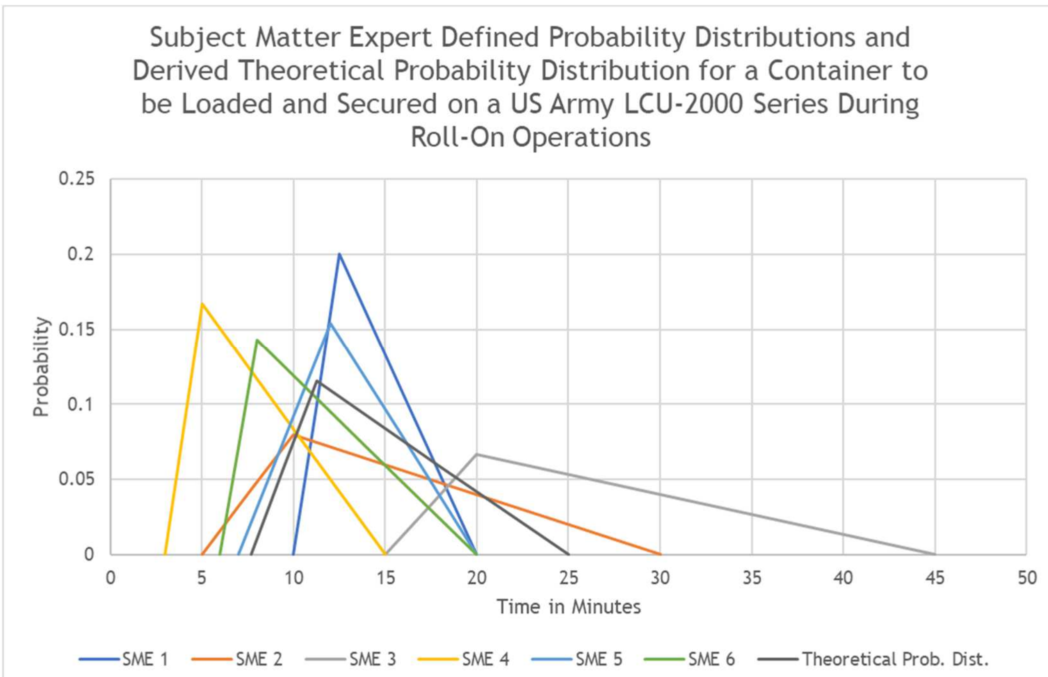

Figure H4. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Loaded and Secured on a US Army LCU-2000 Series During Roll-On Operations.

Table H5. Interview Question 3e - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be loaded and secured on a US Army LCU-2000 series during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	20	30
SME Opinion 2	10	15	30
SME Opinion 3	7	10	20
SME Opinion 4	15	20	35
SME Opinion 5	2	2.5	5
SME Opinion 6	10	18	25
SME Opinion 7	4	6	10
Theoretical	9	13.07142857	22.14285714

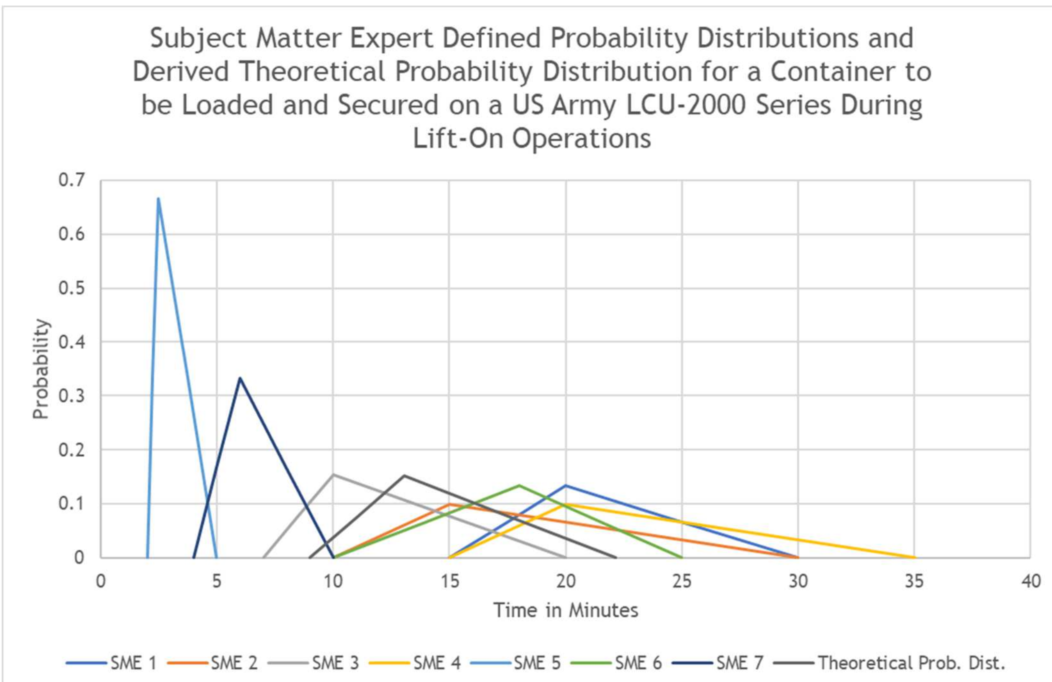

Figure H5. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Loaded and Secured on a US Army LCU-2000 Series During Lift-On Operations.

Table H6. Interview Question 3f - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be loaded and secured on a US Army LCU-2000 series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	7.5	20
SME Opinion 2	5	10	30
SME Opinion 3	12	15	30
SME Opinion 4	10	15	30
SME Opinion 5	2	3	5
SME Opinion 6	10	12	15
SME Opinion 7	2	3	10
Theoretical	6.571428571	9.357142857	20

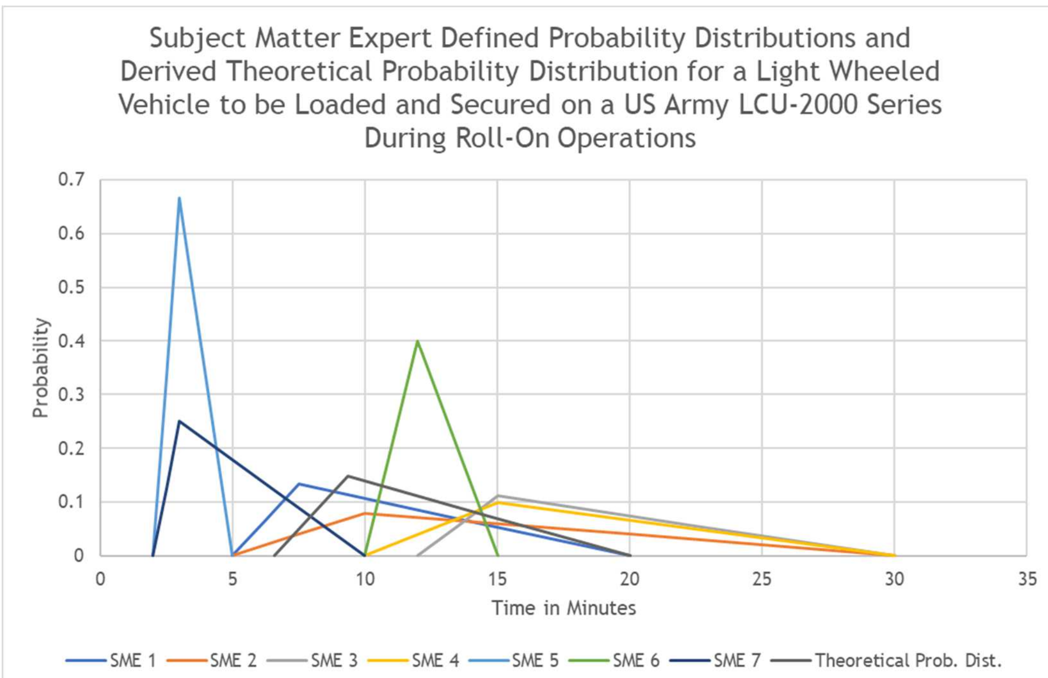

Figure H6. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Loaded and Secured on a US Army LCU-2000 Series During Roll-On Operations.

Table H7. Interview Question 3g - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be loaded and secured on a US Army LCU-2000 series during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	30	45
SME Opinion 2	10	15	30
SME Opinion 3	12	15	30
SME Opinion 4	10	15	30
SME Opinion 5	5	6	15
SME Opinion 6	10	15	20
SME Opinion 7	4	6	10
Theoretical	10.14285714	14.57142857	25.71428571

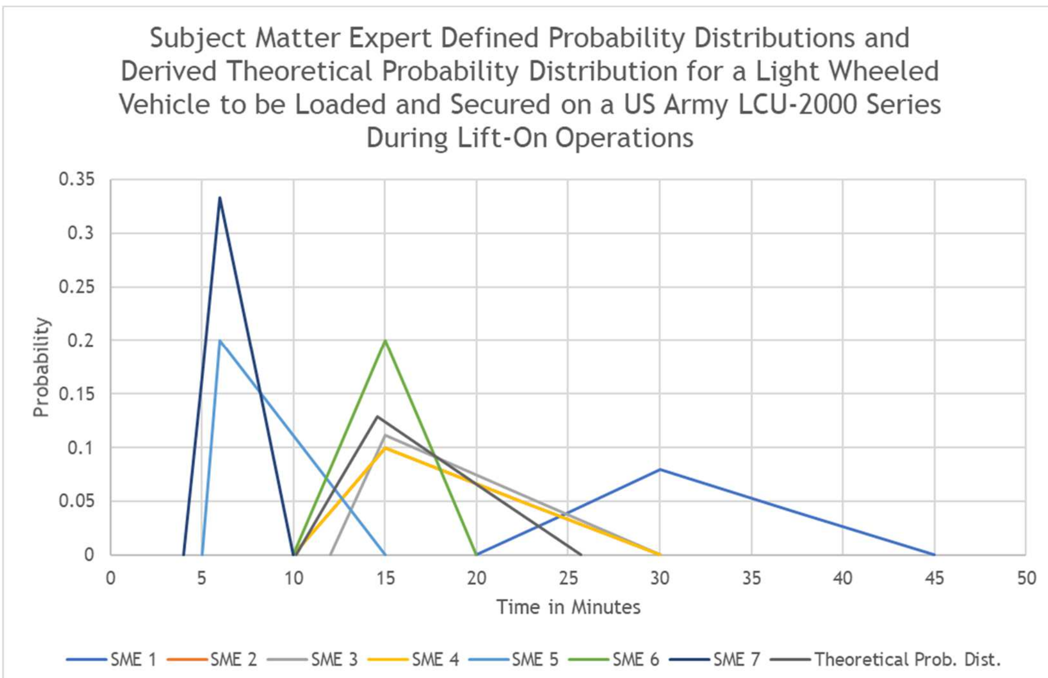

Figure H7. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Loaded and Secured on a US Army LCU-2000 Series During Lift-On Operations.

Table H8. Interview Question 3h - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle with a trailer to be loaded and secured on a US Army LCU-2000 series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	7.5	20
SME Opinion 2	15	20	35
SME Opinion 3	18	25	40
SME Opinion 4	20	25	50
SME Opinion 5	4	5	10
SME Opinion 6	20	25	35
SME Opinion 7	8	10	20
Theoretical	12.85714286	16.78571429	30

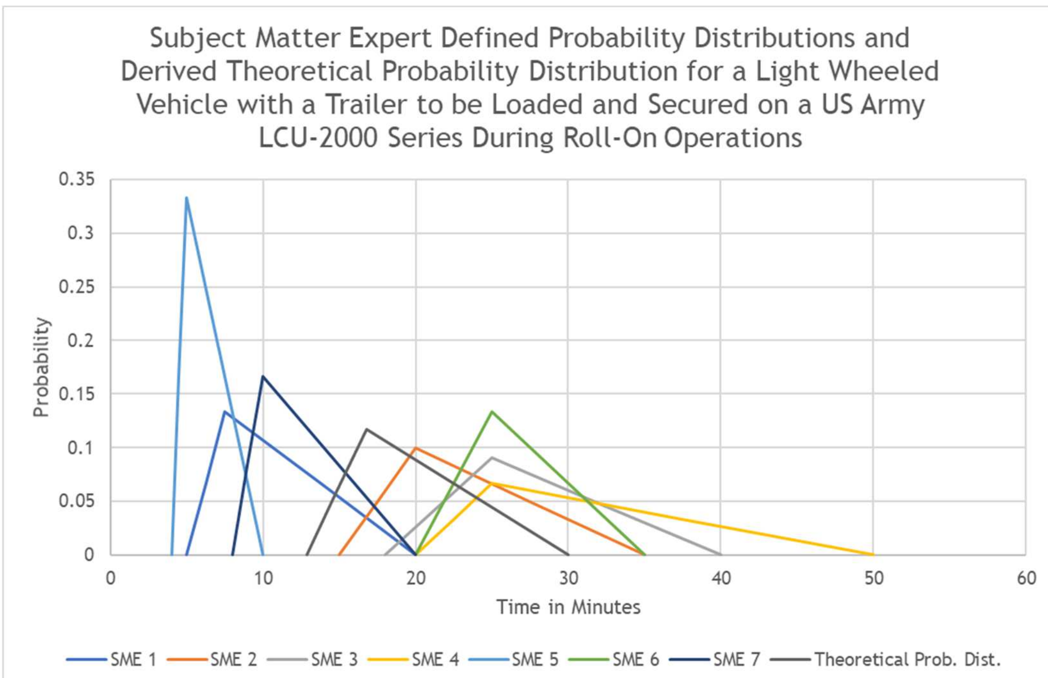

Figure H8. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle with a Trailer to be Loaded and Secured on a US Army LCU-2000 Series During Roll-On Operations.

Table H9. Interview Question 3i - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be loaded and secured on a US Army LCU-2000 series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	30	45
SME Opinion 2	10	15	30
SME Opinion 3	12	15	40
SME Opinion 4	10	15	30
SME Opinion 5	2	3	10
SME Opinion 6	10	12	15
SME Opinion 7	4	6	15
Theoretical	9.714285714	13.71428571	26.42857143

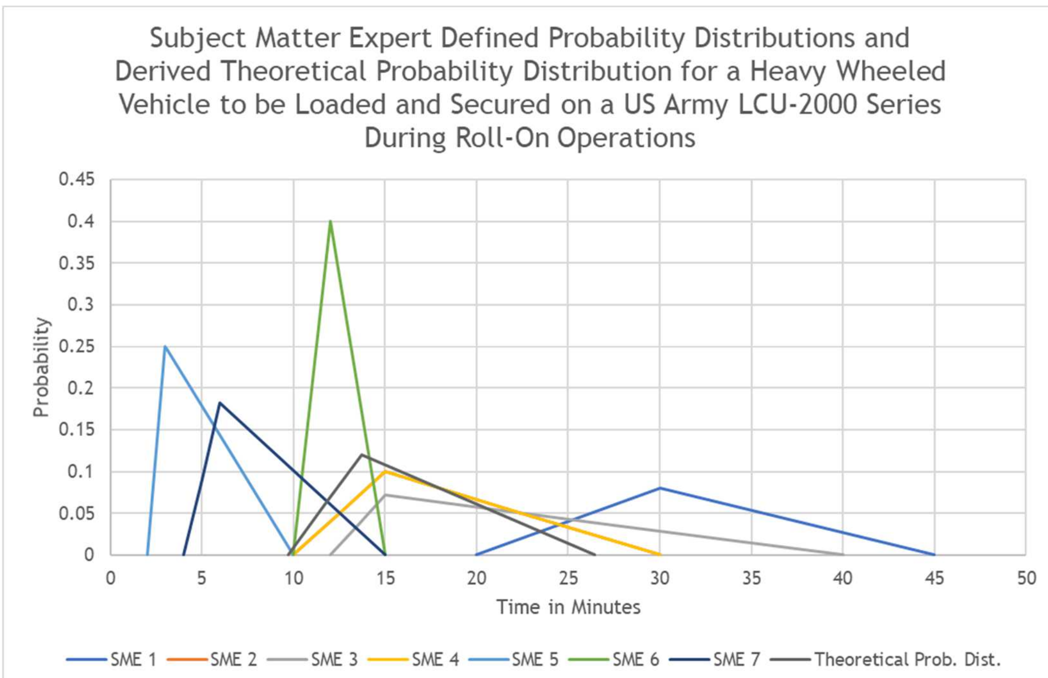

Figure H9. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Loaded and Secured on a US Army LCU-2000 Series During Roll-On Operations.

Table H10. Interview Question 3j - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be loaded and secured on a US Army LCU-2000 series during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	20	40
SME Opinion 2	10	15	30
SME Opinion 3	12	15	30
SME Opinion 4	10	15	60
SME Opinion 5	5	6	10
SME Opinion 6	6	20	30
SME Opinion 7	4	6	10
Theoretical	8.857142857	13.85714286	30

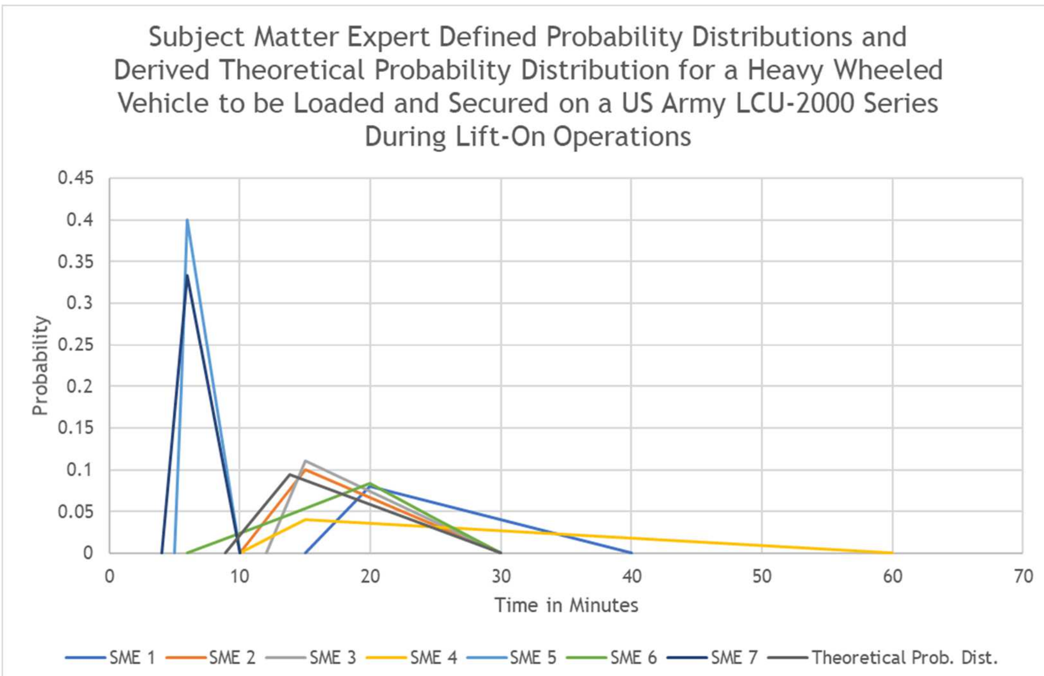

Figure H10. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Loaded and Secured on a US Army LCU-2000 Series During Lift-On Operations.

Table H11. Interview Question 3k - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle with a trailer to be loaded and secured on a US Army LCU-2000 series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	20	45
SME Opinion 2	10	20	35
SME Opinion 3	20	25	45
SME Opinion 4	20	30	60
SME Opinion 5	5	8	20
SME Opinion 6	25	35	40
SME Opinion 7	12	15	30
Theoretical	15.28571429	21.85714286	39.28571429

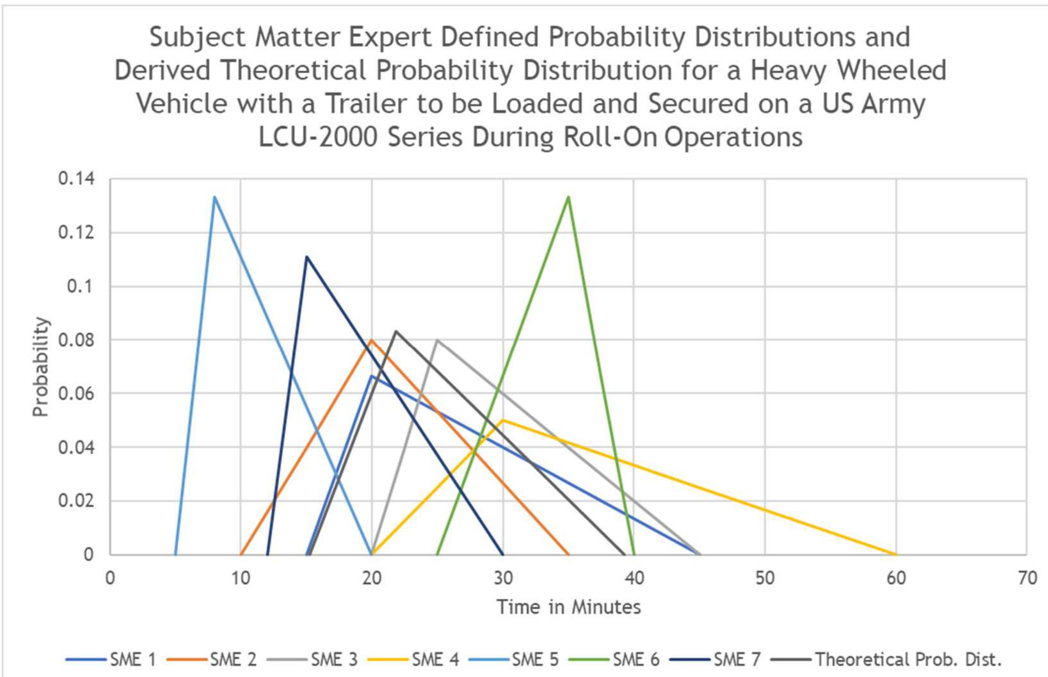

Figure H11. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle with a Trailer to be Loaded and Secured on a US Army LCU-2000 Series During Roll-On Operations.

Table H12. Interview Question 3l - Subject matter expert defined probability distributions and derived theoretical probability distribution for a tracked vehicle to be loaded and secured on a US Army LCU-2000 series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	25	30
SME Opinion 2	10	20	35
SME Opinion 3	20	25	40
SME Opinion 4	10	12	20
SME Opinion 5	2	3	15
SME Opinion 6	6	8	15
Theoretical	10.5	15.5	25.83333333

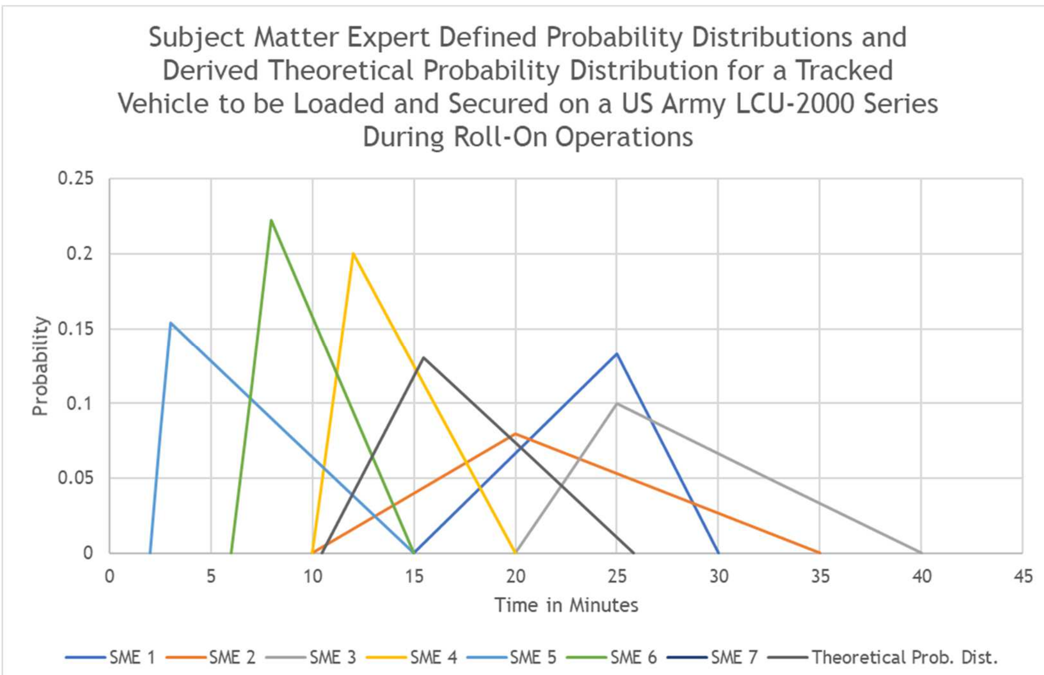

Figure H12. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Tracked Vehicle to be Loaded and Secured on a US Army LCU-2000 Series During Roll-On Operations.

Table H13. Interview Question 3m - Subject matter expert defined probability distributions and derived theoretical probability distribution for a tracked vehicle to be loaded and secured on a US Army LCU-2000 series during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	20	25	40
SME Opinion 3	10	12	15
SME Opinion 4	8	10	20
Theoretical	12	15.5	26.25

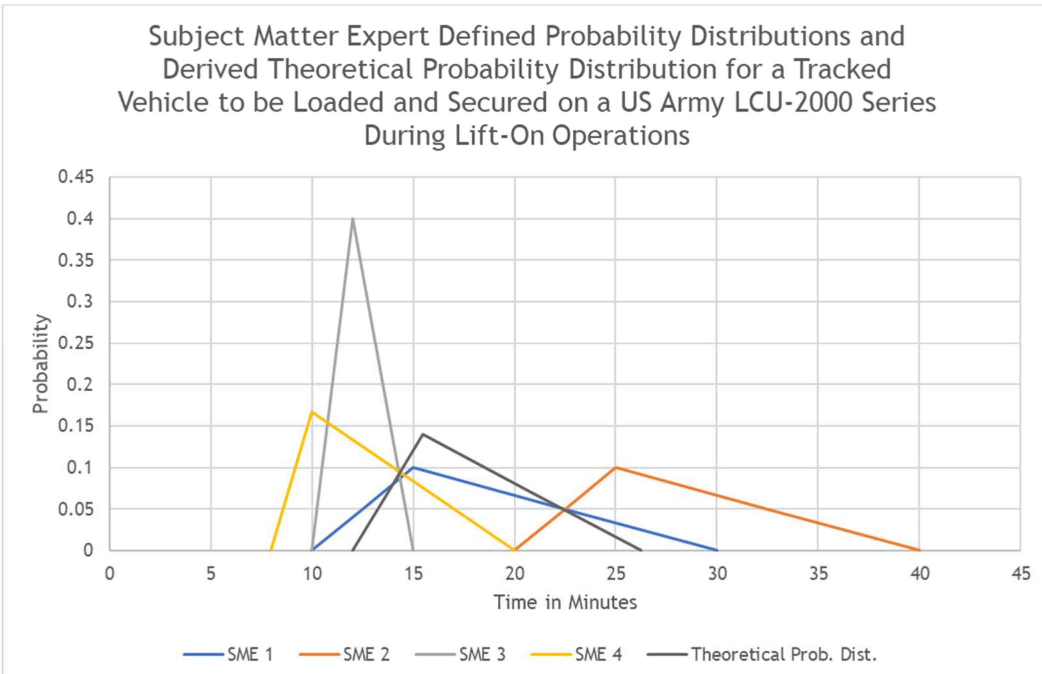

Figure H13. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Tracked Vehicle to be Loaded and Secured on a US Army LCU-2000 Series During Lift-On Operations.

Table H14. Interview Question 3n - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to castoff and clear a US Army RRDF.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	10	15	35
SME Opinion 3	5	10	15
SME Opinion 4	5	8	10
SME Opinion 5	4	5	10
SME Opinion 6	5	7	20
SME Opinion 7	3	5	10
Theoretical	6	9.285714286	18.57142857

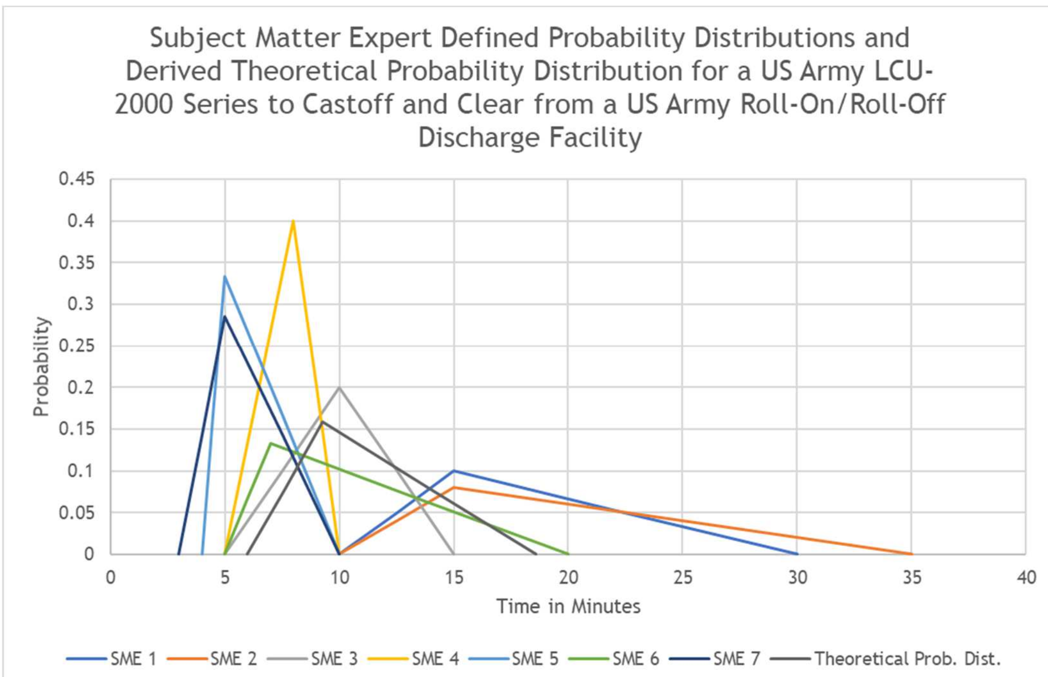

Figure H14. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Castoff and Clear from a US Army RRDF.

Table H15. Interview Question 3o - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to castoff and clear a US Navy RRDF.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	10	20	35
SME Opinion 3	5	10	15
SME Opinion 4	5	5	10
SME Opinion 5	4	5	10
SME Opinion 6	5	7	20
SME Opinion 7	3	5	10
Theoretical	6	9.571428571	18.57142857

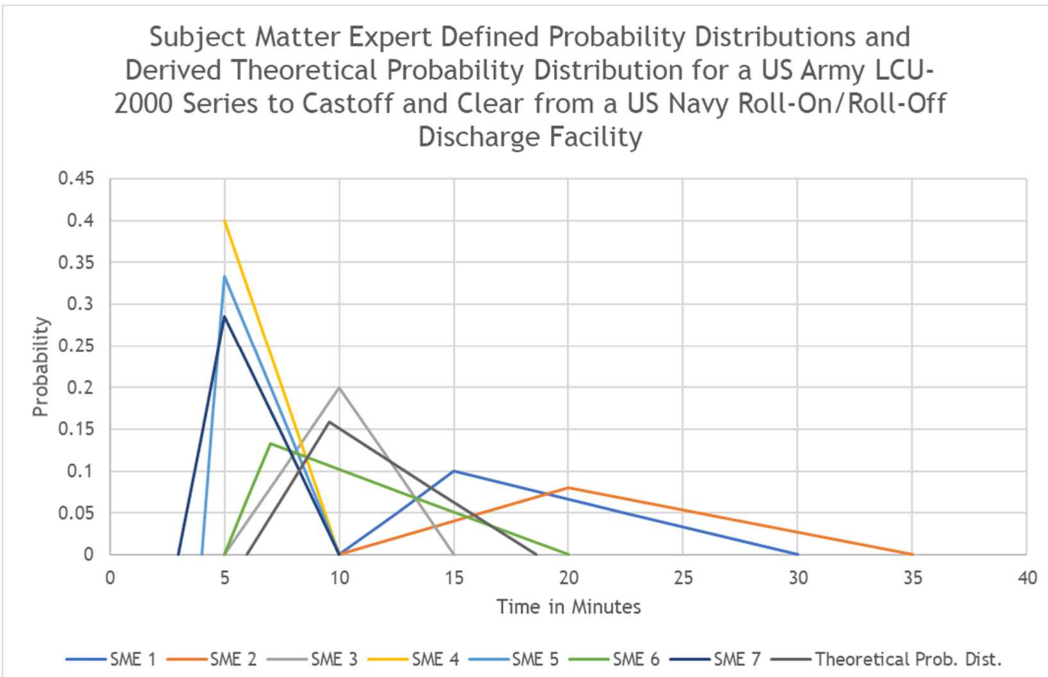

Figure H15. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Castoff and Clear from a US Navy RRDF.

Table H16. Interview Question 3p - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to approach and moor a US Army causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	10	15	30
SME Opinion 3	15	20	40
SME Opinion 4	10	12	15
SME Opinion 5	4	5	10
SME Opinion 6	10	10	25
SME Opinion 7	10	15	25
Theoretical	9.857142857	13.14285714	25

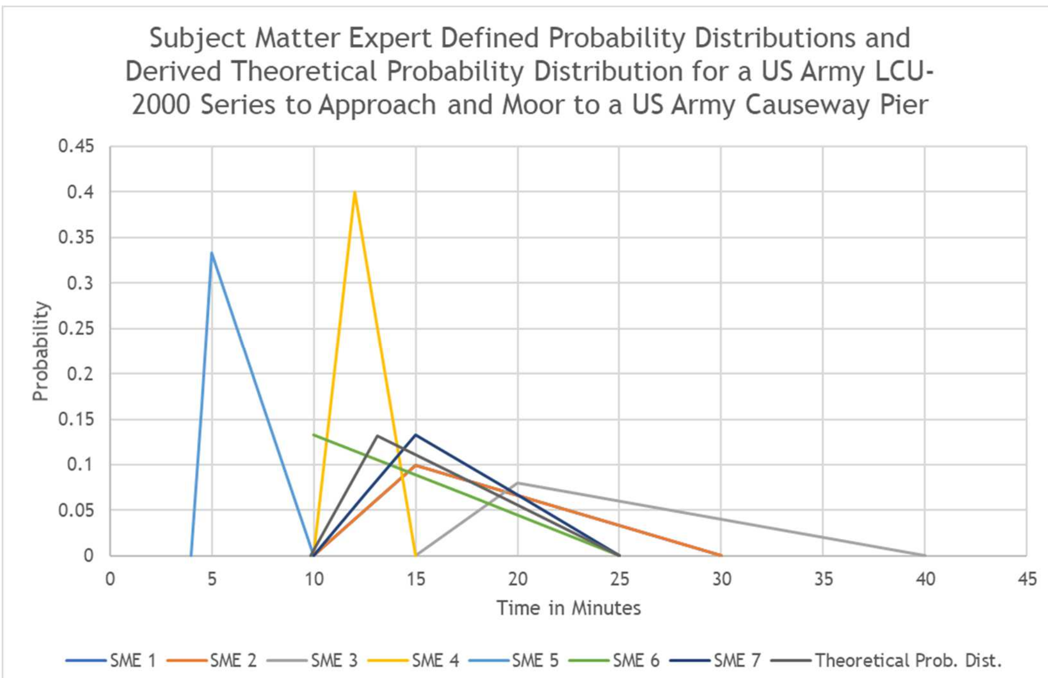

Figure H16. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Approach and Moor to a US Army Causeway Pier.

Table H17. Interview Question 3q - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to approach and moor a US Navy causeway pier without a rhino horn connector.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	25	40
SME Opinion 2	15	20	40
SME Opinion 3	10	15	25
Theoretical	15	20	35

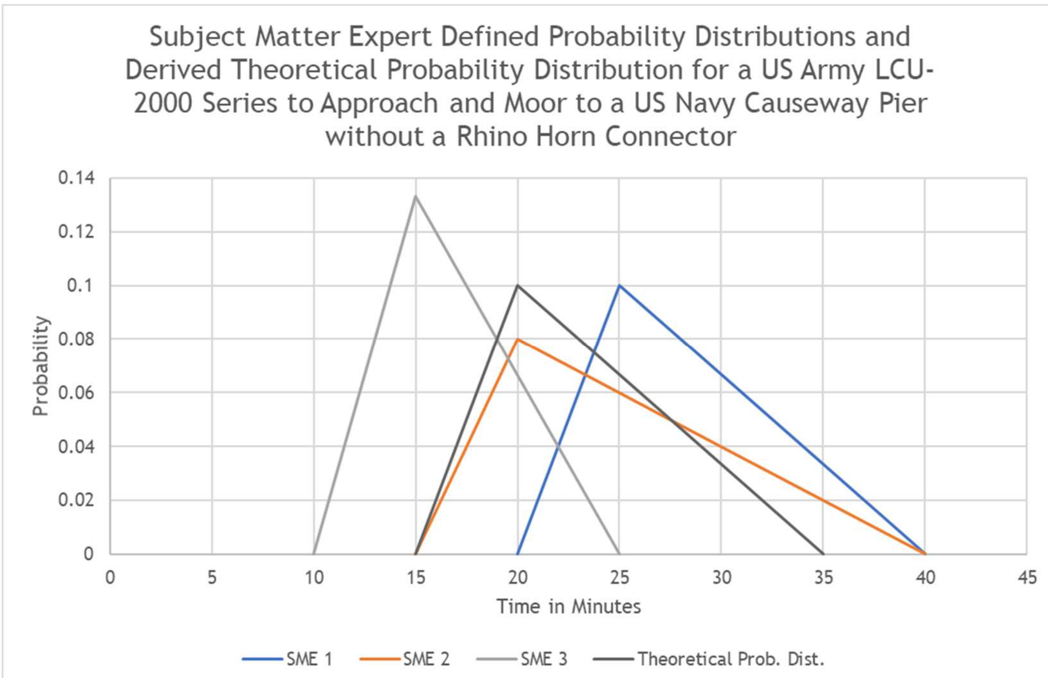

Figure H17. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Approach and Moor to a US Navy Causeway Pier without a Rhino Horn Connector.

Table H18. Interview Question 3r - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to approach and moor a US Navy causeway pier with a rhino horn connector.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	30	40
SME Opinion 2	20	25	60
SME Opinion 3	15	20	30
Theoretical	18.33333333	25	43.33333333

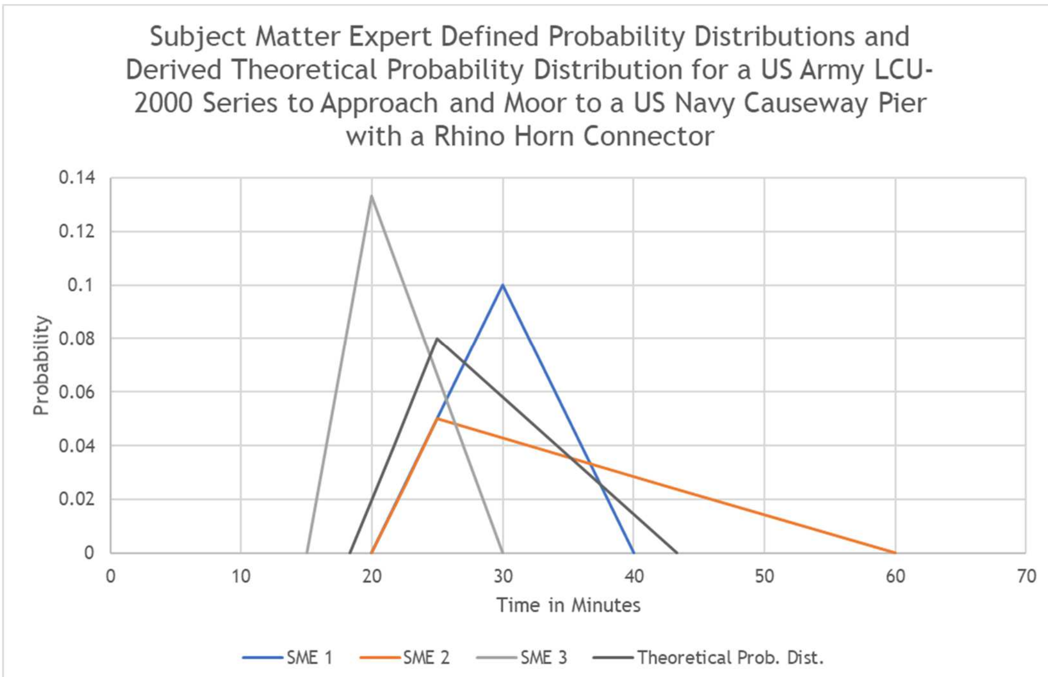

Figure H18. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Approach and Moor to a US Navy Causeway Pier with a Rhino Horn Connector.

Table H19. Interview Question 3s - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to approach and moor to a bare beach landing site.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	30	40
SME Opinion 2	10	20	35
SME Opinion 3	15	25	45
SME Opinion 4	8	10	20
SME Opinion 5	10	20	30
SME Opinion 6	10	15	20
Theoretical	12.16666667	20	31.66666667

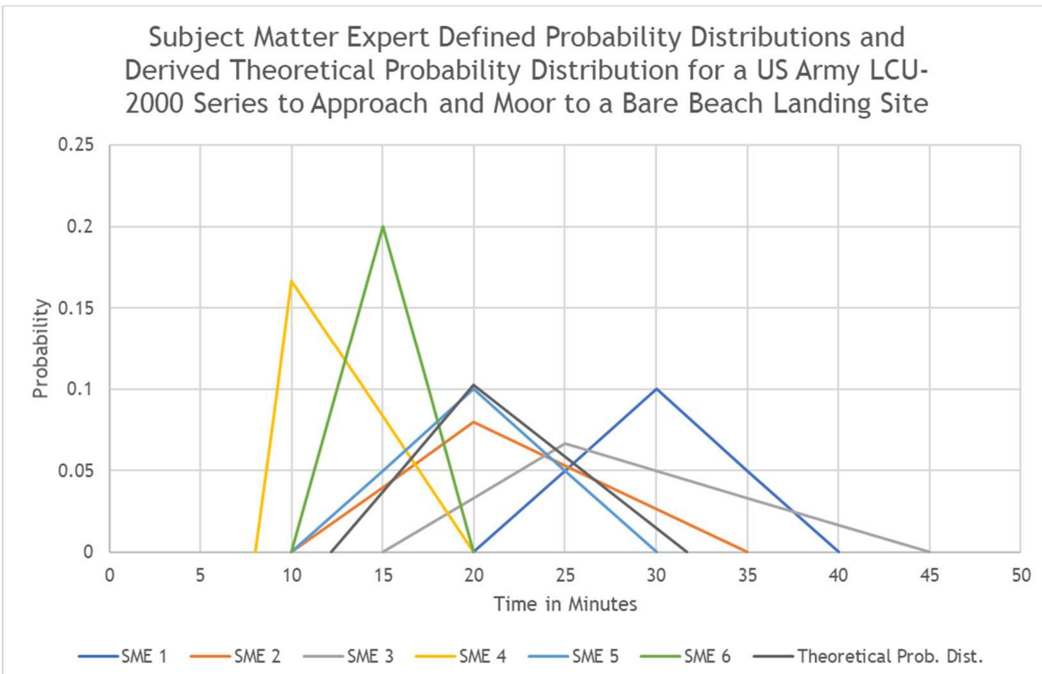

Figure H19. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Approach and Moor to a Bare Beach Landing Site.

Table H20. Interview Question 3t - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be unloaded from a US Army LCU-2000 series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	5	10	20
SME Opinion 3	30	40	50
SME Opinion 4	5	8	13
SME Opinion 5	8	10	25
SME Opinion 6	7	8	10
SME Opinion 7	6	8	15
Theoretical	10.14285714	14.14285714	23.28571429

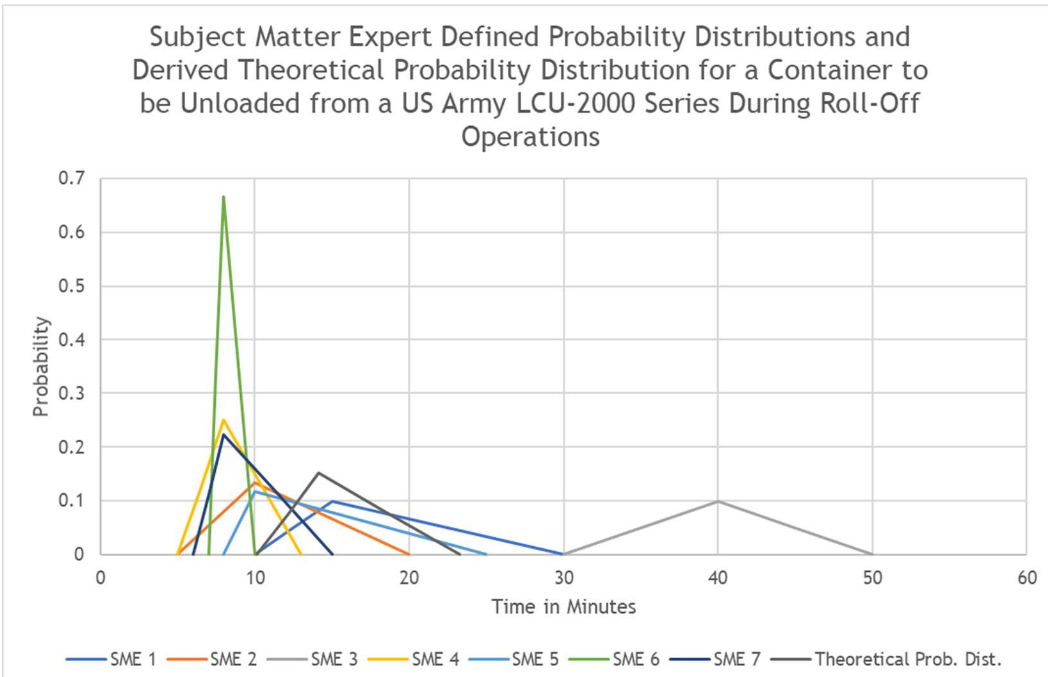

Figure H20. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Unloaded from a US Army LCU-2000 Series During Roll-Off Operations.

Table H21. Interview Question 3u - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be unloaded from a US Army LCU-2000 series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	5	10	20
SME Opinion 3	10	15	20
SME Opinion 4	6	10	15
SME Opinion 5	4	5	10
SME Opinion 6	5	7.5	10
SME Opinion 7	3	5	10
Theoretical	6.142857143	9.642857143	16.42857143

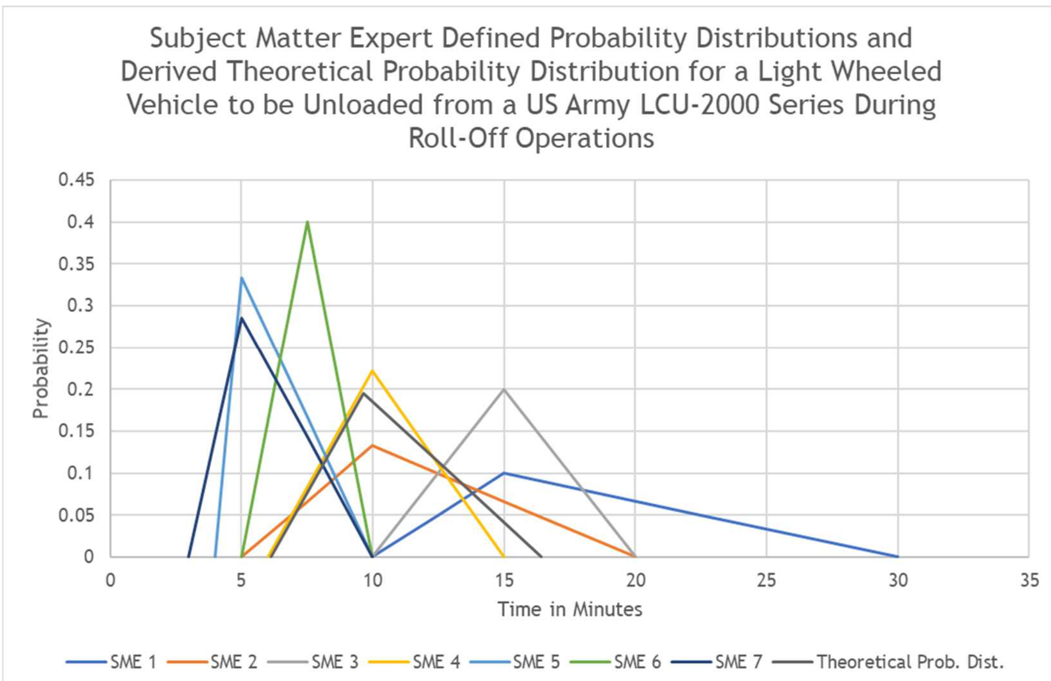

Figure H21. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Unloaded from a US Army LCU-2000 Series During Roll-Off Operations.

Table H22. Interview Question 3v - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle with a trailer to be unloaded from a US Army LCU-2000 series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	10	15	25
SME Opinion 3	12	17	22
SME Opinion 4	8	10	15
SME Opinion 5	5	6	30
SME Opinion 6	15	17	20
SME Opinion 7	3	5	10
Theoretical	9	12.14285714	21.71428571

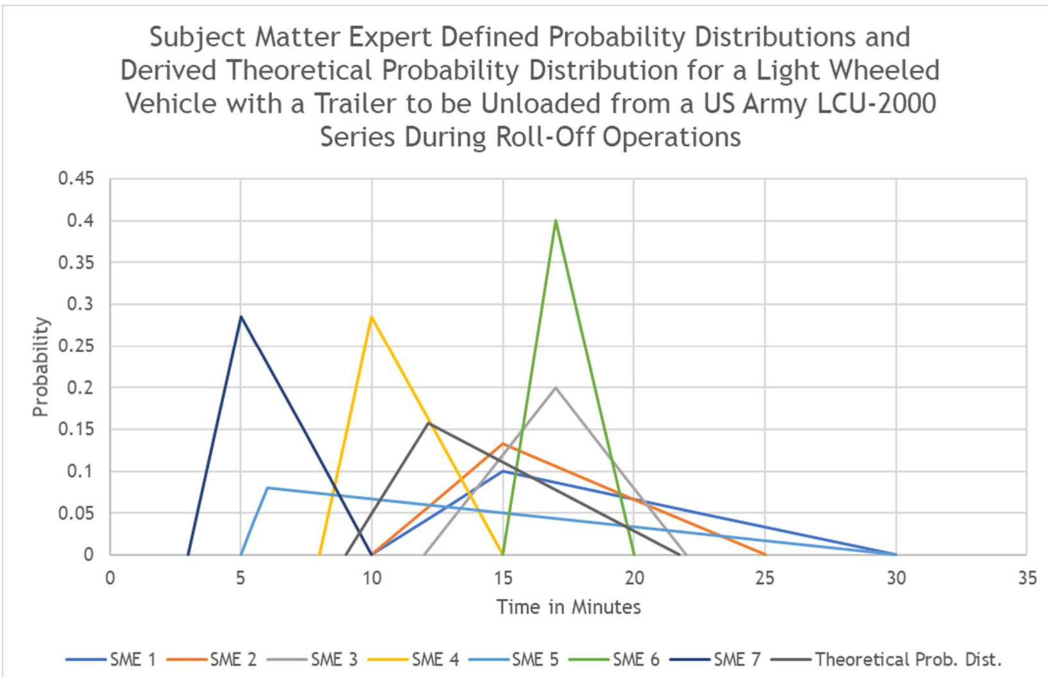

Figure H22. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle with a Trailer to be Unloaded from a US Army LCU-2000 Series During Roll-Off Operations.

Table H23. Interview Question 3w - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be unloaded from a US Army LCU-2000 series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	10	15	25
SME Opinion 3	10	15	20
SME Opinion 4	8	10	15
SME Opinion 5	5	6	10
SME Opinion 6	10	12	15
SME Opinion 7	3	5	10
Theoretical	8	11.14285714	17.85714286

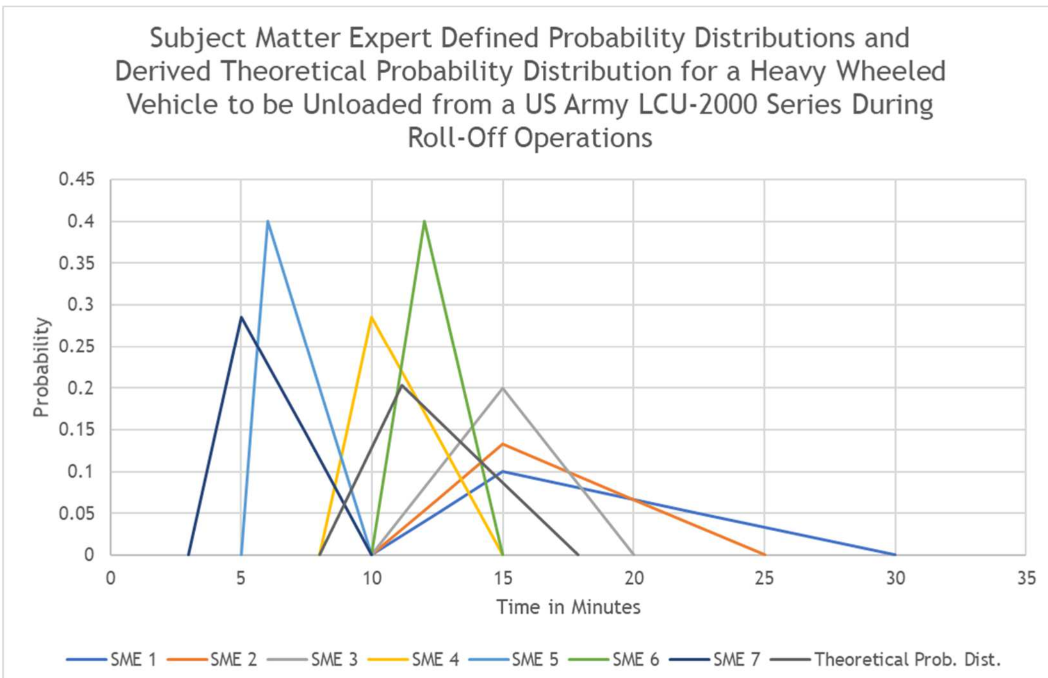

Figure H23. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Unloaded from a US Army LCU-2000 Series During Roll-Off Operations.

Table H24. Interview Question 3x - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle with a trailer to be unloaded from a US Army LCU-2000 series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	20	35
SME Opinion 2	10	20	30
SME Opinion 3	12	17	22
SME Opinion 4	8	10	15
SME Opinion 5	5	6	30
SME Opinion 6	25	35	60
SME Opinion 7	6	8	12
Theoretical	11.57142857	16.57142857	29.14285714

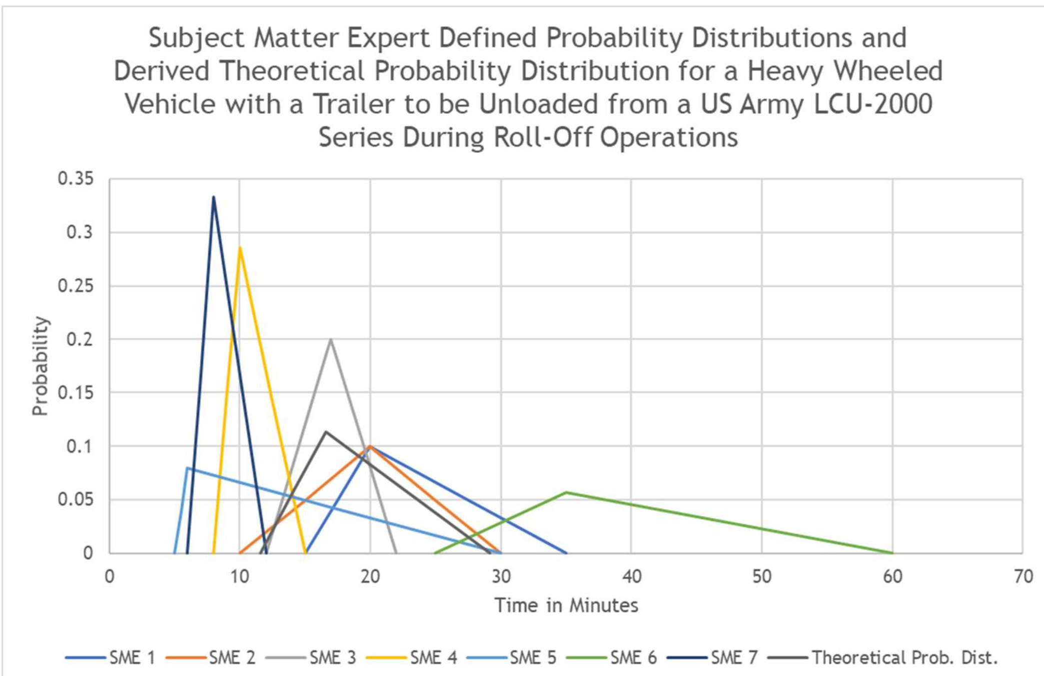

Figure H24. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle with a Trailer to be Unloaded from a US Army LCU-2000 Series During Roll-Off Operations.

Table H25. Interview Question 3y - Subject matter expert defined probability distributions and derived theoretical probability distribution for a tracked vehicle to be unloaded from a US Army LCU-2000 series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	20	40
SME Opinion 2	10	20	30
SME Opinion 3	12	17	22
SME Opinion 4	5	8	12
SME Opinion 5	5	6	10
SME Opinion 6	4	6	10
Theoretical	8.5	12.83333333	20.66666667

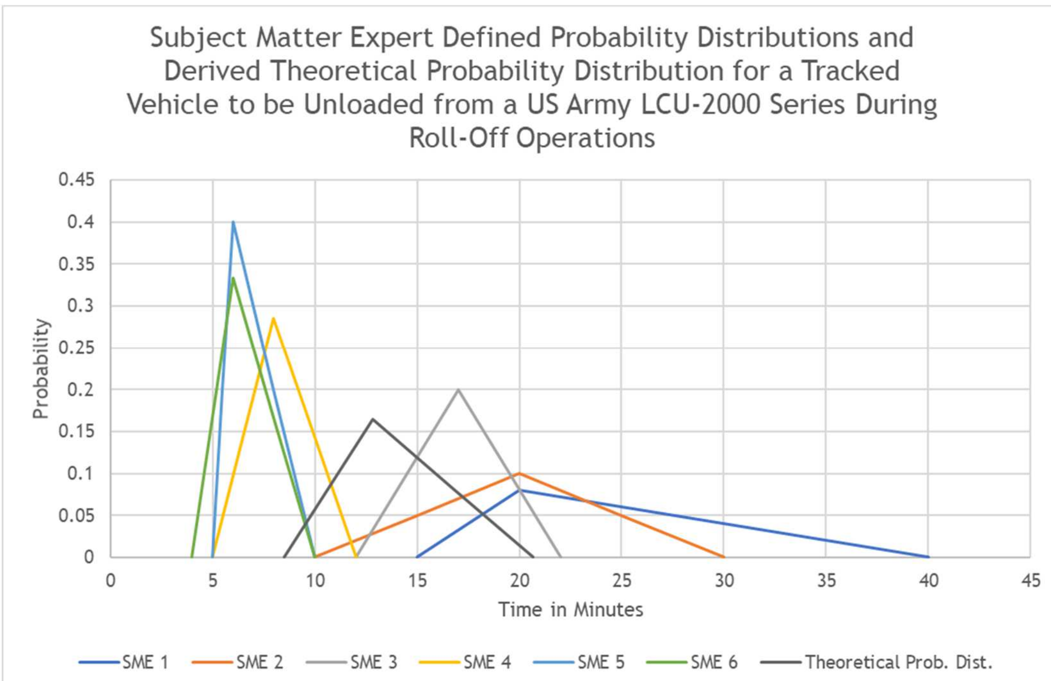

Figure H25. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Tracked Vehicle to be Unloaded from a US Army LCU-2000 Series During Roll-Off Operations.

Table H26. Interview Question 3z - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to castoff and clear a US Army causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	25
SME Opinion 2	10	15	30
SME Opinion 3	5	10	15
SME Opinion 4	5	8	10
SME Opinion 5	4	5	10
SME Opinion 6	5	7	20
SME Opinion 7	3	5	10
Theoretical	6	10	17.14285714

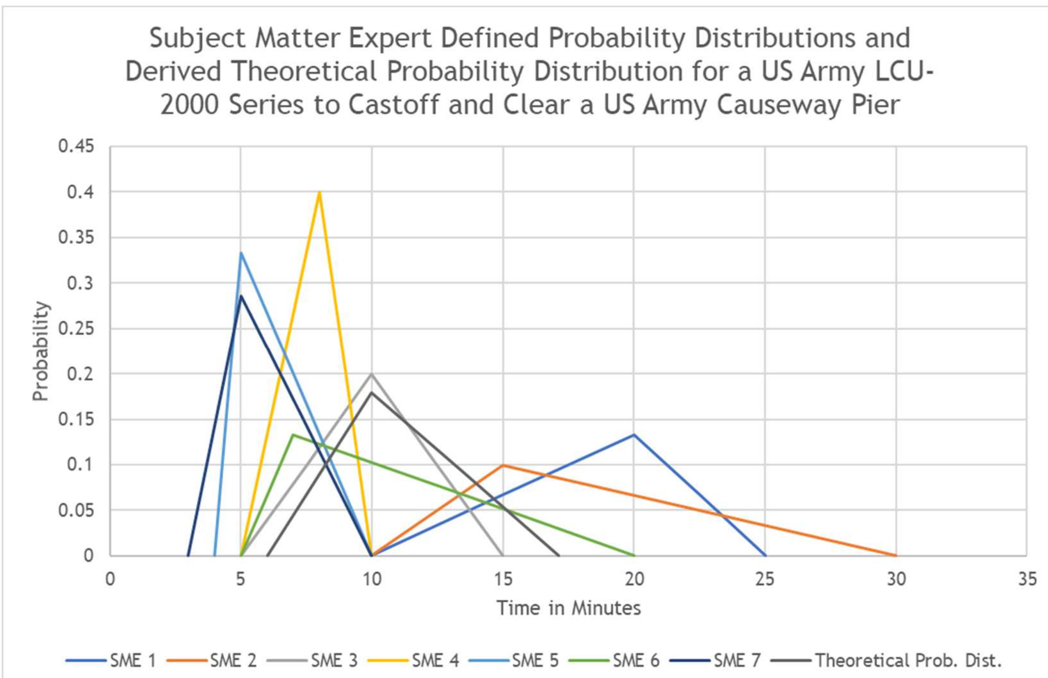

Figure H26. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Castoff and Clear a US Army Causeway Pier.

Table H27. Interview Question 3aa - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to castoff and clear a US Navy causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	35
SME Opinion 2	5	10	15
SME Opinion 3	5	7	20
SME Opinion 4	3	5	10
Theoretical	5.75	10.5	20

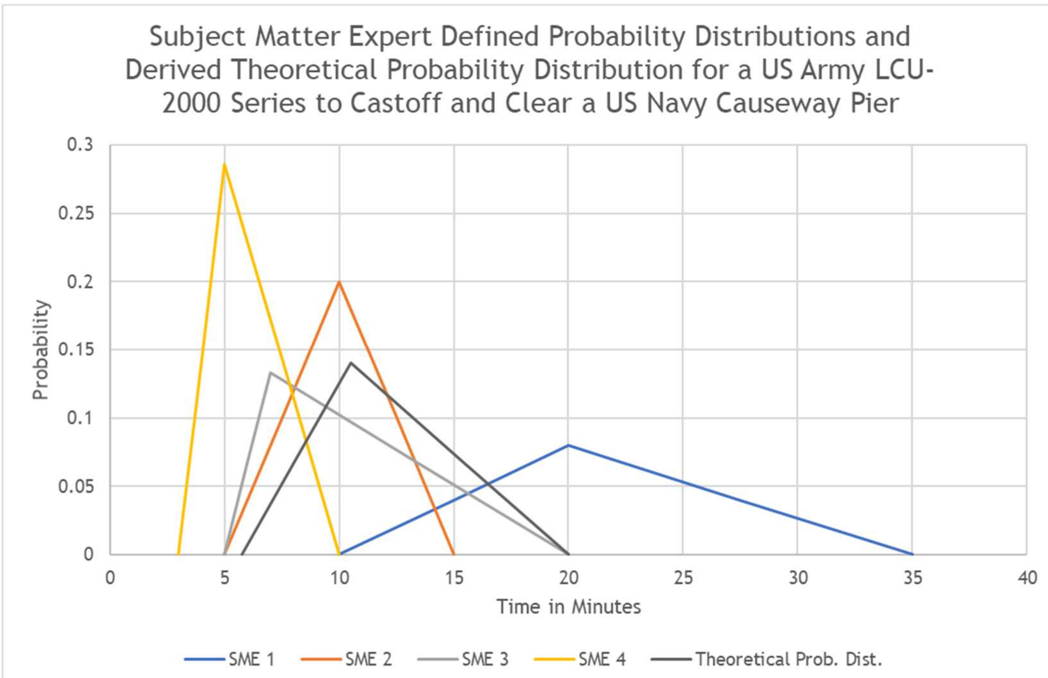

Figure H27. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Castoff and Clear a US Navy Causeway Pier.

Table H28. Interview Question 3bb - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army LCU-2000 series to castoff and clear a bare beach landing site.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	30
SME Opinion 2	10	15	30
SME Opinion 3	10	12	30
SME Opinion 4	12	15	30
SME Opinion 5	10	12	25
SME Opinion 6	8	10	15
Theoretical	10	14	26.66666667

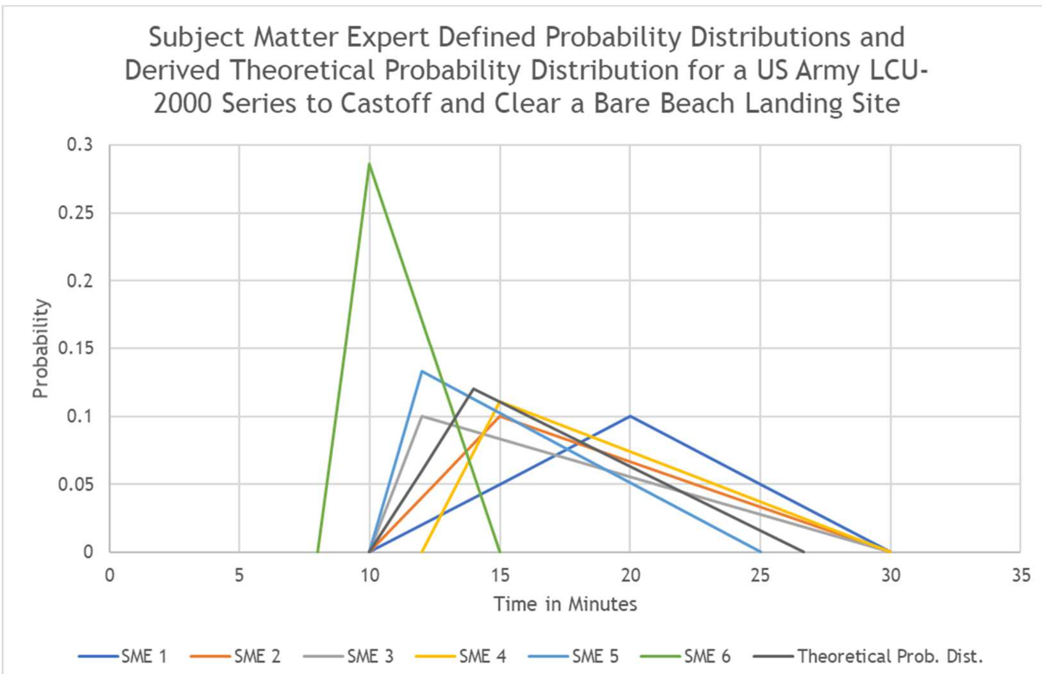

Figure H28. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army LCU-2000 Series to Castoff and Clear a Bare Beach Landing Site.

APPENDIX I. TABLES AND FIGURES OF SUBJECT MATTER EXPERT RESPONSES AND THEORETICAL PROBABILITY DISTRIBUTIONS FOR US ARMY LOGISTICS SUPPORT VESSEL / JLOTS ACTIVITY COMBINATIONS

Table I1. Interview Question 4a - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army Logistics Support Vessel to approach and moor to a US Army RRDF.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	30	60
SME Opinion 2	15	20	30
SME Opinion 3	25	30	60
SME Opinion 4	10	15	45
SME Opinion 5	25	30	45
Theoretical	19	25	48

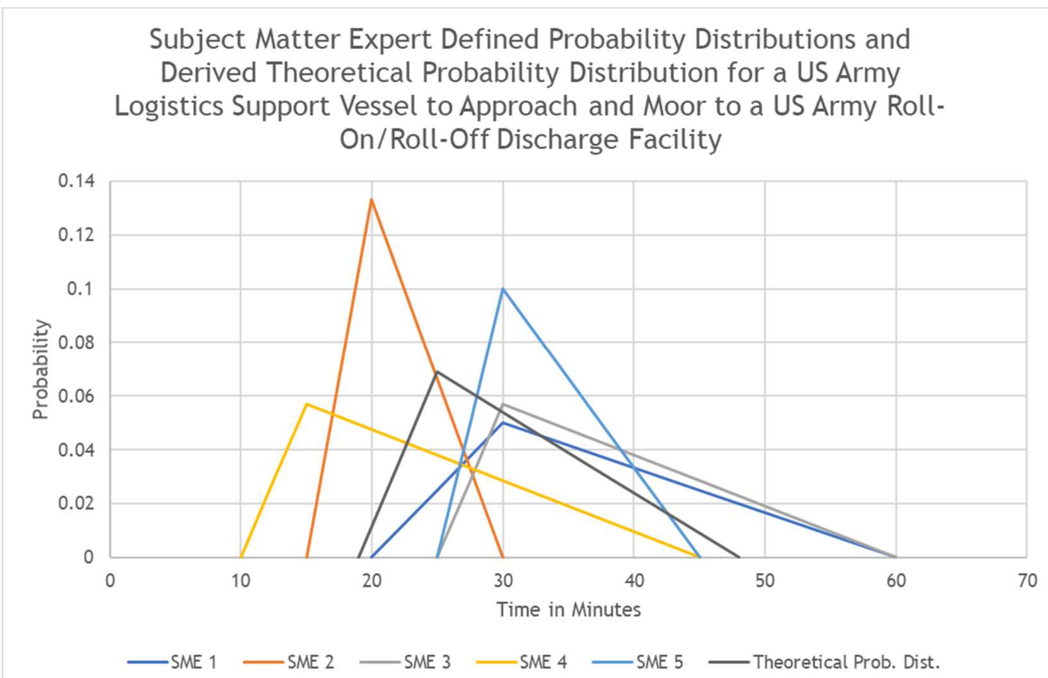

Figure I1. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Logistics Support Vessel to Approach and Moor a US Army RRDF.

Table I2. Interview Question 4b - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army Logistics Support Vessel to approach and moor to a US Navy RRDF.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	30	60
SME Opinion 2	20	25	35
SME Opinion 3	25	30	45
Theoretical	20	28.33333333	46.66666667

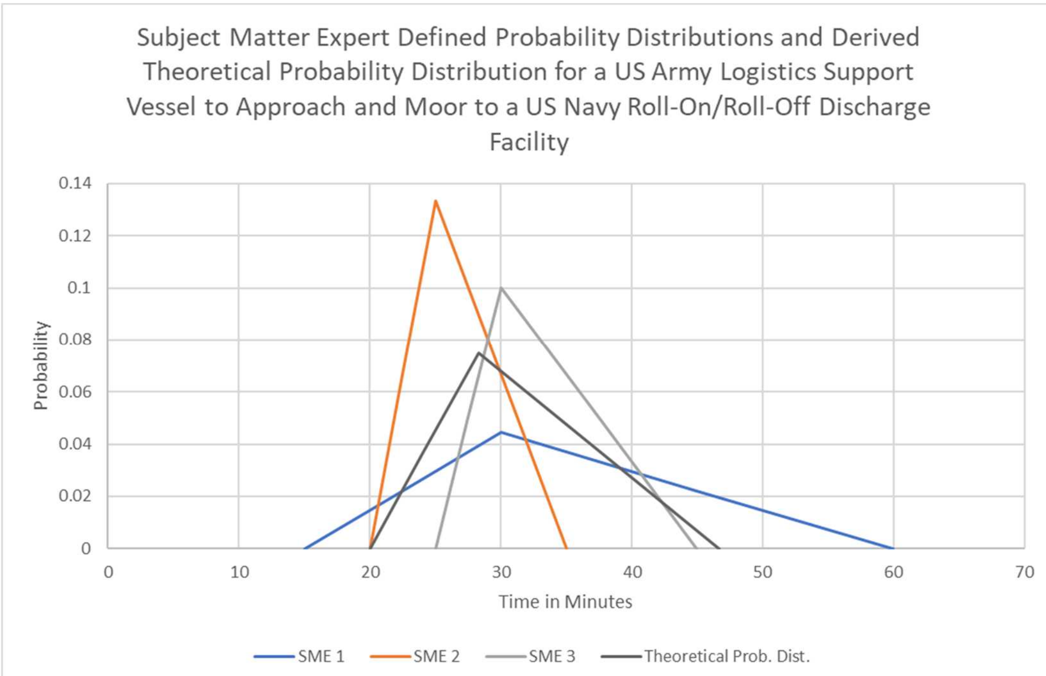

Figure I2. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Logistics Support Vessel to Approach and Moor a US Navy RRDF.

Interview Question 4c – No data since the Logistics Support Vessel cannot moor to a US Navy RRDF with a rhino horn connector.

Table I3. Interview Question 4d - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be loaded on a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	30
SME Opinion 2	15	20	30
SME Opinion 3	5	10	20
SME Opinion 4	15	20	45
SME Opinion 5	12	15	25
SME Opinion 6	6	8	15
Theoretical	9.666666667	13.83333333	27.5

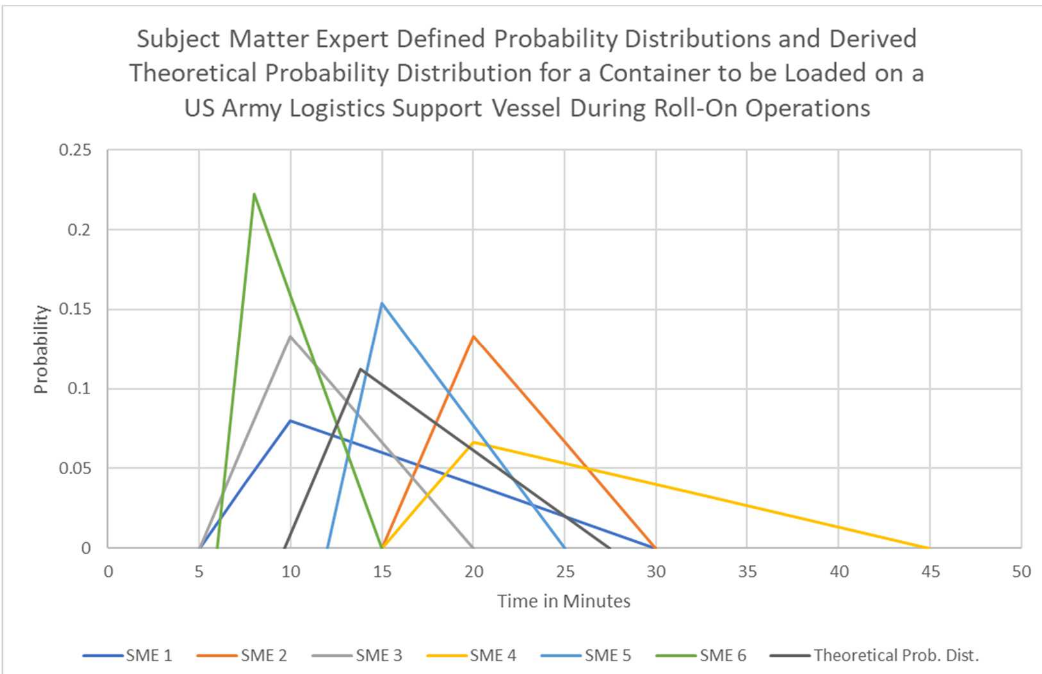

Figure I3. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Loaded on a US Army Logistics Support Vessel During Roll-On Operations.

Table I4. Interview Question 4e - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be loaded on a US Army Logistics Support Vessel during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	20	45
SME Opinion 2	20	20	40
SME Opinion 3	5	10	20
SME Opinion 4	10	15	45
SME Opinion 5	4	6	15
Theoretical	10.8	14.2	33

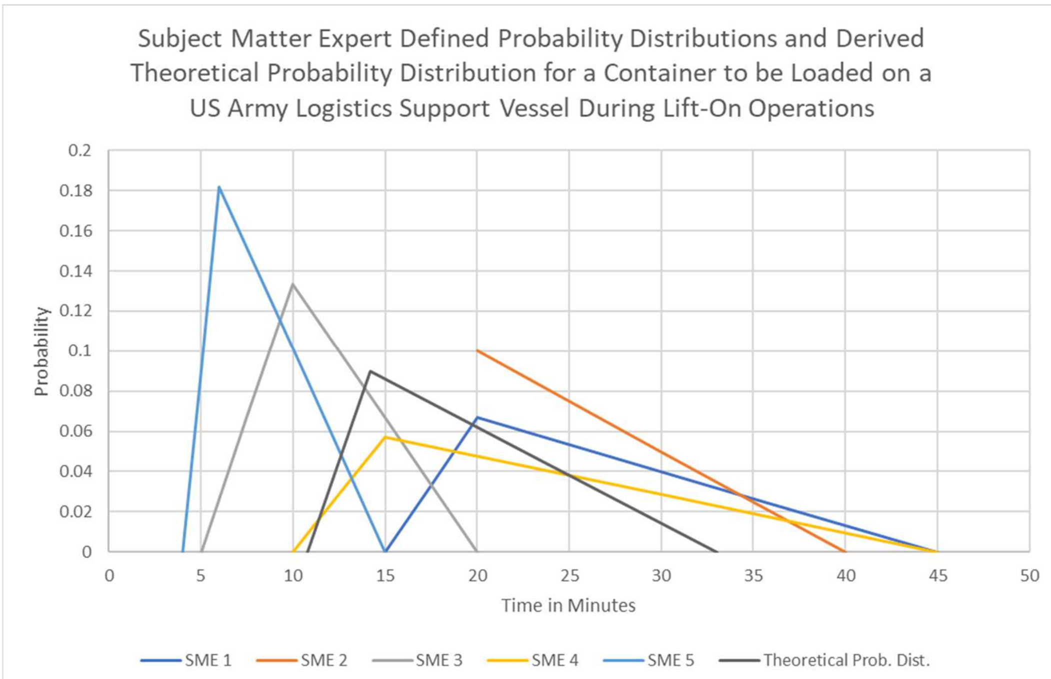

Figure I4. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Loaded on a US Army Logistics Support Vessel During Lift-On Operations.

Table I5. Interview Question 4f - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be loaded on a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	20
SME Opinion 2	15	20	55
SME Opinion 3	10	15	25
SME Opinion 4	10	20	30
SME Opinion 5	7	10	20
SME Opinion 6	8	10	20
Theoretical	9.166666667	14.16666667	28.33333333

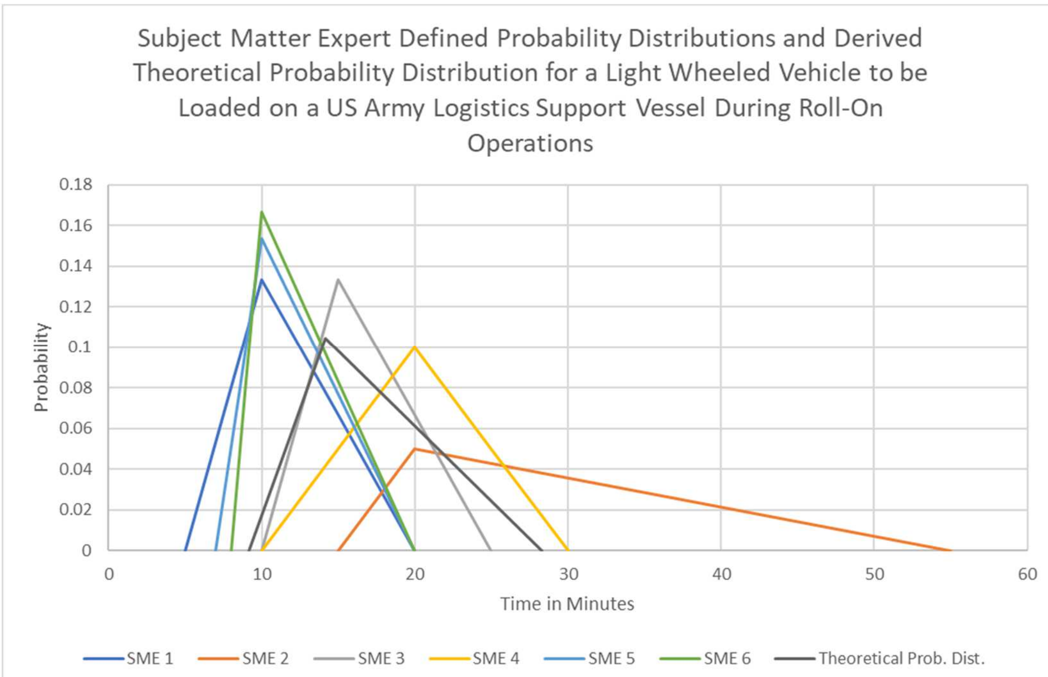

Figure I5. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Loaded on a US Army Logistics Support Vessel During Roll-On Operations.

Table I6. Interview Question 4g - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be loaded on a US Army Logistics Support Vessel during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	25	45
SME Opinion 2	20	25	40
SME Opinion 3	10	15	25
SME Opinion 4	10	20	30
SME Opinion 5	4	6	15
Theoretical	11.8	18.2	31

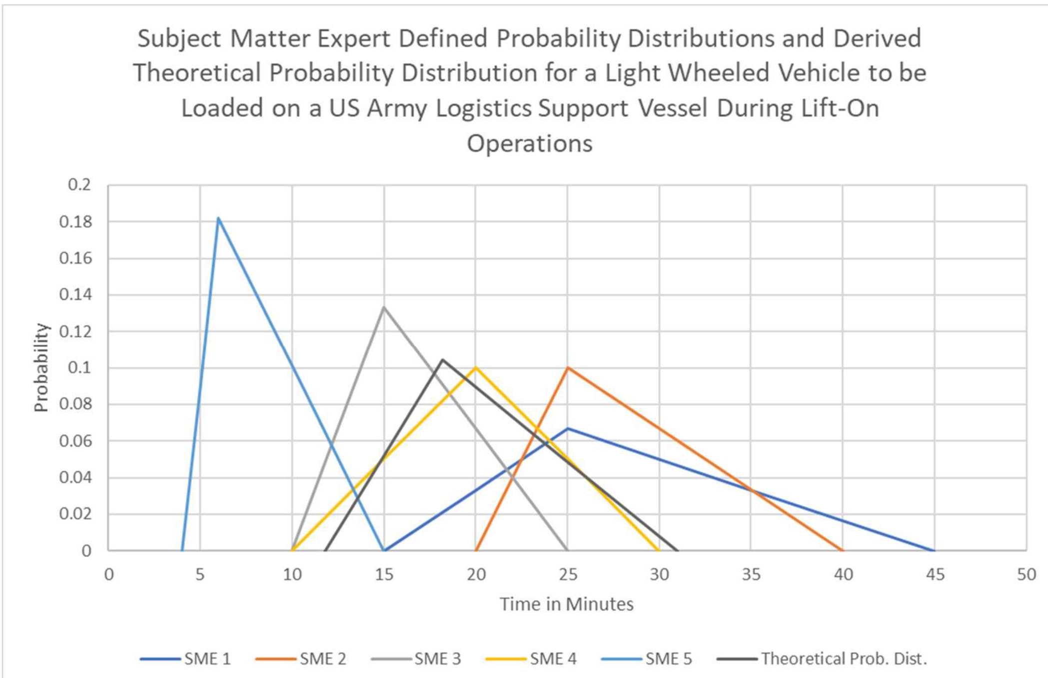

Figure I6. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Loaded on a US Army Logistics Support Vessel During Lift-On Operations.

Table I7. Interview Question 4h - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle with a trailer to be loaded on a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	15	20	35
SME Opinion 3	10	20	30
SME Opinion 4	10	20	30
SME Opinion 5	10	12	25
Theoretical	11	17.4	30

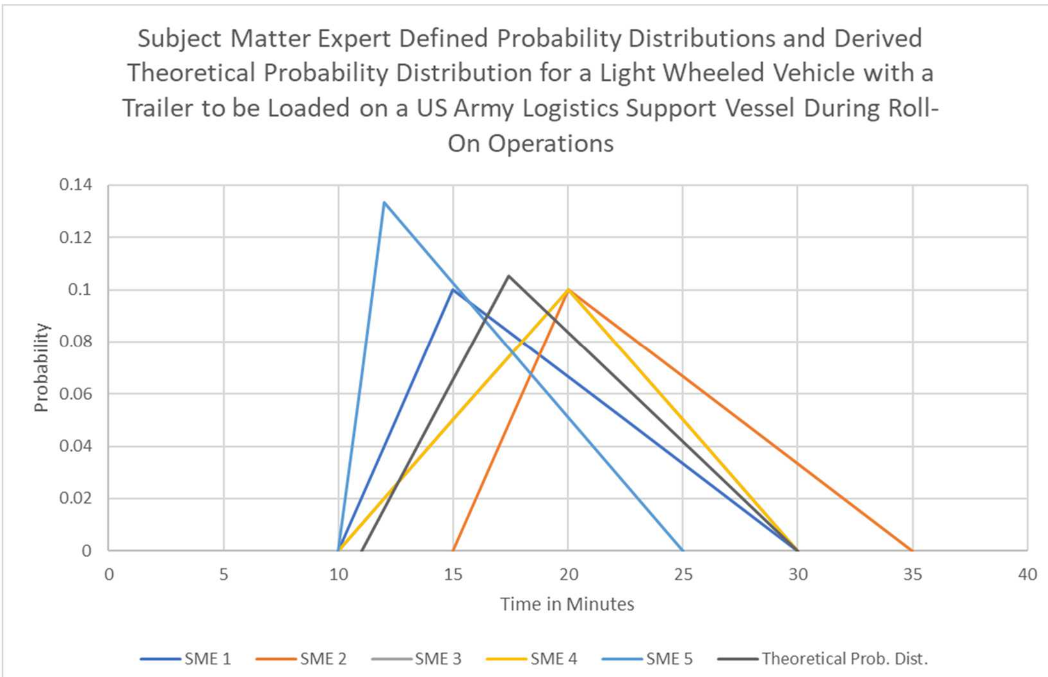

Figure I7. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle with a Trailer to be Loaded on a US Army Logistics Support Vessel During Roll-On Operations.

Table I8. Interview Question 4i - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be loaded on a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	10	15	25
SME Opinion 3	10	20	30
SME Opinion 4	10	15	30
SME Opinion 5	6	8	15
Theoretical	9.2	14.6	26

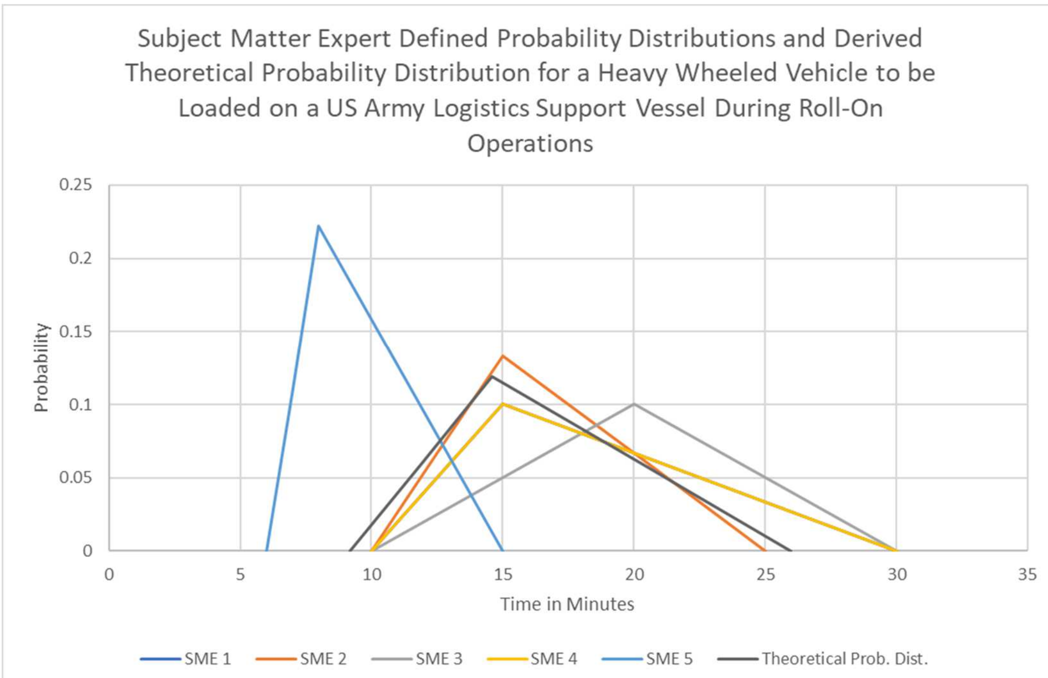

Figure I8. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Loaded on a US Army Logistics Support Vessel During Roll-On Operations.

Table I9. Interview Question 4j - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be loaded on a US Army Logistics Support Vessel during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	25
SME Opinion 2	10	20	30
SME Opinion 3	4	6	15
Theoretical	8	13.66666667	23.33333333

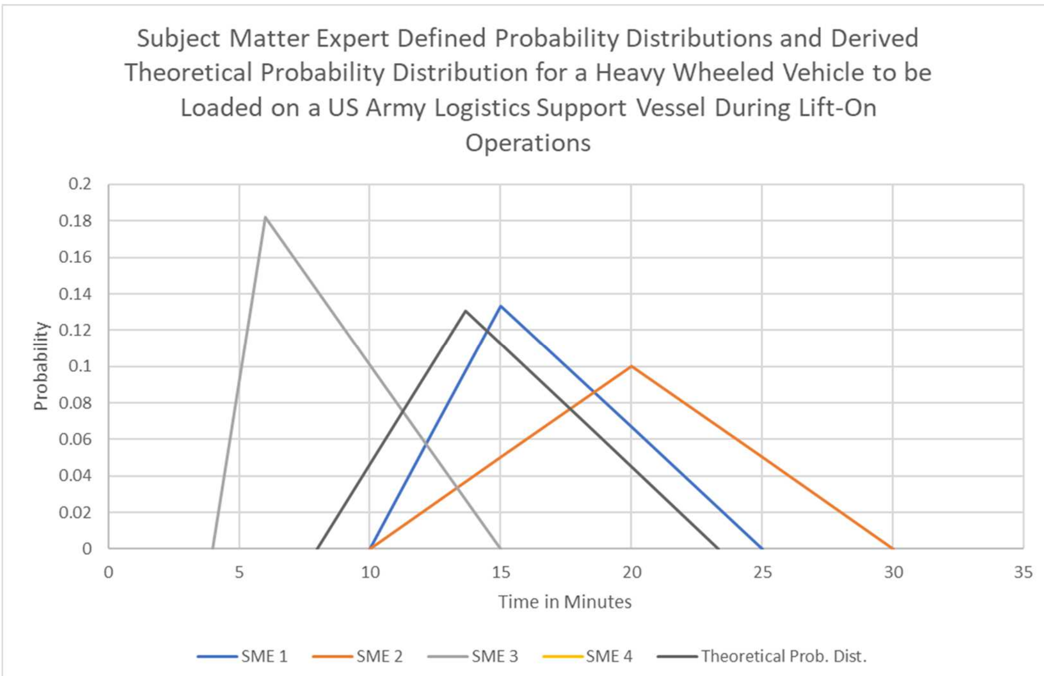

Figure I9. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Loaded on a US Army Logistics Support Vessel During Lift-On Operations.

Table I10. Interview Question 4k - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle with trailer to be loaded on a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	20	35
SME Opinion 2	10	20	30
SME Opinion 3	15	25	30
SME Opinion 4	10	12	20
Theoretical	12.5	19.25	28.75

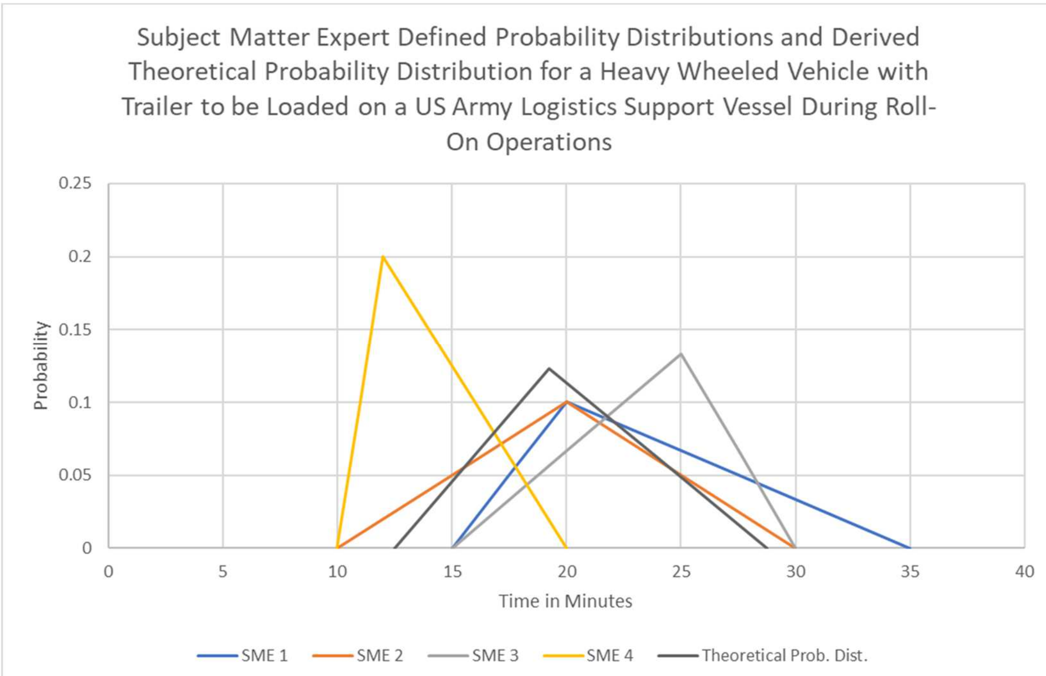

Figure I10. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle with Trailer to be Loaded on a US Army Logistics Support Vessel During Roll-On Operations.

Table I11. Interview Question 4l - Subject matter expert defined probability distributions and derived theoretical probability distribution for a tracked vehicle to be loaded on a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	30
SME Opinion 2	10	20	30
SME Opinion 3	8	10	30
SME Opinion 4	6	8	15
Theoretical	8.5	14.5	26.25

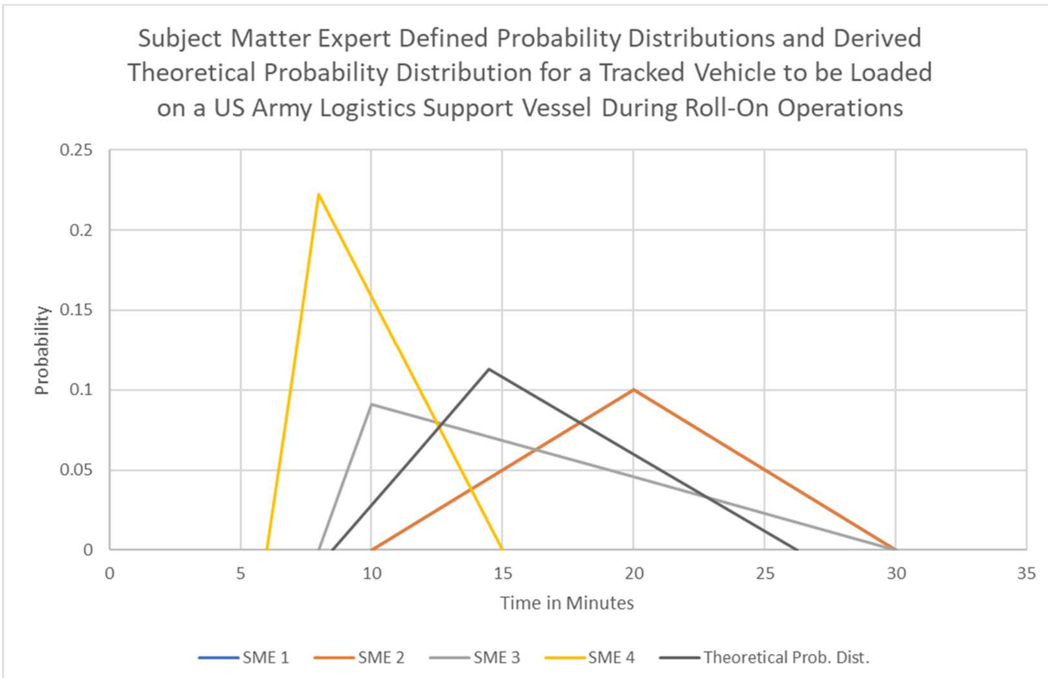

Figure I11. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Tracked Vehicle to be Loaded on a US Army Logistics Support Vessel During Roll-On Operations.

Table I12. Interview Question 4m - Subject matter expert defined probability distributions and derived theoretical probability distribution for a tracked vehicle to be loaded on a US Army Logistics Support Vessel during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	30
SME Opinion 2	10	20	30
SME Opinion 3	8	10	20
Theoretical	9.333333333	16.66666667	26.66666667

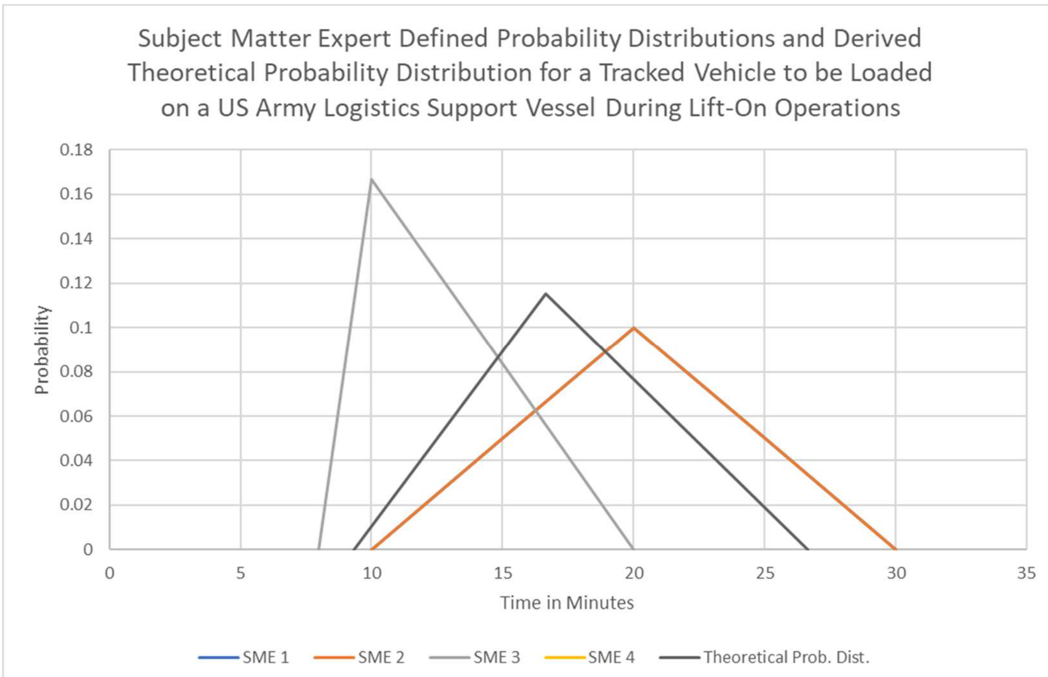

Figure I12. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Tracked Vehicle to be Loaded on a US Army Logistics Support Vessel During Lift-On Operations.

Table I13. Interview Question 4n - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army Logistics Support Vessel to castoff and clear to a US Army RRDF.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	30	45
SME Opinion 2	10	15	30
SME Opinion 3	15	20	45
SME Opinion 4	15	20	30
SME Opinion 5	15	20	30
Theoretical	15	21	36

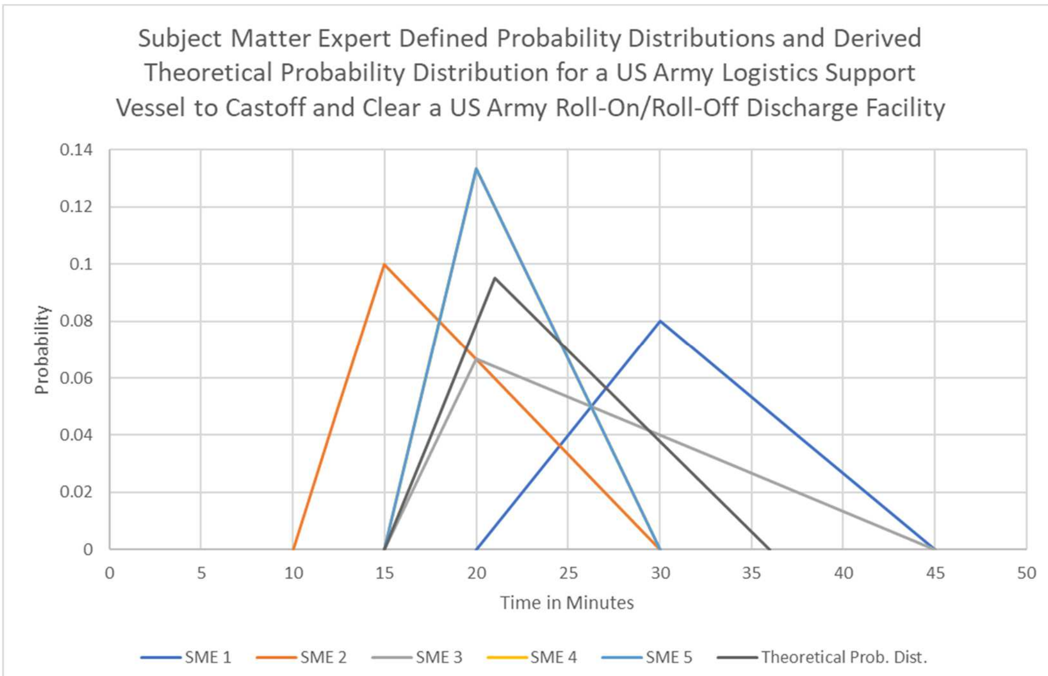

Figure I13. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Logistics Support Vessel to Castoff and Clear a US Army RRDF.

Table I14. Interview Question 4o - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army Logistics Support Vessel to castoff and clear to a US Navy RRDF.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	15	20	30
Theoretical	12.5	17.5	30

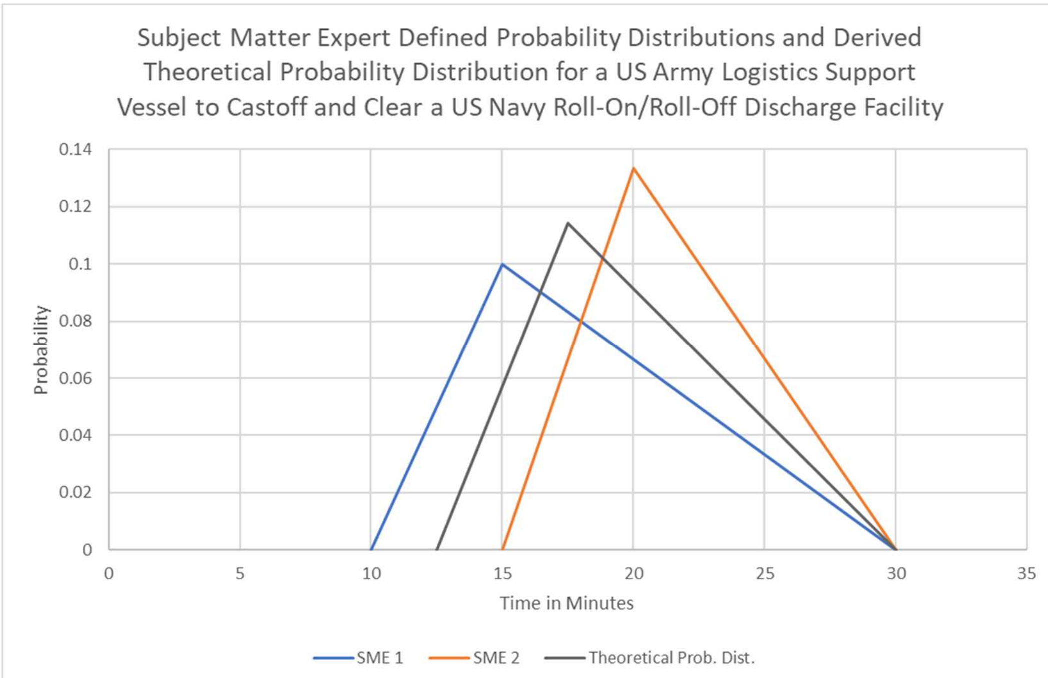

Figure I14. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Logistics Support Vessel to Castoff and Clear a US Navy RRDF.

Table I15. Interview Question 4p - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army Logistics Support Vessel to approach and moor to a US Army causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	20	40
SME Opinion 2	30	45	120
SME Opinion 3	15	20	30
SME Opinion 4	20	30	40
Theoretical	20	28.75	57.5

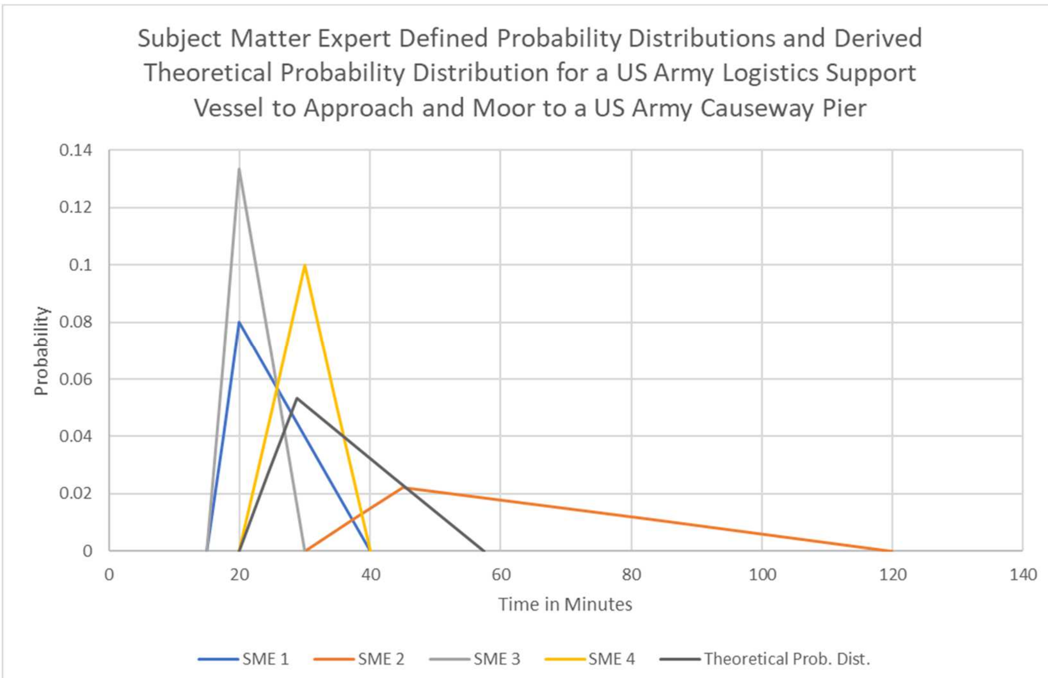

Figure I15. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Logistics Support Vessel to Approach and Moor to a US Army Causeway Pier.

Table I16. Interview Question 4q - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army Logistics Support Vessel to approach and moor to a US Navy causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	20	30
SME Opinion 2	20	30	40
Theoretical	17.5	25	35

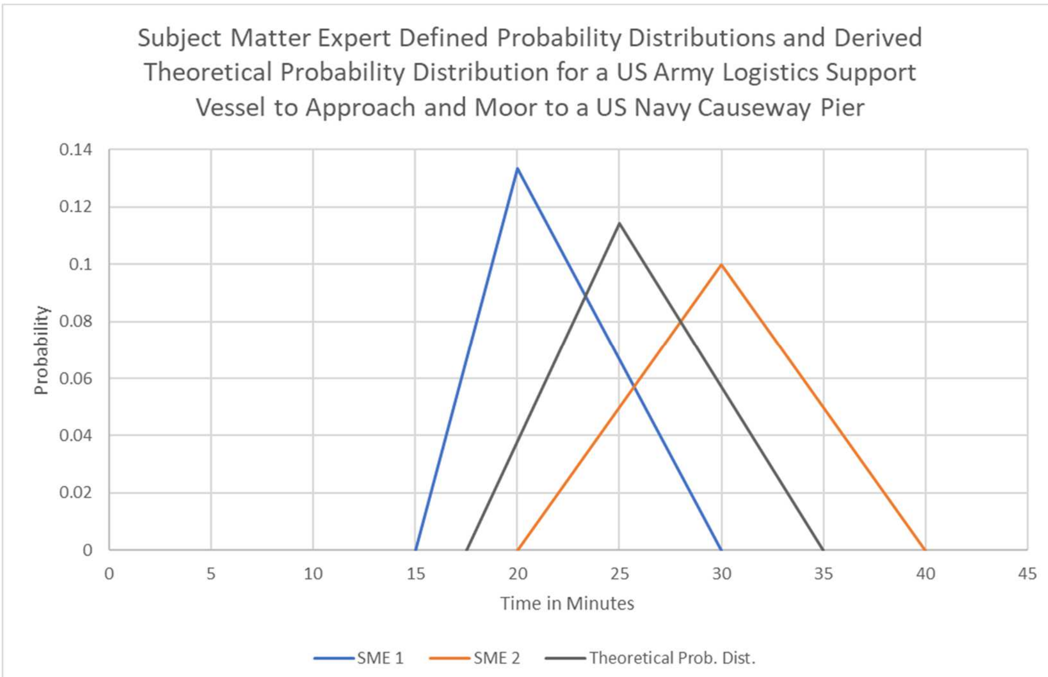

Figure I16. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Logistics Support Vessel to Approach and Moor to a US Navy Causeway Pier.

Interview Question 4r – No data since the Logistics Support Vessel cannot moor to a US Navy RRDF with a rhino horn connector.

Table I17. Interview Question 4s - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army Logistics Support Vessel to approach and moor to a bare beach landing site.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	30	45	60
SME Opinion 2	15	20	35
SME Opinion 3	25	30	60
SME Opinion 4	12	15	25
Theoretical	20.5	27.5	45

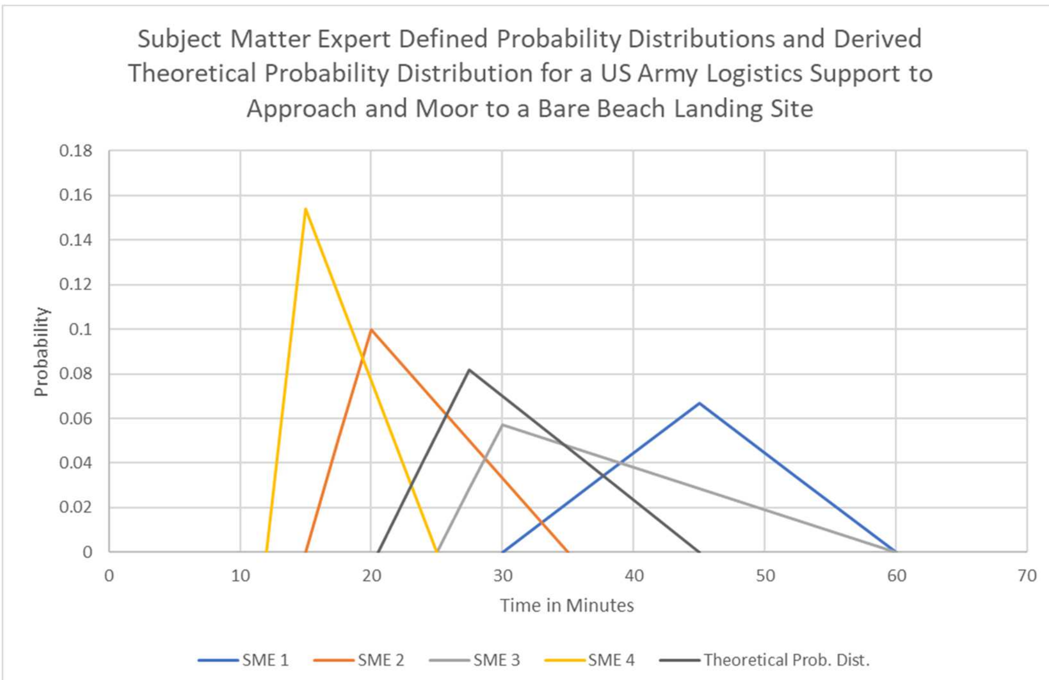

Figure I17. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Logistics Support Vessel to Approach and Moor to a Bare Beach Landing Site.

Table I18. Interview Question 4t - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be unloaded on a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	20	30
SME Opinion 2	5	10	25
SME Opinion 3	10	15	45
SME Opinion 4	20	25	35
SME Opinion 5	8	10	15
Theoretical	11.6	16	30

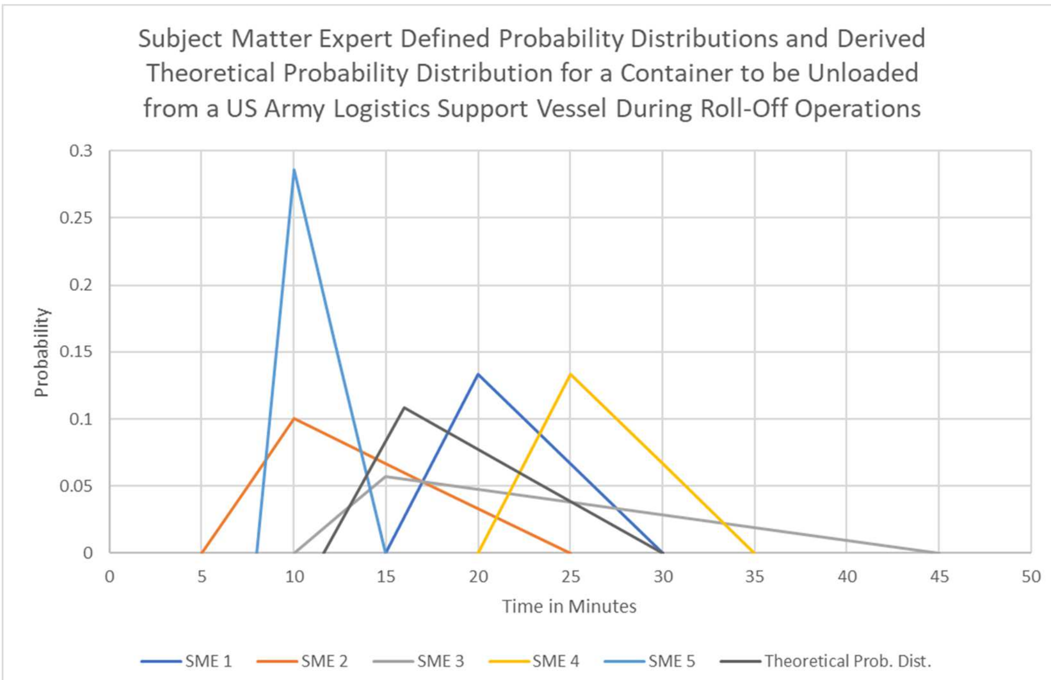

Figure I18. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Unloaded on a US Army Logistics Support Vessel During Roll-Off Operations.

Table I19. Interview Question 4u - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be unloaded from a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	5	10	25
SME Opinion 3	5	10	20
SME Opinion 4	10	15	25
SME Opinion 5	6	8	10
Theoretical	7.2	11.6	22

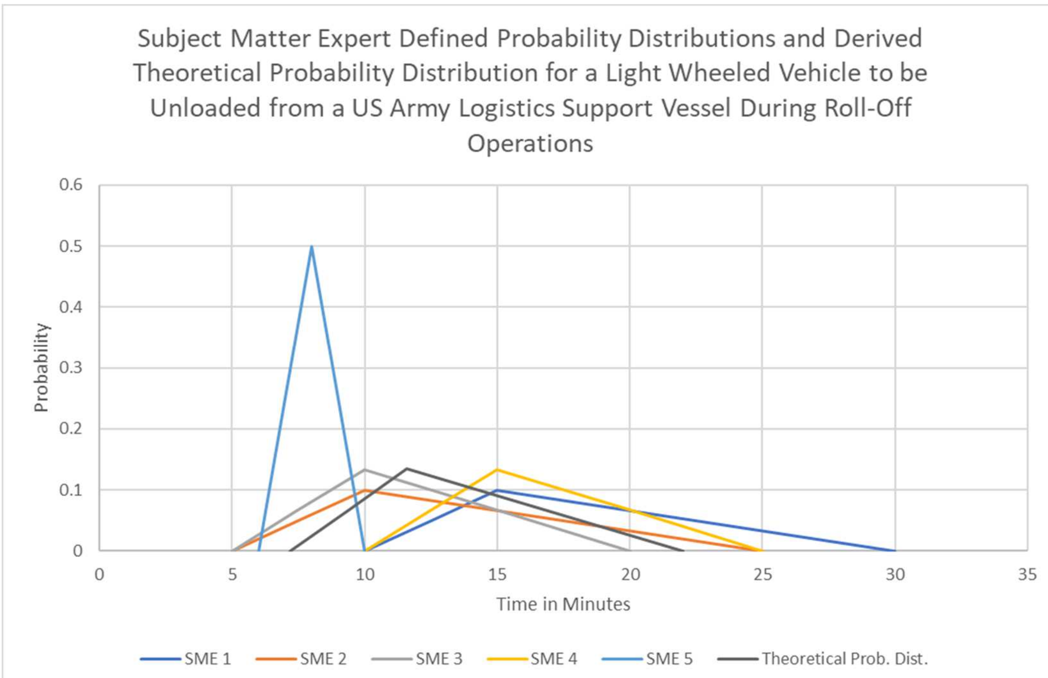

Figure I19. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Unloaded on a US Army Logistics Support Vessel During Roll-Off Operations.

Table I20. Interview Question 4v - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle with a trailer to be unloaded from a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	25	45
SME Opinion 2	10	15	35
SME Opinion 3	5	10	20
SME Opinion 4	10	15	25
SME Opinion 5	6	8	10
Theoretical	9.2	14.6	27

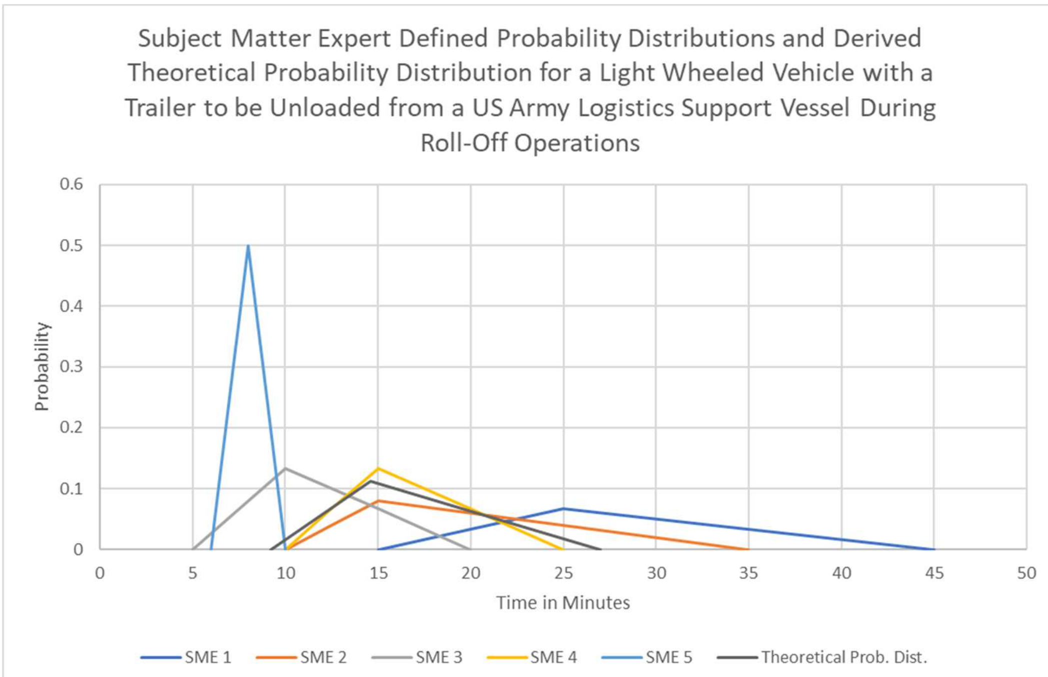

Figure I20. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle with a Trailer to be Unloaded on a US Army Logistics Support Vessel During Roll-Off Operations.

Table I21. Interview Question 4w - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be unloaded from a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	25
SME Opinion 2	5	10	25
SME Opinion 3	5	10	20
SME Opinion 4	10	15	25
SME Opinion 5	6	8	10
Theoretical	7.2	11.6	21

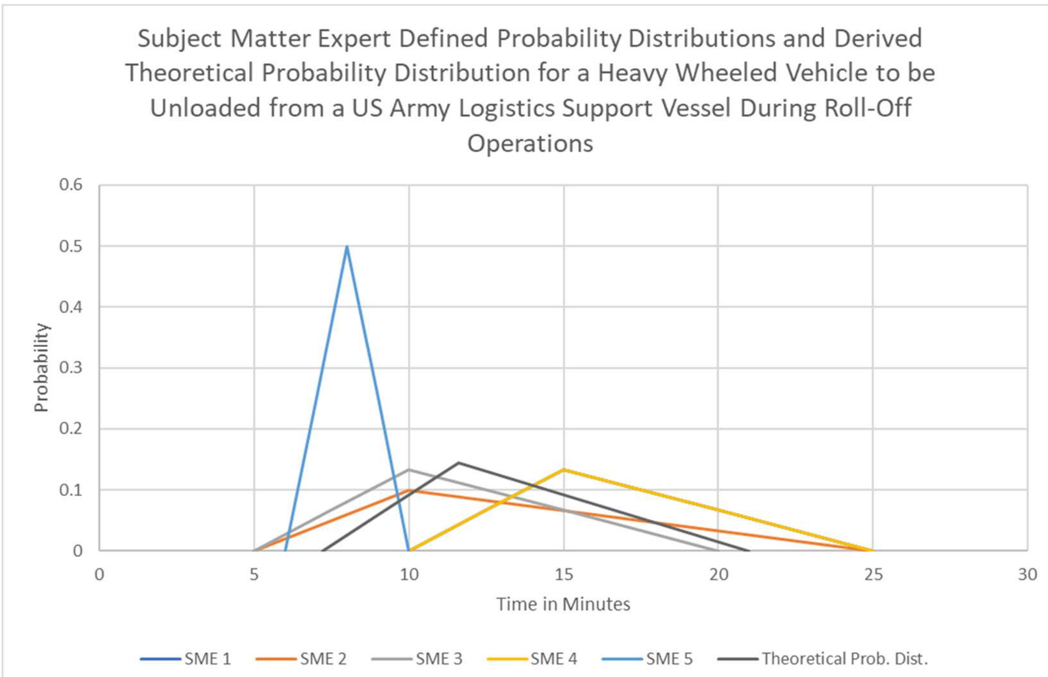

Figure I21. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Unloaded on a US Army Logistics Support Vessel During Roll-Off Operations.

Table I22. Interview Question 4x - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle with a trailer to be unloaded from a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	30	45
SME Opinion 2	5	10	20
SME Opinion 3	5	10	20
SME Opinion 4	10	15	20
SME Opinion 5	10	12	20
Theoretical	10	15.4	25

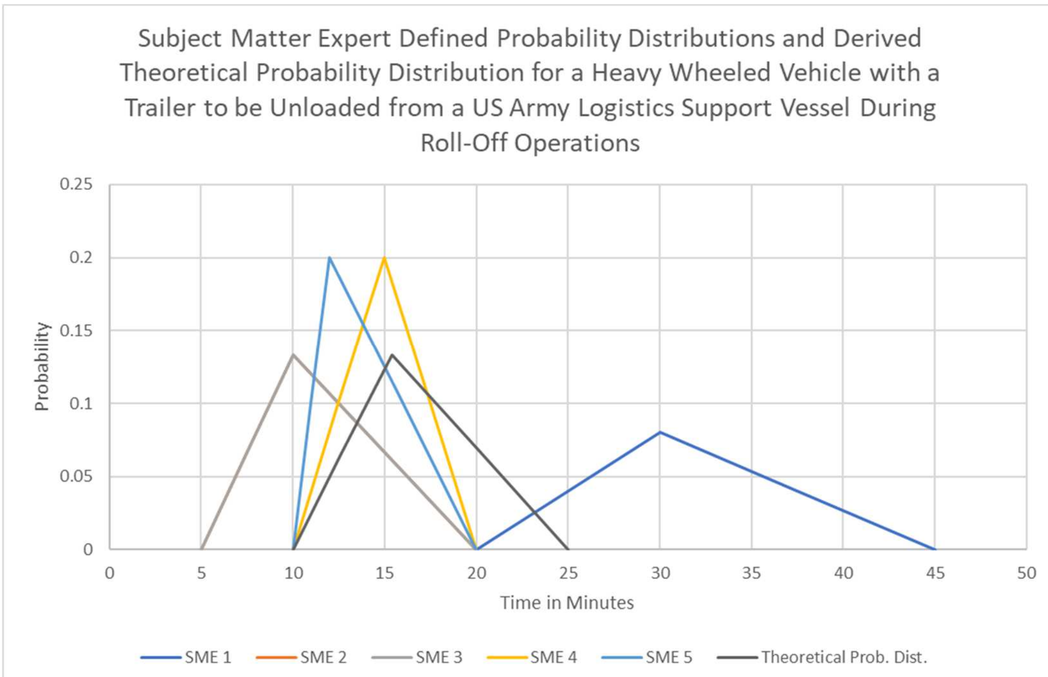

Figure I22. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle with a Trailer to be Unloaded on a US Army Logistics Support Vessel During Roll-Off Operations.

Table I23. Interview Question 4y - Subject matter expert defined probability distributions and derived theoretical probability distribution for a tracked vehicle to be unloaded from a US Army Logistics Support Vessel during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	30
SME Opinion 2	5	10	20
SME Opinion 3	10	20	25
SME Opinion 4	6	8	10
Theoretical	20.5	27.5	45

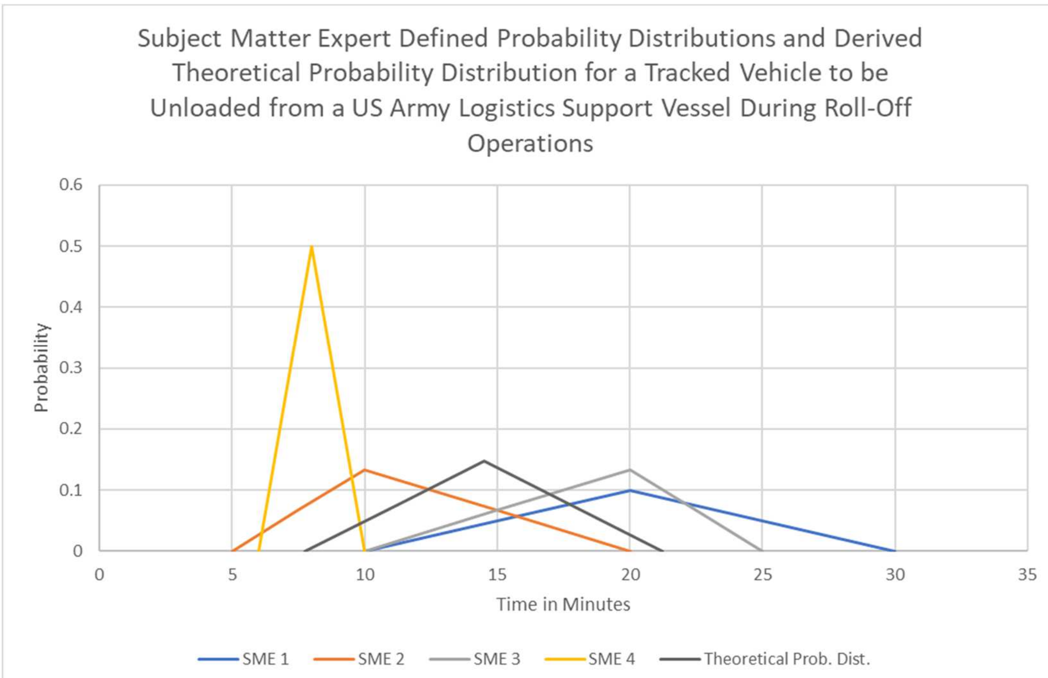

Figure I23. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Tracked Vehicle to be Unloaded on a US Army Logistics Support Vessel During Roll-Off Operations.

Table I24. Interview Question 4z - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army Logistics Support Vessel to castoff and clear to a US Army causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	20	30
SME Opinion 2	15	25	60
SME Opinion 3	15	20	25
SME Opinion 4	20	25	30
Theoretical	15	22.5	36.25

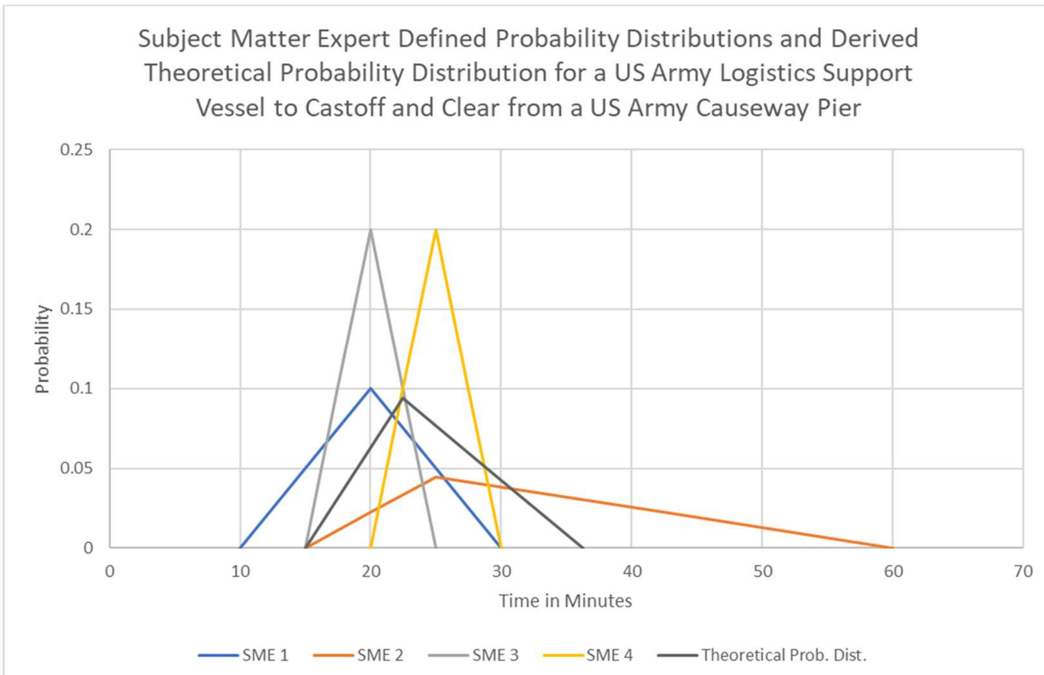

Figure I24. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Logistics Support Vessel to Castoff and Clear from a US Army Causeway Pier.

Table I25. Interview Question 4aa - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army Logistics Support Vessel to castoff and clear to a US Navy causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	30
SME Opinion 2	20	25	30
Theoretical	15	20	30

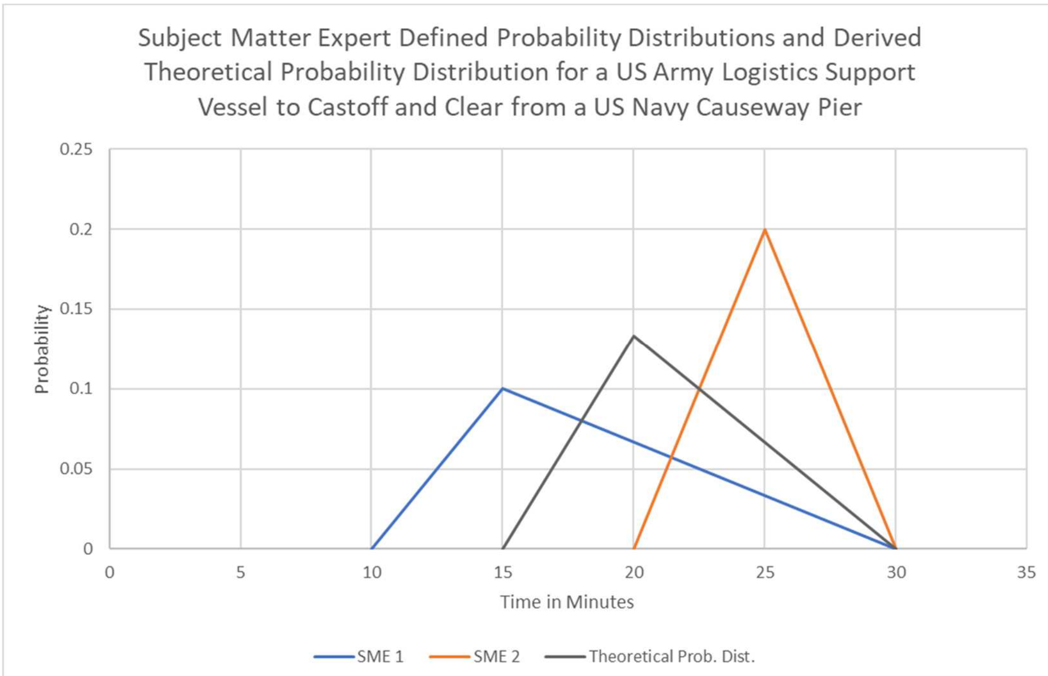

Figure I25. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Logistics Support Vessel to Castoff and Clear from a US Navy Causeway Pier.

Table I26. Interview Question 4bb - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Army Logistics Support Vessel to castoff and clear from a bare beach landing site.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	20	45
SME Opinion 2	10	15	30
SME Opinion 3	30	45	90
SME Opinion 4	15	20	30
SME Opinion 5	15	20	25
Theoretical	17	24	44

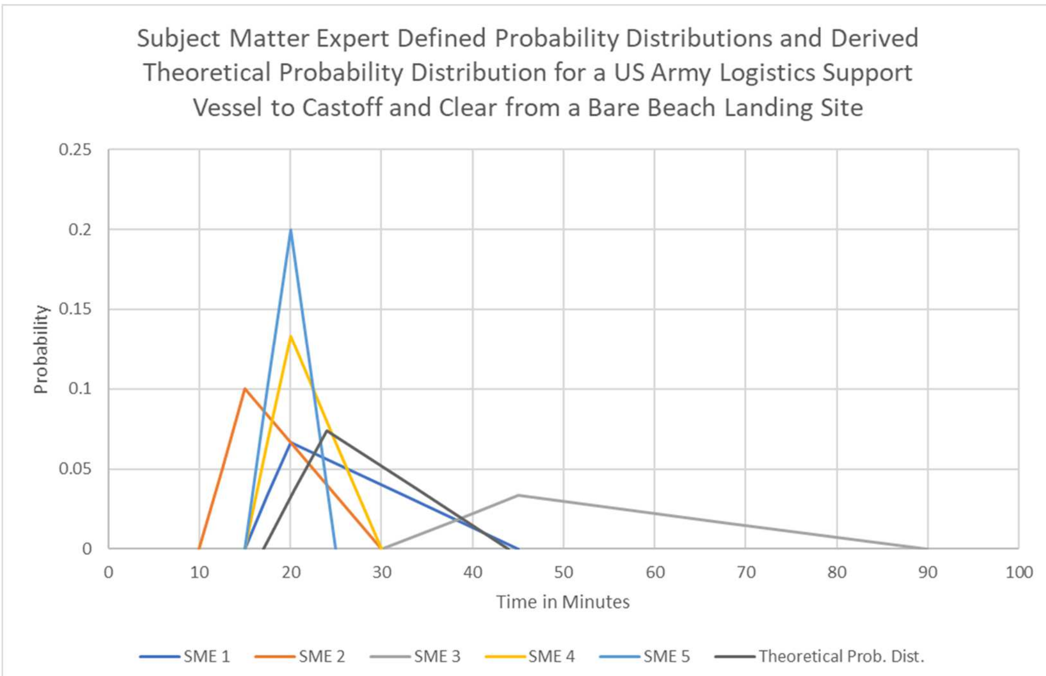

Figure I26. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Army Logistics Support Vessel to Castoff and Clear from a Bare Beach Landing Site.

APPENDIX J. TABLES AND FIGURES OF SUBJECT MATTER EXPERT RESPONSES AND THEORETICAL PROBABILITY DISTRIBUTIONS FOR US NAVY LANDING CRAFT UTILITY 1600 SERIES / JLOTS ACTIVITY COMBINATIONS

Table J1. Interview Question 6a - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Navy LCU 1600-series to approach and moor to a US Army RRDF.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	7	12	20
SME Opinion 2	3	5	10
SME Opinion 3	5	10	15
SME Opinion 4	2	5	30
SME Opinion 5	8	10	20
Theoretical	5	8.4	19

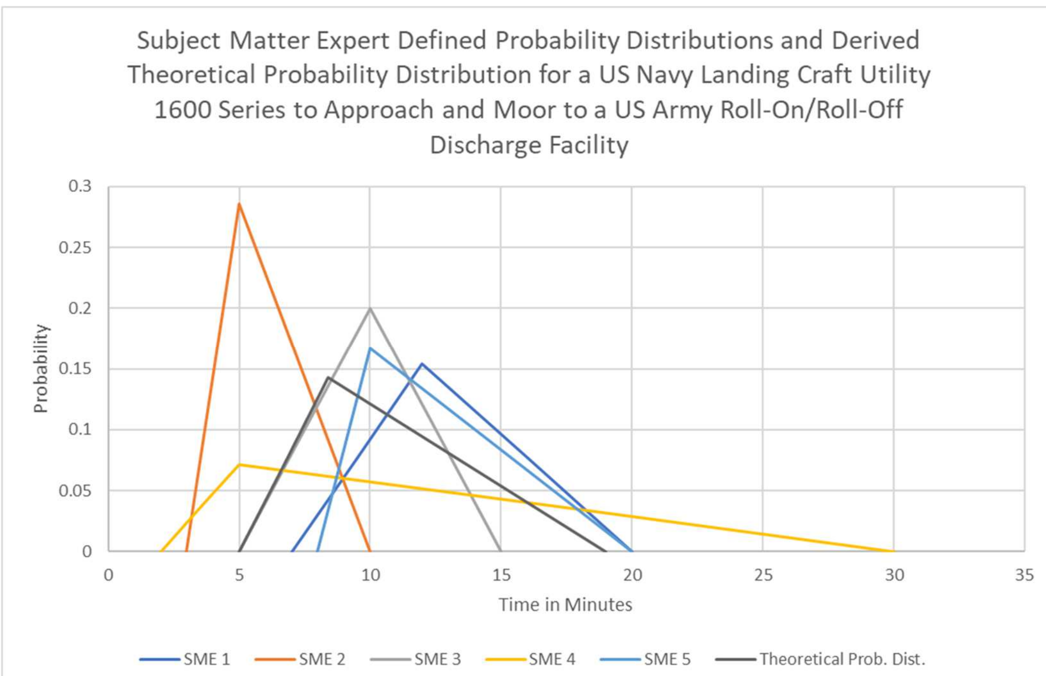

Figure J1. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Navy Landing Craft Utility 1600 Series to Approach and Moor to a US Army RRDF.

Table J2. Interview Question 6b - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Navy LCU 1600-series to approach and moor to a US Navy RRDF.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	7	12	20
SME Opinion 2	4	6	25
SME Opinion 3	0.5	3	10
Theoretical	3.833333333	7	18.33333333

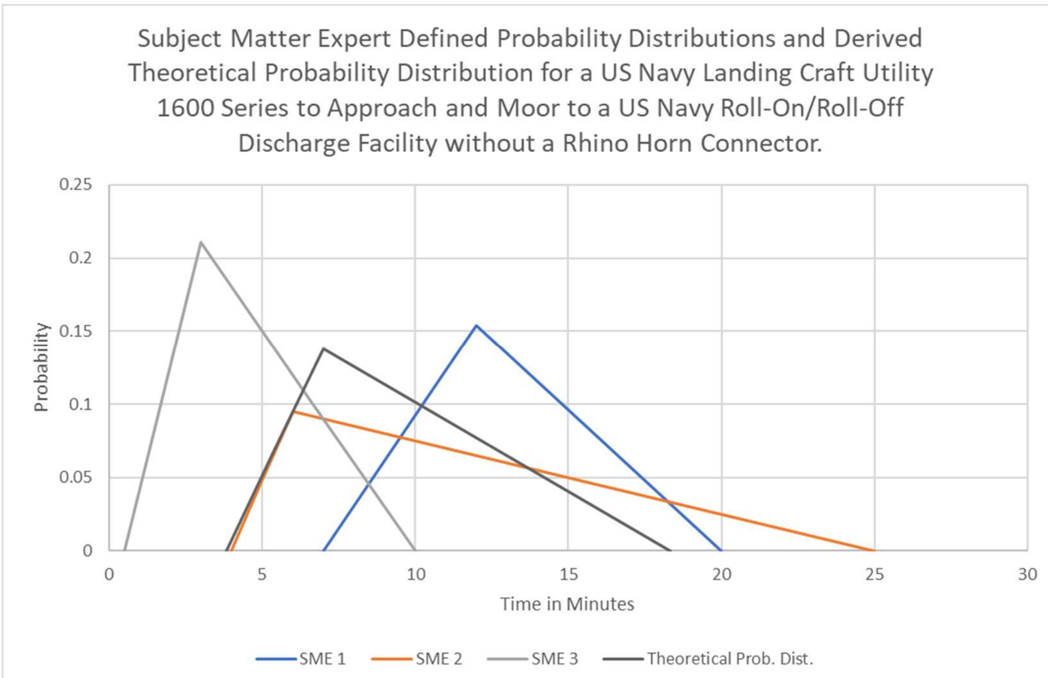

Figure J2. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Navy Landing Craft Utility 1600 Series to Approach and Moor to a US Navy RRDF without a Rhino Horn Connector.

Table J3. Interview Question 6c - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Navy LCU 1600-series to approach and moor to a US Navy RRDF with a rhino horn connector.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	15	35	45
SME Opinion 2	5	8	20
SME Opinion 3	5	10	15
SME Opinion 4	0.5	3	10
Theoretical	6.375	14	22.5

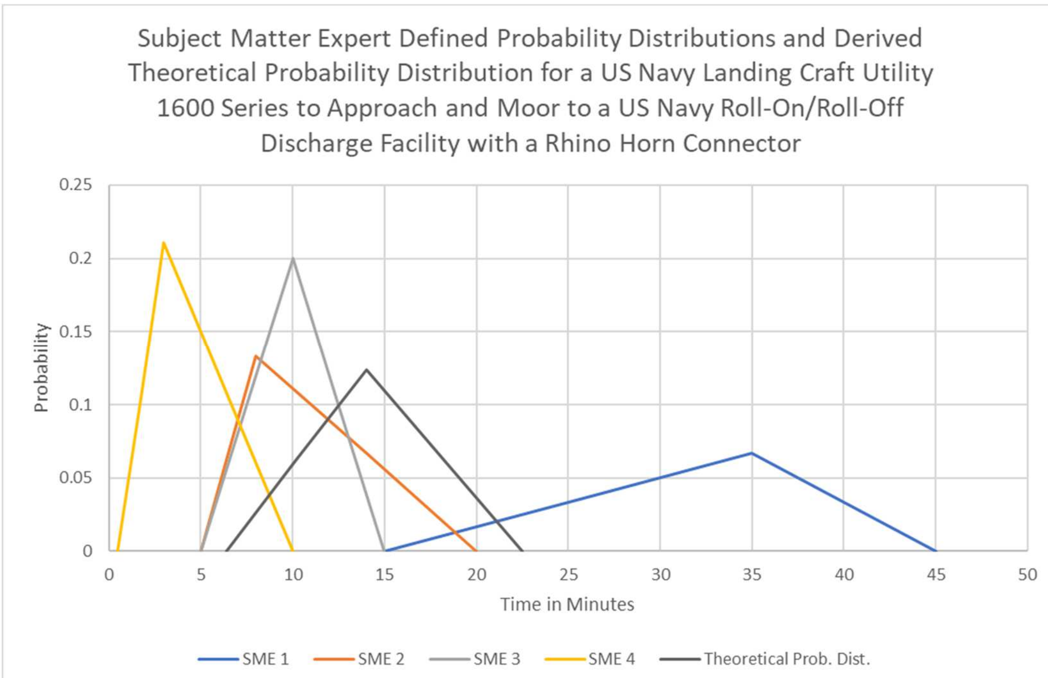

Figure J3. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Navy Landing Craft Utility 1600 Series to Approach and Moor to a US Navy RRDF with a Rhino Horn Connector.

Table J4. Interview Question 6d - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be loaded on a US Navy LCU 1600-series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	21	45
SME Opinion 2	15	30	60
SME Opinion 3	5	10	20
SME Opinion 4	10	15	30
SME Opinion 5	3	4	6
SME Opinion 6	3	15	60
Theoretical	7.666666667	15.83333333	36.83333333

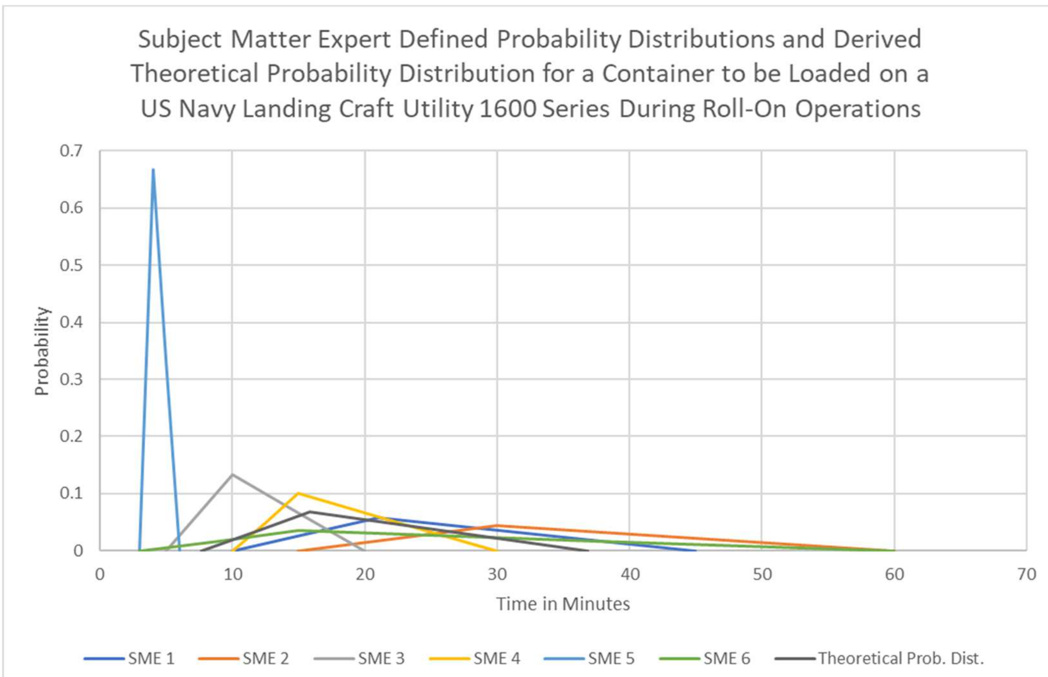

Figure J4. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Loaded on a US Navy Landing Craft Utility 1600 Series During Roll-On Operations.

Table J5. Interview Question 6e - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be loaded on a US Navy LCU 1600-series during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	21	45
SME Opinion 2	5	10	20
SME Opinion 3	5	10	20
SME Opinion 4	3	15	60
Theoretical	5.75	14	36.25

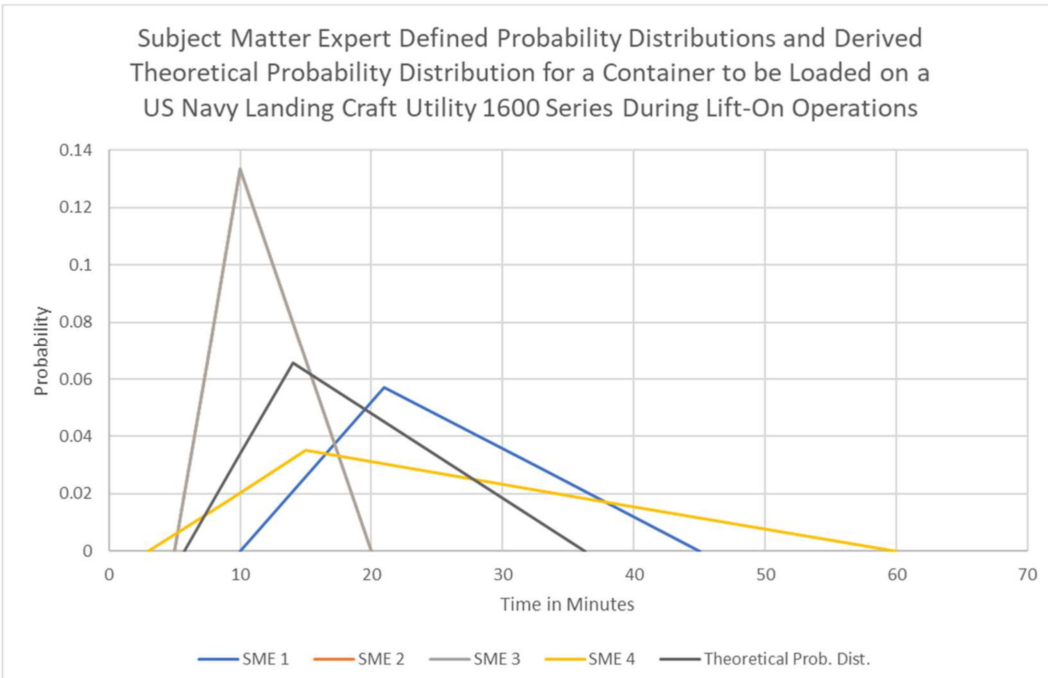

Figure J5. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Loaded on a US Navy Landing Craft Utility 1600 Series During Lift-On Operations.

Table J6. Interview Question 6f - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be loaded on a US Navy LCU 1600-series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	7	20
SME Opinion 2	3	5	8
SME Opinion 3	2	5	10
SME Opinion 4	1	2	4
SME Opinion 5	1	3	20
Theoretical	2.4	4.4	12.4

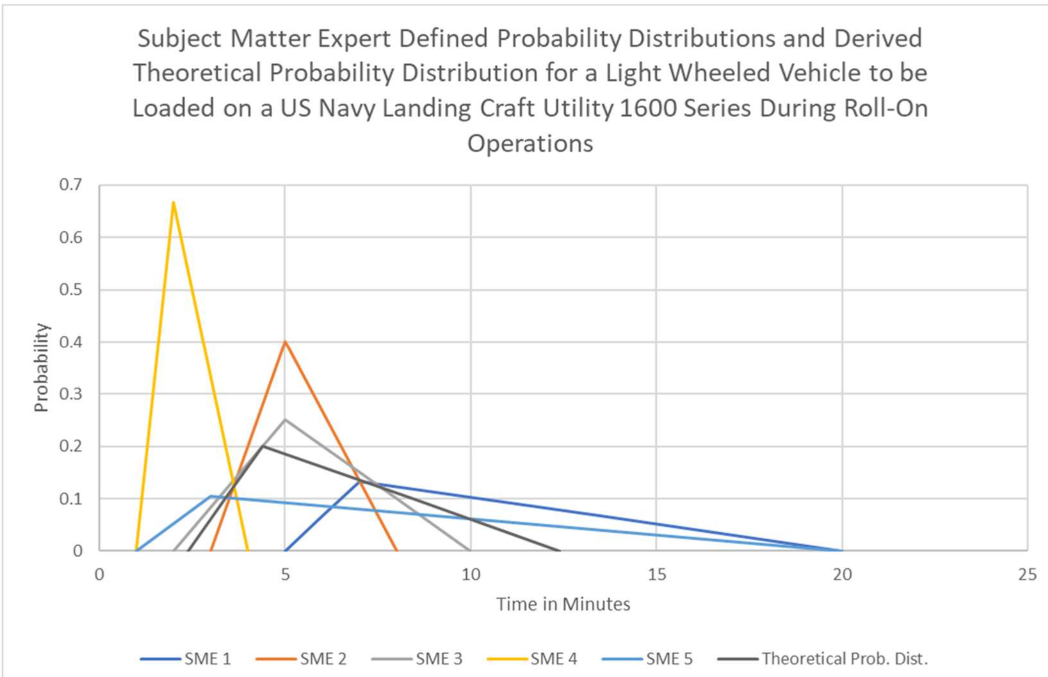

Figure J6. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Loaded on a US Navy Landing Craft Utility 1600 Series During Roll-On Operations.

Table J7. Interview Question 6g - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be loaded on a US Navy LCU 1600-series during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	7	10	25
SME Opinion 2	5	10	20
Theoretical	6	10	22.5

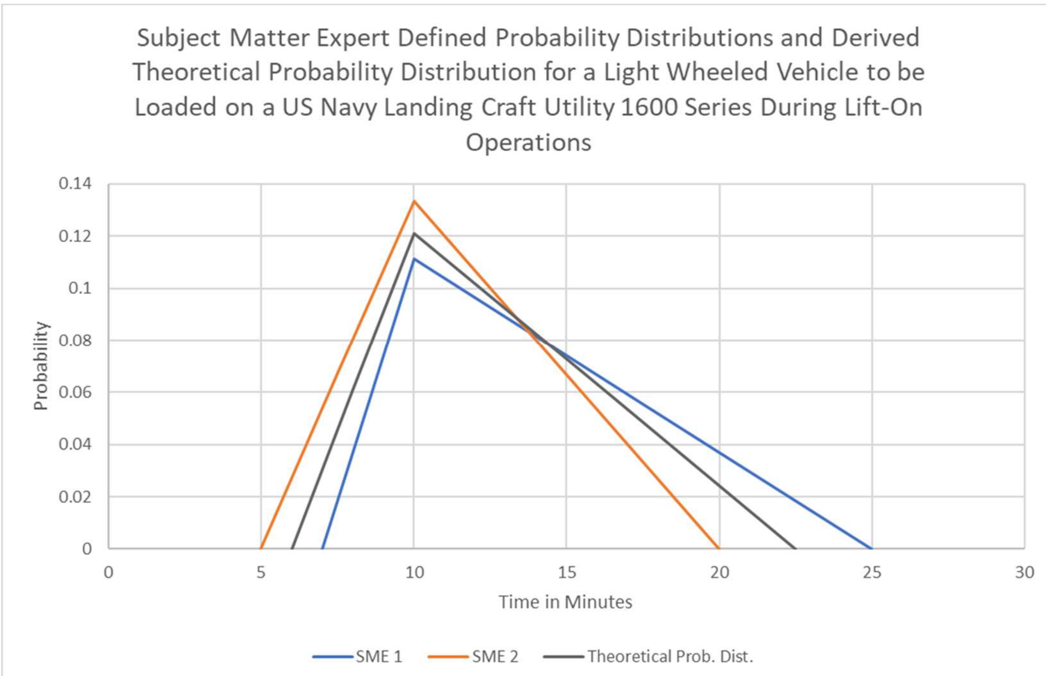

Figure J7. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Loaded on a US Navy Landing Craft Utility 1600 Series During Lift-On Operations.

Table J8. Interview Question 6h - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle with a trailer to be loaded on a US Navy LCU 1600-series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	30	40
SME Opinion 2	4	7	9
SME Opinion 3	5	10	15
SME Opinion 4	3	4	5
SME Opinion 5	3	5	30
Theoretical	7	11.2	19.8

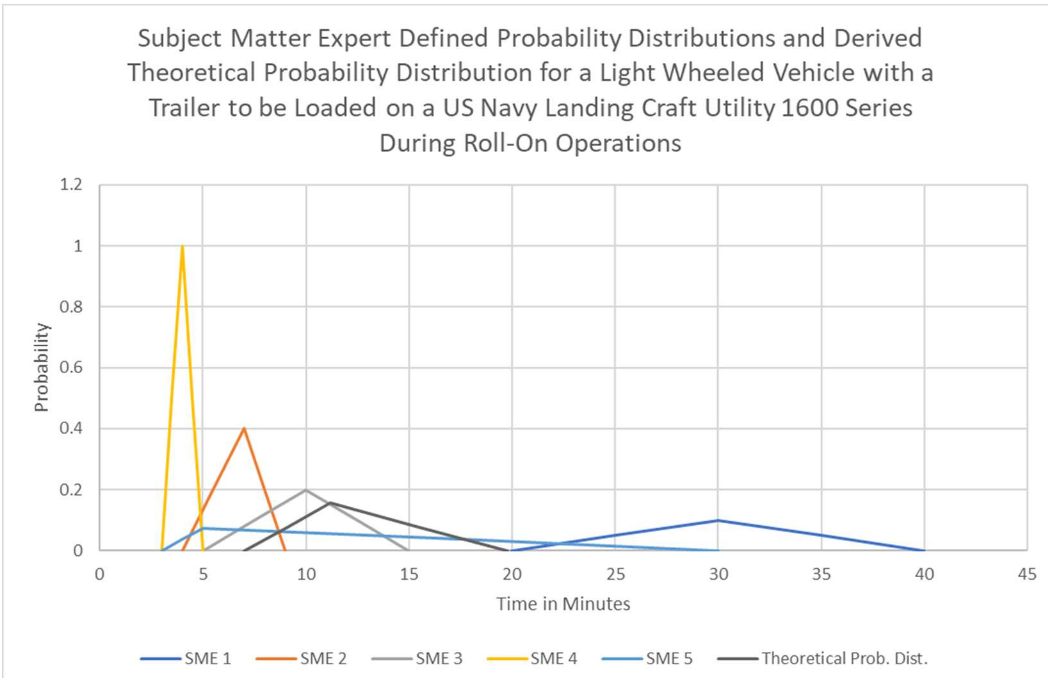

Figure J8. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle with a Trailer to be Loaded on a US Navy Landing Craft Utility 1600 Series During Roll-On Operations.

Table J9. Interview Question 6i - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be loaded on a US Navy LCU 1600-series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	30	45	60
SME Opinion 2	4	5	8
SME Opinion 3	5	7.5	15
SME Opinion 4	2	3	5
SME Opinion 5	5	7	30
Theoretical	9.2	13.5	23.6

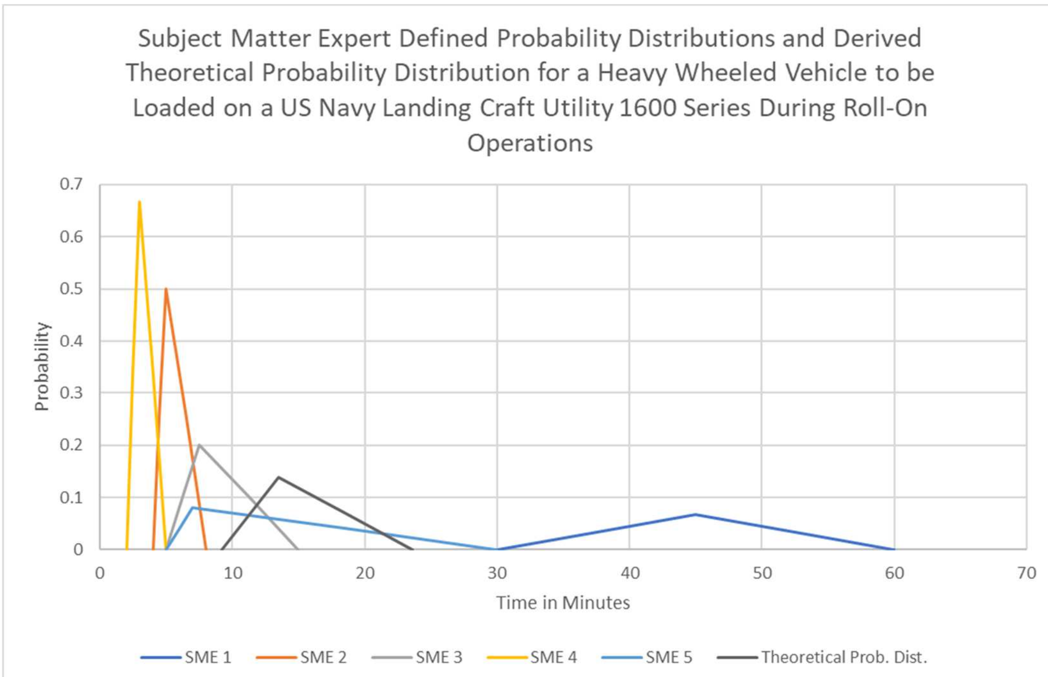

Figure J9. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Loaded on a US Navy Landing Craft Utility 1600 Series During Roll-On Operations.

Table J10. Interview Question 6j - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be loaded on a US Navy LCU 1600-series during lift-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	45	50	70
Theoretical	45	50	70

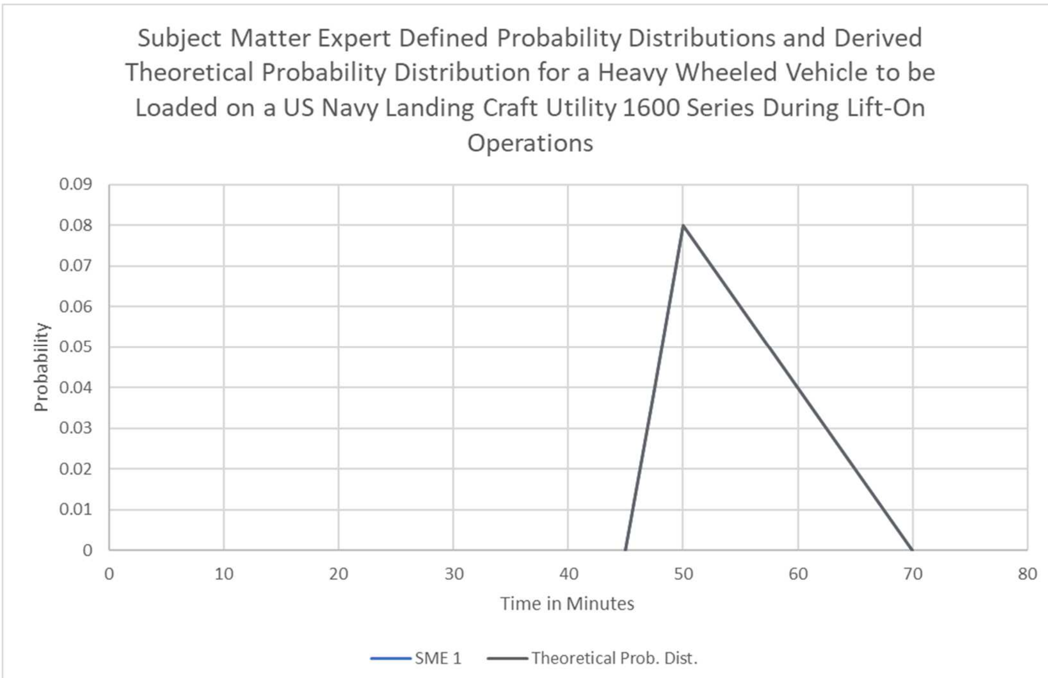

Figure J10. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Loaded on a US Navy Landing Craft Utility 1600 Series During Lift-On Operations.

Table J11. Interview Question 6k - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle with trailer to be loaded on a US Navy LCU 1600-series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	30	36	45
SME Opinion 2	3	4	7
SME Opinion 3	5	10	20
SME Opinion 4	3	4	6
SME Opinion 5	3	5	30
Theoretical	8.8	11.8	21.6

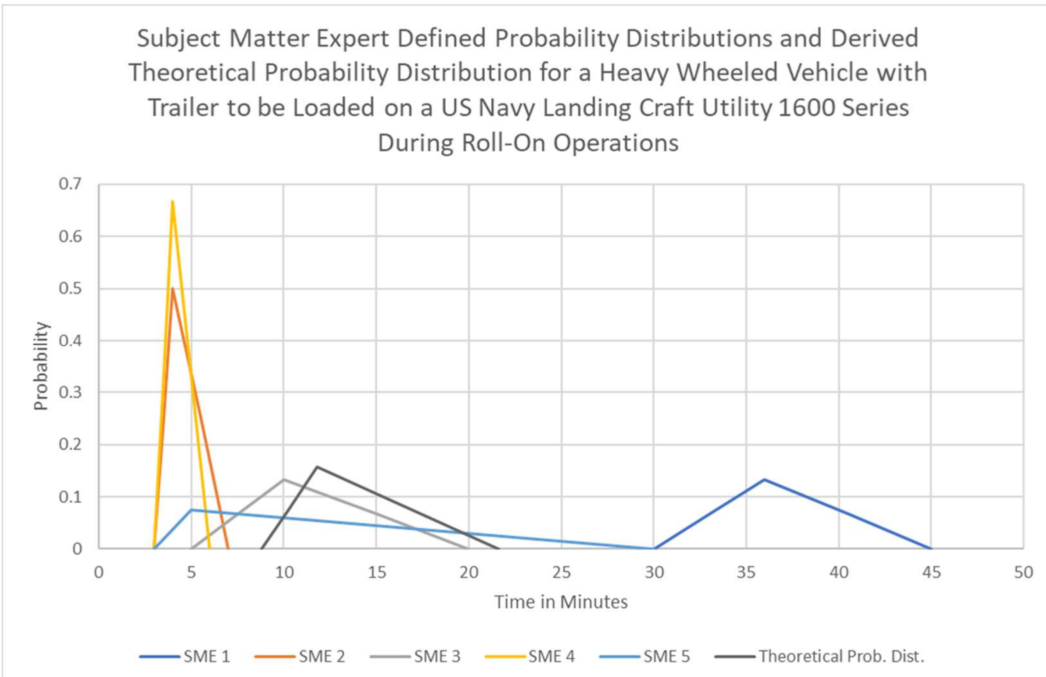

Figure J11. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle with Trailer to be Loaded on a US Navy Landing Craft Utility 1600 Series During Roll-On Operations.

Table J12. Interview Question 6l - Subject matter expert defined probability distributions and derived theoretical probability distribution for a tracked vehicle to be loaded on a US Navy LCU 1600-series during roll-on operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	6	10
SME Opinion 2	5	10	20
SME Opinion 3	10	15	30
SME Opinion 4	3	4	5
SME Opinion 5	10	20	45
Theoretical	6.6	11	22

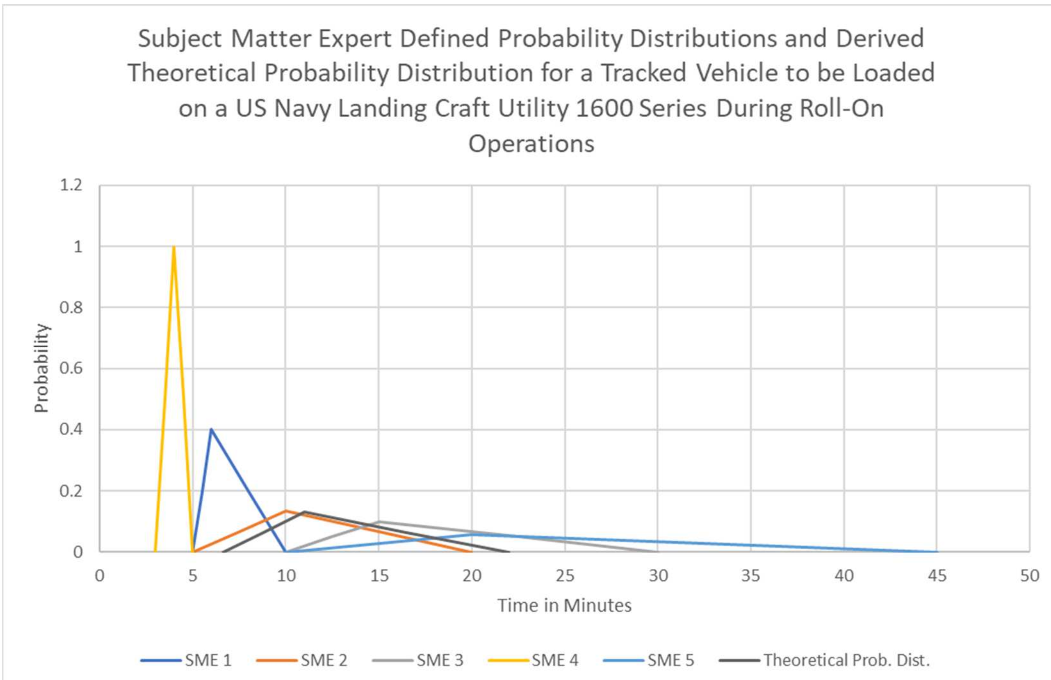

Figure J12. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Tracked Vehicle to be Loaded on a US Navy Landing Craft Utility 1600 Series During Roll-On Operations.

Interview Question 6m – no interviewees had experience with the loading of a tracked vehicle on a US Navy LCU 1600-series during lift-on operations. The loading of tracked vehicles by lifting was not programmed to occur in any of the three models.

Table J13. Interview Question 6n - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Navy LCU 1600-series to castoff and clear from a US Army RRDF.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	15
SME Opinion 2	1	3	5
SME Opinion 3	3	5	30
Theoretical	3	6	16.66666667

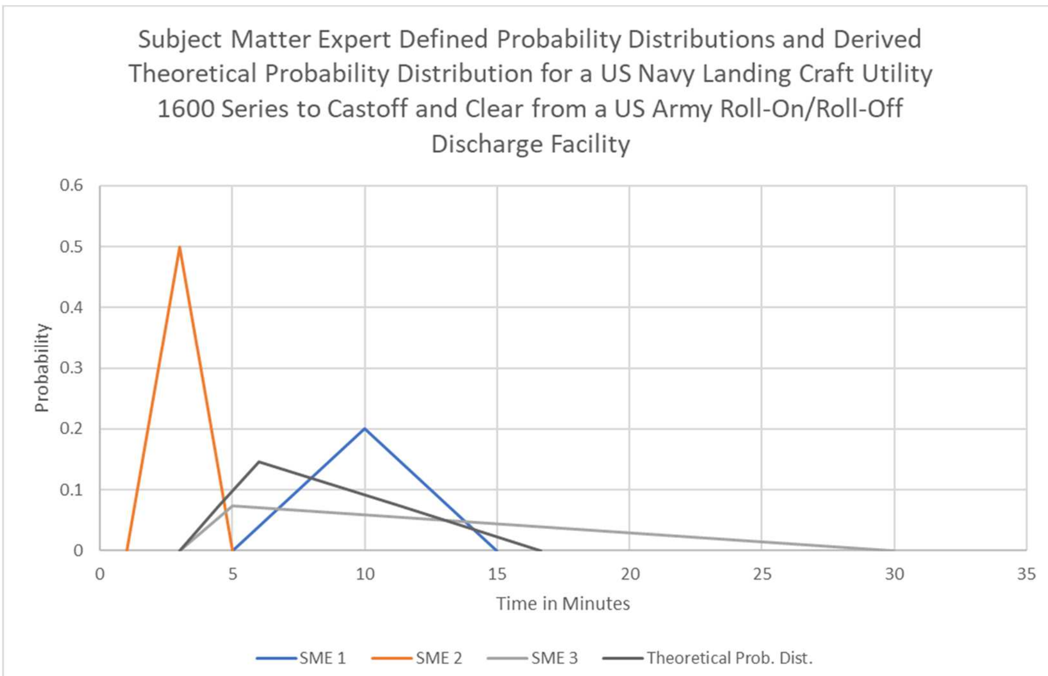

Figure J13. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Navy Landing Craft Utility 1600 Series to Castoff and Clear from a US Army RRDF.

Table J14. Interview Question 6o - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Navy LCU 1600-series to castoff and clear from a US Navy RRDF.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	15
SME Opinion 2	1	3	5
SME Opinion 3	10	15	30
SME Opinion 4	1	2	3
SME Opinion 5	3	5	30
Theoretical	4	7	16.6

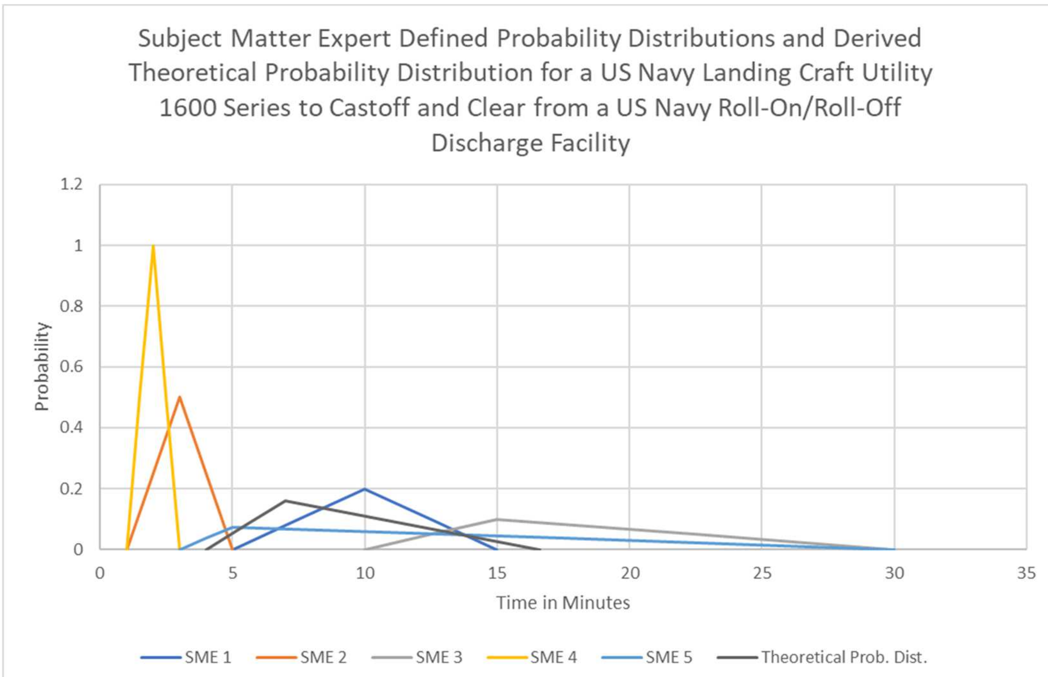

Figure J14. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Navy Landing Craft Utility 1600 Series to Castoff and Clear from a US Navy RRDF.

Table J15. Interview Question 6p - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Navy LCU 1600-series to approach and moor to a US causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	15
SME Opinion 2	3	5	10
SME Opinion 3	2	7	10
SME Opinion 4	5	15	45
Theoretical	3.75	9.25	20

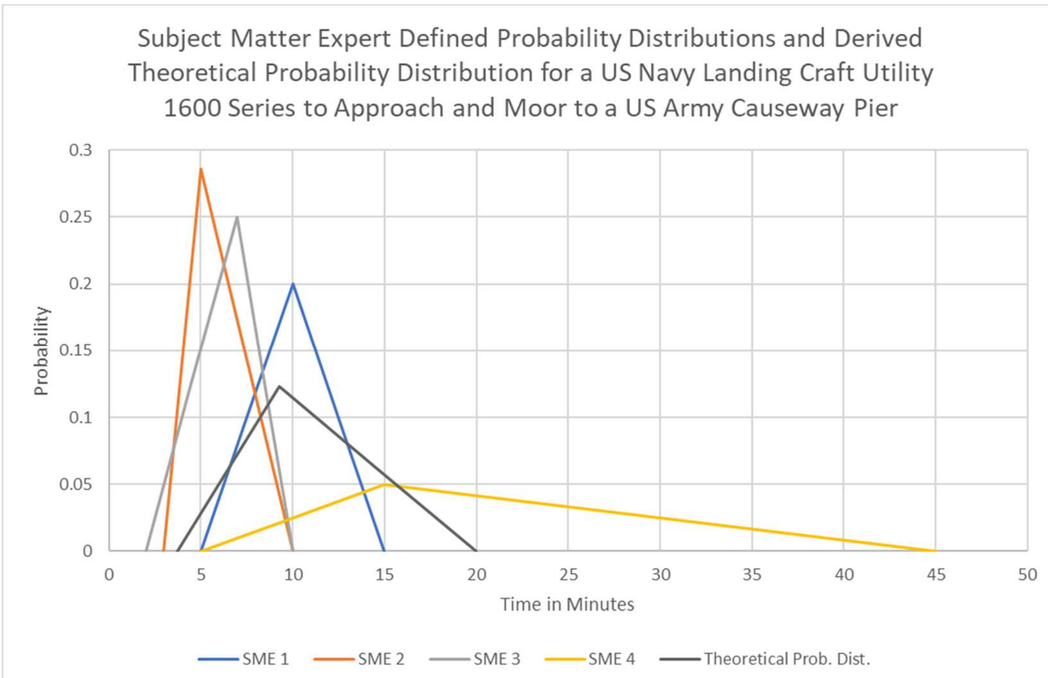

Figure J15. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Navy Landing Craft Utility 1600 Series to Approach and Moor to a US Army Causeway Pier.

Table J16. Interview Question 6q - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Navy LCU 1600-series to approach and moor to a US Navy causeway pier without a rhino horn connector.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	15
Theoretical	5	10	15

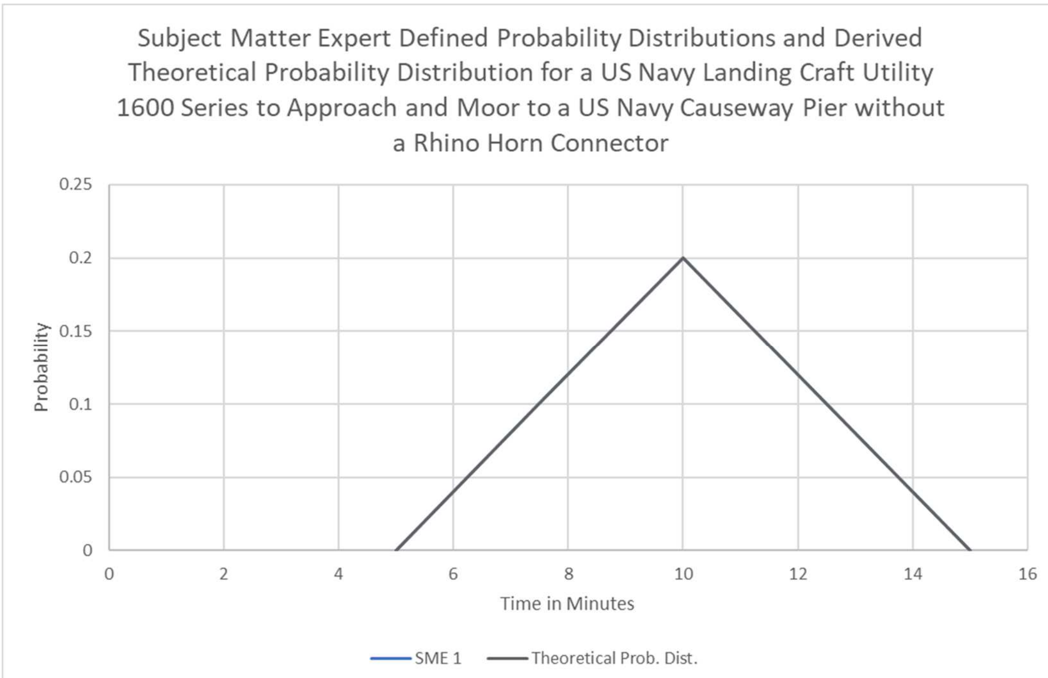

Figure J16. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Navy Landing Craft Utility 1600 Series to Approach and Moor to a US Navy Causeway Pier without Rhino Horn Connector.

Interview Question 6r - No interviewees had experience with approaching and mooring a US Navy LCU 1600-series to a US Navy causeway pier with a rhino horn connector. The use of a US Navy causeway pier with a rhino horn connector was not programmed to occur in any of the three models.

Table J17. Interview Question 6s - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Navy LCU 1600-series to approach and moor to a bare beach landing site.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	10	15	20
SME Opinion 2	3	5	8
SME Opinion 3	5	10	15
SME Opinion 4	5	10	45
Theoretical	5.75	10	22

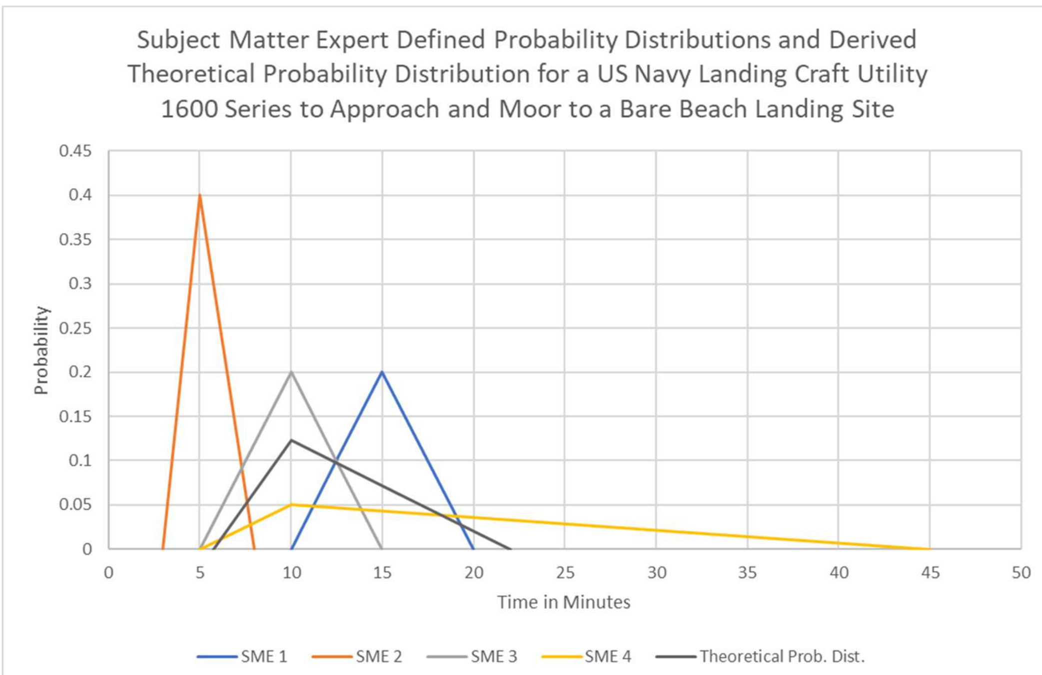

Figure J17. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Navy Landing Craft Utility 1600 Series to Approach and Moor to a Bare Beach Landing Site.

Table J18. Interview Question 6t - Subject matter expert defined probability distributions and derived theoretical probability distribution for a container to be unloaded from a US Navy LCU 1600-series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	12	18	20
SME Opinion 2	3	5	8
SME Opinion 3	3	5	8
SME Opinion 4	10	15	30
SME Opinion 5	3	4	5
SME Opinion 6	10	20	60
Theoretical	6.833333333	11.16666667	21.83333333

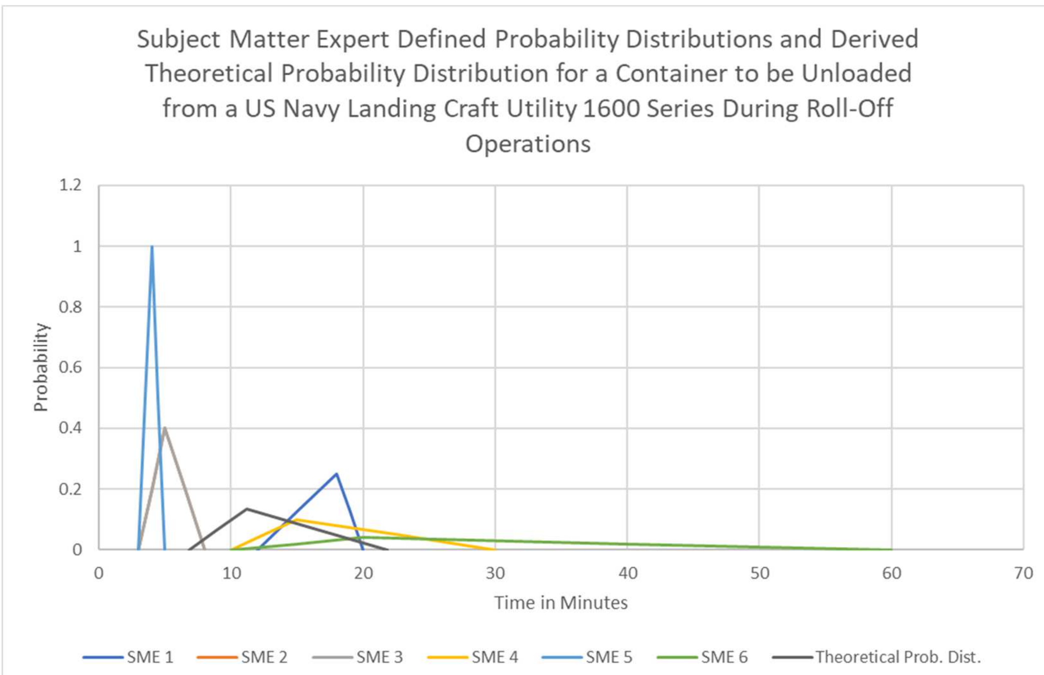

Figure J18. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Container to be Unloaded from a US Navy Landing Craft Utility 1600 Series During Roll-Off Operations.

Table J19. Interview Question 6u - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle to be unloaded from a US Navy LCU 1600-series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	30	40
SME Opinion 2	2	3	5
SME Opinion 3	2	3.5	5
SME Opinion 4	5	10	20
SME Opinion 5	1	2	3
SME Opinion 6	3	5	25
Theoretical	5.5	8.916666667	16.33333333

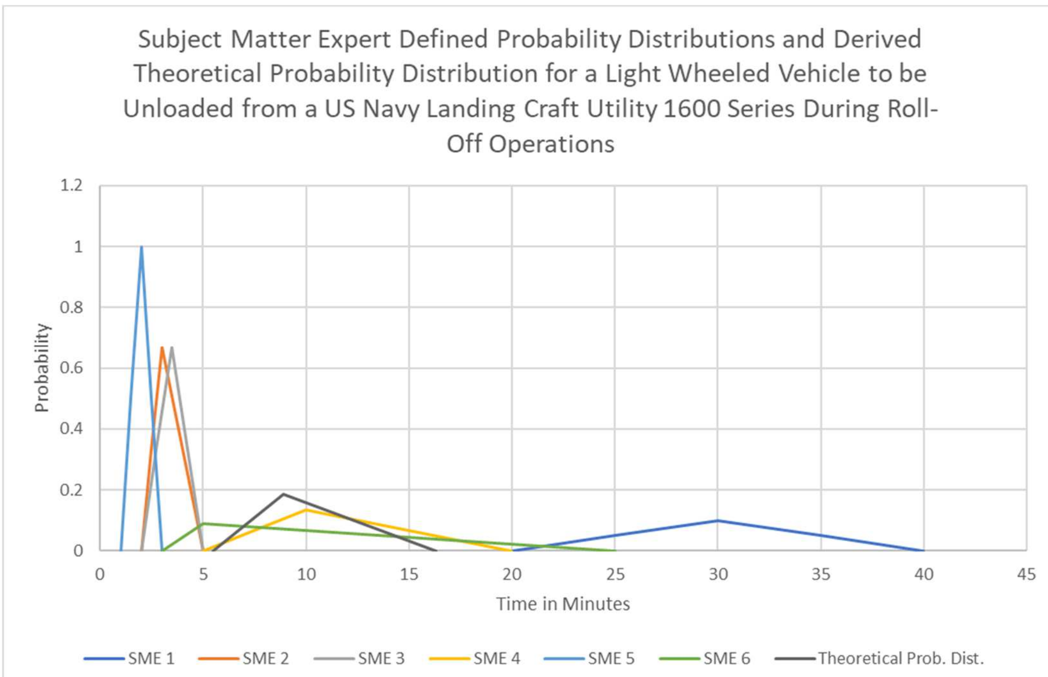

Figure J19. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle to be Unloaded from a US Navy Landing Craft Utility 1600 Series During Roll-Off Operations.

Table J20. Interview Question 6v - Subject matter expert defined probability distributions and derived theoretical probability distribution for a light wheeled vehicle with trailer to be unloaded from a US Navy LCU 1600-series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	25	30	45
SME Opinion 2	2	3	5
SME Opinion 3	3	5	8
SME Opinion 4	5	10	20
SME Opinion 5	2	3	4
SME Opinion 6	5	10	45
Theoretical	7	10.16666667	21.16666667

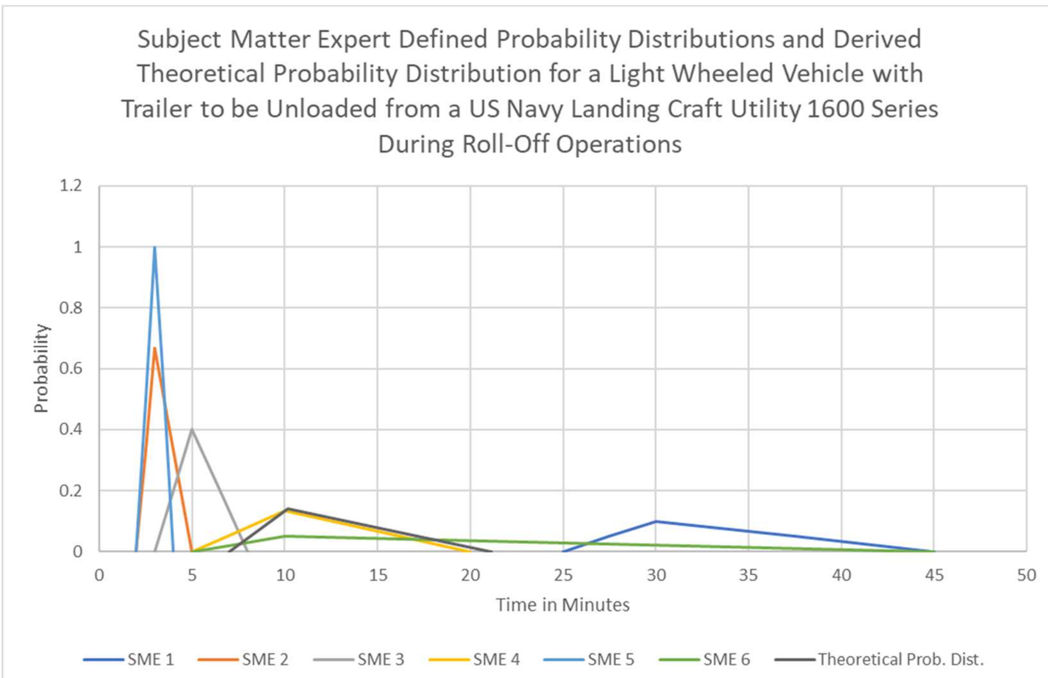

Figure J20. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Light Wheeled Vehicle with Trailer to be Unloaded from a US Navy Landing Craft Utility 1600 Series During Roll-Off Operations.

Table J21. Interview Question 6w - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle to be unloaded from a US Navy LCU 1600-series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	2	3	5
SME Opinion 2	3	5	8
SME Opinion 3	5	10	15
SME Opinion 4	2	3	4
SME Opinion 5	5	10	30
Theoretical	3.4	6.2	12.4

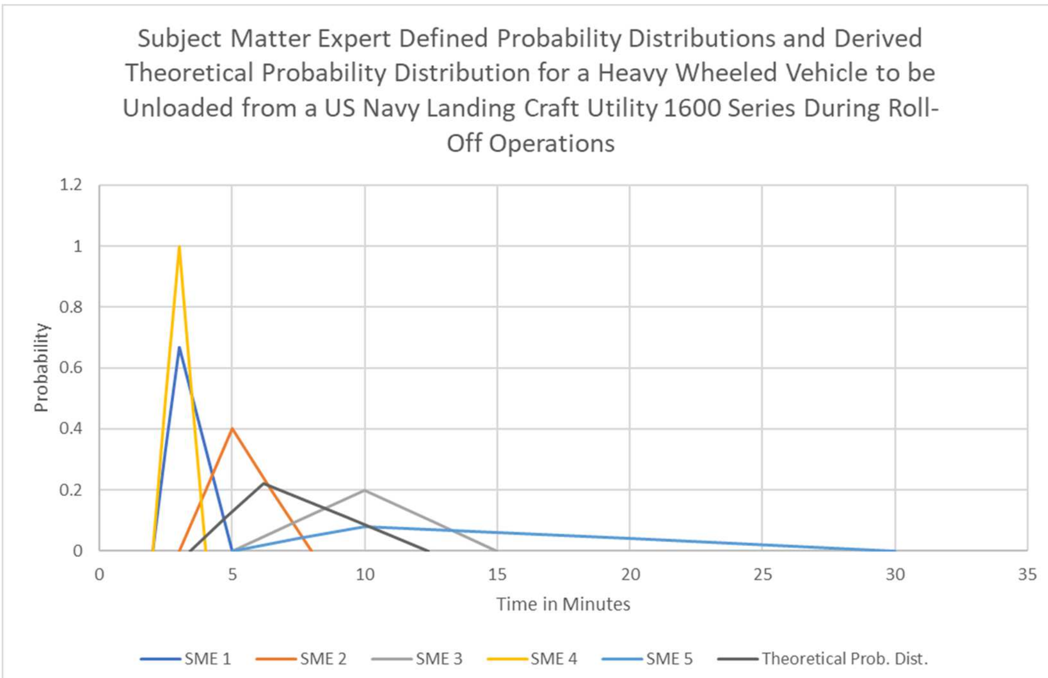

Figure J21. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle to be Unloaded from a US Navy Landing Craft Utility 1600 Series During Roll-Off Operations.

Table J22. Interview Question 6x - Subject matter expert defined probability distributions and derived theoretical probability distribution for a heavy wheeled vehicle with trailer to be unloaded from a US Navy LCU 1600-series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	2	3	5
SME Opinion 2	3	5	8
SME Opinion 3	5	10	15
SME Opinion 4	2	4	4
SME Opinion 5	10	15	35
Theoretical	4.4	7.4	13.4

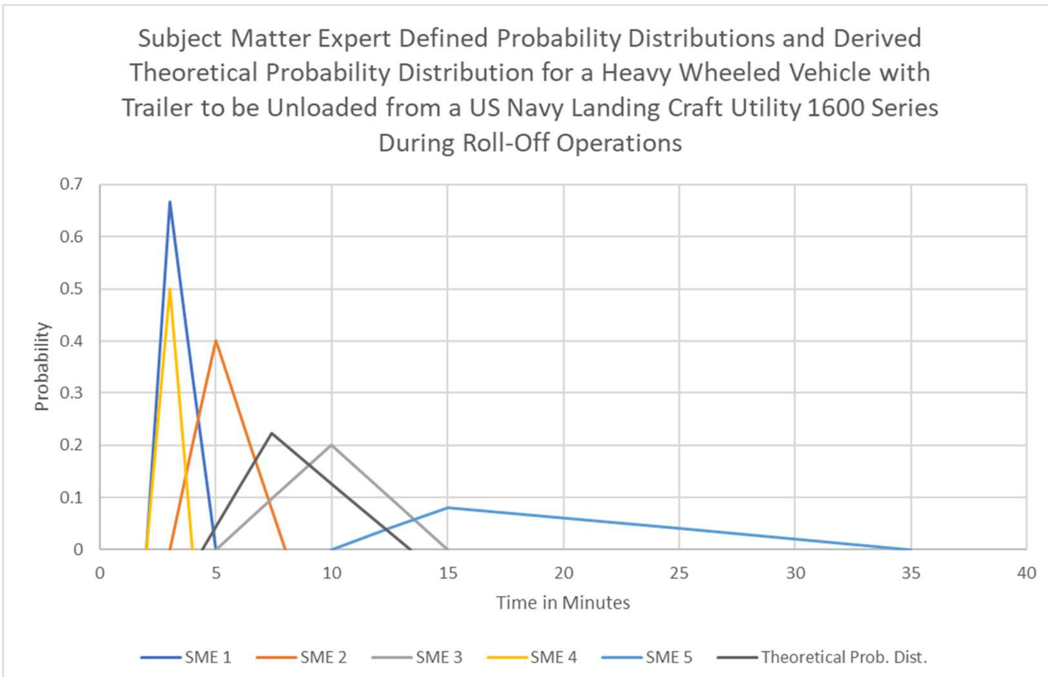

Figure J22. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Heavy Wheeled Vehicle with Trailer to be Unloaded from a US Navy Landing Craft Utility 1600 Series During Roll-Off Operations.

Table J23. Interview Question 6y - Subject matter expert defined probability distributions and derived theoretical probability distribution for a tracked vehicle to be unloaded from a US Navy LCU 1600-series during roll-off operations.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	2	3	5
SME Opinion 2	3	5	8
SME Opinion 3	5	10	15
SME Opinion 4	2	3	4
SME Opinion 5	5	10	30
Theoretical	3.4	6.2	12.4

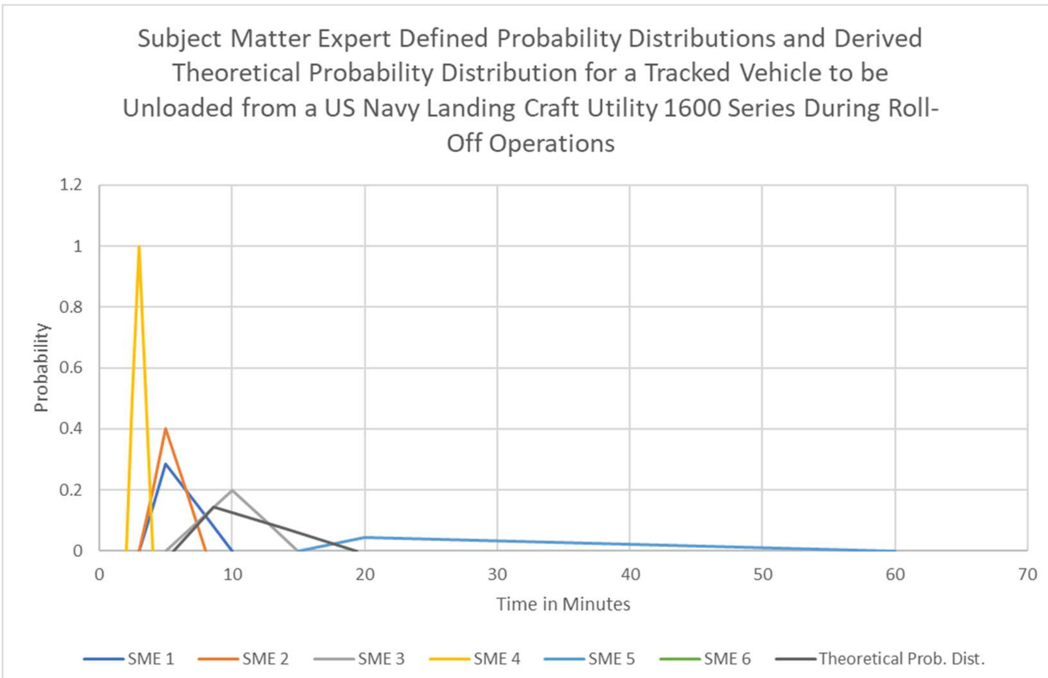

Figure J23. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a Tracked Vehicle to be Unloaded from a US Navy Landing Craft Utility 1600 Series During Roll-Off Operations.

Table J24. Interview Question 6z - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Navy LCU 1600-series to castoff and clear from a US Army causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	2	3	5
SME Opinion 2	2	3.5	5
SME Opinion 3	3	5	30
Theoretical	2.333333333	3.833333333	13.33333333

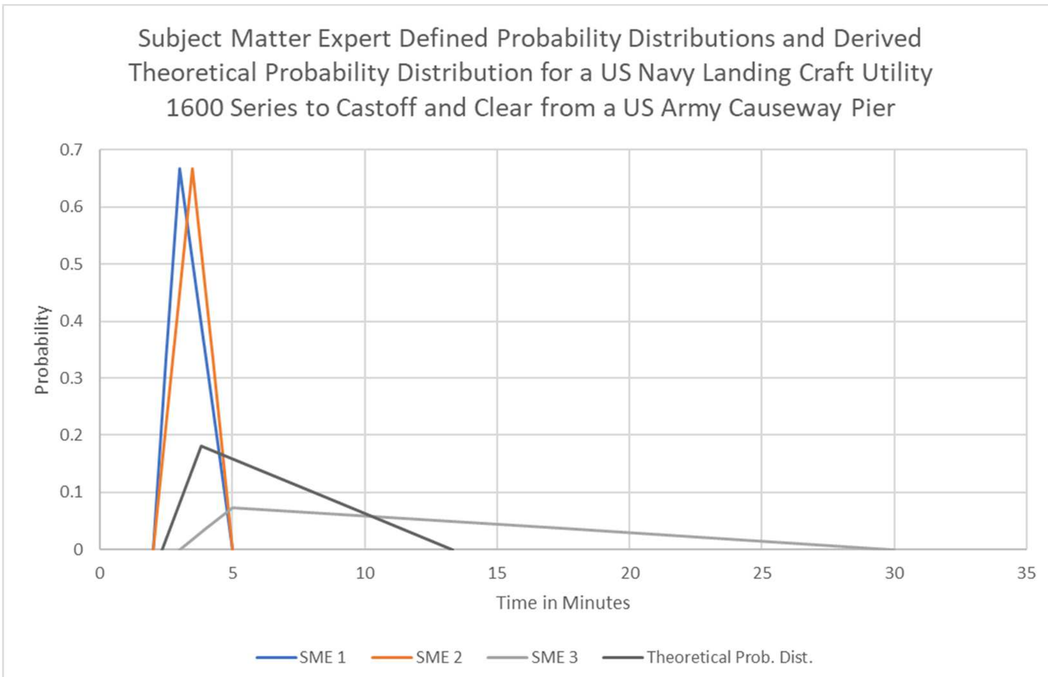

Figure J24. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Navy Landing Craft Utility 1600 Series to Castoff and Clear from a US Army Causeway Pier.

Table J25. Interview Question 6aa - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Navy LCU 1600-series to castoff and clear from a US Navy causeway pier.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	5	10	20
Theoretical	5	10	20

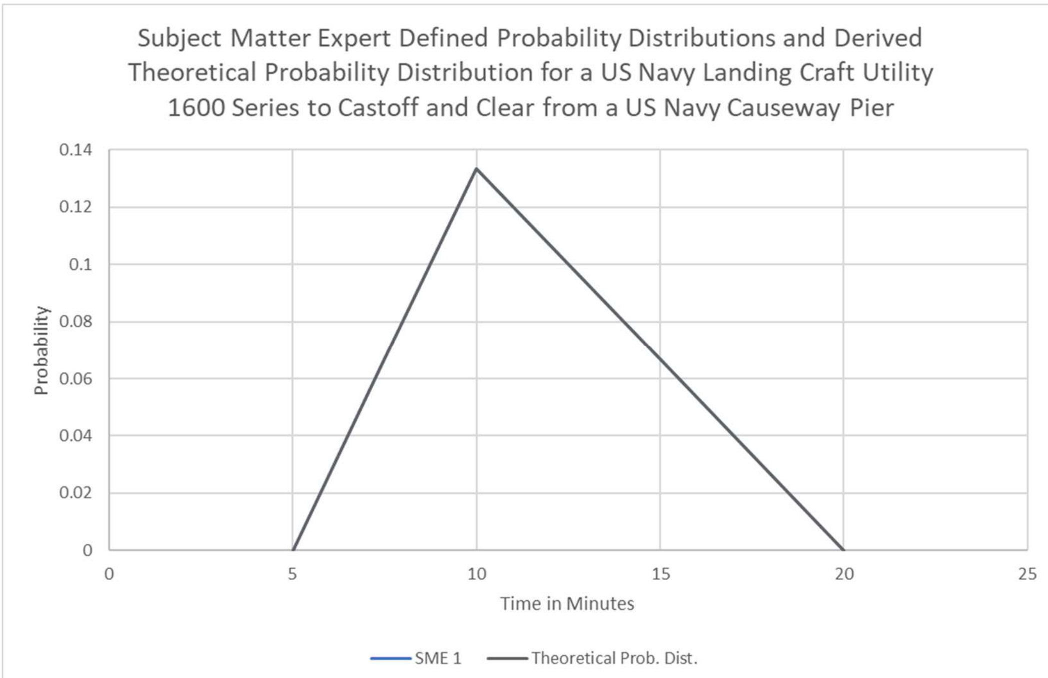

Figure J25. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Navy Landing Craft Utility 1600 Series to Castoff and Clear from a US Navy Causeway Pier.

Table J26. Interview Question 6bb - Subject matter expert defined probability distributions and derived theoretical probability distribution for a US Navy LCU 1600-series to castoff and clear from a bare beach landing site.

Probability Distribution	Best Case Time in Minutes (a term)	Most Likely Time in Minutes (m term)	Worst Case Time in Minutes (b term)
SME Opinion 1	20	25	50
SME Opinion 2	2	3	10
SME Opinion 3	3	6	10
SME Opinion 4	5	10	15
SME Opinion 5	1	2	4
SME Opinion 6	2	5	20
Theoretical	5.5	8.5	18.16666667

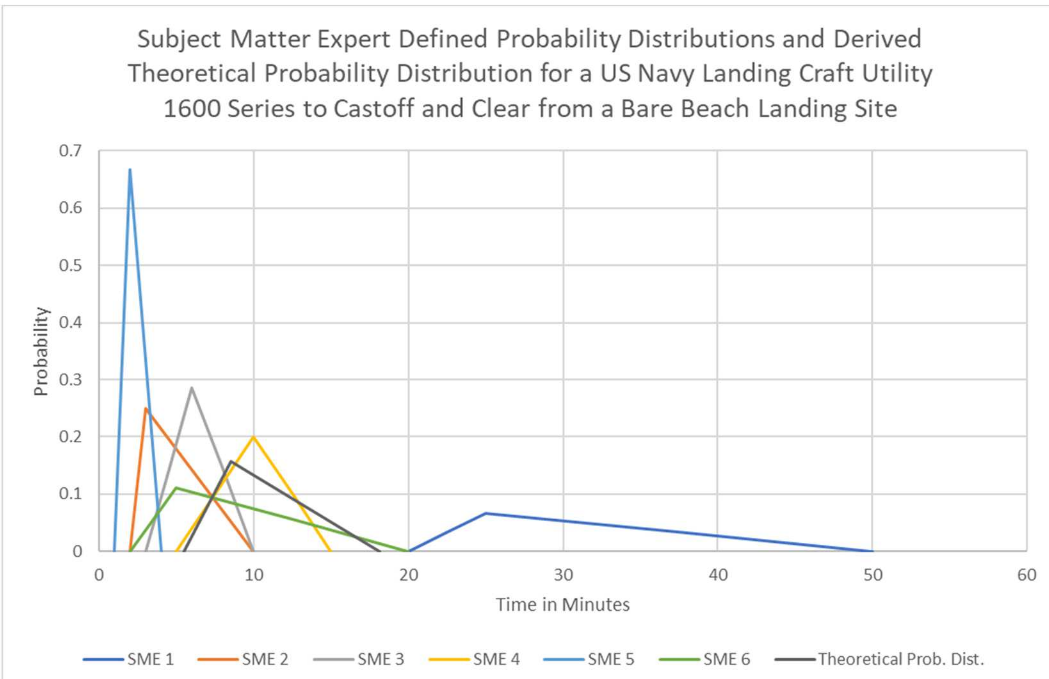

Figure J26. Subject Matter Expert Defined Probability Distributions and Derived Theoretical Probability Distribution for a US Navy Landing Craft Utility 1600 Series to Castoff and Clear from a Bare Beach Landing Site.

APPENDIX K. TABLE OF ONE SAMPLE STUDENT'S *t*-TEST COMPARISON OF DISCRETE-EVENT SIMULATION (EXPERIMENTAL) MODEL RESULTS TO BASELINE (CONTROL) MODEL RESULTS BY ITERATION

	Discrete-Event Simulation (Experimental) Model		Baseline (Control) Model	Statistical Analysis		
Iteration	Estimated Duration (Hours)	Standard Deviation (Hours)	Estimated Duration (Hours)	t Test Value	t Critical Value	Result
1						n/a
2	438.62	16.63265306	208.8419815	138.1487473	1.984216952	Reject
3	489.96	4.285714286	135.3941463	827.3203254	1.984216952	Reject
4	446.93	19.94897959	81.85548368	183.0041054	1.984216952	Reject
5	436.51	2.5	137.8152245	1194.779102	1.984216952	Reject
6	411.54	3.62244898	81.23948203	911.8155144	1.984216952	Reject
7	429.48	4.744897959	68.42331517	760.9366691	1.984216952	Reject
8	424.17	4.336734694	51.6855414	858.9053398	1.984216952	Reject
9	497.37	2.806122449	152.0328585	1230.655995	1.984216952	Reject
10	474.76	4.489795918	76.04551743	888.045893	1.984216952	Reject
11	446.57	4.387755102	66.62707741	865.9164282	1.984216952	Reject
12	439.81	4.489795918	50.61695044	866.8390649	1.984216952	Reject
13	448.99	3.826530612	67.7052819	996.4240633	1.984216952	Reject
14	440.38	4.795918367	49.78829511	814.425257	1.984216952	Reject
15	431.41	3.979591837	47.48929211	964.7238301	1.984216952	Reject
16	428.64	5.102040816	38.27078558	765.1236603	1.984216952	Reject
17						n/a
18	497.37	2.806122449	220.7919815	985.6234842	1.984216952	Reject
19	488.27	4.030612245	135.3941463	875.4894599	1.984216952	Reject
20	446.33	20.56122449	79.06686648	178.6192907	1.984216952	Reject
21	436.22	2.397959184	141.7652245	1227.939064	1.984216952	Reject
22	410.9	3.316326531	86.70065708	977.585711	1.984216952	Reject
23	429.12	4.030612245	69.26824578	892.7967573	1.984216952	Reject
24	423.74	4.030612245	52.17499928	921.8574702	1.984216952	Reject
25	500.74	2.806122449	129.6161918	1322.550298	1.984216952	Reject
26	481.6	4.540816327	72.70538217	900.4870235	1.984216952	Reject
27	446.92	4.234693878	59.29209138	915.3622902	1.984216952	Reject
28	440.95	4.642857143	44.67526716	853.5148092	1.984216952	Reject
29	451.21	4.387755102	61.58689723	887.9782342	1.984216952	Reject
30	442.14	5.306122449	47.99462785	742.8124321	1.984216952	Reject
31	432.37	4.081632653	41.89100048	956.6735488	1.984216952	Reject
32	428.76	4.948979592	37.5063917	790.5743013	1.984216952	Reject
33						n/a
34	324.37	2.397959184	154.0771063	710.1575995	1.984216952	Reject
35	394.74	3.775510204	108.2500841	758.8111286	1.984216952	Reject
36	363.32	16.07142857	61.35968792	187.8864164	1.984216952	Reject
37	333.01	2.091836735	101.4740406	1106.85483	1.984216952	Reject
38	310.82	2.755102041	60.84963102	907.2998578	1.984216952	Reject

	Discrete-Event Simulation (Experimental) Model		Baseline (Control) Model	Statistical Analysis		
Iteration	Estimated Duration (Hours)	Standard Deviation (Hours)	Estimated Duration (Hours)	t Test Value	t Critical Value	Result
39	342.55	4.183673469	52.68633806	692.8448505	1.984216952	Reject
40	336.81	4.693877551	38.21539439	636.1363337	1.984216952	Reject
41	324.03	2.040816327	87.07276515	1161.090451	1.984216952	Reject
42	317.06	3.112244898	55.69899847	839.7828902	1.984216952	Reject
43	337.61	3.571428571	48.71223888	808.9137311	1.984216952	Reject
44	332.09	4.081632653	35.34364079	727.0285801	1.984216952	Reject
45	313.93	2.346938776	46.89286215	1137.810413	1.984216952	Reject
46	309.16	3.418367347	35.4781287	800.6215937	1.984216952	Reject
47	324.65	3.87755102	32.93032305	752.3296932	1.984216952	Reject
48	320.99	4.285714286	27.27027655	685.3460214	1.984216952	Reject
49						n/a
50	327.59	22.19387755	170.7437729	70.6709437	1.984216952	Reject
51	394.11	4.387755102	109.6167508	648.3799634	1.984216952	Reject
52	361.97	4.948979592	62.00427896	606.1163023	1.984216952	Reject
53	332.84	1.989795918	64.23631112	1349.905718	1.984216952	Reject
54	310.62	2.653061224	64.23631112	928.6769812	1.984216952	Reject
55	342.21	3.62244898	53.42681904	797.2042742	1.984216952	Reject
56	336.95	5.204081633	38.65686032	573.190739	1.984216952	Reject
57	325.04	2.091836735	74.77276515	1196.399464	1.984216952	Reject
58	319.43	3.571428571	49.68367623	755.2897066	1.984216952	Reject
59	337.16	3.367346939	45.01573325	867.5799437	1.984216952	Reject
60	331.84	4.183673469	35.45738848	708.42673	1.984216952	Reject
61	314.78	2.346938776	43.59165298	1155.498174	1.984216952	Reject
62	309.45	3.928571429	34.45781417	699.9801094	1.984216952	Reject
63	324.86	3.571428571	31.26348972	822.0702288	1.984216952	Reject
64	321.59	4.234693878	26.18511657	697.5826163	1.984216952	Reject
65						n/a
66	395.6	2.704081633	189.2548667	763.0876628	1.984216952	Reject
67	448.85	4.846938776	125.1014786	667.9443179	1.984216952	Reject
68	414.24	23.7244898	70.09176284	145.0603322	1.984216952	Reject
69	394.58	2.448979592	120.0179879	1121.128216	1.984216952	Reject
39	342.55	4.183673469	52.68633806	692.8448505	1.984216952	Reject
70	375.63	3.214285714	73.88599691	938.7591207	1.984216952	Reject
71	395.9	5.969387755	61.40638866	560.348272	1.984216952	Reject
72	388.69	4.693877551	42.72755971	737.0504163	1.984216952	Reject
73	413.65	2.857142857	104.8378224	1080.842621	1.984216952	Reject
74	406.62	3.724489796	66.33853652	913.6324225	1.984216952	Reject
75	403.18	3.775510204	57.48800097	915.6166461	1.984216952	Reject
76	395.06	4.642857143	44.00193396	756.1250653	1.984216952	Reject
77	392.61	2.806122449	56.22589461	1198.75063	1.984216952	Reject
78	388.34	4.285714286	42.91811787	805.9843916	1.984216952	Reject
79	387.89	4.795918367	39.00017094	727.4724095	1.984216952	Reject
80	382.94	4.540816327	32.33052162	772.1287389	1.984216952	Reject
81						n/a
82	394.2	2.397959184	189.2548667	854.6648112	1.984216952	Reject
83	447.97	4.540816327	125.1014786	711.0362943	1.984216952	Reject
84	414.9	24.79591837	70.09176284	139.058466	1.984216952	Reject

	Discrete-Event Simulation (Experimental) Model		Baseline (Control) Model	Statistical Analysis		
Iteration	Estimated Duration (Hours)	Standard Deviation (Hours)	Estimated Duration (Hours)	t Test Value	t Critical Value	Result
85	394.21	2.653061224	120.0179879	1033.492969	1.984216952	Reject
86	374.65	2.857142857	73.88599691	1052.674011	1.984216952	Reject
87	396.23	4.693877551	61.40638866	713.3198676	1.984216952	Reject
88	387.85	5.102040816	42.72755971	676.439983	1.984216952	Reject
89	414.39	2.908163265	104.8378224	1064.425032	1.984216952	Reject
90	410.1	4.183673469	66.33853652	821.673742	1.984216952	Reject
91	403.74	3.62244898	57.48800097	955.8505889	1.984216952	Reject
92	396.35	4.030612245	44.00193396	874.180012	1.984216952	Reject
93	393.09	3.316326531	56.22589461	1015.774841	1.984216952	Reject
94	388.97	4.897959184	42.91811787	706.5225927	1.984216952	Reject
95	388.68	4.234693878	39.00017094	825.7499578	1.984216952	Reject
96	383.79	4.336734694	32.33052162	810.424209	1.984216952	Reject
97						n/a
98	196.64	2.295918367	51.17344323	633.5876695	1.984216952	Reject
99	188.33	1.683673469	63.72414652	740.083251	1.984216952	Reject
100	243.74	49.43877551	28.62207326	43.51198518	1.984216952	Reject
101	141.03	1.071428571	50.58481893	844.1550233	1.984216952	Reject
102	167.62	20.25510204	25.59280389	70.11922024	1.984216952	Reject
85	394.21	2.653061224	120.0179879	1033.492969	1.984216952	Reject
86	374.65	2.857142857	73.88599691	1052.674011	1.984216952	Reject
87	396.23	4.693877551	61.40638866	713.3198676	1.984216952	Reject
88	387.85	5.102040816	42.72755971	676.439983	1.984216952	Reject
89	414.39	2.908163265	104.8378224	1064.425032	1.984216952	Reject
90	410.1	4.183673469	66.33853652	821.673742	1.984216952	Reject
91	403.74	3.62244898	57.48800097	955.8505889	1.984216952	Reject
92	396.35	4.030612245	44.00193396	874.180012	1.984216952	Reject
93	393.09	3.316326531	56.22589461	1015.774841	1.984216952	Reject
94	388.97	4.897959184	42.91811787	706.5225927	1.984216952	Reject
95	388.68	4.234693878	39.00017094	825.7499578	1.984216952	Reject
96	383.79	4.336734694	32.33052162	810.424209	1.984216952	Reject
97						n/a
98	196.64	2.295918367	51.17344323	633.5876695	1.984216952	Reject
99	188.33	1.683673469	63.72414652	740.083251	1.984216952	Reject
100	243.74	49.43877551	28.62207326	43.51198518	1.984216952	Reject
101	141.03	1.071428571	50.58481893	844.1550233	1.984216952	Reject
102	167.62	20.25510204	25.59280389	70.11922024	1.984216952	Reject
103	164.53	22.95918367	28.38207326	59.29998587	1.984216952	Reject
104	173.53	2.755102041	18.31688401	563.3661247	1.984216952	Reject
105	252.16	3.571428571	39.89373457	594.3455432	1.984216952	Reject
106	245.36	3.316326531	22.51631502	671.9594193	1.984216952	Reject
107	217.21	10.86734694	24.59717962	177.2399662	1.984216952	Reject
108	221.87	4.387755102	16.7321116	467.5235596	1.984216952	Reject
109	195.8	11.32653061	22.49031863	153.0121511	1.984216952	Reject
110	206.13	4.081632653	15.80778095	466.2894367	1.984216952	Reject
111	195.14	3.826530612	16.62424944	466.5211615	1.984216952	Reject
112	195.26	4.387755102	12.63823614	416.2077409	1.984216952	Reject
113						n/a

	Discrete-Event Simulation (Experimental) Model		Baseline (Control) Model	Statistical Analysis		
Iteration	Estimated Duration (Hours)	Standard Deviation (Hours)	Estimated Duration (Hours)	t Test Value	t Critical Value	Result
114	195.97	2.5	51.17344323	579.1862271	1.984216952	Reject
115	187.77	1.785714286	63.72414652	694.6567795	1.984216952	Reject
116	243.9	49.89795918	28.62207326	43.14363358	1.984216952	Reject
117	140.88	1.071428571	50.58481893	842.7550233	1.984216952	Reject
118	166.82	20.35714286	25.59280389	69.374763	1.984216952	Reject
119	163.91	22.75510204	28.38207326	59.55935794	1.984216952	Reject
120	173.02	2.755102041	18.31688401	561.5150136	1.984216952	Reject
121	255.16	3.214285714	39.89373457	669.7172702	1.984216952	Reject
122	247.85	3.775510204	22.51631502	596.8297602	1.984216952	Reject
123	216.75	10.15306122	24.59717962	189.2560442	1.984216952	Reject
124	223.54	4.285714286	16.7321116	482.5517396	1.984216952	Reject
125	196.74	10.86734694	22.49031863	160.3424298	1.984216952	Reject
126	208.38	4.591836735	15.80778095	419.3794993	1.984216952	Reject
127	195.56	3.826530612	16.62424944	467.6187615	1.984216952	Reject
128	195.68	4.285714286	12.63823614	427.097449	1.984216952	Reject

APPENDIX L. TABLE OF ONE SAMPLE STUDENT'S *t*-TEST COMPARISON OF DISCRETE-EVENT SIMULATION (EXPERIMENTAL) MODEL RESULTS TO REVISED BASELINE (EXPERIMENTAL) MODEL RESULTS BY ITERATION

	Discrete-Event Simulation (Experimental) Model		Baseline (Control) Model	Statistical Analysis		
Iteration	Estimated Duration (Hours)	Standard Deviation (Hours)	Estimated Duration (Hours)	t Test Value	t Critical Value	Result
1						n/a
2	438.62	16.63265306	327.4063432	66.86465257	1.984216952	Reject
3	489.96	4.285714286	255.4581046	547.1710893	1.984216952	Reject
4	446.93	19.94897959	142.9183508	152.3945863	1.984216952	Reject
5	436.51	2.5	313.2000145	493.2399419	1.984216952	Reject
6	411.54	3.62244898	160.2968323	693.5726883	1.984216952	Reject
7	429.48	4.744897959	141.7822597	606.3307215	1.984216952	Reject
8	424.17	4.336734694	98.16806144	751.7221171	1.984216952	Reject
9	497.37	2.806122449	301.8094184	696.9068	1.984216952	Reject
10	474.76	4.489795918	135.6427153	755.3066796	1.984216952	Reject
11	446.57	4.387755102	127.8827532	726.3104695	1.984216952	Reject
12	439.81	4.489795918	87.18543088	785.3910858	1.984216952	Reject
13	448.99	3.826530612	139.3921142	809.0824748	1.984216952	Reject
14	440.38	4.795918367	98.15818587	713.568889	1.984216952	Reject
15	431.41	3.979591837	87.90617344	863.1634616	1.984216952	Reject
16	428.64	5.102040816	71.08114814	700.8153496	1.984216952	Reject
17						n/a
18	497.37	2.806122449	337.7630098	568.781274	1.984216952	Reject
19	488.27	4.030612245	256.6053252	574.7629907	1.984216952	Reject
20	446.33	20.56122449	142.4015981	147.8162947	1.984216952	Reject
21	436.22	2.397959184	313.2078566	512.9868108	1.984216952	Reject
22	410.9	3.316326531	160.5112114	755.0185011	1.984216952	Reject
23	429.12	4.030612245	138.2717718	721.5981358	1.984216952	Reject
24	423.74	4.030612245	99.58914407	804.2223767	1.984216952	Reject
25	500.74	2.806122449	310.0055121	679.7083568	1.984216952	Reject
26	481.6	4.540816327	137.6816065	757.3933161	1.984216952	Reject
27	446.92	4.234693878	130.4215129	747.3940177	1.984216952	Reject
28	440.95	4.642857143	90.08296044	755.7136237	1.984216952	Reject
29	451.21	4.387755102	138.1280198	713.5356757	1.984216952	Reject
30	442.14	5.306122449	95.95321025	652.4289499	1.984216952	Reject
31	432.37	4.081632653	96.55953766	822.7356327	1.984216952	Reject
32	428.76	4.948979592	73.36686777	718.1139579	1.984216952	Reject
33						n/a
34	324.37	2.397959184	243.349619	337.872227	1.984216952	Reject
35	394.74	3.775510204	195.5705008	527.530025	1.984216952	Reject
36	363.32	16.07142857	100.1189476	163.7695437	1.984216952	Reject
37	333.01	2.091836735	222.8621054	526.5606668	1.984216952	Reject
38	310.82	2.755102041	115.7870405	707.8974084	1.984216952	Reject

	Discrete-Event Simulation (Experimental) Model		Baseline (Control) Model	Statistical Analysis		
Iteration	Estimated Duration (Hours)	Standard Deviation (Hours)	Estimated Duration (Hours)	t Test Value	t Critical Value	Result
39	342.55	4.183673469	98.18695165	584.0872863	1.984216952	Reject
40	336.81	4.693877551	70.77849006	566.762782	1.984216952	Reject
41	324.03	2.040816327	188.9983302	661.655182	1.984216952	Reject
42	317.06	3.112244898	101.4345523	692.8293072	1.984216952	Reject
43	337.61	3.571428571	93.95612438	682.2308517	1.984216952	Reject
44	332.09	4.081632653	66.17091134	651.5017672	1.984216952	Reject
45	313.93	2.346938776	101.1947259	906.4372547	1.984216952	Reject
46	309.16	3.418367347	69.62087927	700.7413084	1.984216952	Reject
47	324.65	3.87755102	66.3424718	666.1615201	1.984216952	Reject
48	320.99	4.285714286	51.43032785	628.9725684	1.984216952	Reject
49						n/a
50	327.59	22.19387755	250.5718413	34.70243474	1.984216952	Reject
51	394.11	4.387755102	194.3746674	455.210758	1.984216952	Reject
52	361.97	4.948979592	101.0477468	527.2243467	1.984216952	Reject
53	332.84	1.989795918	118.2551872	1078.426239	1.984216952	Reject
54	310.62	2.653061224	118.2551872	725.0673713	1.984216952	Reject
55	342.21	3.62244898	102.958037	660.4702077	1.984216952	Reject
56	336.95	5.204081633	73.86537003	505.5351713	1.984216952	Reject
57	325.04	2.091836735	184.1701548	673.426577	1.984216952	Reject
58	319.43	3.571428571	99.7718548	615.0428066	1.984216952	Reject
59	337.16	3.367346939	94.17779304	721.5835237	1.984216952	Reject
60	331.84	4.183673469	64.33774768	639.3956275	1.984216952	Reject
61	314.78	2.346938776	99.02127135	919.3198003	1.984216952	Reject
62	309.45	3.928571429	69.57443845	610.5923385	1.984216952	Reject
63	324.86	3.571428571	62.66496575	734.1460959	1.984216952	Reject
64	321.59	4.234693878	51.34842287	638.1608327	1.984216952	Reject
65						n/a
66	395.6	2.704081633	299.0326565	357.1169684	1.984216952	Reject
67	448.85	4.846938776	224.7852286	462.2810021	1.984216952	Reject
68	414.24	23.7244898	120.4237143	123.8451441	1.984216952	Reject
69	394.58	2.448979592	267.9984332	516.8747312	1.984216952	Reject
70	375.63	3.214285714	141.1259656	729.568107	1.984216952	Reject
71	395.9	5.969387755	120.3915249	461.5355651	1.984216952	Reject
72	388.69	4.693877551	86.76127224	643.2394635	1.984216952	Reject
73	413.65	2.857142857	233.4770575	630.6052987	1.984216952	Reject
74	406.62	3.724489796	122.9433223	761.6524498	1.984216952	Reject
75	403.18	3.775510204	113.1485145	768.1915022	1.984216952	Reject
76	395.06	4.642857143	78.60068707	681.604674	1.984216952	Reject
77	392.61	2.806122449	118.4916974	976.8579511	1.984216952	Reject
78	388.34	4.285714286	84.15924794	709.7550881	1.984216952	Reject
79	387.89	4.795918367	78.82788041	644.4273983	1.984216952	Reject
80	382.94	4.540816327	61.80068131	707.2281625	1.984216952	Reject
81						n/a
82	394.2	2.397959184	297.6171009	402.7712386	1.984216952	Reject
83	447.97	4.540816327	224.7130049	491.6670903	1.984216952	Reject
84	414.9	24.79591837	122.5532999	117.9011383	1.984216952	Reject
85	394.21	2.653061224	267.05019	479.2946685	1.984216952	Reject

	Discrete-Event Simulation (Experimental) Model		Baseline (Control) Model	Statistical Analysis		
Iteration	Estimated Duration (Hours)	Standard Deviation (Hours)	Estimated Duration (Hours)	t Test Value	t Critical Value	Result
86	374.65	2.857142857	139.315602	823.670393	1.984216952	Reject
87	396.23	4.693877551	120.409413	587.6177723	1.984216952	Reject
88	387.85	5.102040816	85.34110843	592.9174275	1.984216952	Reject
89	414.39	2.908163265	240.2885679	598.6645734	1.984216952	Reject
90	410.1	4.183673469	125.1012732	681.216469	1.984216952	Reject
91	403.74	3.62244898	111.9371115	805.5403681	1.984216952	Reject
92	396.35	4.030612245	77.48165769	791.1163936	1.984216952	Reject
93	393.09	3.316326531	123.9271044	811.6296544	1.984216952	Reject
94	388.97	4.897959184	85.43311043	619.7211495	1.984216952	Reject
95	388.68	4.234693878	80.84273897	726.9410019	1.984216952	Reject
96	383.79	4.336734694	59.9622136	746.7087781	1.984216952	Reject
97						n/a
98	196.64	2.295918367	99.55308212	422.8674645	1.984216952	Reject
99	188.33	1.683673469	112.4602574	450.6202897	1.984216952	Reject
100	243.74	49.43877551	53.08082235	38.56470466	1.984216952	Reject
101	141.03	1.071428571	83.31459437	538.6771192	1.984216952	Reject
102	167.62	20.25510204	45.68606043	60.19912382	1.984216952	Reject
103	164.53	22.95918367	48.52179534	50.52801803	1.984216952	Reject
86	374.65	2.857142857	139.315602	823.670393	1.984216952	Reject
87	396.23	4.693877551	120.409413	587.6177723	1.984216952	Reject
88	387.85	5.102040816	85.34110843	592.9174275	1.984216952	Reject
89	414.39	2.908163265	240.2885679	598.6645734	1.984216952	Reject
90	410.1	4.183673469	125.1012732	681.216469	1.984216952	Reject
91	403.74	3.62244898	111.9371115	805.5403681	1.984216952	Reject
92	396.35	4.030612245	77.48165769	791.1163936	1.984216952	Reject
93	393.09	3.316326531	123.9271044	811.6296544	1.984216952	Reject
94	388.97	4.897959184	85.43311043	619.7211495	1.984216952	Reject
95	388.68	4.234693878	80.84273897	726.9410019	1.984216952	Reject
96	383.79	4.336734694	59.9622136	746.7087781	1.984216952	Reject
97						n/a
98	196.64	2.295918367	99.55308212	422.8674645	1.984216952	Reject
99	188.33	1.683673469	112.4602574	450.6202897	1.984216952	Reject
100	243.74	49.43877551	53.08082235	38.56470466	1.984216952	Reject
101	141.03	1.071428571	83.31459437	538.6771192	1.984216952	Reject
102	167.62	20.25510204	45.68606043	60.19912382	1.984216952	Reject
103	164.53	22.95918367	48.52179534	50.52801803	1.984216952	Reject
104	173.53	2.755102041	32.5135961	511.8373179	1.984216952	Reject
105	252.16	3.571428571	82.8025054	474.2009849	1.984216952	Reject
106	245.36	3.316326531	44.44229535	605.8441555	1.984216952	Reject
107	217.21	10.86734694	48.33302737	155.3985288	1.984216952	Reject
108	221.87	4.387755102	31.83594663	433.1008658	1.984216952	Reject
109	195.8	11.32653061	41.58879797	136.1504306	1.984216952	Reject
110	206.13	4.081632653	29.07205612	433.7919625	1.984216952	Reject
111	195.14	3.826530612	30.43277062	430.4348928	1.984216952	Reject
112	195.26	4.387755102	23.12695896	392.3032098	1.984216952	Reject
113						n/a
114	195.97	2.5	99.55308212	385.6676715	1.984216952	Reject

	Discrete-Event Simulation (Experimental) Model		Baseline (Control) Model	Statistical Analysis		
Iteration	Estimated Duration (Hours)	Standard Deviation (Hours)	Estimated Duration (Hours)	t Test Value	t Critical Value	Result
115	187.77	1.785714286	112.4602574	421.7345588	1.984216952	Reject
116	243.9	49.89795918	53.08082235	38.24188018	1.984216952	Reject
117	140.88	1.071428571	83.31459437	537.2771192	1.984216952	Reject
118	166.82	20.35714286	45.68606043	59.50439137	1.984216952	Reject
119	163.91	22.75510204	48.52179534	50.70871774	1.984216952	Reject
120	173.02	2.755102041	32.5135961	509.9862067	1.984216952	Reject
121	255.16	3.214285714	83.71359915	533.3888026	1.984216952	Reject
122	247.85	3.775510204	44.72192502	538.0149013	1.984216952	Reject
123	216.75	10.15306122	48.57387868	165.6408029	1.984216952	Reject
124	223.54	4.285714286	32.01932721	446.8815699	1.984216952	Reject
125	196.74	10.86734694	41.76633514	142.6048747	1.984216952	Reject
126	208.38	4.591836735	29.22324662	390.1635963	1.984216952	Reject
127	195.56	3.826530612	30.76932721	430.6529582	1.984216952	Reject
128	195.68	4.285714286	23.21833094	402.4105611	1.984216952	Reject

APPENDIX M. TABLES OF ESTIMATED OPERATING COSTS BY CARGO EQUIPMENT TYPE

Table M1. Estimated Operating Costs for Lighterage to Transport ABCT Equipment.

Iteration	Baseline (Control) Cost	Revised Baseline (Experimental) Costs	Discrete-Event Simulation (Experimental) Costs
1	$-	$-	$-
2	$446,273.72	$699,633.51	$937,285.59
3	$328,984.18	$620,718.68	$1,190,517.42
4	$373,811.27	$652,668.43	$2,041,005.22
5	$270,425.74	$614,571.76	$856,534.83
6	$333,011.26	$657,077.68	$1,686,956.27
7	$300,519.30	$622,716.17	$1,886,301.87
8	$337,452.65	$640,935.00	$2,769,387.47
9	$228,936.39	$454,475.16	$748,957.11
10	$277,013.40	$494,110.00	$1,729,423.22
11	$262,221.57	$503,303.12	$1,757,547.97
12	$307,374.33	$529,438.52	$2,670,771.41
13	$234,806.59	$483,421.48	$1,557,128.32
14	$279,061.68	$550,173.26	$2,468,314.78
15	$280,086.85	$518,461.36	$2,544,410.79
16	$307,497.78	$571,122.20	$3,444,032.98
17	$-	$-	$-
18	$471,809.64	$721,764.63	$1,062,828.27
19	$328,984.18	$623,506.22	$1,186,411.01
20	$361,076.43	$650,308.56	$2,038,265.19
21	$278,176.56	$614,587.15	$855,965.78
22	$355,397.33	$657,956.44	$1,684,332.83
23	$304,230.28	$607,297.90	$1,884,720.73
24	$340,648.30	$650,213.19	$2,766,580.02
25	$195,180.59	$466,817.12	$754,031.77
26	$264,846.19	$501,537.13	$1,754,339.50
27	$233,353.55	$513,294.81	$1,758,925.45
28	$271,293.12	$547,033.94	$2,677,694.12
29	$213,587.61	$479,037.51	$1,564,827.44
30	$269,008.24	$537,814.45	$2,478,179.52
31	$247,068.71	$569,497.99	$2,550,072.77
32	$301,356.03	$589,487.48	$3,444,997.16

Table M2. Estimated Operating Costs for Lighterage to Transport IBCT Equipment.

Iteration	Baseline (Control) Cost	Revised Baseline (Experimental) Costs	Discrete-Event Simulation (Experimental) Costs
1	$-	$-	$-
2	$329,246.85	$520,012.98	$693,145.16
3	$263,028.84	$475,202.23	$959,149.41
4	$280,212.66	$457,215.44	$1,659,181.56
5	$199,115.83	$437,307.63	$653,443.59
6	$249,430.59	$474,626.22	$1,274,091.82
7	$231,401.55	$431,242.97	$1,504,500.11
8	$249,506.65	$462,109.68	$2,199,017.84
9	$131,117.21	$284,600.28	$487,935.68
10	$202,896.50	$369,498.84	$1,154,964.46
11	$191,714.84	$369,779.42	$1,328,718.39
12	$214,626.28	$401,826.65	$2,016,635.54
13	$162,627.68	$350,950.30	$1,088,730.92
14	$198,853.69	$390,222.64	$1,732,831.19
15	$194,219.58	$391,280.92	$1,914,751.54
16	$219,110.98	$413,231.96	$2,579,087.69
17	$-	$-	$-
18	$364,861.79	$535,446.12	$700,025.96
19	$266,349.60	$472,296.57	$957,618.62
20	$283,156.33	$461,457.00	$1,653,016.49
21	$126,046.68	$232,044.37	$653,110.01
22	$263,313.04	$484,743.48	$1,273,272.00
23	$234,653.79	$452,197.86	$1,503,006.81
24	$252,388.96	$482,263.79	$2,199,931.89
25	$112,595.44	$277,329.85	$489,456.58
26	$180,984.29	$363,442.08	$1,163,597.73
27	$177,166.65	$370,651.83	$1,326,947.34
28	$215,317.02	$390,694.66	$2,015,117.40
29	$151,178.86	$343,412.61	$1,091,678.78
30	$193,134.87	$389,962.34	$1,734,456.63
31	$184,388.77	$369,591.37	$1,915,990.10
32	$210,391.95	$412,573.87	$2,583,908.57

Table M3. Estimated Operating Costs for Lighterage to Transport SBCT Equipment.

Iteration	Baseline (Control) Cost	Revised Baseline (Experimental) Costs	Discrete-Event Simulation (Experimental) Costs
1	$-	$-	$-
2	$404,418.08	$639,001.87	$845,356.30
3	$303,974.79	$546,188.93	$1,090,627.28
4	$320,089.62	$549,941.67	$1,891,719.07
5	$235,503.39	$525,875.68	$774,258.35
6	$302,868.36	$578,493.79	$1,539,756.49
7	$269,700.54	$528,766.79	$1,738,816.50
8	$278,966.38	$566,460.57	$2,537,740.10
9	$157,868.45	$351,577.90	$622,888.61
10	$241,653.48	$447,849.52	$1,481,207.49
11	$226,253.26	$445,314.15	$1,586,779.66
12	$267,204.26	$477,307.17	$2,399,024.47
13	$194,995.28	$410,937.39	$1,361,598.59
14	$240,554.58	$471,709.70	$2,176,632.37
15	$230,018.90	$464,918.54	$2,287,734.41
16	$259,769.00	$496,555.58	$3,076,843.02
17	$-	$-	$-
18	$404,418.08	$635,976.98	$842,364.65
19	$303,974.79	$546,013.44	$1,088,489.03
20	$320,089.62	$559,666.89	$1,894,733.10
21	$235,503.39	$524,015.00	$773,532.32
22	$302,868.36	$571,072.87	$1,535,739.34
23	$269,700.54	$528,845.35	$1,740,265.88
24	$278,966.38	$557,188.38	$2,532,255.78
25	$157,868.45	$361,834.91	$624,002.93
26	$241,653.48	$455,710.35	$1,493,884.20
27	$226,253.26	$440,546.48	$1,588,983.63
28	$267,204.26	$470,511.80	$2,406,858.07
29	$194,995.28	$429,787.76	$1,363,263.26
30	$240,554.58	$478,849.65	$2,180,163.50
31	$230,018.90	$476,801.97	$2,292,393.74
32	$259,769.00	$481,783.88	$3,083,672.59

Table M4. Estimated Operating Costs for Lighterage to Transport HADR Supplies.

Iteration	Baseline (Control) Cost	Revised Baseline (Experimental) Costs	Discrete-Event Simulation (Experimental) Costs
1	$-	$-	$-
2	$329,246.85	$520,012.98	$693,145.16
3	$263,028.84	$475,202.23	$959,149.41
4	$280,212.66	$457,215.44	$1,659,181.56
5	$199,115.83	$437,307.63	$653,443.59
6	$249,430.59	$474,626.22	$1,274,091.82
7	$231,401.55	$431,242.97	$1,504,500.11
8	$249,506.65	$462,109.68	$2,199,017.84
9	$131,117.21	$284,600.28	$487,935.68
10	$202,896.50	$369,498.84	$1,154,964.46
11	$191,714.84	$369,779.42	$1,328,718.39
12	$214,626.28	$401,826.65	$2,016,635.54
13	$162,627.68	$350,950.30	$1,088,730.92
14	$198,853.69	$390,222.64	$1,732,831.19
15	$194,219.58	$391,280.92	$1,914,751.54
16	$219,110.98	$413,231.96	$2,579,087.69
17	$-	$-	$-
18	$364,861.79	$535,446.12	$700,025.96
19	$266,349.60	$472,296.57	$957,618.62
20	$283,156.33	$461,457.00	$1,653,016.49
21	$126,046.68	$232,044.37	$653,110.01
22	$263,313.04	$484,743.48	$1,273,272.00
23	$234,653.79	$452,197.86	$1,503,006.81
24	$252,388.96	$482,263.79	$2,199,931.89
25	$112,595.44	$277,329.85	$489,456.58
26	$180,984.29	$363,442.08	$1,163,597.73
27	$177,166.65	$370,651.83	$1,326,947.34
28	$215,317.02	$390,694.66	$2,015,117.40
29	$151,178.86	$343,412.61	$1,091,678.78
30	$193,134.87	$389,962.34	$1,734,456.63
31	$184,388.77	$369,591.37	$1,915,990.10
32	$210,391.95	$412,573.87	$2,583,908.57

APPENDIX N. HISTOGRAMS OF OBSERVED DURATIONS OF JLOTS ACTIVITIES

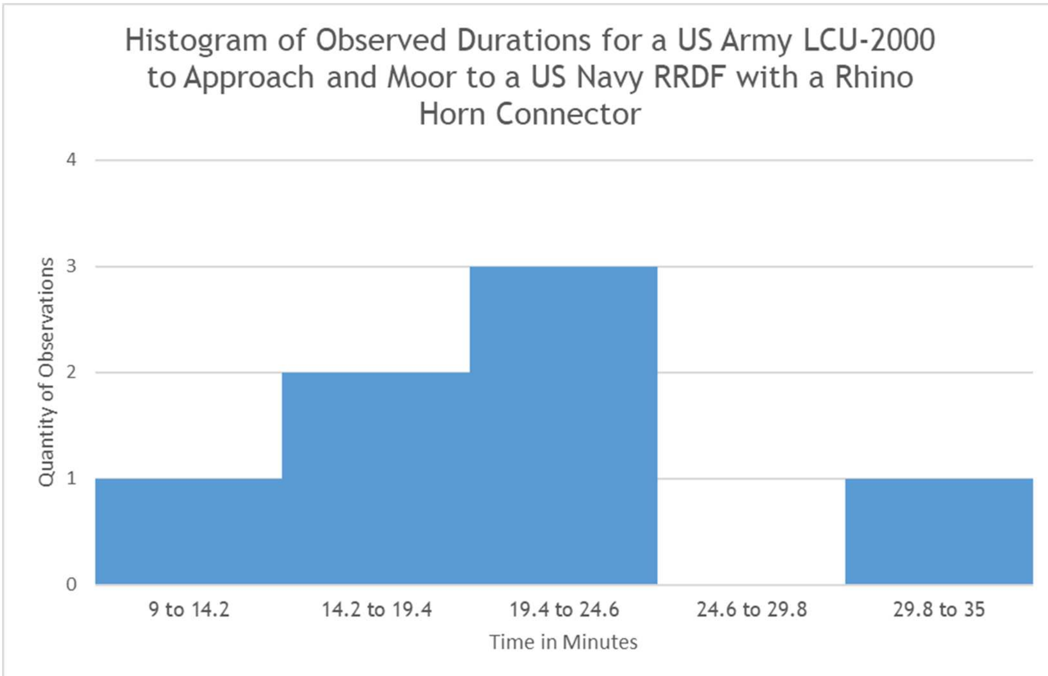

Figure N1. Histogram of Observed Durations for a US Army LCU-2000 to Approach and Moor to a US Navy RRDF with a Rhino Horn Connector.

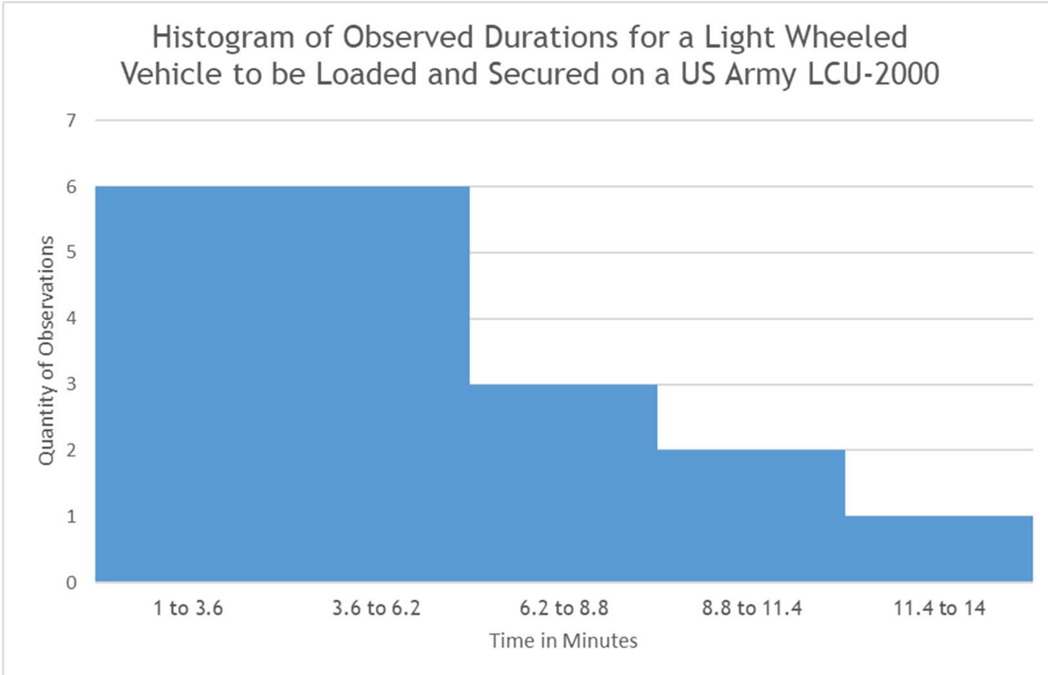

Figure N2. Histogram of Observed Durations for a Light Wheeled Vehicle to be Loaded and Secured on a US Army LCU-2000.

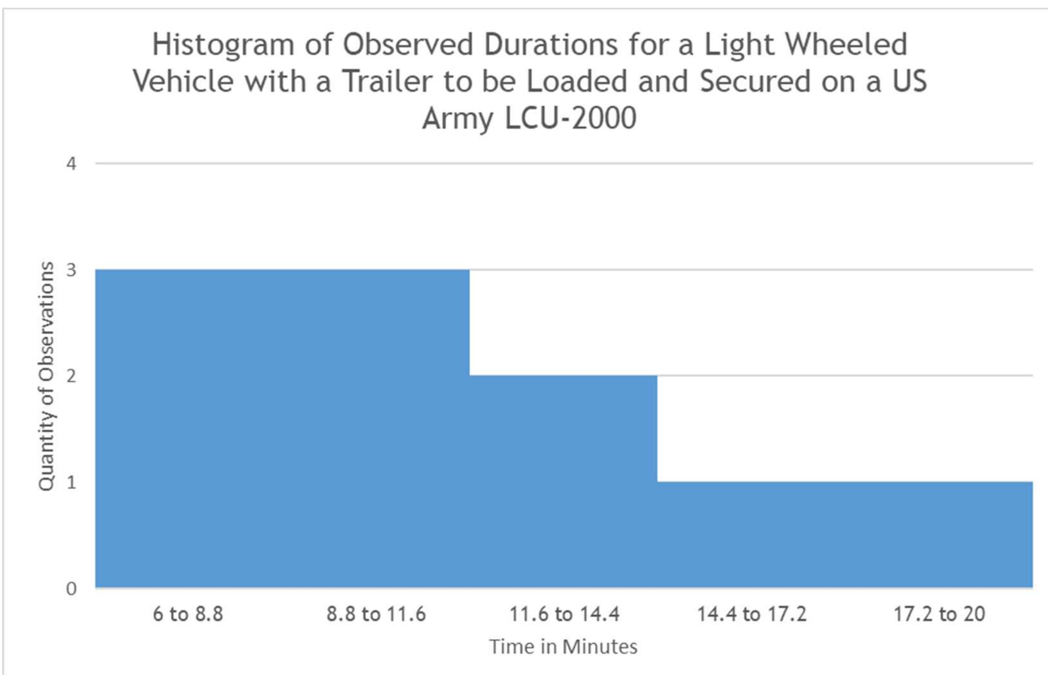

Figure N3. Histogram of Observed Durations for a Light Wheeled Vehicle with a Trailer to be Loaded and Secured on a US Army LCU-2000.

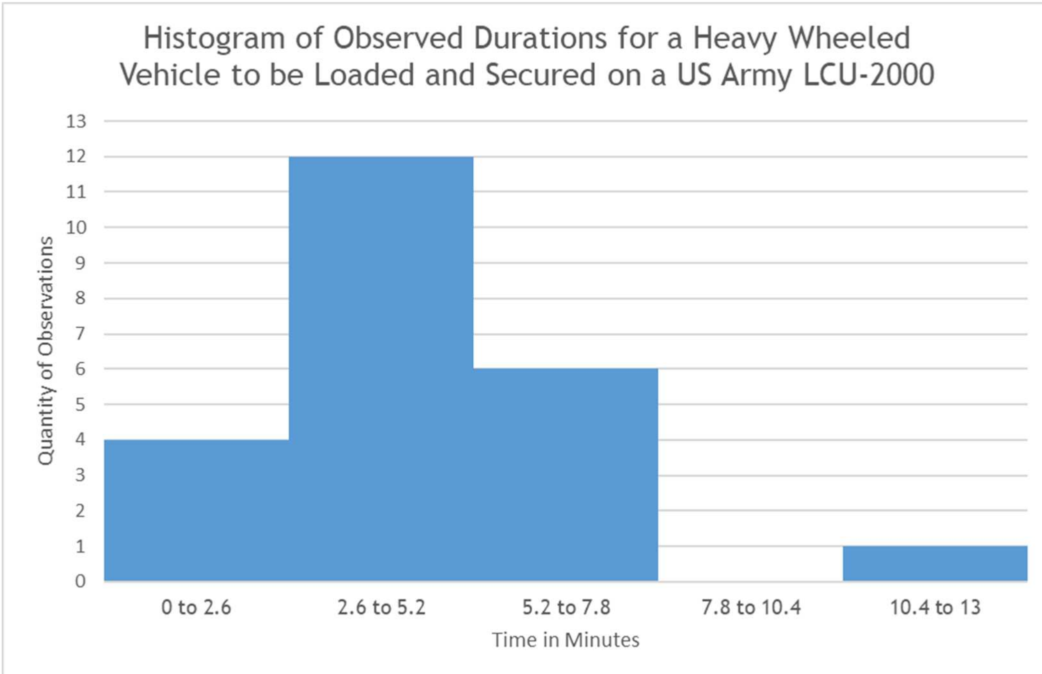

Figure N4. Histogram of Observed Durations for a Heavy Wheeled Vehicle to be Loaded and Secured on a US Army LCU-2000.

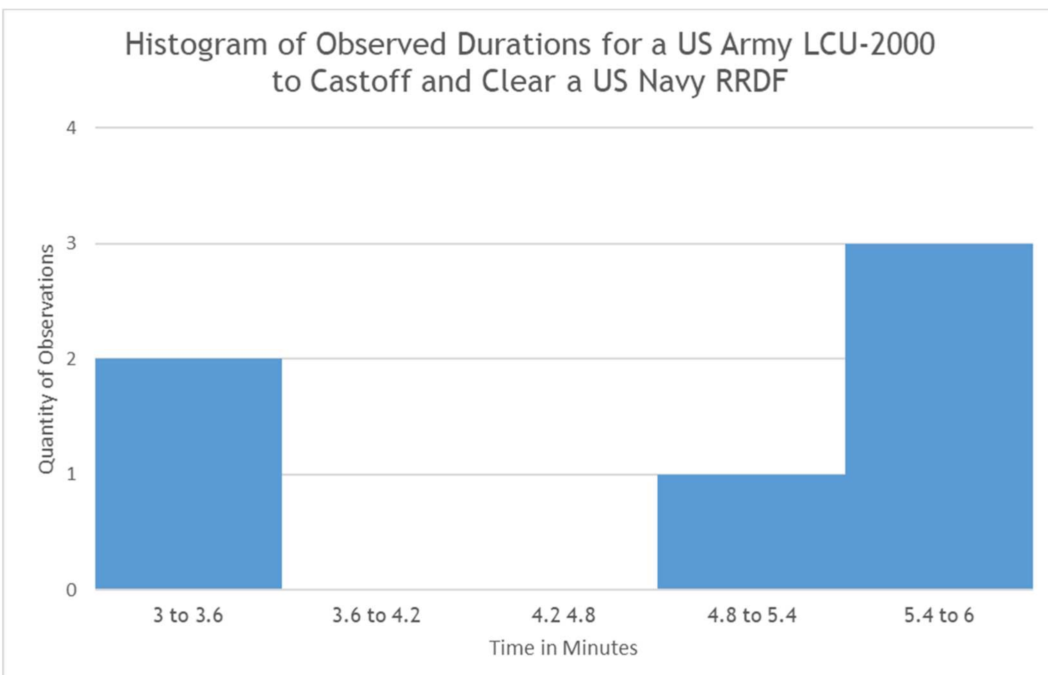

Figure N5. Histogram of Observed Durations for a US Army LCU-2000 to Castoff and Clear a US Navy RRDF.

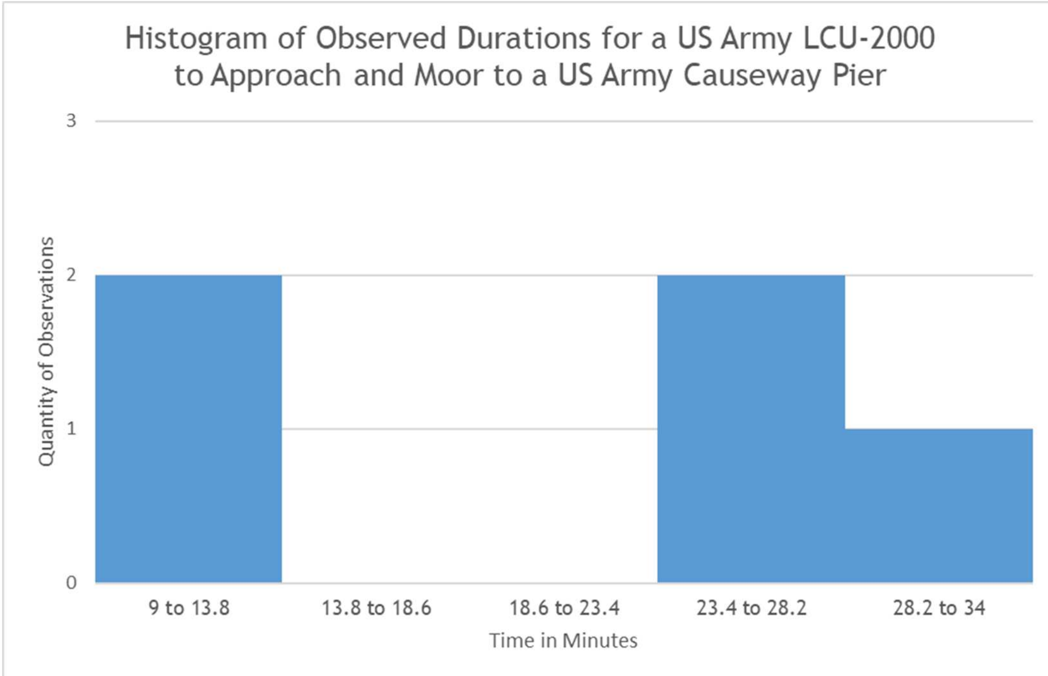

Figure N6. Histogram of Observed Durations for a US Army LCU-2000 to Approach and Moor to a US Army Causeway Pier.

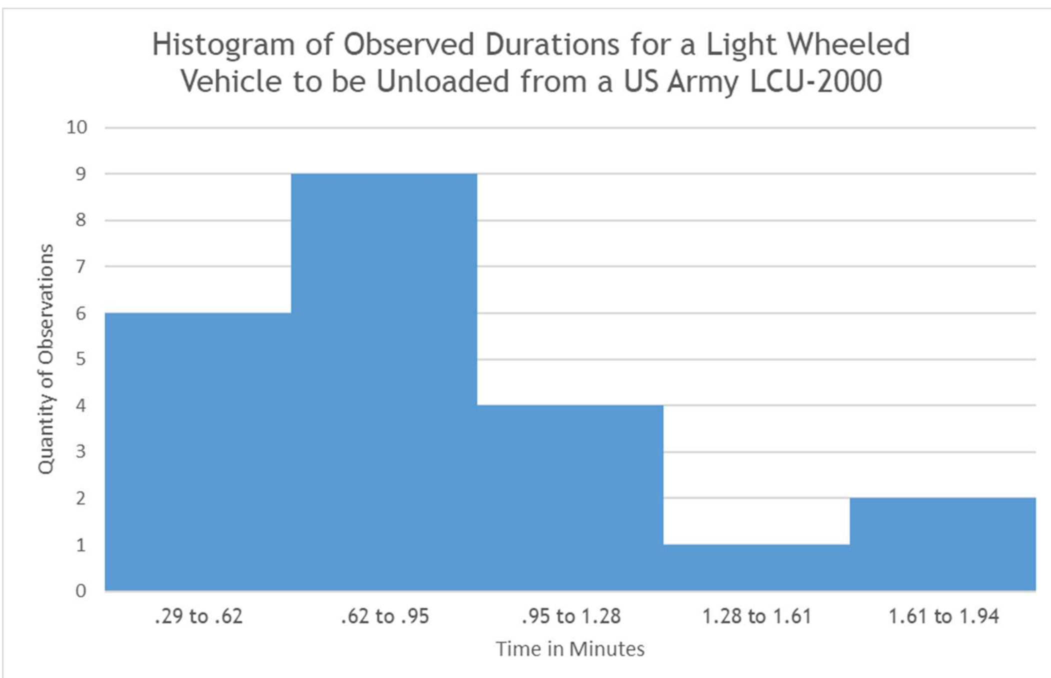

Figure N7. Histogram of Observed Durations for a Light Wheeled Vehicle to be Unloaded from a US Army LCU-2000.

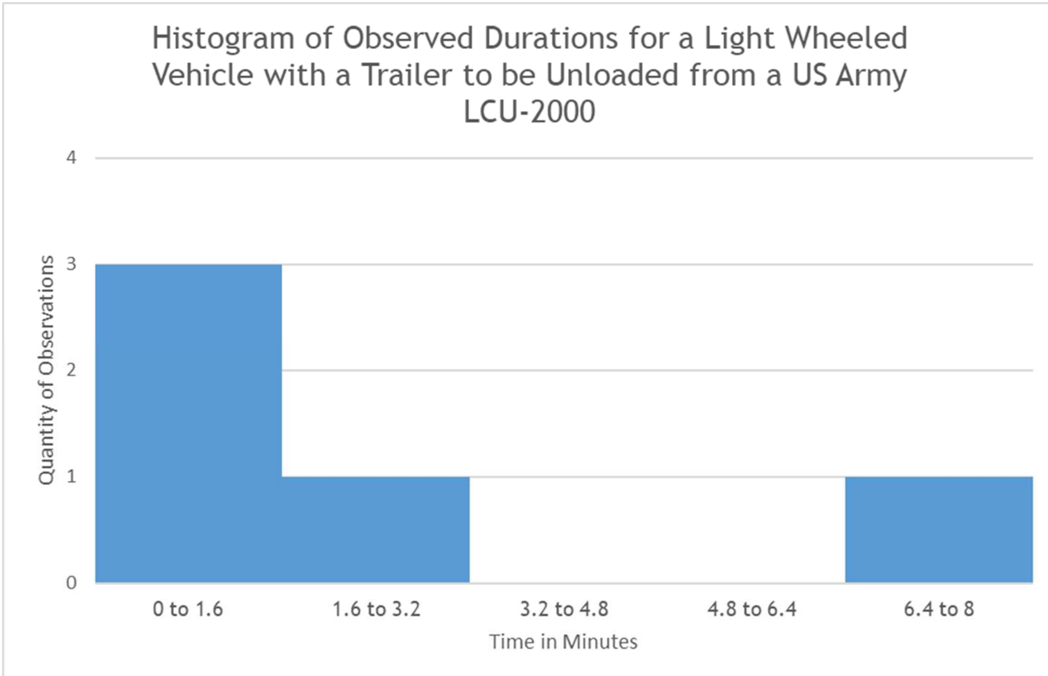

Figure N8. Histogram of Observed Durations for a Light Wheeled Vehicle with a Trailer to be Unloaded from a US Army LCU-2000.

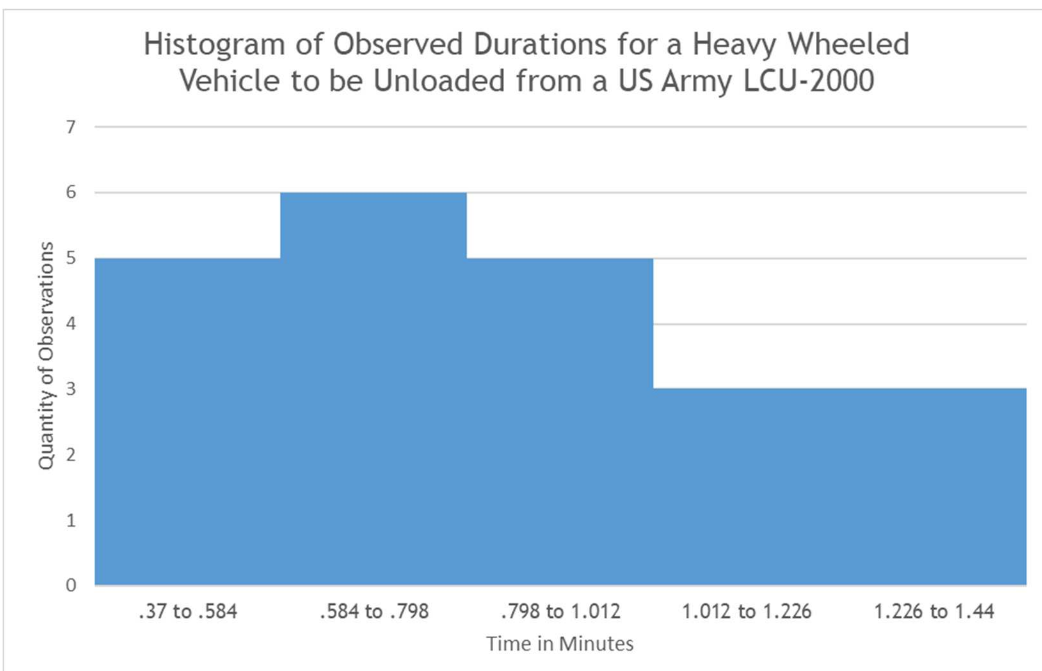

Figure N9. Histogram of Observed Durations for a Heavy Wheeled Vehicle to be Unloaded from a US Army LCU-2000.

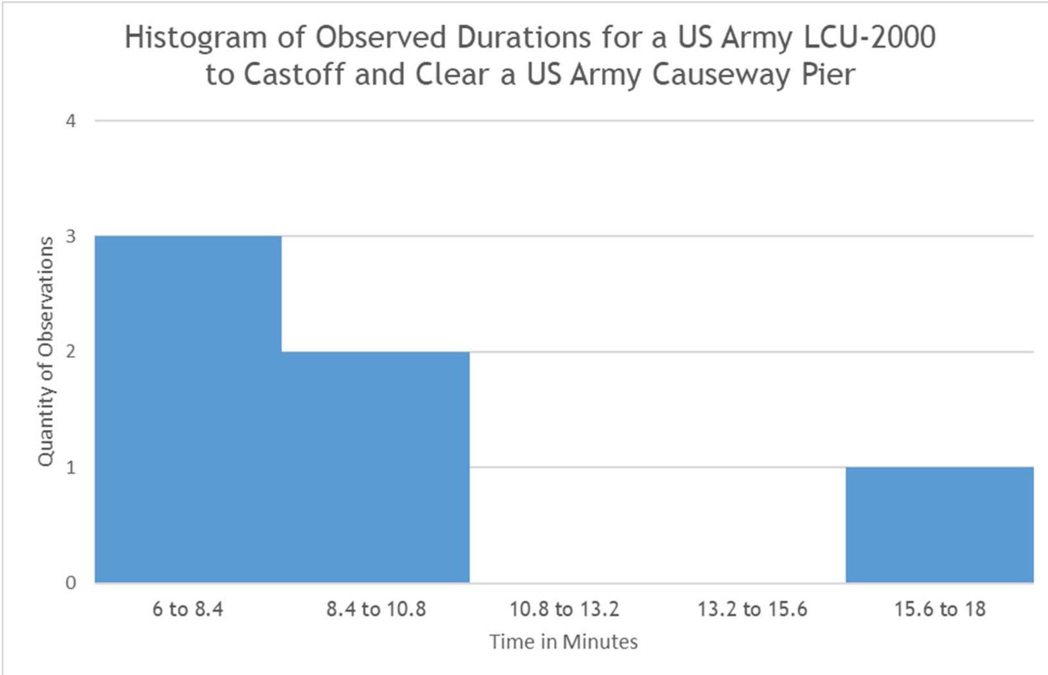

Figure N10. Histogram of Observed Durations for a US Army LCU-2000 to Castoff and Clear a US Army Causeway Pier.