THE IMPACT OF AUTOMATED REQUISITIONING SYSTEMS ON THE EFFECTIVENESS OF EMERGENCY SUPPLY CHAINS

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ABSTRACT

This research examines the relevance of an automated requisitioning system on an emergency supply chain's performance. In this context, "automated requisitioning" refers to the ability to transmit requisitions through an automated method that can be viewed and acted upon by multiple members of the supply chain. Automated requisitioning suggests some sophistication compared to manual methods which include phone calls, email and text messaging. These manual methods carry an implied higher probability of error and also have a limited capacity to process higher volumes of requisitions.

Emergency supply chains are characterized by some demand that can be anticipated and other demand that must be addressed through a requisitioning procedure. Two subcategories of emergency supply chains are military expeditions and nongovernmental organizations. While military and disaster relief supply chains each provide supplies to different customers, they are similar in their need to both push and pull required commodities. Although military supply chains support soldiers while disaster relief supply chains provide relief to people in need, both supply chains involve pushing supplies while requesting specific needs based on the particular situation, overall addressing a demand that is largely unknown.

This research examines the role automated requisitioning plays in the midst of these push and pull systems by simulating automation in a military expedition, then generalizing the results to suggest conclusions regarding a disaster relief supply chain.

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LIST OF ABBREVIATIONS

AAR ....After Action Review

APOD..Aerial Port of Debarkation

APOE ....Aerial Port of Embarkation

AR ....Army Regulation

ASC ....Army Sustainment Command

ASL ....Authorized Stockage List

BCT...Brigade Combat Team

BSB ....Brigade Support Battalion

CSS ....Combat Service Support

CWT..Customer Wait Time

COSCOM...Corps Support Command

DCB ....Dollar Cost Banding

D-Day..Deployment Day

DISCOM ....Division Support Command

DOS ....Days of Supply

ESC ....Expeditionary Sustainment Command

FM...Field Manual

GRF...Global Response Force

HLS ....Humanitarian Logistics Software

IFRC..International Federation of the Red Cross

ITV ....In Transit Visibility

JIT ....Just in Time

LCOP ....Logistics Command Operating Procedure

NA ....Net Asset Position

NGO..Non Governmental Organization

NICP ....National Inventory Control Point

OEF ....Operation Enduring Freedom (OEF) --Afghanistan

OIF ....Operation Iraqi Freedom (OIF) -- Iraq

OUR ....Operation Unified Response (OUR) -- Haiti

RFill ....Fill Rate from Readiness Driver Requisitions

RO ....Requisitioning Objective

ROP...Reorder Point

RMT..Request for Movement Table

RWT..Requisition Wait Time

SARSS ....Standard Army Retail Supply System

SSA ....Supply Support Activity

TAV ....Total Asset Visibility

TFill ....Total Fill Rate

TPFDD..Time-Phased Force Deployment Data

TPSD...Time Priority Sourcing Determination

TRADOC ....Training and Doctrine Command

VMI...Vendor Managed Inventory

VSAT ....Very Small Aperture Terminal

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CHAPTER 1. INTRODUCTION

"At present, a typical emergency aid appeal assigns inventory to a particular destination at the supply chain source. In other words, the inventory is committed to the donor's desired destination. Perhaps the supply chain academic community has a role to play in disseminating the concepts of its discipline in a way that convinces humanitarian donors of the importance and value of providing resources for appropriate information systems and supply chain processes as much as for tangible relief supplies."

--Oloruntoba & Gray, 2006

Emergency operations are characterized by a need for effectiveness first and efficiency later. Whether it be a military no-notice intervention in a failing country, or non-governmental support to a country following a disaster, such operations are defined by responsiveness. As a result, supply chains initially supporting such operations are often defined by manual procedures, involving phone calls, text messaging and other means of communicating logistics requirements. While the use of automated requisitioning systems during such operations are described in military doctrine, history has continued to show the use of manual means of communication (phone calls, text and email messaging) is more common. Further, disaster relief operations continue to rely on these manual methods as the sole means to transmit supply needs. Therefore, the purpose of this research is to examine the impact automated requisitioning methods may have on improving the emergency supply chain's performance.

This introduction is organized in the following manner: a need for study, a statement of the problem, contributions this research will make, and a summary of the theoretical frameworks involved with the problem. This chapter also describes the organization of this document.

Need for Study

This research is relevant in four general areas:

<u>Military Return to Unified Land Operations</u>

After spending the previous ten years conducting counterinsurgency operations in

Operation Iraqi Freedom (Iraq) and Operation Enduring Freedom (Afghanistan), the Army is returning to Unified Land Operations, which includes disaster relief. The U.S. Army's Sustainment Vision of the future (TRADOC Pam 525-1, 2010) depicts a Haiti-relief model of world-wide rapid deployment; Marine Corps doctrine maintains a similar vision (U.S. Marine Corps, 1998). Moreover, research suggests that the number of disaster situations are increasing, along with their magnitude and accompanying complexity (Oloruntoba, 2010), which will in turn require an enhanced response capability from those executing disaster supply chains (Thomas & Kopczak, 2005; Boin, 2009, Elsevier, 2010; Tabbara, 2008).

Critical Role of Sustainment in Emergency Operations

Logistics and supply chains throughout military and disaster relief research have been recognized as the key to sustaining such operations (Van Wassenhowe, 2006). Without supplies, the majority of relief efforts quickly lose relevance and value (Elsevier, 2010; TRADOC PAM 525-1 2009). Military operations have shown that while deploying forces under emergency conditions is difficult, sustaining these forces is absolutely imperative to the operation's success (U.S. Marine Corps, 1998).

Increasing Interest in Improving Supply Chain Performance During Emergency Operations

There is a growing need to rapidly establish logistic teamwork across networks in the face of disasters to improve supply chain effectiveness (Center for Joint & Strategic Logistics, 2010; OUR Army Sustainment AAR, 2010; FM 4-0, 2009). Military and NonGovernmental Organizations (NGOs) are seeking to learn more about each other to better support the emergencies of the future, and there are over 100 research organizations, each with budgets exceeding $1 million, studying how to conduct disaster relief supply chains more effectively (Whybark, 2007).

Further, development of automated requisitioning procedures as a means to increase supply chain performance is an area of continually growing interest. Some researchers have labeled current manual procedures as less effective (Balick et al; Tabbara, 2008). Oloruntoba & Gray suggest that an automated pull system could increase supply chain performance and reducing waste (2006). Past instances of lost and stolen donations by NGOs have made donors wary of how their money is spent and have contributed to the call for validated performance metrics (Balick & Beamon, 2008). Future military doctrine contains a heavy reliance on technology and automation to sustain such operations across strategic distances (TRADOC Pam 525-1, 2010; FM 10-72, 1993; Peltz et al).

The Enduring Need for Efficiency in Emergency Supply Chains

The need to conduct disaster relief operations efficiently remains an enduring imperative across the long-term (U.S. Marine Corps, 1998; Department of the Army (Sustainment), 2009). With NGOs, money wasted in the short-run degrades an organization's ability to contribute over time. The Army identifies "economy" as one of eight characteristics of Sustainment Operations (Department of the Army (Sustainment), 2009). If logistics automated requisitioning systems provide increased effectiveness during emergency operations, they may also increase efficiency, which may make investing in their development worthwhile.

Statement of Problem

At some point during emergency operations, the ability to requisition supplies from a higher source becomes necessary. While push methods are necessary to meet immediate needs and sustain operational tempo, more specialized demand is realized as operations progress. This specialized demand cannot be captured through forecasts, and a pull system is necessary to communicate these requirements. This necessity is associated with the impact of demand not met by push supplies, prepositioned stocks, commodities purchased locally and accompanying supplies. At the point requisitioning becomes necessary, the effectiveness of the requisitioning system also becomes significant. A requisitioning system that is responsive and able to accommodate high volume potentially contributes to better satisfaction of demand.

The timing of establishing an effective requisitioning system is also significant. It must be balanced with the other inputs into the supply chains (as listed above) and their respective ability to meet the demand of the supply chain. If automated requisitioning systems offer gains in effectiveness to the emergency supply chain, understanding the point, or window, when establishing automated supply chains provide the greatest gains may be worthwhile.

Within military operations, these requirements may for be specialized repair parts that are not habitually stocked within military warehousing operations. Within disaster relief operations, these specialized needs address requirements specific to the affected country's culture that cannot be met by initial donations and generic pushed commodities. These specialized needs may merit an automated pull signal in order to sustain operations.

Requisitioning in emergency supply chains typically begins through manual procedures. Automated requisitioning systems are largely not used in NGO disaster relief supply chains, due to constantly changing stakeholders, challenges in compatibility, and funding. However, researchers have suggested that improved use of requisitioning technology could improve the effectiveness of humanitarian supply chains by improving the ability to match specific demand requirements with available stocks (Oloruntoba & Gray, 2006). While capabilities within the military have grown over the last two decades, guidelines on how or when to deploy this capability have not kept pace. Actual employment of this capability has shown challenges not covered in doctrine, such as time requirements to change strategic parameters for funding and managerial control (CW4 Eden interview, 2011).

Without a quantifiable demonstration of the automated requisitioning system's contribution towards operational effectiveness, its implementation and improvement risks falling behind other priorities. Without additional research to explore the potential contributions automated requisitioning may provide, operators and donors within humanitarian assistance may continue to operate at potentially sub-optimal levels.

Research Areas Investigated

This research provides findings on the impact the automated requisitioning system has on the performance of emergency supply chain operations. Specifically, this research provides findings on the degree of effectiveness and added value the automated requisitioning system provides to emergency supply chains, recommendations on the optimal time to establish the automated requisitioning system, and areas in which this study is generalizable to both military and disaster relief supply chains. These contribution are covered later in this chapter, following some necessary preliminary background on theoretical frameworks.

Summary of Theoretical Frameworks

To assess the potential efficacy of logistics automation requisitioning systems on emergency supply chains, a detailed understanding of the environment must be captured. Therefore, a theoretical framework was derived from several sub-models and case studies to understand the nature of military expeditionary supply chains and disaster relief supply chains. These theoretical frameworks are described in Chapters 2 and 6. To provide context for this research, emergency supply chains are defined as disaster relief operations by NGOs or the rapid projection of military forces with little to no prior notice or preparation.

Critical Differences and Similarities between Military Expeditionary and Disaster Relief Supply Chains

To construct one model to represent both the military and disaster relief supply chain would be erroneous. When both supply chains exist simultaneously, they support different customers: the military supply chain sustains soldiers performing the operation, while the NGO supply chain supports those affected by the disaster. While military forces often facilitate the distribution of humanitarian supplies within such an operation, rarely, if ever, do military supply chains consist of humanitarian supplies. These commodities come from NGO supply chains supporting the same operation.

These different customer bases bring differences in customer demand patterns. While the military knows more about the demand patterns of their deployed forces, determining the disaster relief requirements carries more uncertainty, specifically in assessing the amount of people and infrastructure affected. The two supply chains also differ greatly in terms of resources and infrastructure. While military forces deploy logistics formations to distribute supplies to soldiers, NGOs may lack the organic assets to distribute disaster relief supplies and may be dependent on local or contracted assets. Further up the supply chain, military supply chains are supported by a well-established Department of Defense depot infrastructure. While disaster relief chains have some continuity in supply sourcing, they mostly change vendors and donors from operation to operation, making it difficult to establish habitual relationships.

However, there are sufficient similarities between the two supply chains so that simulating one can provide some generalizability for the other. The key similarity between military and NGO emergency supply chains is the dynamic of simultaneous push and pull operations. Some required commodities may continue to be pushed throughout the operation, with some refinement from the ground through reporting procedures. Other commodities may need to be requisitioned by on-ground logistics forces due to an operation's uniqueness. Both chains may employ one of several methods prevent supply chains from being interrupted, such as prepositioning supplies and sending "push packages" for sustainment prior to the supply chain's maturation. Finally, both chains may attempt to meet immediate requirements by purchasing supplies from the local economy. All of these techniques may mitigate demand not met for specialty supplies. Figure 1 displays the relationship between these push and pull operations within both supply chains: those commodities that are initially pushed and continue to be pushed throughout the operation; those supplies that are initially pushed or procured through the described methods, and those supplies that must be pulled because they are otherwise unavailable. Obviously, not all requirements can be prestocked or pushed without specific justification, so there remains a need for both chains to be able to requisition supplies as they become identified requirements.

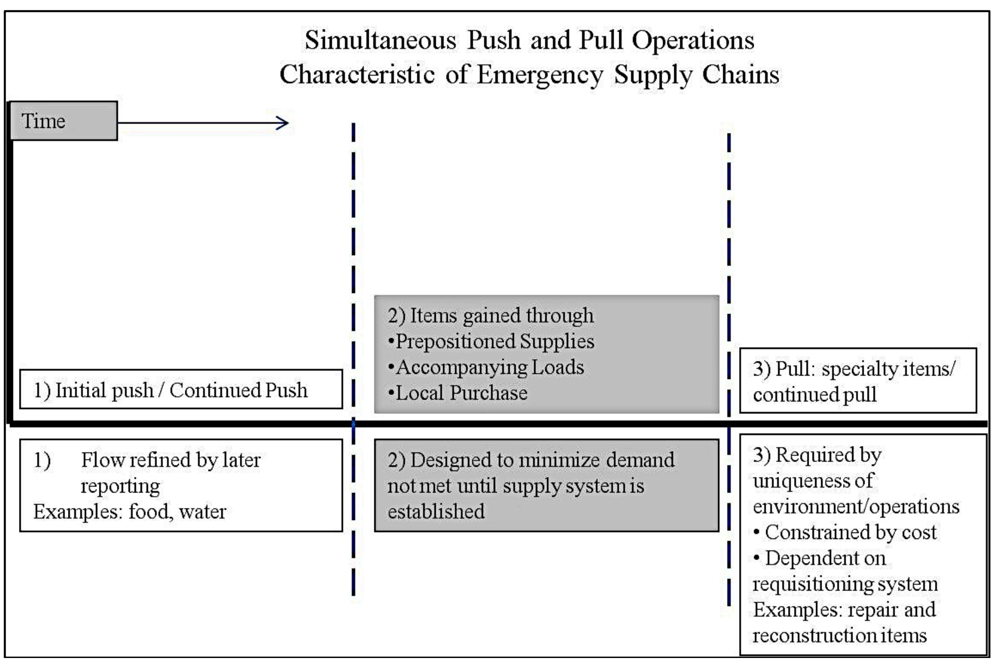


Figure 1. *Simultaneous Push and Pull Characteristics of Emergency Supply Chains*

Therefore, at some point in time, both types of emergency supply chains have the need to requisition supplies from a higher source. Oloruntoba and Gray (2006) propose a model of the humanitarian supply chain that describes the chain as a combination of two decoupling points. A decoupling point is "where a product in the supply chain ceases to be forecast-based and becomes a specific customer order, or where market pull meets upstream push." Therefore, one decoupling point occurs downstream in the supply chain, when generic inventory that has been pushed marries up with a specific customer order. The second decoupling point occurs upstream in the supply chain, where the same process occurs by specific demand information meeting generic inventory held at the strategic level. Figure 2 describes the relationship of the two decoupling points to the push and pull aspects of the humanitarian supply chain. Understanding where these two points occur can facilitate an effective hybrid supply chain that is both lean upstream and agile downstream, ultimately increasing overall effectiveness. While this model is written for the humanitarian supply chain, it could apply to the military emergency supply chain, based on its common push/pull nature. Oloruntoba and Gray (2006) suggest that information technology can play a significant role in developing these decoupling points. It is from this model that this research proposes to further define this concept, particularly as it applies to emergency military supply chains.

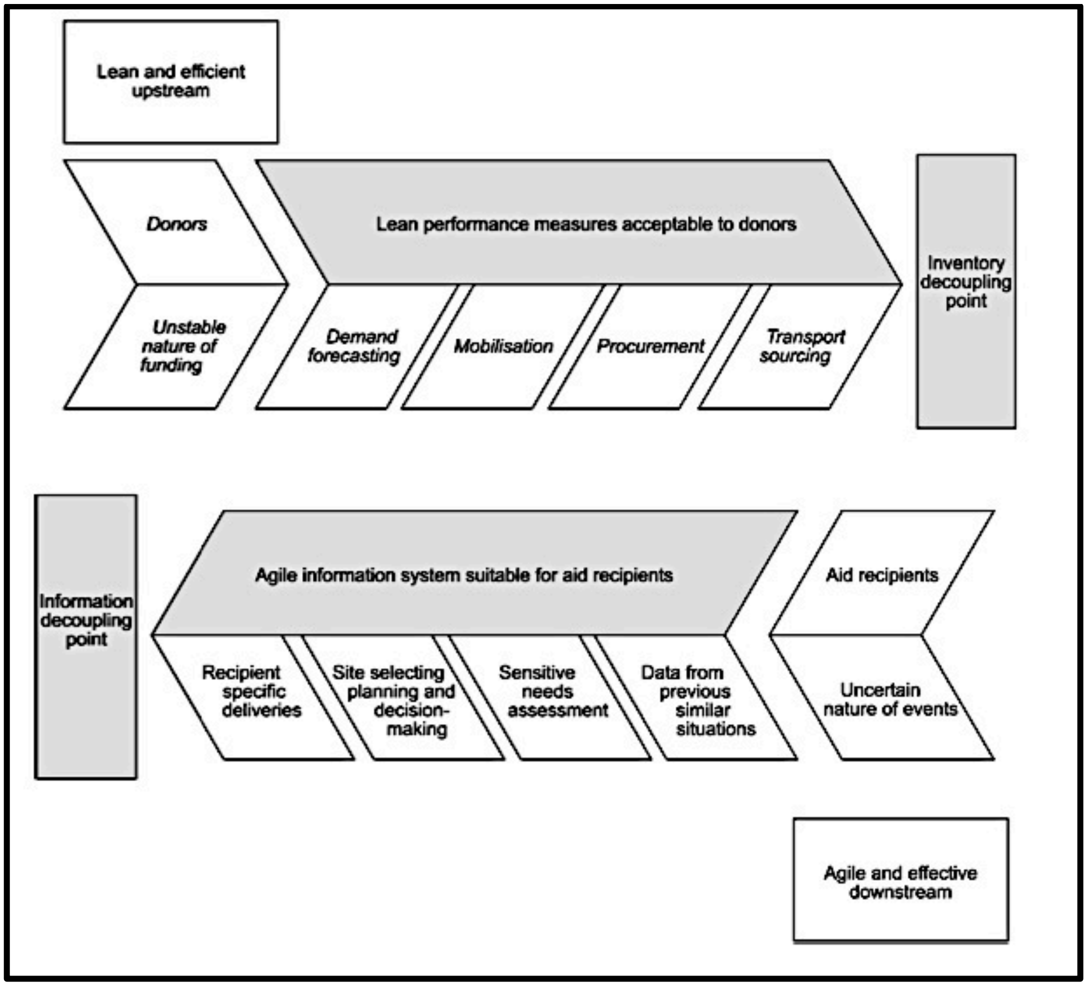


Figure 2. *Decoupling Points in the Humanitarian Supply Chain (Oloruntoba & Gray, 2006)*

Contributions this Research Makes to the Literature

This research makes four areas of contribution to the existing literature: findings on the overall effectiveness of an automated requisitioning system, optimal time ranges to establish an automated requisitioning system, development of the decoupling point concept and the generalizability of automated requisitioning systems to disaster relief environments.

Overall Effectiveness of an Automated Requisitioning System

This research measures the impact of an automated requisitioning system on the overall effectiveness of an emergency supply chain. Effectiveness is addressed by examining the responsiveness of automated requisitioning systems and their ability to contribute to the quantity of demands received. The significance of these findings may affect the urgency the automated requisitioning system is afforded within military operations and may lead to increased research within disaster relief circles.

Optimal Time Ranges to Establish the Automated Requisitioning System

This research examines the optimal time range to establish an automated requisitioning system in support of emergency operations. Because the emergency supply chain described is a combination of push and pull methods, it may be premature to establish an automated system at an early point due to unrealized demand. Airlift during these periods may be better utilized to deploy capabilities with higher short-term payoff such as weapons systems or distribution assets. Conversely, delaying employment of an automated requisitioning system may have an adverse effect on supply chain effectiveness. This research seeks to identify an optimal window for employment during a military expeditionary or disaster relief supply chain's development.

Development of the Decoupling Point Concept

This research examines points at which the preponderance of demand shifts from being met through supplies available to supplies that must be provided by a higher source. As Oloruntoba and Gray (2007) propose, closing the time between supplies and requisitions equates to a more effective supply chain. This study examines the impact establishing the automated requisitioning system may have on realizing decoupling points and if this changes the effectiveness of the supply chain.

Generalizability of Automated Requisitioning Systems to Disaster Relief Environments

To contribute to the body of knowledge on disaster relief supply chains, this research presents several areas in which the automated supply chain could potentially increase the effectiveness of disaster relief supply chains. Focusing on the common characteristics between military expeditions and disaster relief operations, the results gained from the simulation are coupled with knowledge of the NGO disaster relief framework. The outcome is a conceptual discussion on the possible benefits an automated requisitioning system can provide to a disaster relief operation. The significance of these findings may affect the emphasis the automated requisitioning system is given within the disaster relief community.

How this Research is Organized

This research is organized with the following structure: first, a brief summary of theoretical frameworks is provided to define the similarities and differences between military expeditions and disaster relief operations, the two components of emergency operations. Next, in chapter 2, a Literature Review of support to military expeditions is provided, which sets the stage for Chapter 3, Materials and Models. Chapter 3 outlines how a military supply chain simulation was researched and modeled to generate data for performance analysis. Chapter 4 provides the results of that data, with its accompanying analysis in Chapter 5. Chapter 6 discusses the potential areas of generalizability of this analysis towards the disaster relief operations. Chapter 7 concludes the research by providing areas for future researchers.

Conclusion

This chapter provides the relevance of this research on the effectiveness of establishing an automated requisitioning system in an emergency supply chain. It presents the overall statement of the problem, the research areas investigated, how the research is organized, a summary of theoretical frameworks, critical differences and similarities between military expeditionary and disaster relief supply chains, and the contributions this research makes.

CHAPTER 2. LITERATURE REVIEW ON MILITARY FRAMEWORK

This chapter covers the key definitions, delimitations, framework and literature review necessary to understand the emergency military supply chain. The framework and literature review for the disaster relief supply chain will be discussed in Chapter 6.

Key Definitions

Emergency Supply Chains

It is necessary to define several key terms to provide structure to this research. "Emergency supply chains' is not a commonly-used term. For this research, it is composed of two previously defined categories: disaster relief supply chains and support to military expeditions.

The Marine Corps Expeditionary Warfare Manual defines disasters as "accidents or calamities that cause suffering on a massive scale, which create societal and political instability (U.S. Marine Corps, 1998)." The disaster relief supply chain is defined as ''the process and systems involved in mobilizing people, resources, skills and knowledge to help vulnerable people affected by disaster (Elsevier, 2010)". Although disaster relief efforts may involve military forces, most often they do not.

No-notice military operations, or expeditions, are defined as "military operations by an armed force to accomplish a specific objective in a foreign country (U.S. Marine Corps, 1998)". These operations are considered temporary and different than deliberate operations. Expeditions are defined by several critical characteristics. They involve the projection and sustainment of forces into a foreign country at the onset of a crisis. This involves establishing a new supply chain that is extended from the forces' home base. While expeditions can vary in size, their crisis characteristic implies little to no time to establish this supply chain prior to the expedition. Expeditions can involve disaster relief, as well as preserving stability, establishing peace and protecting U.S. citizens abroad. While not defined by a specific length, these operations are distinguished from operations involving a "permanent or indefinite presence supported by a standing organization or infrastructure" which results in a permanent basing of forces, or a deliberate rotational schedule (U.S. Marine Corps, 1998). The change from an expeditionary to a steady-state or more permanent nature is usually accomplished through achieving certain operational effects, such as stabilizing the population, as opposed to maturing the supply chain.

Automated Requisitioning

"Automated requisitioning" refers to the ability to transmit requisitions through an automated, enterprise method that can be viewed and acted upon by multiple members of the supply chain. This definition also implies that all members can see the same details about a particular individual requisition, and the same data when viewing the system as a whole. Email, text and exchanging spreadsheet files are not considered automated requisitioning systems. While electronic, these systems require a higher degree of coordination to enable multiple supply chain stakeholders to view the transactions. These transactions are considered manual transactions; they carry an implied higher probability of error and limit the system's capacity to handle higher volumes of requisitions.

Supply Terminology

A*ccompanying and Follow-on Supplies*

For military operations, "accompanying supplies" refer to the " supplies that must accompany the assault force to enable it to sustain itself until it is resupplied; follow-on supplies "replenish combat losses that are generally pulled from a higher source of supply (FM 10-27, 1993)." Both accompanying and follow-on supplies are designed to sustain deployed forces before supply chains mature.   Follow-on supplies are delivered by air until sea lines of communication are established (FM 10-27, 1993). For this research, the "assault force" will be defined by the U.S. Army's Brigade Combat Team, which has been the Army's "unit of action", as demonstrated by the commencement of operations in Iraq, Afghanistan, and Haiti.

Safety stock

Safety stock is "the quantity of stock intended to permit continued support in the event of minor interruption of stockage replenishment or unpredictable fluctuation in demand rate, or both (AR 710-2, 2008)."

Performance

Effectiveness is defined as the extent which customer requirements are met, while efficiency is the measure of how economically the resources are utilized when providing a given level of effectiveness (Balik et al).

Requisition Wait Time

Requisition Wait Time (RWT) is different than Customer Wait Time (CWT). While RWT ends with receipt at the retail location (defined as the Supply Support Activity for the Brigade Combat Team), CWT ends with the end user's receipt of the item (Davidson, 2006). This research will focus on the performance of the supply chain from order to receipt at the retail location and will not examine the tactical distribution further downstream from the retail activity.

Delimitations

Automated Requisitioning

This research will examine the role and effect of automated requisitioning systems, which are primarily designed to submit orders and gain status on order fulfillment. The majority of the disaster relief research refers to “information technology”, meaning movement tracking and visibility and not requisitioning. Military literature tends to define requisitioning procedures separate from movement tracking by using different terms, such as Total Asset Visibility (TAV) (Department of the Army (Sustainment), 2009). Total Asset Visibility is defined as “The capability for operational and logistics managers to act on information on the location, quantity, condition, movement, and status of assets throughout the Department of Defense’s logistic system (FM 4-94, 2010).” Similarly, while achieving TAV involves logistics reporting, “logistics reporting” should not be confused with “logistics requisitioning. The former is a status report, the latter is an ordering process that initiates supply action (FM 4-90, 2009)”.

Military literature also refers to movement performance in terms of deploying capability, coordinated and measured by the Time-Phased Force-Deployment and Data (TPFDD) system. While the deployment of military capability is governed and measured by this system, sustainment movements beyond accompanying loads are not; therefore, this research will remain centered on literature concerning the transportation of sustainment movements.

While examining the military’s use of the Standard Army Retail Supply System (SARSS) this research is not meant to be limited to an examination of this specific systems’ performance. Instead, it is meant to explore the value of using an automated system, as defined previously, during emergency operations.

International and Strategic Distances

While lessons can certainly be gleaned from domestic disaster relief operations, such as the U.S. Army’s participation following Hurricane Katrina, or the use of the Australian Defense Force following Cyclone Larry, this research will remain focused on emergency support situations spanning international distances.

Size

While the size of military expeditions can vary, this research limits the size of the deployed military force to the Brigade Combat Team (BCT).

Detailed Description of Military Framework

A framework is necessary to understand the nature of a military expedition. The framework presented in Figure 3 describes the nature of supply chains supporting such operations within their first four weeks: their push/pull dynamics, the development of demand and safety stocks. This framework also describes several impacting factors that may increase difficulty in execution. This framework was developed through a combination of doctrinal and real-world study of military expeditions. Military doctrine largely details sustainment procedures in established theaters; therefore, this framework was compiled through a combined review of case study, doctrinal literature, lessons learned and interviews.

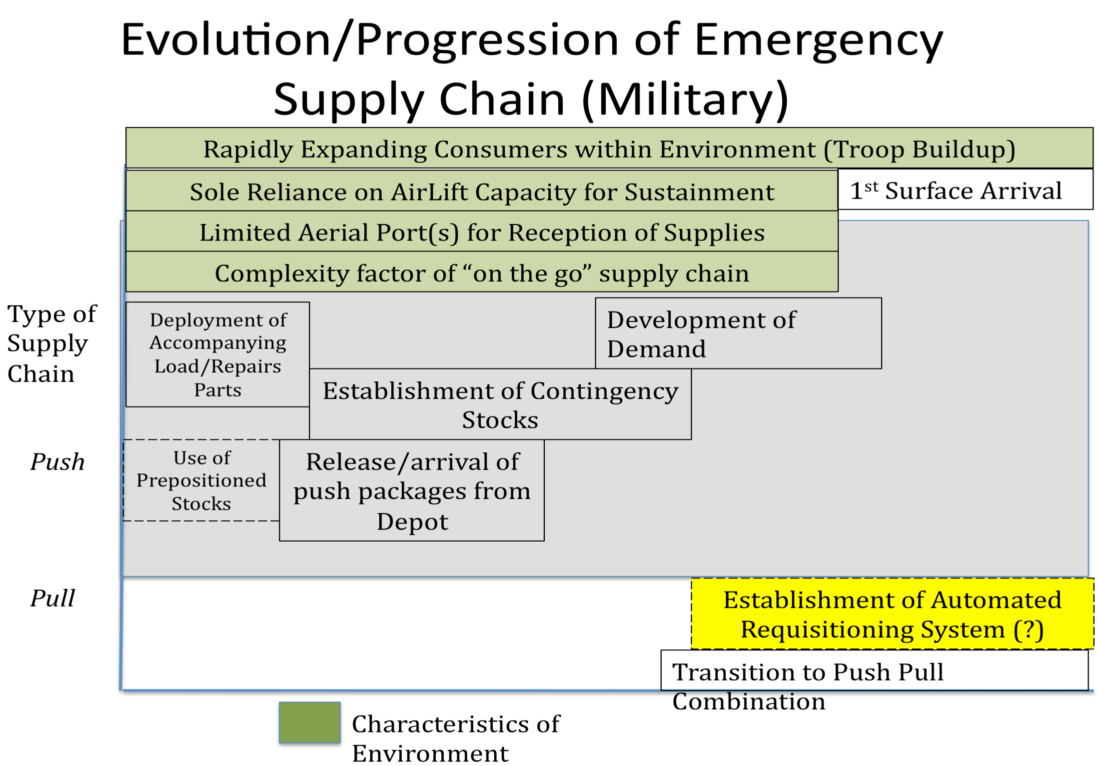


Figure 3. *Emergency Supply Chain (Military) Framework*

General

While the Brigade Combat Team (BCT) is the focus of this framework and is usually the force deployed to develop military expeditions, it is important to note that for the last decade Army BCTs have been used to perform deliberate rotations in Iraq and Afghanistan, not contingencies or expeditions (OUR Army Sustainment AAR, 2010). The 2nd Brigade Combat Team, 82nd Airborne Division, was an exception. In June 2009, it assumed the mission as part of the Global Response Force (GRF), ready to deploy worldwide on little to no notice (Shatzkin, 2011).

Characteristics

Reliance on Airlift and Limited Airports for Reception

One of the most significant characteristics of the military emergency supply chain is the sole use of aerial transport (FM 10-27, 1993). This is necessary due to its responsiveness and suitability, as ocean surface means of transport is not fast enough, surface ports may be damaged beyond use and ground surface transportation is not feasible with international distances. However, the dependence on air greatly constrains the overall amount of soldiers, capabilities and supplies that can be deployed rapidly. As deploying soldiers is initially the priority, accompanying supplies, follow-on supplies or sustainment capabilities may be delayed, as decisions on aircraft utilization usually follow a hierarchy that is governed by the expected utility that personnel and equipment will provide (Shatzkin, 2011). Even as the BCT deploys, other non-BCT and non-Army forces, deploy and thus compete to utilize the limited air pipeline (Government Accounting Office, 2010; OUR Army Sustainment AAR, 2010). Further, the limited capacity on the ground to receive and issue incoming supplies can backlog the receiving aerial ports. This may cause accountability and delays in processing time, particularly if incoming supplies are poorly marked (OUR Army Sustainment AAR, 2010). Non-BCT units may deploy without their respective sustainment organizations and may rely on the BCT for temporary support until their supporting element arrives (Shatzkin, 2011; Government Accounting Office, 2010; OUR Army Sustainment AAR, 2010). Past contingencies have demonstrated that military response forces not initially designated as rapid response forces, such as higher-level sustainment organizations, may arrive to the conflict later, requiring the BCT to support customers not normally within their support base (OUR Army Sustainment AAR, 2010; Shatzkin, 2011).

Complexity

The military supply chain is characterized by complexity within the amount of stakeholders supporting the supply chain, which extends from the national base to tactical operations. Comprising this supply chain are a significant number of operators who normally operate independently; the emergency requires them to come together quickly. The coordination and information-sharing requirements of these temporary networks are vast (Jahre, 2009).

How Demand is Met

Role of Accompanying and Follow-on Supplies

The Brigade Combat Team begins the deployment by sustaining through their accompanying load, which is doctrinally three Days of Supply (DOS) (FM 10-72, 1993). The accompanying load must compete for transportation with the remainder of the BCT's personnel and equipment; therefore, these supplies rarely move as a single entity, but flow into the theater in concert with the rest of the BCT (Shatzkin, 2011). While the military describes procedures prewritten requisitions prior to known operations, during emergency situations, the BCT has little time to prepare and send these orders. Instead, follow-on supplies are coordinated manually through the BCT's higher headquarters, the Division staff, and are potentially funded by the next higher headquarters, the Corps staff. The Corps staff passes these requisitions to the NICP for sourcing (CW4 Eden Interview, 2011). These push supplies are usually barrier materials, bottled water and rations and medical supplies based on a hasty forecast (CW2 Bernard Interview, 2011).

Doctrinally, these requisitions are meant to complement the BCT's accompanying supplies and sustain the BCT as higher-level logistics units deploy and the theater's infrastructure develops. Pre-coordinated requisitions are intended to arrive and sustain the BCT from the fifth day of the operation through the fifteenth day (FM 10-27, 1993). These follow-on stocks are meant to sustain the BCT until "demand supported resupply starts in a theater of operations (FM 10-27, 1993)", although doctrine does not describe when the automated requisitioning system should be established.

Use of Prepositioned or Purchased Supplies

Deliberate, non-emergency deployments rely heavily on prepositioned stocks to facilitate uninterrupted sustainment. However, in emergency situations, pre-positioned stocks may be limited or completely unavailable (FM 10-27, 1993). While the BCT may purchase or acquire supplies through host nation sources, these supplies may also be limited, particularly during a disaster relief with considerable damage to the area's infrastructure (FM 10-27, 1993).

General Flow of Automated Requisitions

Figure 4 depicts the flow of requisitions once an automated requisitioning system is established within a military supply chain.

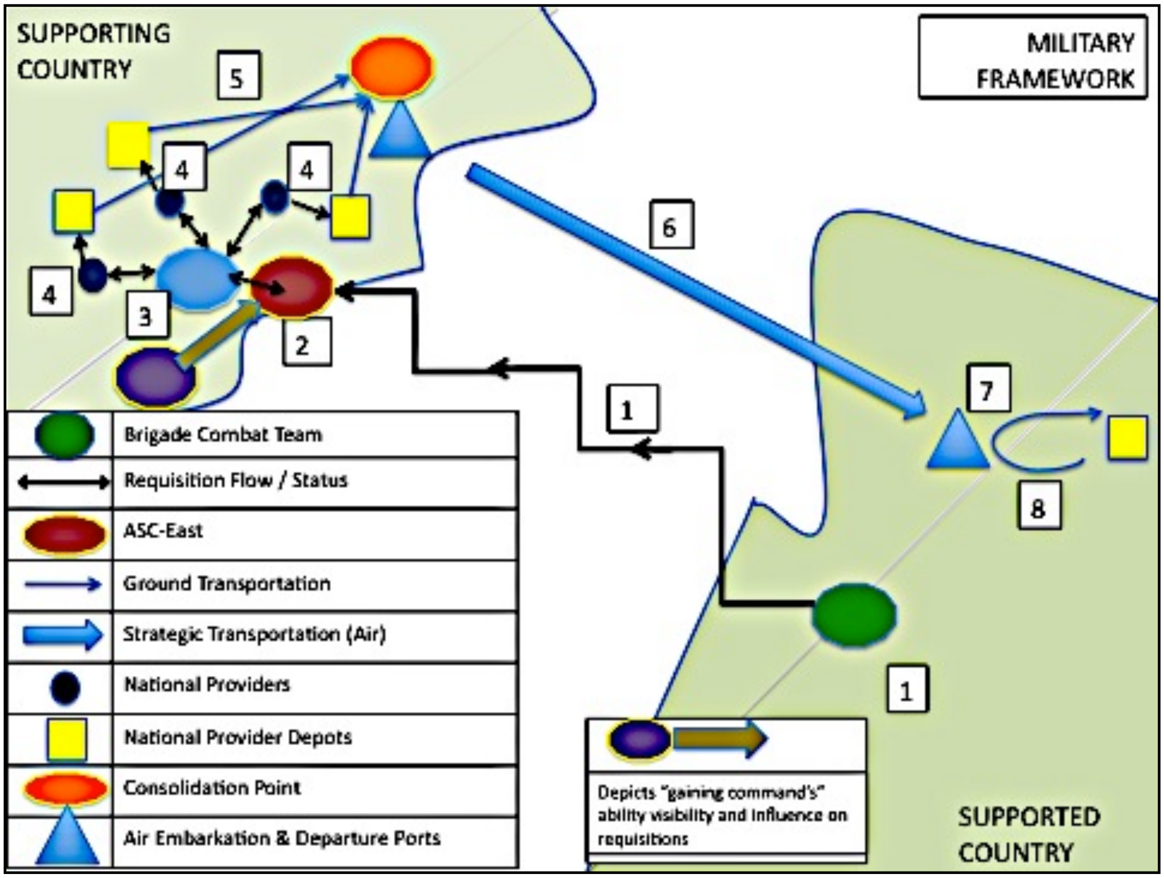


Figure 4. *Emergency Supply Chain (Military) General Flow*

Requisitions generally flow in the following sequence:

(1) Once SARSS connectivity is established, requisitions are electronically routed to the BCT's servicing agency.

(2) Before deployment, each BCT has a peacetime servicing agency that feeds their requisitions to a central database: the Corps Theater Automated Support Center located at Redstone, Alabama.

(3) The requisitions are sent to the National Inventory Control Point (NICP), a centralized location that can route the requisition to the national provider who produces the item at the national level.

(4) Each national provider further processes their requisitions, determining which depot will fill the requisition, and where the order will be sent for consolidation once pulled.

(5) After packing the items, national providers transport the items to an overall consolidation point for final strategic transportation to the theater of conflict.

(6) The items are transported to theater of conflict by a combination of military and commercial aircraft, although threat or runway conditions can prevent the latter.

(7) The arriving items are processed by theater opening capabilities (Shatzkin, 2011; Haiti After Action Review).

(8) These items picked up by the Brigade Support Battalion (BSB) or delivered to the BSB by a higher-level logistics organization. Further historical details on the difficulty of establishing SARSS for emergency operations are covered in the Literature Review section of this proposal (CW4 Eden Interview, 2011).

Literature Review

Real-world accounts on the performance of automated requisitioning are scarce; those found are largely anecdotal. Fontaine's examination of operations in Rwanda showed that units employed SARSS but also made direct calls to the NICP, overloading some theater throughput nodes. Later operations in Rwanda exposed units' difficulty in establishing SARSS connectivity (Fontaine, 1994), a friction point that was also encountered six years later in Desert Storm/Shield during operations on the move (CSS VSAT Operators manual; Peltz et al).

With the formation of the Army Brigade Combat Team in mid-2005 came the requirement to support agile, expeditionary operations (Brownlee & Schoomaker, 2004). Although this concept initially proposed Just in Time (JIT) delivery methods to support military expeditions (Anteon Corporation, 2004), a Rand Study on the initial ground assault during Operation Iraqi Freedom both validated Desert Storm's lessons on SARSS shortcomings and also suggested limitations in implementing a Distributed Logistics System (similar to a JIT system) too early within an expedition (Peltz et. al, 2005). In 2005, Army logistics units were fielded the Very Small Aperture Terminal (CSS VSAT Ops Manual). This provided the capability to connect to the internet and conduct decentralized requisitioning (CSS VSAT Ops Manual).

Current Doctrine

In describing the specific nature and procedures of establishing an automated requisitioning system to support an emergency situation, differentiated from a planned and deliberate buildup, a review of current military literature brings relatively limited information. Army Field Manual Sustainment 4-0, the Army's primary manual on Sustainment, has one sentence on the topic. Field Manual 3-35, Deployment and Redeployment, discusses the movement of troops and their equipment, but does not address the supply chain. Field Manual 10-72, General Supply Operations in the Theater, provides some guidelines for "contingency force operations (10-72, 1993)". However, this manual is dated 1993, prior to several critical events: Army fielding of VSAT capability and Army modularization in 2006, making the Brigade Combat Team the Army's "Unit of Action", which dissolved support structures such as the Division Support Command (DISCOM) and Corps Support Command (COSCOM) and replaced them with Sustainment Brigades and the Expeditionary Support Command. Further, FM 10-72 references FM 63-6 , Support to Contingency Operations, which is no longer in publication. The Army currently does not possess a manual that specifically addresses support to emergency operations. The preponderance of the doctrine addresses known and deliberate buildup to conflict and procedures for an established theater of war.

While the Army Supply Warrant Officer Survival Guide provides a simple expectation for establishing SARSS to an immature theater ("You will be expected, once you hit ground, to start requisitioning."), accounts of real-world contingency support seem more complicated. As an example, during Operation Unified Response, the following events had to be resolved prior to establishing SARSS connectivity for the 407th Brigade Support Battalion:

(1) Army Materiel Command had to authorize the unit's Authorized Stockage List (ASL) for deployment. Generally the Army does not deploy SARSS separate from deploying the ASL, as problems inevitability arise from having inventory in one location and the accounting capability in another.

(2) Determination how the automated requisitions would flow between the 407th Brigade Support Battalion, Forces Command and Southern Command. While it seemed beneficial to change the peacetime flow of requisitions through Forces Command to the gaining higher headquarters of Southern Command, operators found this change required 7-10 days to process. While an alternate solution was established, some time was consumed determining the flow of requisitions.

(3) Changing the 407th BSB's receiving address from Fort Bragg, North Carolina to Port au Prince, Haiti.

(4) Determining how the 407th BSB's Authorized Stockage List (ASL) would be transported. While the desired method was by air due to speed, the U.S. Air Force deemed the ASL "transportation unworthy" in its present configuration. After spending some time debating air worthiness, the ASL moved by surface vessel. This delayed the departure of SARSS by 7 days, as the Supply Technician worked through the issues (CW4 Eden Interview, 2011). Figure 5 depicts the impacting factors and total time required to establish SARSS for this operation. While this is one example, it demonstrates that establishing an automated requisitioning system in an expeditionary setting involves some procedures that may cause delays.

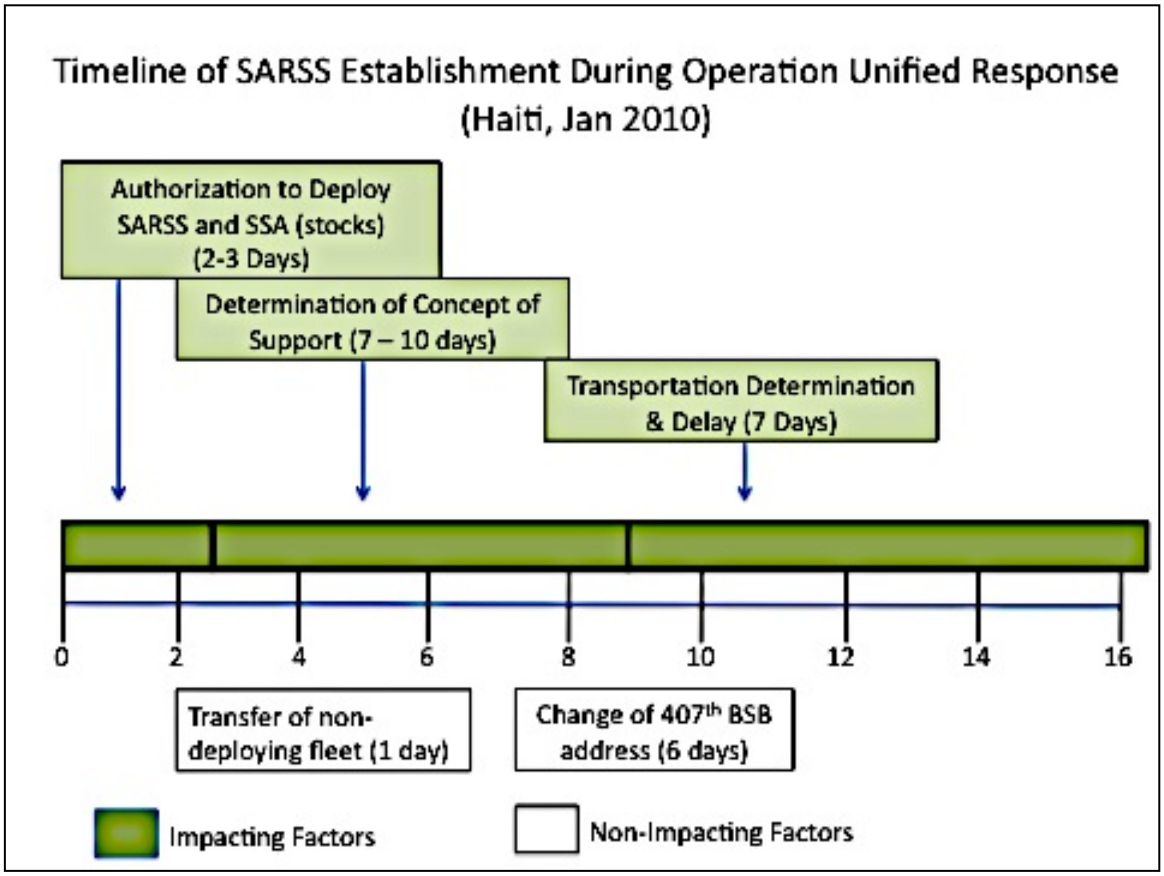


Figure 5. *Timeline of SARSS Establishment During Operation Unified Response*

Future Doctrine

The Army's picture of sustaining future conflict in Figure 6 relies heavily on the ability to establish automated systems during expeditionary operations, referring to Operation Unified Response as an operational model: "The past decades highlight the need for an effective system that can rapidly deploy self- sustaining forces to austere locations that support themselves for extended periods of time with limited infrastructure, such as required following the Haiti earthquake in January 2010. Future Army forces require support which can prolong endurance and extend operational reach. Successful sustainment operations will require deployment and distribution systems capable of delivering and sustaining an expeditionary Army from strategic bases to multiple points of employment and/or need within and throughout the future operational environment (TRADOC PAM 525-4-1)."

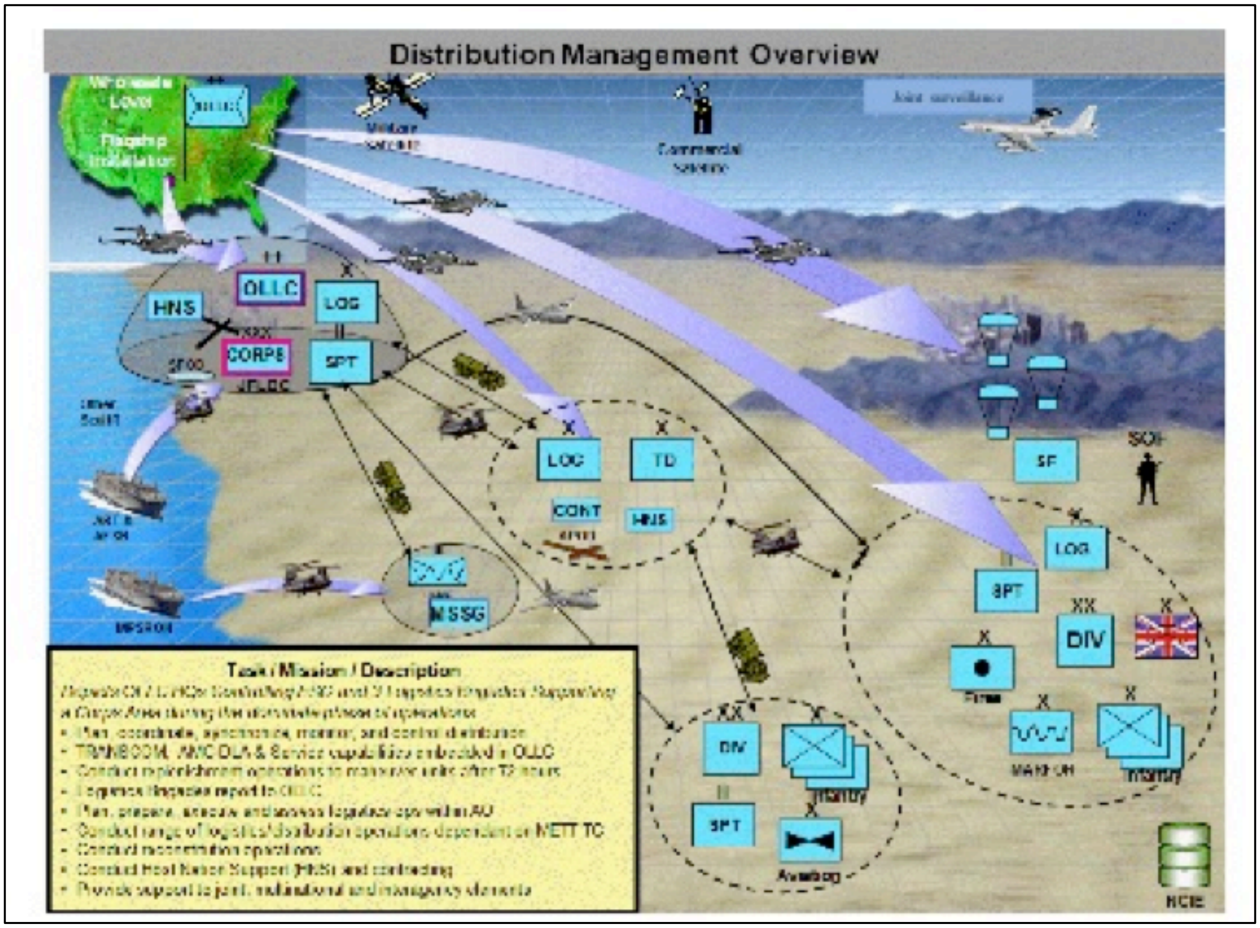


Figure 6. *TRADOC PAM 525-1, The United States Army Functional Concept for Sustainment, 2016-2028 (Figure 3-2)*

<u>Research in Cognate Areas Related to the Topic</u>

Petit and Beresford (2005) outline the dynamics of humanitarian aid in conjunction with military forces as a means of accomplishing a political end. Therefore, military forces will be involved in larger scale disasters. In such cases military involvement in the supply chain will be high at the beginning due to an ability to rapidly respond, but will taper off as NGOs arrive. Balick et al cite that military forces, by nature, can provide capability and knowledge in emergency supply chains through the ability to move large amounts of personnel and equipment under short notice. In reviewing the Australian Defense Forces (ADF) contributions in the aftermath of Cyclone Larry, Oloruntoba (2010) highlights the military's ability to rapidly mobilize, provide stability and overall unity of command for the relief effort. While Cyclone Larry relief did not span strategic distances, it remains noteworthy that the ADF's leading units in the operation were logistics units and that "Operation Larry Assist" is regarded as a more responsive effort than other operations within the disaster relief community. Byman et al discuss the balance between seeking a unified command and maximizing the strengths of Non Governmental Organizations.

Davidson (2006) outlined several similarities between military and disaster relief supply chains: (1) the agility required to establish a foreign-based, functioning supply chain under short notice, (2) the ability to function under highly variable, unknown and dangerous conditions and (3) measuring success not by cost-savings, but by the ability to accomplish the mission.

Critique of the Validity of the Appropriate Theory and Research Literature

The overall shortcoming of the military literature is the lack of specificity of the employment and establishment of an automated logistics network, as well as quantifiable analysis to support the network's utility. Army regulations largely discuss procedures for building stocks in established theaters but are sparse in addressing methods for doing so under immature conditions. What literature that does exist remains compartmentalized within sustainment doctrine, as opposed to being embedded in operational doctrine. If establishing automated logistics network is truly significant in sustaining operational momentum in conducting expeditionary operations, then its importance should be stressed to those leaders making operational decisions and their supporting staffs as a critical event to accomplish.

The main literature in this area does not address the procedures necessary to employ the SARSS and establish the network under emergency conditions. A search of over 300 articles from the Army's Center for Army Lessons Learned database (CALL) contained no discussion on the challenges involved in establishing SARSS for 2nd Brigade, 82nd Airborne Division during Operation Unified Response (OUR). The literature does not address the strategic level parameter changes that must occur and the time required to implement such changes.

While the literature on disaster relief supply chains points to the disconnect between specialized needs in the field and donations generated by donors, the field is missing research that quantifies the extent of the disconnect and its true impact on the effectiveness of operations. While such information is difficult to garner due to the manual nature of these operations, such research would support a paradigm shift towards the investment and development of automated requisitioning systems. The potential benefit is discussed in Chapter 6.

Conclusion

This chapter covers the key definitions, delimitations, framework and literature review necessary to understand the emergency military supply chain. It establishes a foundation to develop a simulation of such a supply chain. The Materials and Methods used for this simulation are discussed in Chapter 3.

CHAPTER 3. MATERIALS, MODEL AND METHODS

Introduction

The purpose of this chapter is to provide information concerning the data and methodology used to model manual and automated requisitioning procedures sustaining a military expedition. The Materials section describes the means of gathering and organizing data for the model's parameters. The Model section describes the automated and manual requisitioning systems. The Method section describes how the materials and model were used to develop the simulation and generate results for analysis, which will be described in Chapter 4.

Materials

<u>Source of Data</u>

The data used was gained from the U.S. Logistics Support Activity (LOGSA) Logistics Information Database (LIDB). The data selected was specifically from the 407th Brigade Support Battalion conducting Earthquake relief activities in support of Operation Unified Response and was gained through the assistance of senior logistics technicians within LOGSA. Reports gained included information on requisitions submitted in two formats: requisitions filled from stocks on hand (Customer Wait Time (CWT)) and requisitions passed to wholesale for higher-level sourcing determination (Requisition Wait Time (RWT)).

Additionally, an Authorized Stockage List (ASL) with which 407th BSB began the deployment was gained from LOGSA to establish start up data for the simulation. It was determined that 271 of 2,367 lines of ASL were actually utilized; these lines were given abbreviated reference numbers of 1-271. Specific National Stock Numbers (NSNs), ASL reference numbers, start-up on hand quantities, requisition objectives and reorder points are detailed in Table A1 of the Appendix.

Establishing Start Up Data

To establish start up data for each run, a lookup table was compiled containing the following information: quantity required, requisitioning objective (RO), reorder point (ROP), Quantity Due In (OUT) and Readiness Driver. RO and ROP were taken directly from the unit ASL the 407th BSB used during Operation Unified Response. Due to the nature of switching delivery addresses from home station to the deployed address, it was assumed start up quantities due in were 0. The average quantity required was used to determine the quantity required for a specific ASL number.

Certain NSNs have been identified by the Army as 'readiness drivers', as they contribute more significantly to readiness than other NSNs. To identify readiness drivers, NSNs were matched against the Army Table of readiness drivers. NSNs appearing on the list were assigned a value of 1, NSNs not on the list were assigned a value of 0. This start up table is depicted in Table A1 of the Appendix.

Further, each NSN has a supply category of material code which describes its general purpose. These codes were gained from the requisition data provided by LOGSA and organized into a lookup table. Explanation for these codes was referenced in Department of the Army Pamphlet 708-2, Cataloging and Supply Management Data Procedures for the Army Central Logistics Data Bank, Table 3-42.

Determining Overall Time Period Examined

The timeframe for the data selected was all requisitions submitted from January 13, 2010 through March 26, 2010. January 13th was the actual notification date of the 407th BSB's deployment and March 26 was the date of redeployment. The 407th BSB received requisitions after 26 March; however, as the unit had already redeployed by this point, these requisitions did not increase the readiness of equipment during the deployment and were therefore not used.

Establishing a General Process Model for Organizing Data

The structure of the automated portion of this model was based on Army doctrine and standardized processes (Rand Arroyo Center, 2003). The manual portion was constructed based on interviews with several technical experts who were involved supporting the 2nd Brigade Combat Team, 82nd Airborne during Operation Unified Response in 2010 (Interviews with Bertrand, Evans, 2011). Assumptions concerning manual process rates had to be made, which are described later in this chapter. Methods in which the Army uses Reorder Points (ROP) and Requisition Objectives (RO) to determine new order quantities were gained from Army Supply Regulation (AR 710-2, 2008).

Organizing the Data to Two Time Periods

Research on the frequency of demand for both time periods revealed a distinct difference in requisition patterns between the beginning of the operation and its remainder. Around day 20, requisitions develop at a much higher volume and frequency. Based on this difference, the data was sorted into two time periods for further organization: ‘Time Period 1’ refers to days 1-19 of the operation and ‘Time Period 2’ refers to days 20-60. Figure 7 depicts the demand pattern for the entire operation.

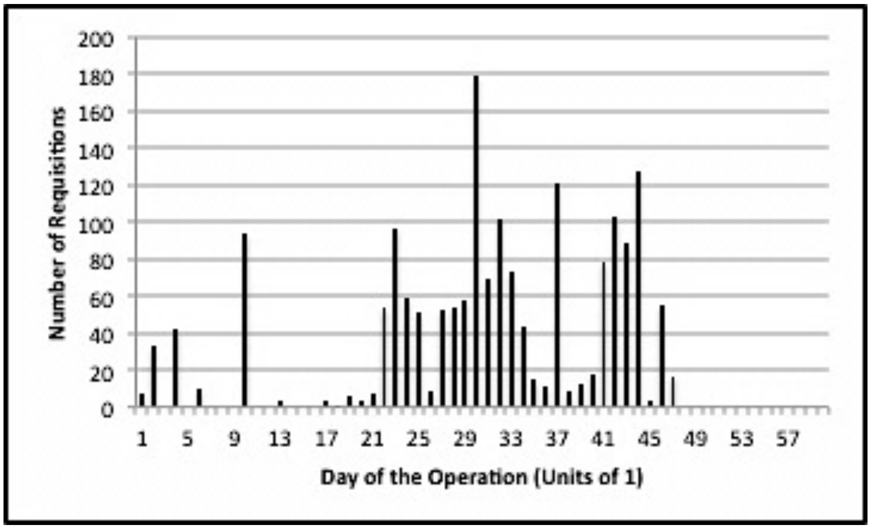


Figure 7. *Demand Pattern for Entire Operation*

<u>Examining Relevant Distributions and Probability Tables to Determine Model Parameters</u>

To establish parameters, the following information was organized and examined for these two Time Periods:

--Probability of Time Between Requisitions Demanded

--Probability of Specific NSNs Demanded

--Probability of Sourcing and Depot Determination for Items Passed to Higher Sources of Supply

--Lead Time Performance of Relevant Sourcing and Depot Combinations

--Probability of Sourcing and Depot Determination for Replenishment Requisitions

--Lead Time Performance for Replenishment Requisitions

--SSA Processing Time for Stocks on Hand

Tables A2-A12 of the Appendix present these parameters.

<u>Organization of Requisitions by Priority</u>

Requisitions were organized to two groups for further study based on Priority. Most requisitions possessed a Priority of 1 while smaller amounts possessed a Priority of 2 or 3. Priority 1 requisitions were initiated by customers supported by the Supply Support Activity, while the Priority 3 requisitions were initiated by the SSA to replenish warehouse stocked items based on levels falling below the Reorder Point (ROP). Priority 2 requisitions indicate a lower urgency of need. Designating Priority 2 requisitions occurs more often in peacetime settings; thus it is not as clear why Priority 2 was utilized. In Time Period 1, 10 Priority 2 requisitions were found, compared to a total of 188 Priority 1 requisitions. In Time Period 2, 149 Priority 2 requisitions were found, compared to a total of 1266 Priority 1 requisitions. Due to their comparatively small number and potential ambiguity, Priority 2 requisitions were treated as Priority 1 requisitions.

Sourcing and Depot Possibilities

Requisitions were organized into groups based on their Source of Fill and Depot. There were three Sources of Fill: Lateral-On, Wholesale, and Direct Vendor. A particular Source of Fill refers to the method in which the National Inventory Control Point (NICP), the central disposition authority within the Army supply system above the retail level, decides to fill the item. Lateral-On usually refers to a possible transfer from another retail location, whereas wholesale refers to filling from depot level stocks within the national-level inventory. Direct Vendor may refer to filling the item directly from the national vendor who produces the item. Within these sources of fill, there was at least one option for a depot, based on the time period. Tables 1 and 2 show the options for depots based on Time Period and Source of Fill.

Table 1

Depot Possibilities for Priority 1 Requisitions in Time Period 1

Source of Fill	Depot
WHSL	BO, AN5, GN3, AQ5
DVD	BO
LAT	ON

Table 2
Depot Possibilities for Priority 1 Requisitions in Time Period 2

Source of Fill	Depot
WHSL	BO, AN5, GN3
DVD	BO
LAT	ON

Handling of Requisitions Without a Depot Listed

In both Time Periods, some requisitions were found to be 'untagged' without a Depot specified. Requisitions with one option for the depot, such as DVD-BO, were included in the DVD-BO-DVD data group. Untagged WHSL requisitions were divided based on the distribution of the known population. For example, in Time Period 1, there were 59 Priority 1 'WHSL' requisitions without tags. Of the tagged population, there were 314 WHSL-AN5, 18 WHSL-AQ5 and 65 WHSL-GN3 requisitions. Therefore, the untagged 59 requisitions were divided and added to the tagged subgroups in accordance with Table 3. The untagged Time Period 2 requisitions were divided using in a similar method captured in Table 4. It is important to note that because untagged requisitions did not contain total processing time, these additions only had an impact on the probability of their respective sourcing-depot combination occurring.

Table 3
Treatment of Time Period 1 Untagged WHSL Requisitions

	Start Total	% of Total	# added	New Total
WHSL-AN5	314	0.7909	47	361
WHSL-AQ5	18	0.0453	3	21
WHSL-GN3	65	0.0163	9	74
WHSL no tag	59			

Table 4
Treatment of Time Period 2 Untagged WHSL Requisitions

	Start Total	% of Total	# added	New Total
WHSL-AN5	31	0.2500	20	51
WHSL-GN3	93	0.7500	61	154
WHSL no tag	81			

Handling of Requisitions of Smaller Depot Populations

In Time Period 2, within the Wholesale source of fill, several depots were found to carry a comparatively small amount of requisitions each. These requisitions are depicted in Table 5. The other combinations for this category were the following: WHSL-AN5 with 248 requisitions, WHSL-AQ5 with 16 requisitions and WHSL-GN3 with 12 requisitions. There were 59 requisitions without a depot tag. Therefore, the requisitions listed in Table 5 were added to the larger total of WHSL-AN5 requisitions and handled as part of this group.

Table 5
Smaller Requisitions in Time Period 2 for Source of Supply Wholesale ('WHSL')

GN4	1
SDD	1
SDT	1
SDU	1
SGW	2
SLM	2
SRR	5

Model

This section will describe how the automated and manual requisitioning systems operate, as well as their relationship. The following definitions are necessary to facilitate this description:

Requisition Information

Information concerning a required item, before a clerk has entered this information into an automated system. In an automated system, requisition information is processed into the automated system at the Supply Support Activity (SSA). In a manual system, requisition information is passed manually through email, telephone calls or other manual means. This occurs until the item is located or determined it cannot be located. If the item cannot be located, the 'sponsor' (see below) enters the requisition information into the automated system so that it can be sourced from the wholesale supply system (see below).

Supply Support Activity (SSA)

The Army's retail location for general supplies and repair parts, not to include fuel or ammunition. The SSA maintains an Authorized Stockage List (ASL) to accommodate demand.

Wholesale Supply System

The Department of Defense (DOD) supply system which supports demand that cannot be satisfied from ASL.

Non-deployed

Describing an SSA's status, this means the SSA is operating in a garrison location, such as Fort Bragg, North Carolina or Fort Hood, Texas.

Deployed

Describing an SSA's status, this means the SSA is operating in a location other than its non-deployed location for the purpose of performing a specific mission.

Home station

Refers to an SSA's location when not deployed or prior to a deployed status. For example, an SSA deployed to Port a Prince, Haiti may have a home station of Fort Bragg, North Carolina.

Higher Headquarters

Is located at the deployed SSA's home station and assists a deployed SSA that has not yet connected to the automated requisitioning system. The higher headquarters, by coordinating with non-deployed SSAs on the same home station, searches for demanded items that cannot be met through the deployed SSA's ASL. The higher headquarters is not a supply activity. The higher headquarters works in conjunction with a 'sponsor', which is located on the same home station (see below).

Sponsor

This term is used to describe a non-deployed SSA that resides at the deployed SSA's home station. For all items that the higher headquarters cannot locate at the home station, the sponsor receives requisition information from the higher headquarters and inputs this information into the automated requisitioning system. Once entered into the automated requisitioning system, the wholesale supply system sources these requisitions and delivers them to the deployed SSA.

When operating at home station in a non-deployed status, all Army retail locations operate using the automated requisitioning system. They maintain an Authorized Stockage List (ASL), which continually evolves based on their respective home station demand. To stock over 900 SSAs throughout the Army, the Army Materiel Command (AMC) uses the Dollar Cost Banding (DCB) algorithm to manage ASLs in conjunction with each SSA's home station demand. The DCB process is described in Chapter 5.

When a non-deployed SSA gets a requisition that cannot be met through ASL, the retail location orders the item through the wholesale supply system, the first step of which involves manually entering (or "keystroking") the requisition item information into the automated system. The wholesale supply system in turn determines the disposition from a number of depots, or ships the item directly from the manufacturing vendor. In some cases, when a non-deployed retail activity does not have a required requisition on hand, they may search other SSAs at the same home station to find the item locally and avoid incurring wholesale system lead time.

Figure 8 depicts an example of multiple non-deployed units at a home station operating under the automated system.

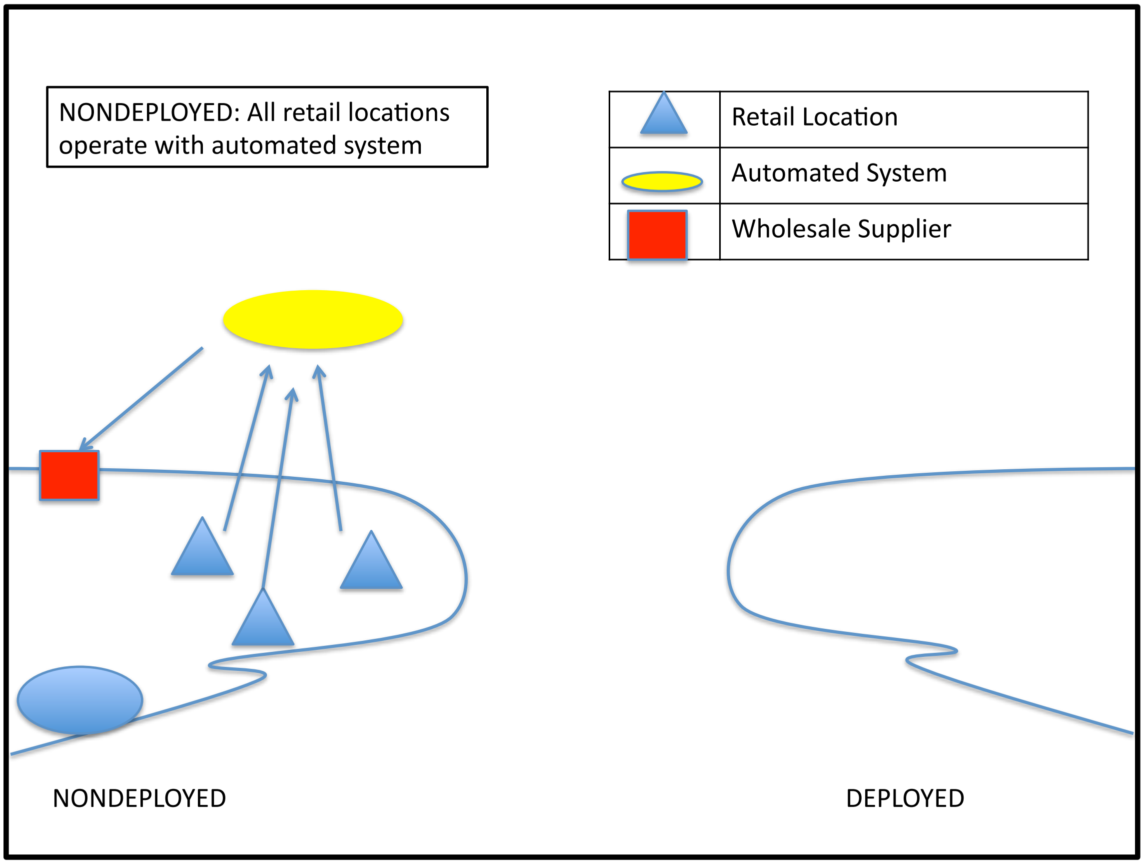


Figure 8. *Multiple Non-deployed Units Operating with the Automated System*

When a SSA deploys in an emergency setting, it works to re-establish the automated system within the deployed environment. Based on competing priorities, problems during contingency deployment and the uncertainty of such a deployment as described in Chapter 2, the SSA may not be able to re-establish the automated system right away. In the interim, the deployed SSA must operate with a manual system. Under the manual system, the deployed retail location receives the requisition. If the requisition cannot be met from the ASL, the deployed retail location seeks it through the manual system, by first contacting its home station higher headquarters. The higher headquarters conducts a local search by contacting the non-deployed SSAs, through email or phone, to determine if the item is on hand at any of the non-deployed locations. If the item is on hand, it is shipped to the deployed retail activity. If it cannot be found, the item must be ordered from the wholesale supply activity. To do so, the higher headquarters, with the assistance of one of the non-deployed SSAs acting as a sponsor, enters the requisition information into the automated system, ordering the item for the deployed SSA. The wholesale supply system sources the item and delivers it to the deployed unit's location. Figure 9 shows the conduct of the manual system.

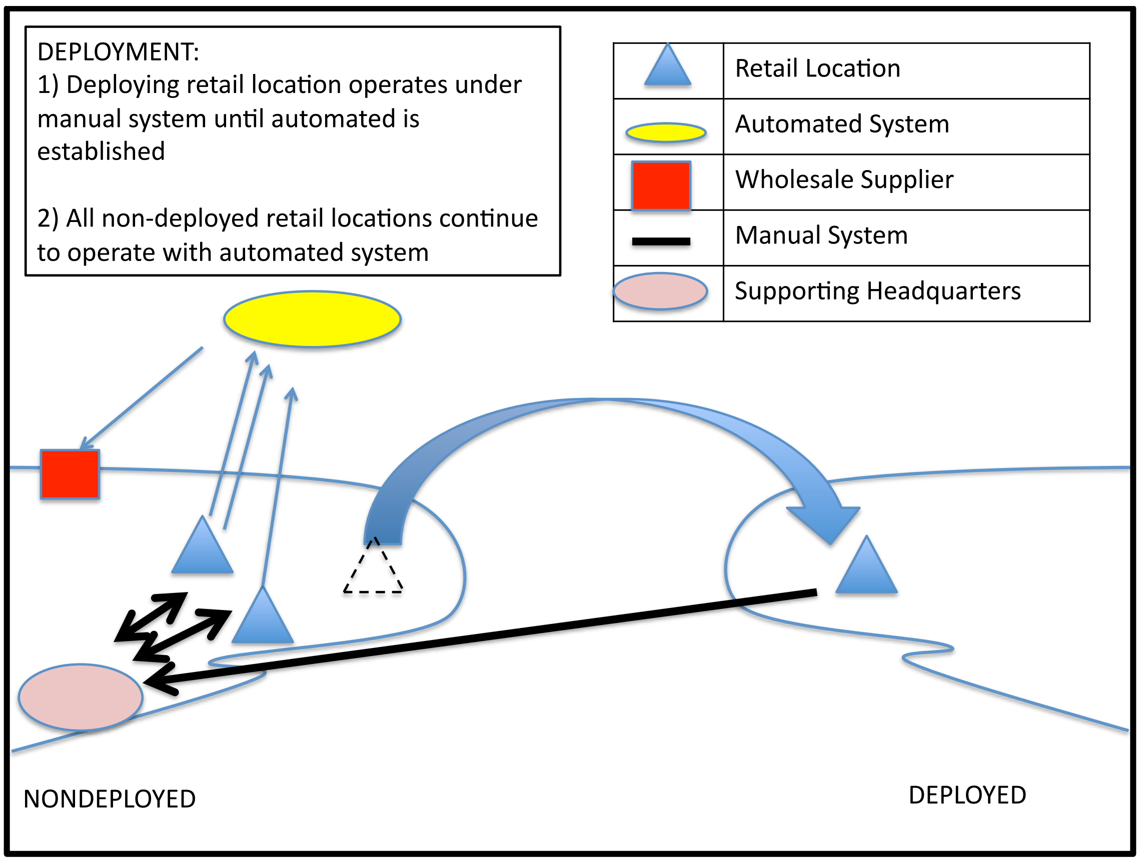


Figure 9. *Conduct of the Manual System*

If the deployed unit is able to establish the automated system at their deployed location, the system operates in the same manner as it did at home station. If on hand, requisitions are filled through ASL, otherwise they are ordered through the wholesale system, and eventually delivered to the deployed SSA. Figure 10 depicts how the deployed SSA operates the automated system.

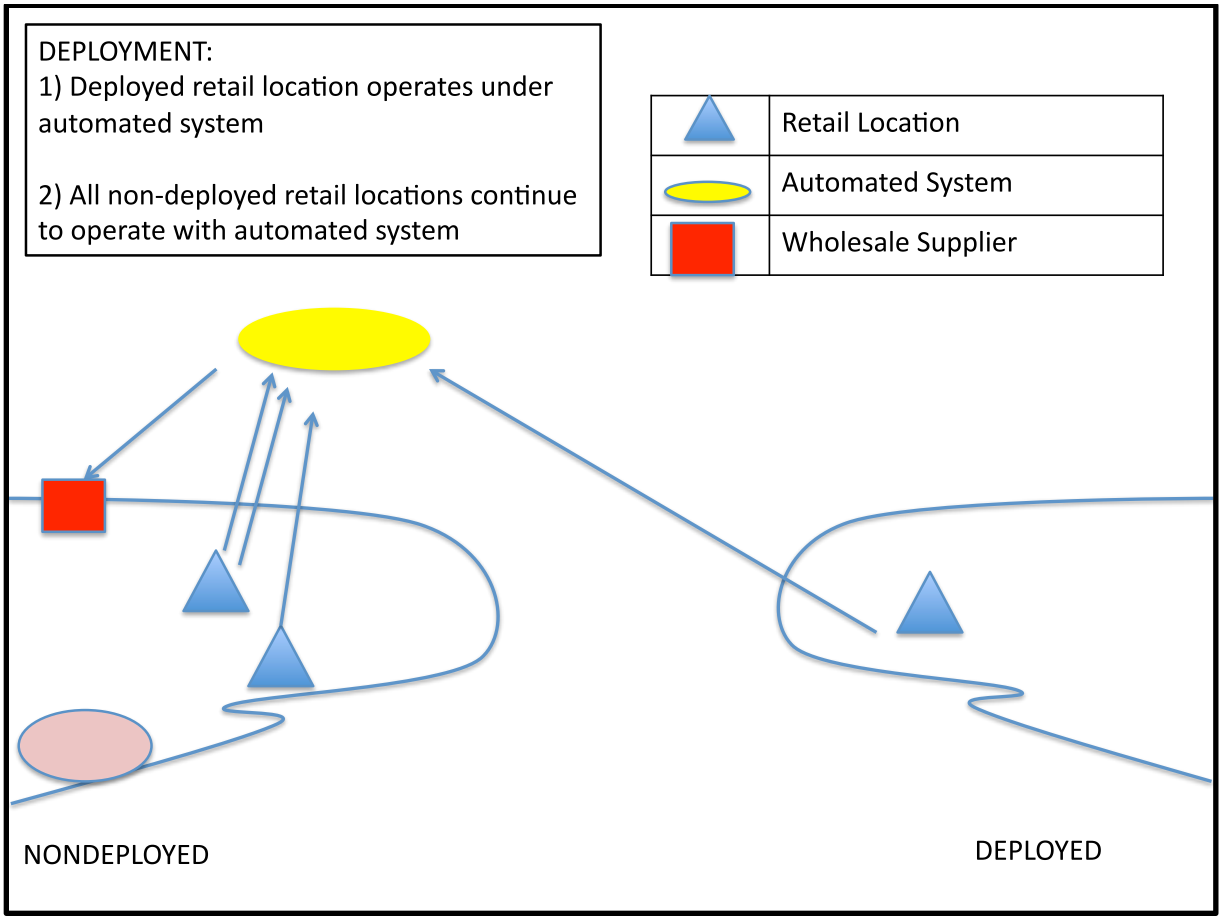


Figure 10. *How the Deployed SSA Operates the Automated System*

<u>Distinguishing Between the Manual and Automated Processes</u>

It is important to highlight the distinction between manual and automated systems. The manual system contains two contingencies if the item is not on hand at the SSA: either it is found through a higher headquarters search, or it is entered into the automated system to be passed to a wholesale level of supply. However, this should still be considered a manual system, as the deployed unit does not have an automated requisitioning system "on ground" and is dependent on another agency for inputting the requisition data into an automated system to source the item. In contrast, under an automated system, the deployed unit can automate a requisition independently.

Method

The ExtendSim8 program was used to build a discrete-event simulation depicting both the automated and manual systems. Simulation lengths of 600 days were run to allow all requisitions to close and exit the system.

The simulation was built with the following major sections: Requirements Generator, Admin Count, Warehouse Initial, Manual Process, Automated Process, Warehouse Final and Performance Computations.

- The Requirements Generator section builds the requisitions and assigns attributes that will guide requisitions routing through the system.
- The Admin Count section captures requisition data that is used to derive performance computations.
- The Warehouse Initial section checks to see if the requisitions are on hand.
- The Manual and Automated Process sections replicate the respective steps performed to either find the item or source it from a higher level of supply. As this is the overall independent variable, requisitions only flow through one of the two blocks.
- The Warehouse Final section processes requisitions that were originated to replenish inventory.
- The Performance Computation section captures the performance of the model.

The order and flow of these sections are described in Figure 11.

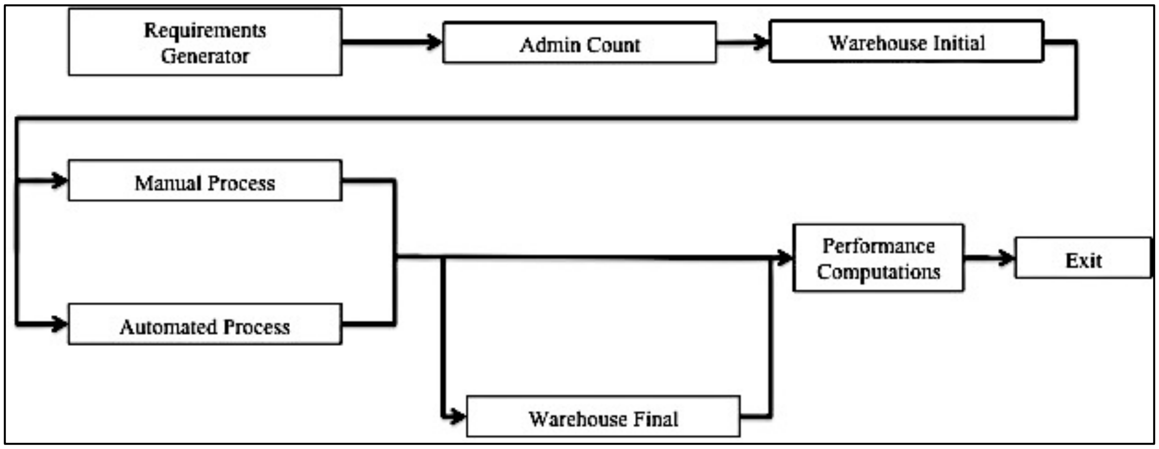


Figure 11. *Construction of Model*

Requirements Generator

The purpose of the Requirements Generator is to introduce requisitions in accordance with the probability and characteristics with which they occur. Requisitions first enter the model based the Table of Time Between Arrivals described in Table A2 of the Appendix. Next, the model assigns a set of attributes:

--*Auto* (0 for a manual, 1 for automated)

--*Fill* (all requisitions are initially assigned 0)

--*Ret* (all requisitions are initially assigned 0)

--*Day* (simulation day when requisition was created; non-integer value)

--*Pri* (all requisitions are assigned 1)

Next, requisitions are routed by Time Period. If requisitions were created on Simulation day 19 or earlier, they are routed through a Time Period 1 leg; otherwise they are routed through Time Period 2. The reason for this routing is to assign the Time Period-dependent attributes of ASL number (*ASL*) and source of fill/depot combination, referred to as Time/Priority/Source of Fill/Depot or *TPSD* attribute. Both *ASL* and *TPSD* are assigned from discrete probability tables with the respective probabilities for the particular time period. Items with ASL numbered 272-998 refer to items not on stocked on the ASL.

Finally, the requisitions are merged and assigned four additional attributes that will assist with routing later in the model.

--*ReadDr* identifies the item as a Readiness Driver. This is determined by referencing the ASL number attribute on a lookup table. Requisitions that are readiness drivers are assigned a value of 1, otherwise 0.

--*QtyReq* refers to the item's required quantity. This is determined by referencing the ASL number attribute on a lookup table. Values range from 1-3000 dependent on the specific ASL number.

--*Com* refers to the item's supply category of material code. This is determined by referencing the item's ASL number attribute on a lookup table. These codes are described in Table 6.

--*Sto* refers to if the item is on the stockage list. Items with an *ASL* attribute greater than 271 are assigned a *Sto* value of 1, all others are assigned a *Sto* value of 0. All requisitions proceed from the Requirements Generator to the Admin Count section.

ReadDr, *QtyReq* and *Com* information for each type of item is listed in Table A13 of the Appendix.

Table 6
Types of Material Codes

2	Special Tools and Handling Equipment; General Supplies
2B	Components of Sets, Kits and Outfits
2E	Expendable Items (Eg Office Supplies)
2F	Clothing and Textiles, Tarpaulins
2K	General Supplies for Tactical Vehicles, Less Repair Parts
2T	General Industrial Supplies
4X	Construction, Fortification and Barrier Materials
	Repair Parts (Listed Below)
9A	Aviation or Airdrop
9B	Sets, Kits & Outfits
9G	Communications & Electronics
9K	Tactical Vehicles
9M	Weapons
9O	Combat Vehicles
9T	Fabrication Items and Hardware
9W	Ground Equipment (Water Systems)
9Z	Chemical Systems (Protective Masks, Smoke Generators)
U	Unknown

Admin Count

The purpose of the Admin Count is to gain specific counts to later be used in the Performance Computations section of the model. The total amount of requisitions opened are captured. All requisitions proceed from the Admin Count section to the Warehouse Initial section.

Warehouse Initial

The purpose of the Warehouse Initial section is to determine the availability of stocks on hand towards meeting incoming requisitions. This section also determines the amount of replenishment items required and orders them as necessary.

The Warehouse Initial and Warehouse Final sections reference a global array which contains On Hand Quantity, Requisition Objective, Reorder Point, and Current Quantity Due In for each ASL Number stocked (items 1 – 271). Through the functioning of the Warehouse Initial and Final blocks, the global array maintains the current status of the warehouse within these supply categories. The Warehouse Database, containing the original start up data quantities, initializes the global array at the beginning of each run.

All requisitions are screened to determine processing in the Warehouse block. Requisitions entering the Warehouse Initial Section face three possibilities

---*Item is not on hand.* Requisitions that are stocked at warehouse but are not on hand trigger an order to a higher source of supply as a backorder. Backorders are depicted by a negative on-hand inventory. The requisition remains at a Priority 1 and continues to a higher source of supply by exiting the Warehouse Initial and entering the manual or automatic process section, based on the type of simulation run (manual or automatic).

--*Item is on hand; New On Hand Quantity is not below Reorder Point (ROP).* Requisitions in this category are filled. The required quantities are subtracted from on hand stocks, the attribute *Fill* is changed to 1, SSA time is processed and the requisition exits the system. These requisitions are not included in further calculations of Requisition Wait Time, as described in Performance Computations section.

--*New On Hand Quantity is below Reorder Point (ROP).* Requisitions in this category fall into two sub-categories: On hand quantity is greater than or equal to 0, or on hand balance is less than 0.

If the new on hand balance is greater than or equal to 0, the original requisition was filled. Its required quantities are subtracted from on hand stocks, the attribute *Fill* is changed to 1, SSA time is processed and the original requisition exits the system.

Simultaneously, the requirement for a replenishment requisition is determined. In the model, the Warehouse Inventory Position is equal to the Requisition Objective for any particular item. To determine new order quantity required, the sum of the On Hand Quantity and Quantity Currently on Order are subtracted from the Requisition Objective. The model determines the new quantity required for the item using the following logic:

$$if\ (RO - New\ OH) > OUT, QtyReq = (RO - New\ OH) - OUT); \quad (1)$$

$$else\ QtyReq = OUT - (RO - New\ OH),$$

where

OUT = Amount currently on order for the line number/item

RO = Item's Requisition Objective

New OH = New quantity on hand for the item after the initial requisition is filled

This new *QtyReq* is assigned as the quantity required for the new replenishment order. These orders are assigned a *TPSD* attribute based on a discrete probability table with a priority of 3. These orders are also given a new *Ret* value of 1, so they will process through the Warehouse Final section following higher-level sourcing.

If the new on hand balance is less than 0, the original requisition was not filled. Its required quantities are still subtracted from on hand stocks, replicating a back order. The order quantity is updated based on the same logic described above, and the requisition is given a new Ret value of 1 so it will process through the Warehouse Final section following higher-level sourcing.

Requisitions departing the Warehouse Initial Block exit the system if they are filled, or flow through the Manual or Automated hierarchy blocks based on the type of simulation run (manual or automated).

Manual Process

The requisition is passed to an item search activity that determines if the item can be located. If the item is located, then the item is passed to an activity that represents physically acquiring the item, moving it to the local APOE and transporting it to the deployed Supply Support Activity. If the item cannot be located, the requisition is entered in the higher-level automated requisitioning system, where it is passed higher upstream for sourcing determination.

If the requisition is entered into the automated system and is sent to a higher source of supply, its source of fill and corresponding depot are determined by its *TPSD* attribute. Its respective lead time is determined from a discrete probability table. This particular TPSD lead time table is also used in the manual system, as it is assumed that once manual requisitions are inputted to the automated system, they will possess the same depot lead time performance as the automated requisitions.

Significant within the manual process is the system's capacity to search for multiple items simultaneously, the probability of a successful local search, and lead time for items found through local search. Because data is scarce to quantify parameters for a manual process, several assumptions were necessary. These assumptions are discussed later in this chapter.

Automated Process

The automated process represents a Supply Support Activity an activity processing a requisition into an automated system. If the item was listed on the ASL but not on hand, then this time accounts for the SSA's time required to request the item from a higher source of supply. Lead times for requisitions are determined based on the attribute *TPSD* and a discrete probability table. The same discrete probability table is used in the manual system if necessary, described above.

Warehouse Final

The purpose of this section is to update inventory status based on items being received at the warehouse. The model routes all requisitions with a *Ret* value of 1 to the Warehouse Final section to fill backorders and replenish stock. As requisitions enter this section, their respective quantities are simultaneously added to the on hand balance and subtracted from the quantity out balance. All requisitions depart this section for the Performance Computations section.

Performance Computations

The purpose of this section is to collect final performance data on all requisitions as they exit the system. The requisition's end time is captured in the attribute *End* and used with the attribute *Day* to determine the requisition's total time in the system. Additionally, total time is also captured for requisitions possessing a *Read Dr* value of 1, a Fill value of 1, and those requisitions possessing both *Read Dr* and *Fill* values of 1. Capturing these specific counts enables computing the performance measures detailed below.

To evaluate and compare performance amongst runs while changing several independent variables, six performance measures were developed and computed. In the discussion of performance measures below, requisitions refers to Priority 1 requisitions, as these originate from customers. Priority 3 requisitions are used to replenish warehouse stocks and are therefore not used within these measurements.

Total Requisition Wait Time (TRWT)

Total Requisition Wait Time (TRWT) measures the responsiveness of delivery of all requisitions that cannot be filled from ASL and must be sourced from another means, whether it from a higher level search or source of supply. TRWT is measured by the total amount of time the requisition spends in the system, which includes all processing and lead time.

$$TRWT = \frac{\sum Processing\ Time\ of\ all\ Requisitions\ Closed\ to\ Date}{Count\ of\ all\ Requisitions\ Closed\ to\ Date} \quad (2)$$

Requisition Wait Time for Readiness Driver Items (RRWT)

This performance measure captures the Total Requisition Wait Time for only the requisitions for items that carry a *Read Dr* value of '1' (referred to as 'RReqs' in the formula below) assigned in the model. This performance measure is a subset of TRWT above and is meant to examine the system's responsiveness towards meeting demand for those items which contribute most to readiness.

$$RRWT = \frac{\sum Processing\ Time\ for\ all\ RReqs\ Closed\ to\ Date}{Count\ of\ all\ RReqs\ Closed\ to\ Date} \quad (3)$$

Total Requisition Fill (TFill)

This performance measure captures the system's ability to meet the total amount of requisitions submitted to higher sources of supply. It does not include the amount of opened requisitions that were filled by ASL.

$$TFill = \frac{Count\ of\ Requisitions\ Closed\ to\ Date\ (Not\ Filled\ by\ ASL)}{Count\ of\ Requisitions\ Opened\ to\ Date} \quad (4)$$

Total Requisition Fill for Readiness Driver Items (RFill)

This performance measure captures the system's ability to meet the total amount of RReqs submitted to higher sources of supply. Like RRWT, this is a subset of TFill and is meant to examine the system's ability to deliver items that contribute most to readiness. It does not include the amount of opened readiness requisitions that were filled by ASL.

$$RFill = \frac{Count\ of\ RReqs\ Closed\ to\ Date\ (Not\ Filled\ by\ ASL)}{Count\ of\ RReqs\ Opened\ to\ Date} \quad (5)$$

Total Requisition Fill by ASL (TASL)

This performance measure captures the total amount of requisitions that were filled from the Authorized Stockage List (ASL) versus being passed to a higher source of supply. The numerator below refers to those closed requisitions possessing a *Fill* value of 1.

$$TASL = \frac{Count\ of\ Requisitions\ Closed\ to\ Date\ (Filled\ by\ ASL)}{Count\ of\ Requisitions\ Opened\ to\ Date} \quad (6)$$

Total Requisition Fill by ASL for Readiness Driver Items (RASL)

This performance measure captures the total amount of RReqs that were filled from the ASL versus being passed to a higher source of supply.

$$RASL = \frac{Count\ of\ RReqs\ Closed\ to\ Date\ Filled\ by\ ASL}{Count\ of\ RReqs\ Opened\ to\ Date} \quad (7)$$

Critical Necessary Assumptions About the Manual Process

While data existed to establish parameters governing the automated process, several critical assumptions had to be made concerning the manual process. Many of these assumptions were based on interviews concerning the manual process (Bertrand, Eden, Tingler, 2011). These assumptions are the following:

--The steps of the manual process followed a certain order:

- Email or phone contact between the deployed SSA and higher headquarters in search of an item
- Local search by higher headquarters
- If the item was found locally, it was transported to local aerial port for shipment
- If the item was not found, it was entered into local automated requisitioning system for sourcing through the formal supply system

--Capacity of higher headquarters to conduct local searches of multiple items. For this parameter, the assumed value was 10 items working at one time.
--Time required to conduct local search. For this parameter, the assumed performance was a mean of 2 days with a standard deviation of 1 day.
--Probability of local search finding item. For this parameter, the assumed success rate was 0.25.
--Processing time required to input unfound items into local automated system. For this parameter, the assumed value was a mean of 2 days with a standard deviation of 1 day.
--Lead-time from local search location to in-theater location. For this parameter, the assumed performance was a mean of 7 days with a standard deviation of 2 days.

Known Data Limitations

There are patterns in the Logistics Database Data that indicate the 'time tag' information, commonly used to measure arrival at the Supply Support Activity, may instead indicate when a warehouse operator closed the requisition in their system. This may occur for several reasons: the receiving operator may 'batch' the items to close them out all at the same time, or the operator may experience a delay in closing out items due to competing priorities. Still, this end date is the date used by the Army to compute Requisition Wait Time (RWT), as it is the closest measurement of actual closing time. Therefore, it is used within this research in the same manner.

Conclusion

This chapter describes the following:
--The source of data used to develop this model and how it was organized to develop parameters for the model.
--The method used to develop the automated and manual processes within the model.

--How the model was built in ExtendSim8.

--The performance measures that will be used to compare and analyze models for significant contributions.

--Necessary assumptions about the manual model.

The next chapter will describe the specific results from comparing the automated and manual systems.

CHAPTER 4. RESULTS AND ANALYSIS

This chapter presents the results and analysis on the performance of the automated and manual systems, as modeled in the simulation described in Chapter 3. These findings demonstrate the automated system is more effective than the manual system, based on responsiveness, Total Fill Rate (TFill) and Total Requisition Wait Time (TRWT). These findings also suggest that establishing the automated system early is most optimal, with a statistically significant difference in automated and manual fill rates occurring as early as the 1-6 day interval. These findings are valuable in understanding the weaknesses of the manual system and how operating with a manual system would potentially adversely impact the effectiveness of an emergency supply chain. These findings also provide ideas on how to mitigate the vulnerabilities of a manual system and therefore improve its performance.

This chapter is organized in the following manner: a description on the assumed parameters for the base manual system, the method used to generate data on the automated and manual systems, the results of this data based on performance measures defined in Chapter 3, the results of the chi squared contingency table comparisons and sensitivity analysis. The chapter concludes by providing methods to potentially mitigate the vulnerabilities of the manual system.

Establishing Base Parameter Settings for the Manual and Automated Systems

As described at the end of Chapter 3, the challenge with modeling the manual system is that little data is kept during the conduct of manual systems in emergency operations. To determine a set of base results for comparison and analysis between the automated and manual systems, certain parameters had to be assumed. These parameters and their assumed base values are depicted in Table 7**.**

Table 7
Assumed Base Parameters of Manual System

Manual System Assumed Parameters	Short Terminology	Base Value
Amount of items that can be searched for simultaneously	Search Activity	10
Probability of a successful search at home station	Search Success	0.25
Lead time for items successfully found at home station	Manual System Lead Time	7 days
Rate at which the sponsor (non-deployed unit) can process unfound requisitions in support of the deployed unit	Processing Activity	75 / day

Parameters for generating the automated system results were derived from the research outline in Chapter 3. To avoid a biased advantage for the automated system, the automated system's base processing activity (i.e., the rate at which the deployed unit can enter requisition information into the automated system) was set to the same rate as the manual system's processing activity. These parameters were used to complete the base settings for the automated and manual simulation models.

Method of Generating Data for Analysis

Results were generated from running the automated and manual models at their base settings for 60 runs each. These runs were conducted using the same random seeds for each run. For example, run 1 for both the manual and automated system used random seed 1, run 2 for both used random seed 2, etc. For each run, the performance measures of Total Requisition Wait Time (TRWT), Readiness Requisition Wait Time (RRWT), Total Fill (TFill) and Readiness Driver Fill (RFill) were collected. The formulas for each of these performance measures are described in Chapter 3. This produced a set of base results for the automated and manual systems.

For each performance measure, runs were put in order by the day of the closing performance measure. Based on this order, runs 1-6 were collected as the "early" group, runs 27-32 as the "typical" group and runs 55-60 as the "late" group.

Data for each group was further organized into subgroups based on the observation's x value (day of the operation). The subgroups were specified by 10 day intervals. Within each subgroup, the average of the performance measure was computed and graphed. This produced an early, typical and late line for each performance measure for both the manual and automated systems for a total of six lines. As an example, the graph depicted in Figure 12 shows the overall performance of TFill with early, typical and late lines for both the automated and manual systems.

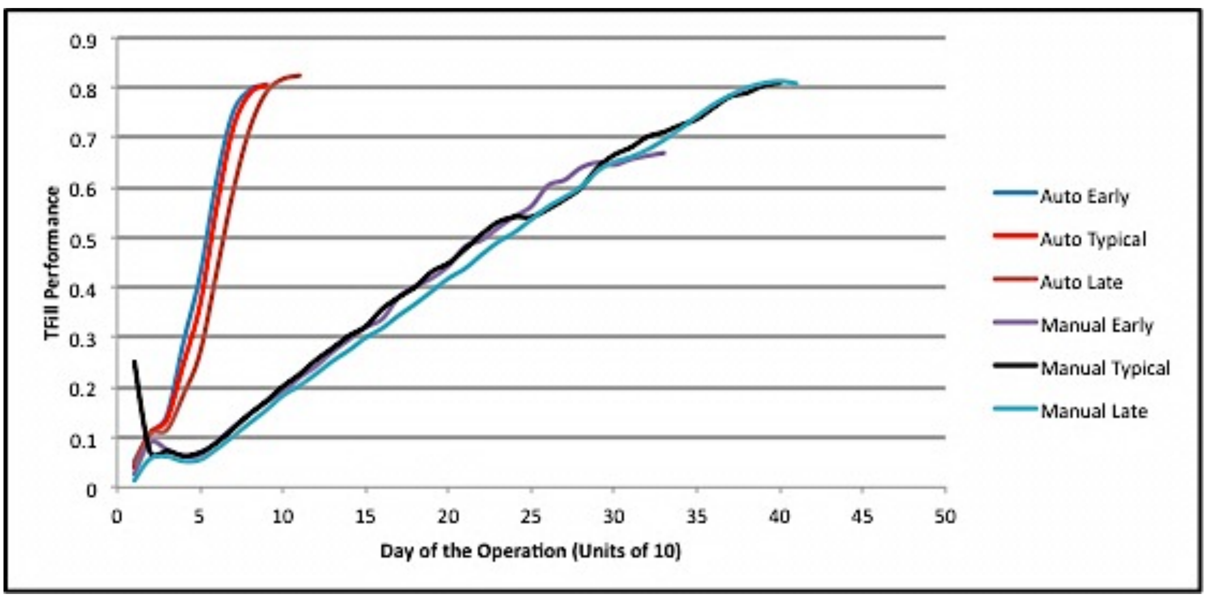


Figure 12. *TFill Automated and Manual System Base Results*

<u>General Performance Results</u>

The automated system achieved better measures of performance than the manual system. The automated system's closure rate was faster, fill rate was higher in a shorter amount of time, and response time was faster.

--Particularly with fill rate performance measures (TFill and RFill), the automated system responds better than the manual system to the increase in demand that occurs in the18-22 day range. Figure 13 demonstrates the manual and automated system's response to this increase in demand. The typical demand is indicated in green and is scaled on the figure's secondary axis on the figure's right side. Around the 30 day mark, TFill for the automated system continues to increase across all early, late and typical groups, while TFill for the manual system's groups ranges 0.0696-0.0665 between days 20-60. As shown in Figure 12, when the automated system closes between days 81-110 at a range of 0.8058-0.8245, the manual system is at 0.1498-0.3137, and does not reach the 0.8058-0.8245 range until days 330-410.

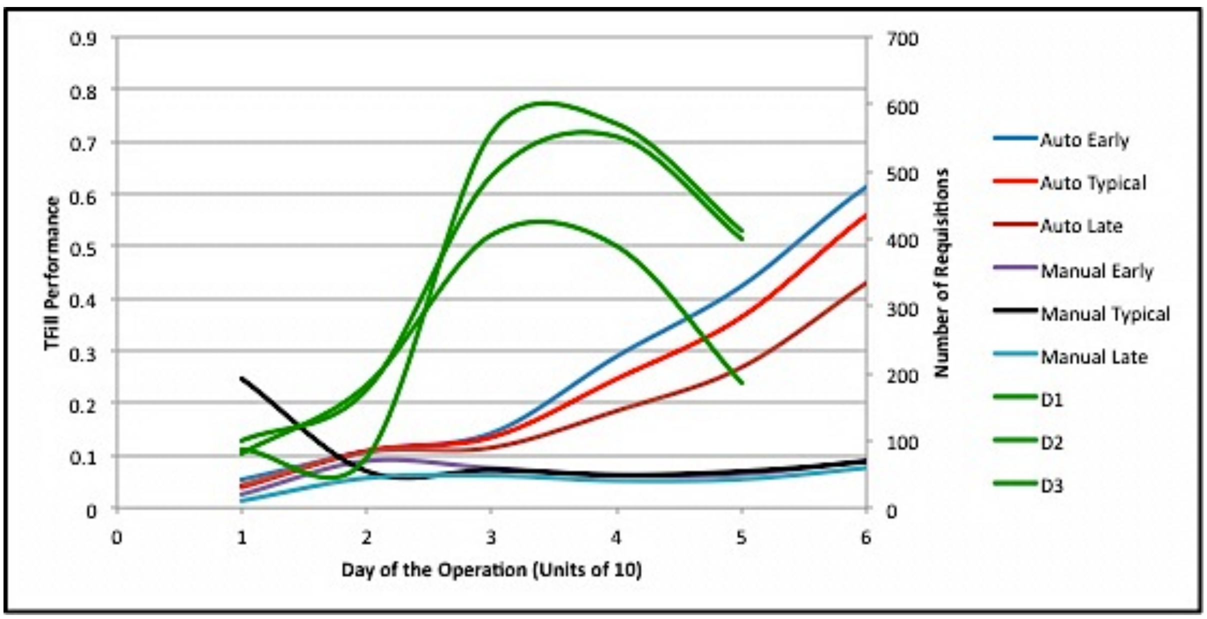


Figure 13. *Manual and Automated TFill Performance in Response to Demand Increase*

--For closure, the manual system typically required an average of 200 days more than the automated system to close all requisitions. The automated system's closure of requisitions ranged from 81-110 days, with the automated typical group ranging from 91-100 days. The manual system's closure ranged within 330-410 days, with the typical group requiring 391-400 days.   These differences are graphically depicted in Figure 12.

--Performance achieved by the 60-90 day range was also examined, as short durations characterize military expeditions and humanitarian operations. In the 60 - 90 day range, there was a 0.4663–0.5722 difference between typical group TFill performances. At the 60 day mark, the time of the simulated expedition's end, the automated system TFill ranged from 0.4298 – 0.6135 with the typical group achieving 0.5591. At the same mark, the manual system TFill ranged from 0.7661 – 0.9041 with the typical group achieving 0.8843.

--The automated system typically achieved a lower Requisition Wait Time (RWT) than the manual system. The automated system closed at a range of 16.17–24.90 days to process total requisitions (TRWT), with the typical group closing at 18.24 days RWT. The manual system closed at a TRWT range of 128.37–188.22 days, with the typical group requiring 131.24 days RWT. At the 60 day mark, the automated system TRWT ranged from 13.44-16.86 days, with the typical group achieving 15.44 days. At the same point, the manual system TRWT ranged from 24.85-26.18 days, with the typical group achieving 25.50 days RWT. Figure 14 graphically demonstrates these differences in Requisition Wait Time between the automated and manual systems.

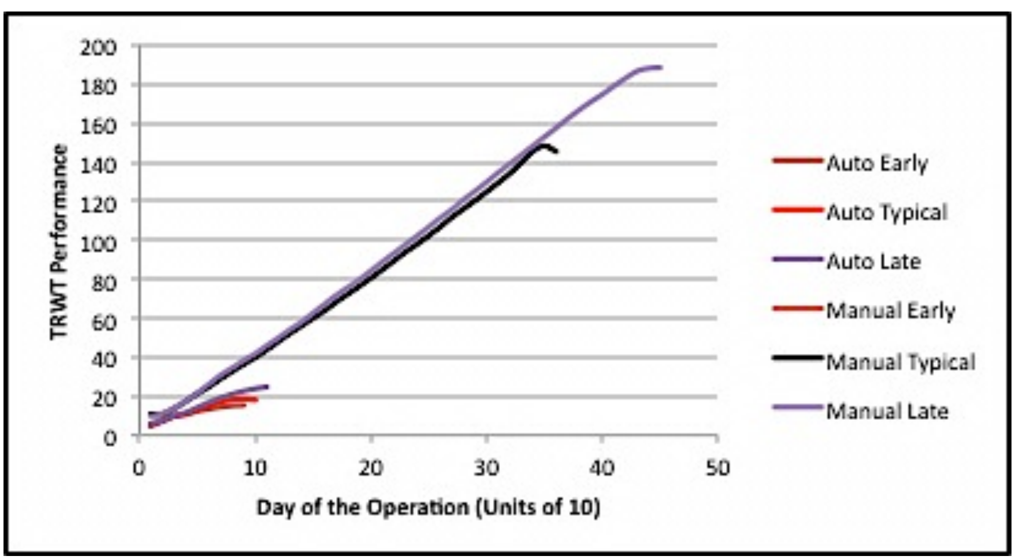


Figure 14. *TRWT Automated and Manual System Base Results*

The performance of requisitions coded as readiness drivers, which contribute most to operational readiness as defined in Chapter 3, were also examined.

--For closure, the manual system required an average of 260 days more than the automated system to close all readiness driver requisitions. The automated system's closure of readiness driver requisitions ranged from 90-110 days, with the automated typical group ranging from 90-97 days. The manual system's closure ranged within 270-380 days, with the typical group requiring 350 days. RFill at the 60 day mark for the automated and manual systems was 0.4838 and 0.0797, respectively. These differences are graphically depicted in Figure 15.

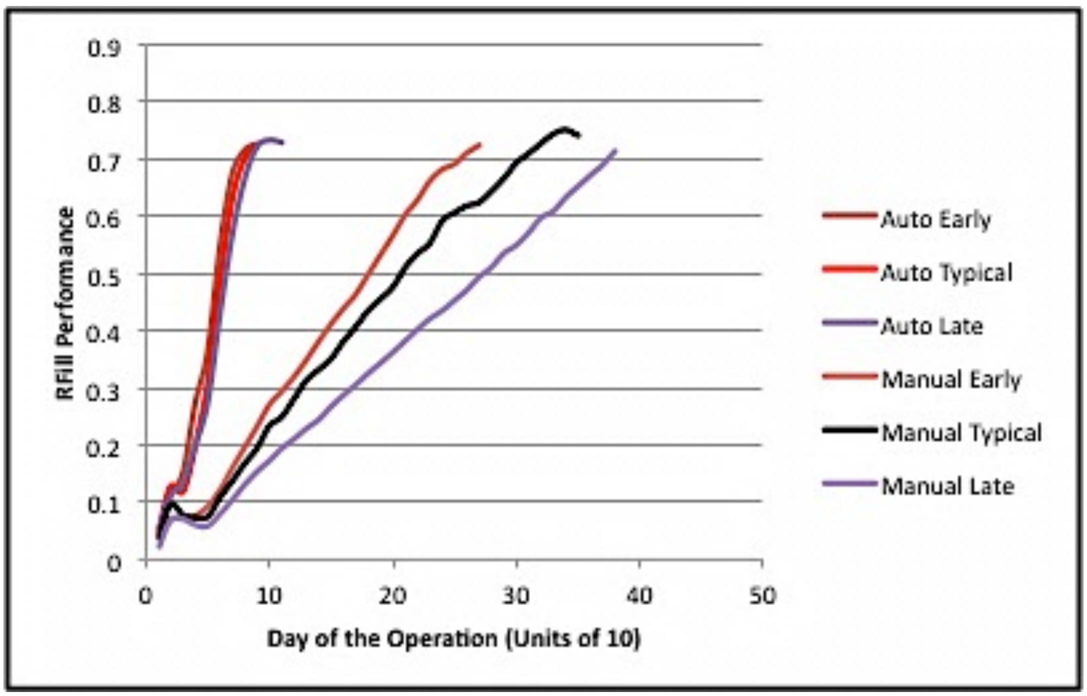


Figure 15. *RFill Automated and Manual System Base Results*

--The automated system typically achieved a lower Readiness Requisition Wait Time (RRWT) than the manual system. The automated system typical group closed at 17.08 days RRWT, and the manual system typical group closed at 137.40 days RRWT. RRWT at the 60 day mark for the automated and manual systems was 14.76 and 25.85 days, respectively. The differences in these performances are depicted in Figure 16.

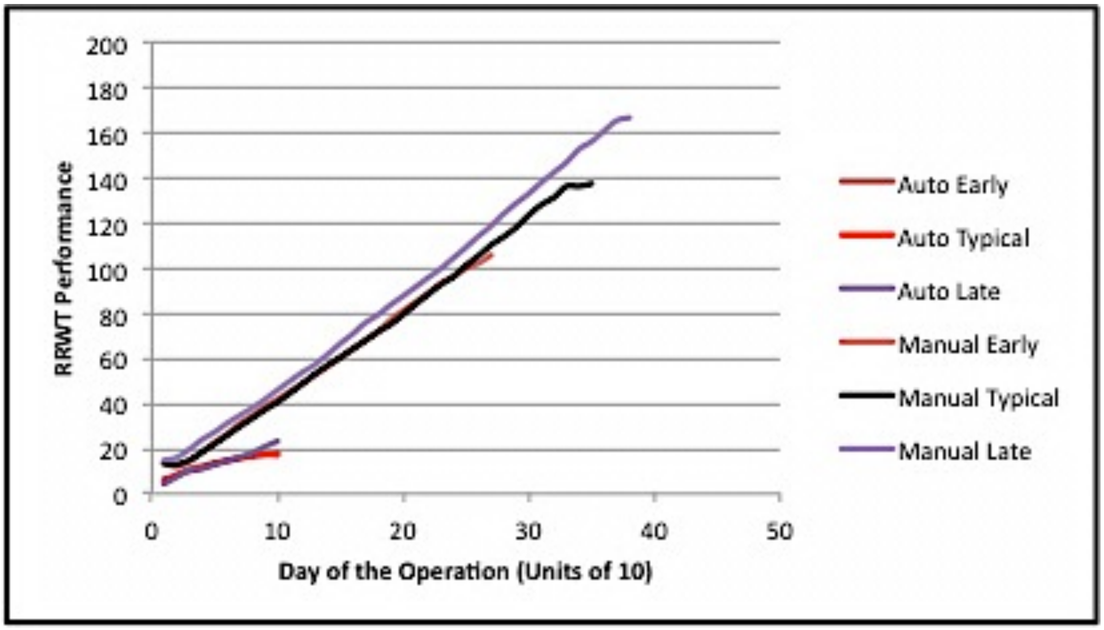


Figure 16. *RRWT Automated and Manual System Base Results*

<u>Chi Squared Results / Statistical Significance</u>

To assess the statistical significance of the difference between these base results, a 2 x 2 contingency table method was used to compare the TRWT, TFill, RRWT and RFIll performance measures of the manual and automated models. To do so, the quantity of increasing and decreasing values from each model were compared using a chi-squared test. Data were compared in intervals of 3 days time, beginning with the first interval of 1-3 and continuing until interval 57-60. Interval 57-60 was chosen as an end point for comparison due to the operation's end in this range.

In this section, the term 'interval' refers to the set of performance measure values that occur for both the manual and automated systems in a particular range of simulation days. For example, 'TRWT interval 1-3' refers to the manual and automated system TRWT values that occur between days 1-3.

If the resulting p from a particular interval's chi squared comparison was not less than 0.01, the interval's values were combined with the next adjacent interval and the comparison was performed again. This comparison was performed until a significant difference (p<=0.01) was found. If there was a significant difference found within a certain interval, the next interval would be compared using the same method, but the two sets of interval values would not be combined.

For example, a chi squared comparison of the TRWT performance results of the automated and manual systems within interval 1-3 resulted in a no value for p. Therefore, the values from this interval were combined with the values from interval 4-6, producing a new interval for comparison, interval 1-6. The chi squared comparison of interval 1-6 produced p=0.1523. The interval 1-6 values were combined with interval 7-9, producing another new interval for comparison (days 1-9). For the TRWT results, intervals required combining in this manner until the interval of 1-45, which produced p=0.0015. Because interval 1-45 produced a p<=.01, interval 46-48 was compared next. Table 8 depicts the chi squared tests for TRWT results between the automated and manual systems.

The results of the contingency table/chi squared comparisons show that for TFill and RFill performance measures, there was a significant statistical difference (p<=0.01) between the manual and automated systems at interval 1-6. For the TRWT and RRWT performance measures, there was a significant statistical difference between the manual and automated systems across the broader interval of days 1-45. The complete tables for the TRWT, TFill, RRWT and RFill chi square comparisons are Tables A13, A14, A15 and A16 of the Appendix.

Table 8
TRWT Chi Squared Comparison Results

Interval ---------	P Value ----------	Action
1-3	No Value	Combined
1-6	0.1523	Combined
1-9	0.8299	Combined
1-12	0.6689	Combined
1-15	0.6586	Combined
1-18	0.8519	Combined
1-21	0.1751	Combined
1-24	0.2871	Combined
1-27	0.3000	Combined
1-30	0.2147	Combined
1-33	0.0712	Combined
1-36	0.0308	Combined
1-39	0.0178	Combined
1-42	0.0104	Combined
1-45	0.0015	---------
46-48	0.2562	Combined
46-51	0.1266	Combined
46-54	0.0679	Combined
46-57	0.0313	Combined
46-60	0.0252	Combined

Analysis of Base Results

These findings demonstrate the overall effectiveness of the automated system as compared to the manual system. These findings also suggest that early employment of the automated system is most optimal, with a statistically significant difference in automated and manual TFill and RFill rates occurring as early as interval 1-6. These findings also show the adverse impact not establishing the automated system early may have on fill rate, responsiveness and the ability to close all requisitions.

The sensitivity analysis further explains the limitations of the manual system and explores changes in system settings that would enhance manual system performance. The sensitivity analysis also explores changes in system settings that would decrement automated system performance.

Sensitivity Analysis

Sensitivity analysis was conducted to determine the combination of settings that would potentially cause the manual system to perform similar to the automated system and would cause the automated system to perform similar to the manual system. This sensitivity analysis was performed by adjusting the one or more of the variable settings described in Table 17, conducting a set of 60 simulation runs, then forming early, typical and late groups based on closure times. To form these early, typical and late groups, the method for collecting and organizing the base results described earlier in this chapter was used. The lines depicting the 'typical' groupings were used to compare performance among different parameter setting combinations.

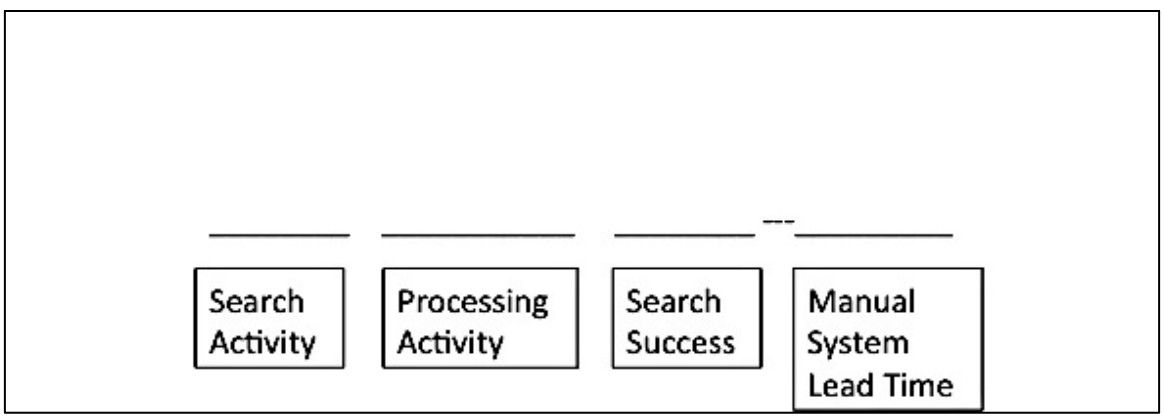


Figure 17. *Notation for Manual System Adjusted Settings*

Throughout this section, different combinations of manual and automated system settings are described. The numbers reflect those settings that have been changed from the base settings. Figure 17 reflects the notation for manual system settings. For example, a setting combination of 150100 reflects a manual system simulation set with the search activity at 150 and processing activity at 100. This setting also reflects the remaining two variables, search success and manual system lead time, remain unchanged at 0.25 and 0.5 respectively. A setting such as 150100.5-3 denotes a change in four manual system settings: search activity to 150, processing activity to 100, search success to 0.5, and manual system lead time to 3 days. A setting notation with one value, such as 100, indicates a change in the automated system's processing activity.

Throughout this sensitivity analysis, findings for RFill and RRWT adjustments reflected the findings found in TFill and TRWT adjustments, therefore, only TFill and TRWT are discussed.

TFill Sensitivity Analysis Findings

For the manual system to achieve a TFill performance similar to the automated system, the search activity required an increase from its base setting of 10 to 150 and the processing activity required an increase from its base setting of 75 to 100. At this setting of 150100, the manual system produced a superior or similar typical TFill rate compared with the automated typical base TFill rate.

Increasing the manual system's processing activity before increasing the search activity. to 120 (for example, 40100, 75120) did not result in a manual typical TFill performance superior to the automated system. Conversely, decreasing the manual system's processing activity from 75 once the search activity had been increased to 120 (for example, 12050, 12025) resulted in worse TFill performance.

Settings lower than the combination of 120100 were not affected by adjustments in search activity success or manual system lead time. At this combination, increasing the search probability of success from 0.25 to 0.5 (120100.5) resulted in a manual typical TFill performance superior to the automated typical base system and superior to the manual typical TFill performance at 150100, particularly in the 1-50 day timeframe. At the 120100.5 setting, the manual system also became sensitive to adjustments in lead time. At this setting, adjusting the manual system lead time from 7 to 2 days (120100.5-2) resulted in an improved manual typical TFill performance.

Figure 18 describes these findings. The black and red lines depict base typical TFill performances from the manual and automated systems, respectively. The line '120100.5-2' represents the manual system with the first activity set at 120, the second set at 100, search success set at 0.5 and manual system lead time set at 2. The line '120100.5' represents the manual system with the first activity set at 120, the second set at 100, with the search success set at 0.5. The line '150100' represents the manual system with the first activity set at 150 and the second set 100. All lines depict typical groupings. Whereas Figures 14, 15 and 16 have an x-axis that extends to 50, the Figure 18 x-axis ends at 14 to best show the differences in performances.

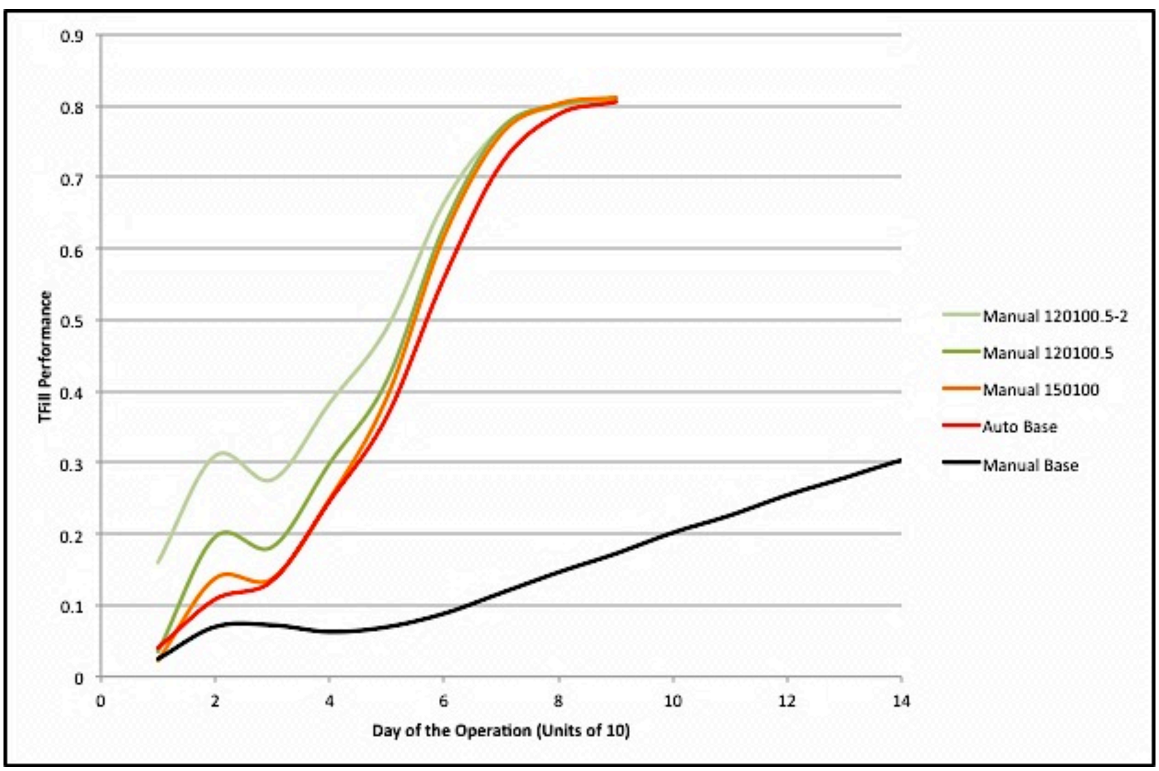


Figure 18. *TFill Typical Sensitivity Findings, Manual System Adjustments*

The automated system's processing activity was also examined to determine its sensitivity. Reducing this activity from the base settings of 75 to 5 resulted in a lower automated typical TFill performance compared to the manual system's base settings. Across the typical groups, this adjustment resulted in the automated system requiring 500-510 days to close all TFill requisitions, compared to the manual system's ability to close all TFill requisitions within a range of 391-400. The difference between the TFill performance of the two systems at these adjusted settings is graphically demonstrated in Figure 19. The lines in red and black represent the automated and manual typical base TFill performances and the line 'Auto 5' represents the automated typical TFill performance at a processing activity of 5.

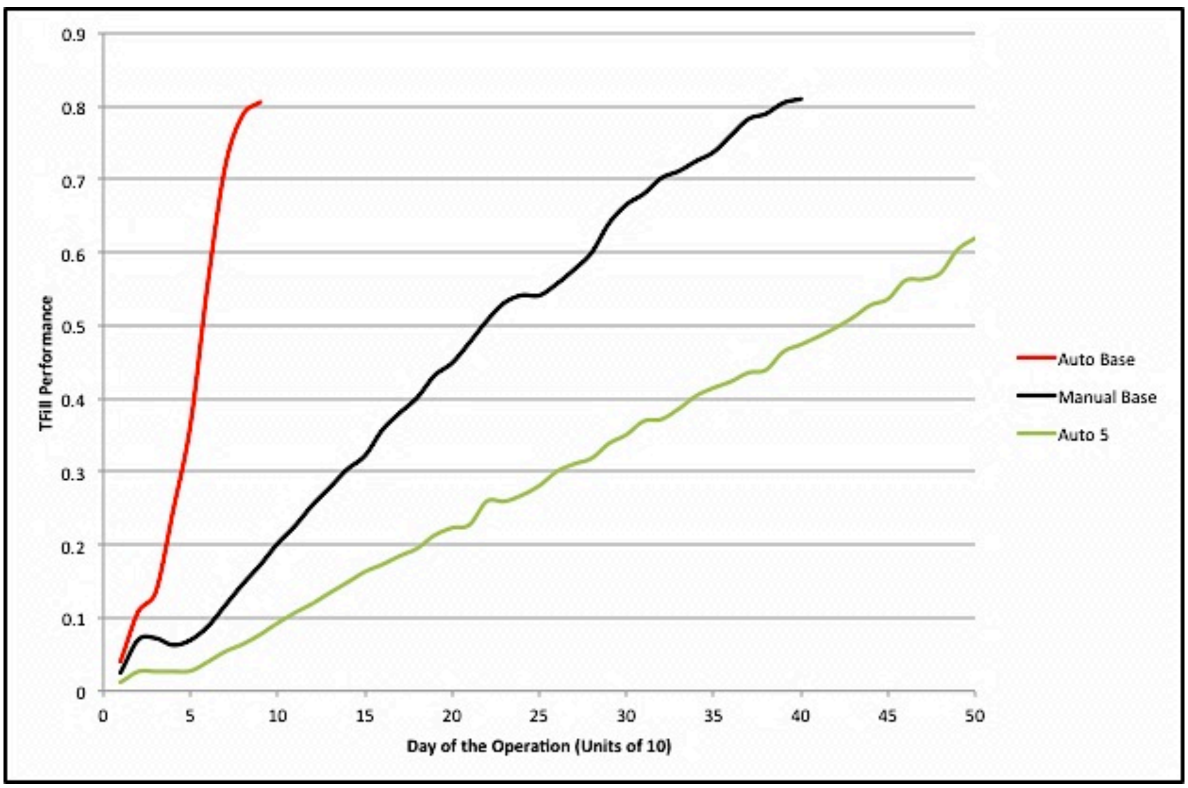


Figure 19. *TFill Typical Sensitivity Findings, Automated System Adjustments*

<u>TRWT Sensitivity Analysis Findings</u>

For the manual system to achieve a TRWT performance similar than the automated system, the search activity must increase from its base setting of 10 to 150. The processing activity must increase from its base setting of 75 to 100. At these settings of 150100, the manual TRWT performance only exceeded the typical performance of the automated system after the 21-30 day range. Also at these settings, both search success and lead time of the manual system became sensitive. Adjusting the probability of search success from 0.25 to 0.5 while decreasing lead time of the manual system from 7 to 3 days resulted in a more effective manual typical TRWT performance compared to the automated typical base TRWT performance.

Figure 20 describes these findings. All lines depicted reflect typical group performances. '150100' represents the manual system with the first activity set at 150 and the second set 100. For an adjusted setting to possess an overall better performance than the typical automated based performance, it must be lower than the red line and must end earlier or in the same range. The '150100' line remains above the red line until the 21-30 day range. The '150100.5-3' line, reflecting adjustments in all four manual settings of search activity, processing activity, search success and lead time is the typical performance that graphs lower than the automated typical base performance.

Similar to its impact on TFill, reducing the automated system's processing activity from the base settings of 75 to 5 resulted in a typical TRWT performance that was less effective than the typical manual base TRWT performance. Across the typical groups, this adjustment resulted in the automated system closing at a TRWT of 227.7 at a range of 481-490 days, compared to the manual system's closing at a TRWT of 148.4 at a range of 341-350 days. Figure 21 shows this difference in performance. The 'Auto 5' line, representing the automated typical TRWT performance at the processing activity of '5', is higher than the 'Manual Base' line, which is the manual typical base performance. The 'Auto 5' line also takes approximately 140 additional days to close all requisitions.

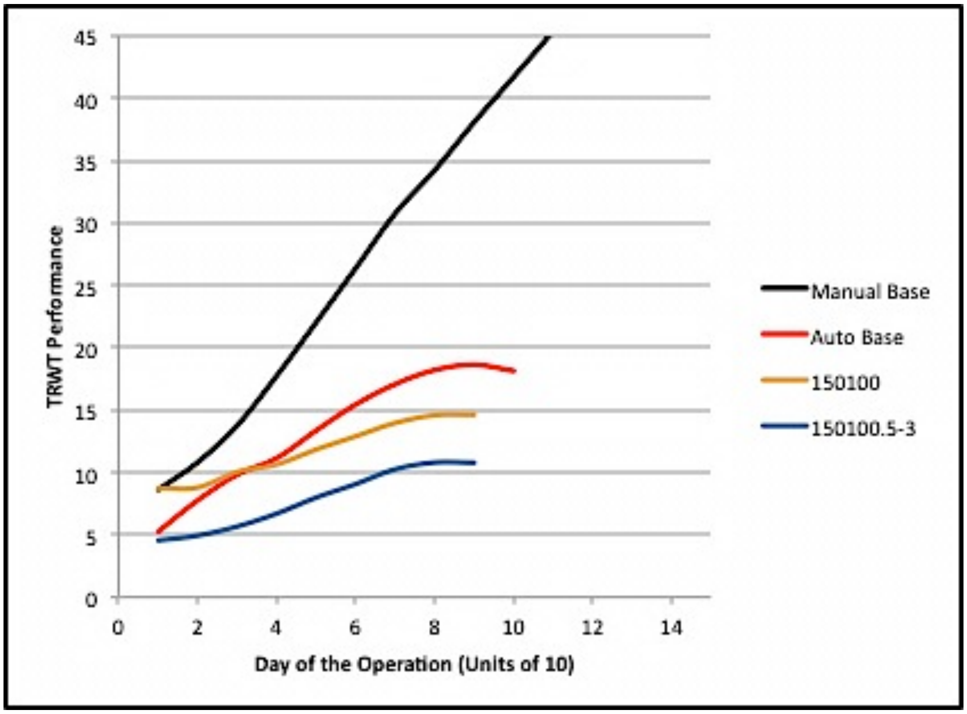


Figure 20. *TRWT Typical Sensitivity Findings, Manual System Adjustments*

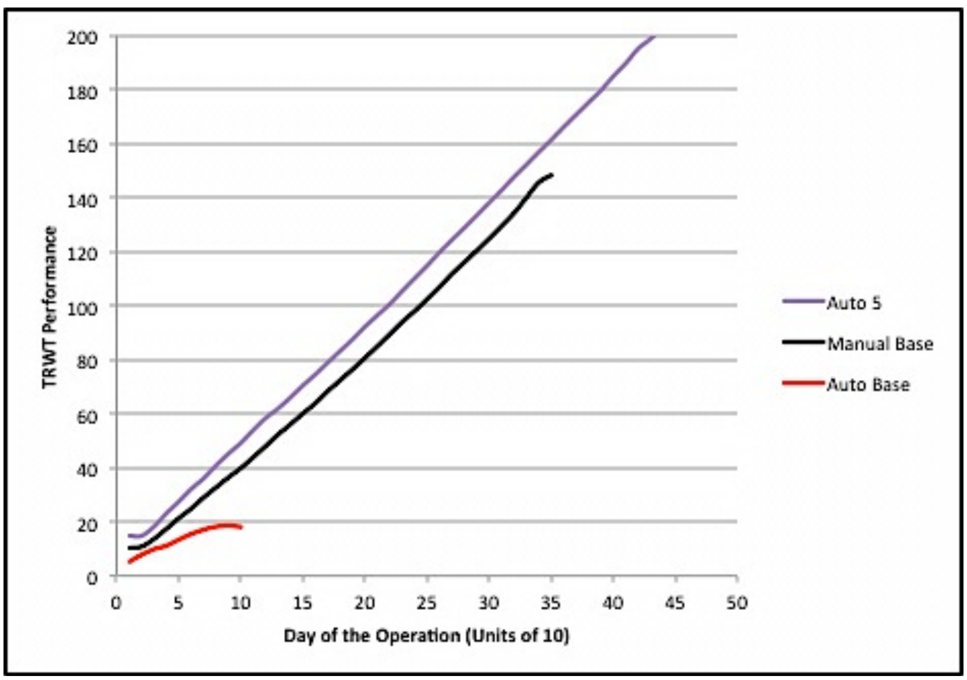


Figure 21. *TRWT Typical Sensitivity Findings, Automated System Adjustments*

Further Analysis

The manual system's search activity capacity creates a backlog that affects performance. This is caused by the search activity's difficulty maintaining a processing speed that matches the increasing rate of demand, particularly around days 18-21, as depicted in Figure 13.

To analyze the impact of queue backlog within the automated and manual system, three queues were examined: the search activity queue within the manual system (noted as Queue 1, or Q1), the processing activity within the manual system (noted as Q2) and the processing activity within the automated system (noted as Q3). For all these queues, queue backlog, or the portion of Requisition Wait Time spent in a particular queue, was computed by capturing the cumulative sum of days all requisitions closed to date spent in that queue, divided by the sum of the requisitions closed for the same date. This computation is consistent with the method for TRWT described in Chapter 3. Equation 8 depicts this computation. While Equation 8 depicts the method for computing the manual system's search activity queue backlog (Q1 RWT), this method was also used for computing manual system processing activity queue backlog (Q2 RWT) and automated system processing activity backlog (Q3 RWT).

$$Q1\ RWT = \frac{\sum Queue\ 1\ Wait\ Time\ for\ all\ Requisitions\ Closed\ to\ Date}{\sum All\ Requisitions\ Closed\ to\ Date} \quad (8)$$

At the manual typical base settings of 1075, Q1 RWT results in a backlog that begins between days 18-21 and continues to accumulate as the simulation continues. This backlog accounts for the majority of Requisition Wait Time at the base setting. As the search activity's capacity is increased, cumulative queue wait time decreases, and so does Requisition Wait Time. Figure 22 depicts the amount of Q1 RWT that comprises TRWT for two manual typical groups at the different settings of 1075 and 150100.5-3. The top half of the figure shows Q1 RWT and TRWT at the base settings of 1075. The lower half of the figure shows Q1 RWT and TRWT at the adjusted settings of 150100.5-3. At the settings of 1075, Q1 RWT accounts for a large portion of TRWT and the group closes at the range of 341-350 days with a TRWT of 144.7 and a Q1 RWT of 122.2. At the settings of 150100.5, the group closes at the range of 81-90 days with a TRWT of 11.23 with no Q1 RWT.

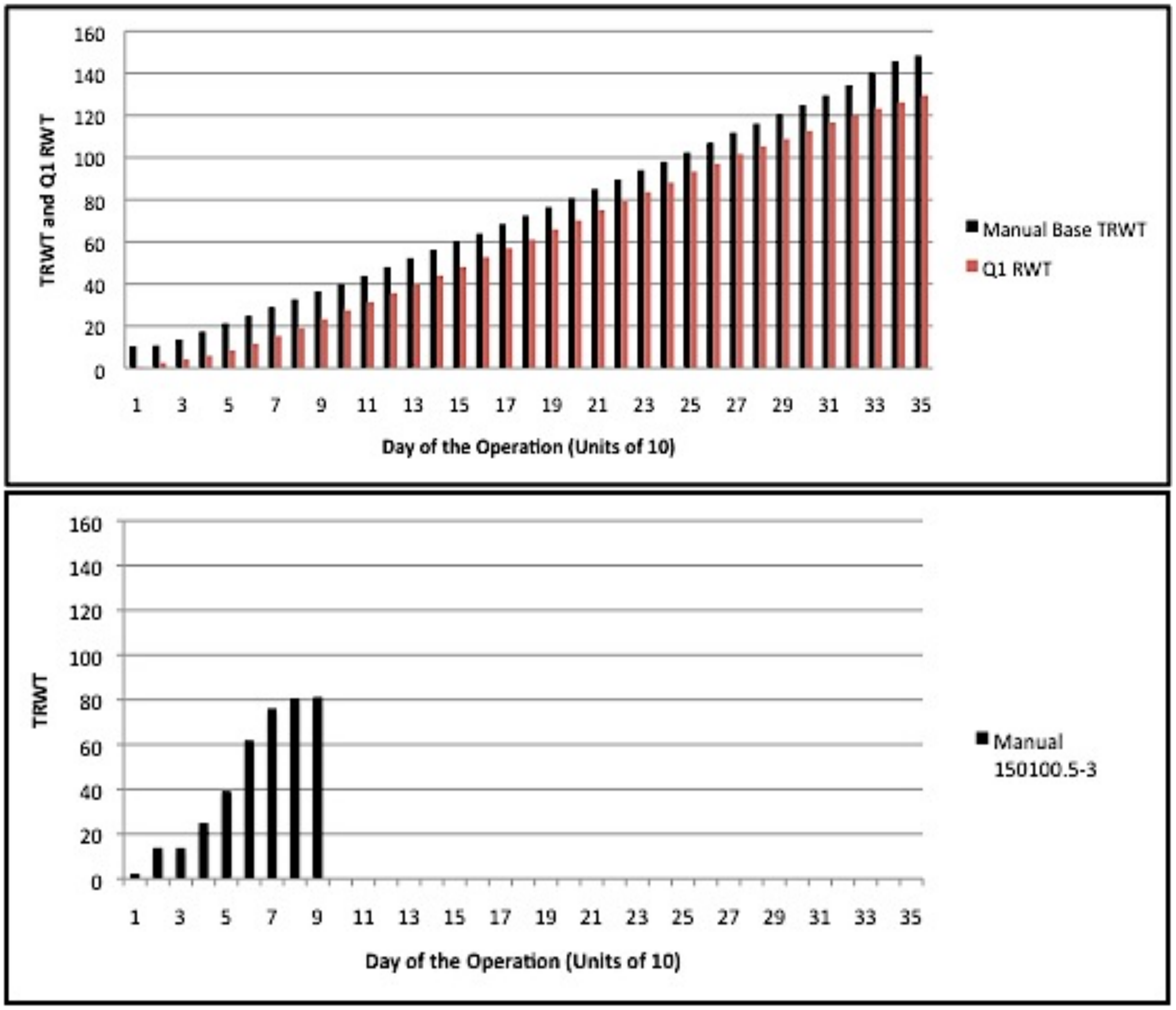


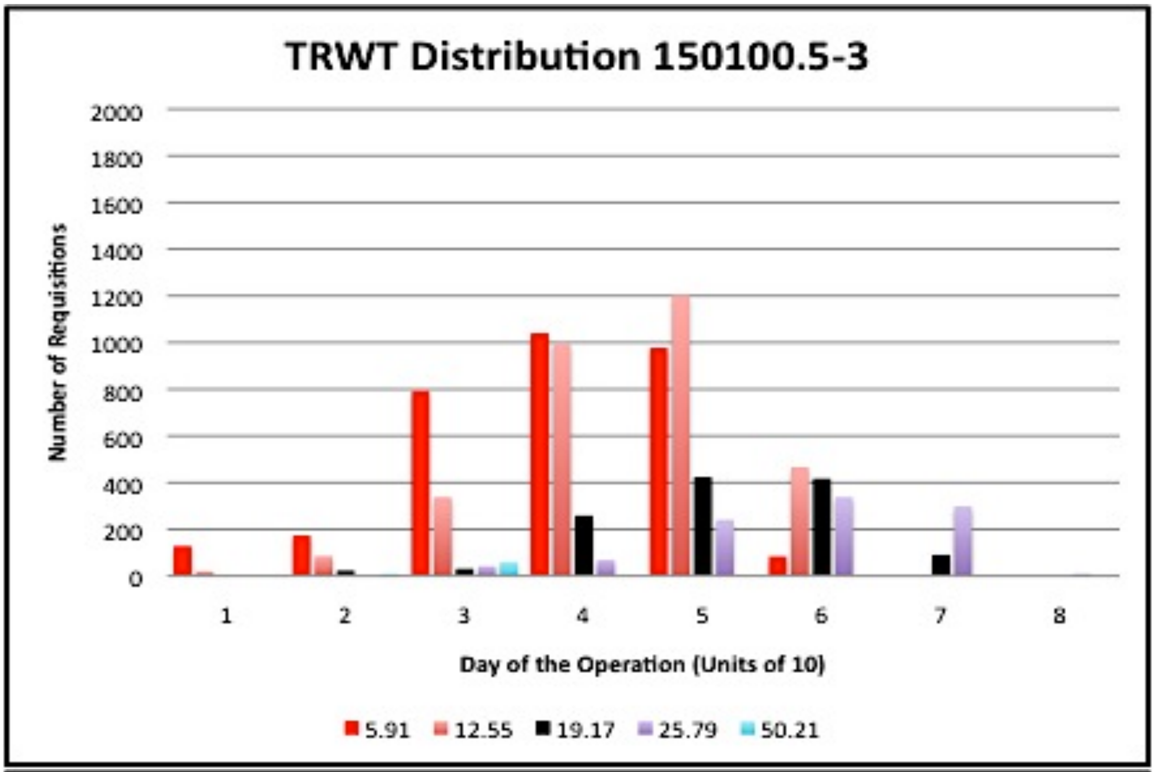
Figure 22. *TRWT and Queue 1 Requisition Wait Time at Manual Typical Base and Manual Typical 150100.5-3 Settings*

At the search activity setting of 150, search success probability required an increase from 0.25 to 0.5 and manual system lead time required a decrease from 7 to 3 days to produce a manual typical TRWT performance superior to the automated base TRWT performance. These adjustments resulted in 50% of requisitions having a 3 day lead time, which increased the amount of requisitions closing in the 3-20 day range.

Figure 23 further explains the effect adjusting search success and manual system lead time has on TRWT performance at these settings. The top half of the figure shows the manual typical TRWT distribution at 150100, the bottom half shows the manual typical TRWT distribution at 150100.5-3. The legend for both graphs depicts the breakdown of scores, for example, '5.91' represents the amount of respective requisitions that closed in 5.91 days or less. The notable difference between the two distributions is the number of requisitions that close in less than 5.91 days and between 5.91 and 12. 55. The 150100.5-3 totaled 301 requisitions in the 1-20 day period, compared to the 150100 performance of 29 in the same period. The 150100.5-3 totaled 2808 5.91 requisitions in the 21-50 day period compared to the 150100 performance of 302 requisitions in the same period. At the same time, the 150100.5-3 setting had 1565 less requisitions closing between 5.91–12.55 days in the 21-50 day period than the 150100 setting, (2539 vs 4104). The 150100.5-3 was able to increase the amount of requisitions closing in the 1-20 and 21-30 day periods by decreasing the lead time to 3 days; this increased amount of requisitions closing under 5.91 days, particularly in the 1-20 day range, enabled a faster TRWT performance line than the automated typical TRWT base performance.

Additionally, the manual system's search activity backlog has an adverse effect on TFill performance. Figure 24 depicts the effect cumulative queue 1 wait time has on TFill, with the top half depicting queue 1 wait time and TFill at 1075, and the bottom half depicting queue 1 wait time and TFill at 150100.5-3. In the top figure, at the base settings of 1075, Q1 RWT continues to rise and the manual typical base group closes at the 341-350 day range at a TFill of

0.7712. In the bottom figure, the manual typical group at 150100.5-3 has no Q1 RWT and closes at the 81-90 day range at 0.8004 TFill.



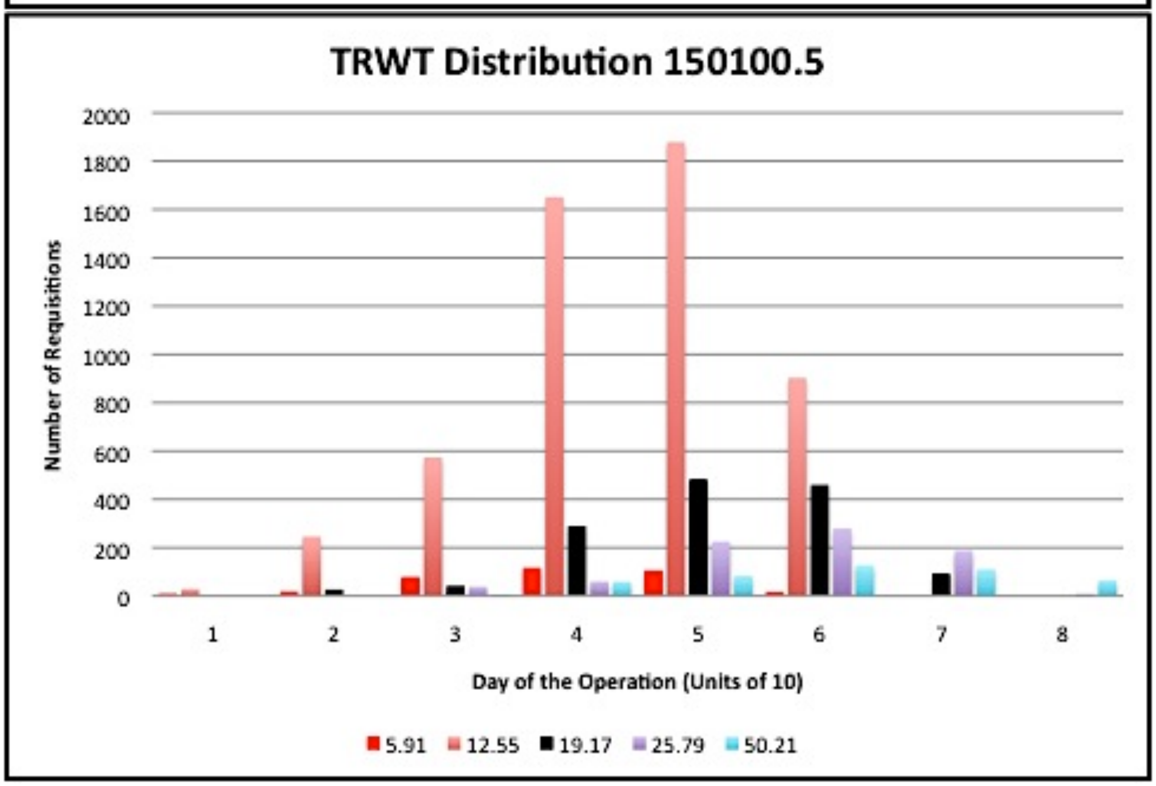


Figure 23. *TRWT Distribution of 150100.5 and TRWT Distribution of 150100.5-3*

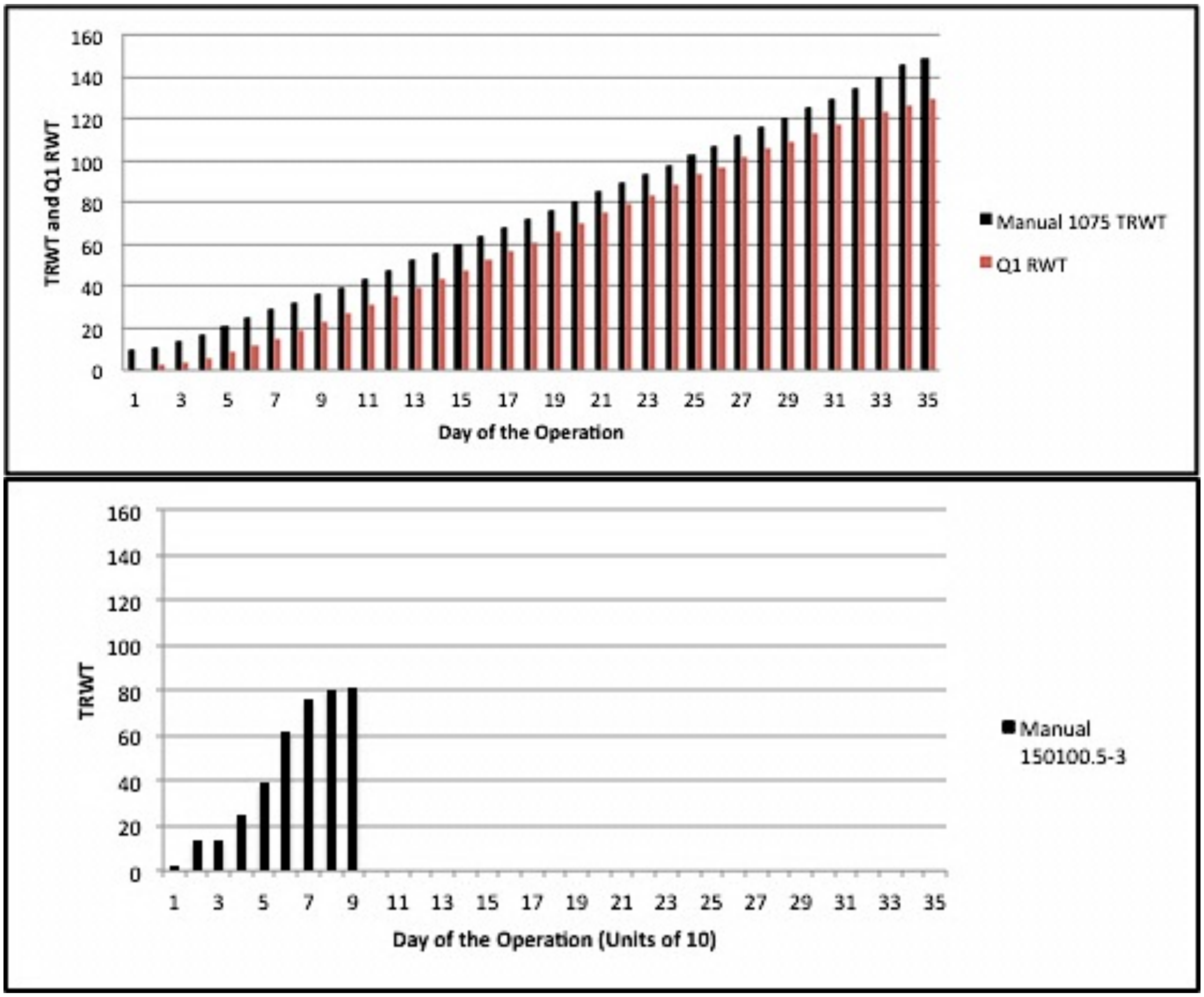


Figure 24. *TFill and Queue 1 Requisition Wait Time at Typical Base Manual and 150100.5-3 Settings*

At settings under 120, the manual system's search activity queue accumulates backlog, while the processing activity's throughput remains unaffected. Conversely, when the search activity is set to 120 or higher, decreasing the processing activity from 75 generates more processing activity queue backlog which adversely affects TRWT and TFill performance. Reducing the processing activity from 75 to 5 while keeping the search activity at a setting of 120 (a setting of '12005') results in a TRWT and TFill typical performance that requires longer to close all requisitions and performs less effectively than the manual typical base TRWT and TFill performances. Figure 25 demonstrates the difference in TFill performance.

The top portion of the figure shows the impact of processing activity queue backlog on TFill at the setting of 12005. The blue bars of the top portion indicate processing activity queue wait time (Q2 RWT). The bottom portion shows the difference between TFill typical performances of the manual system at its base setting of 1075 and the adjusted setting of 12005. The 12005 setting does not close all requisitions until days 491-500, versus the 1075 setting's closure of all requisitions around days 391-400.

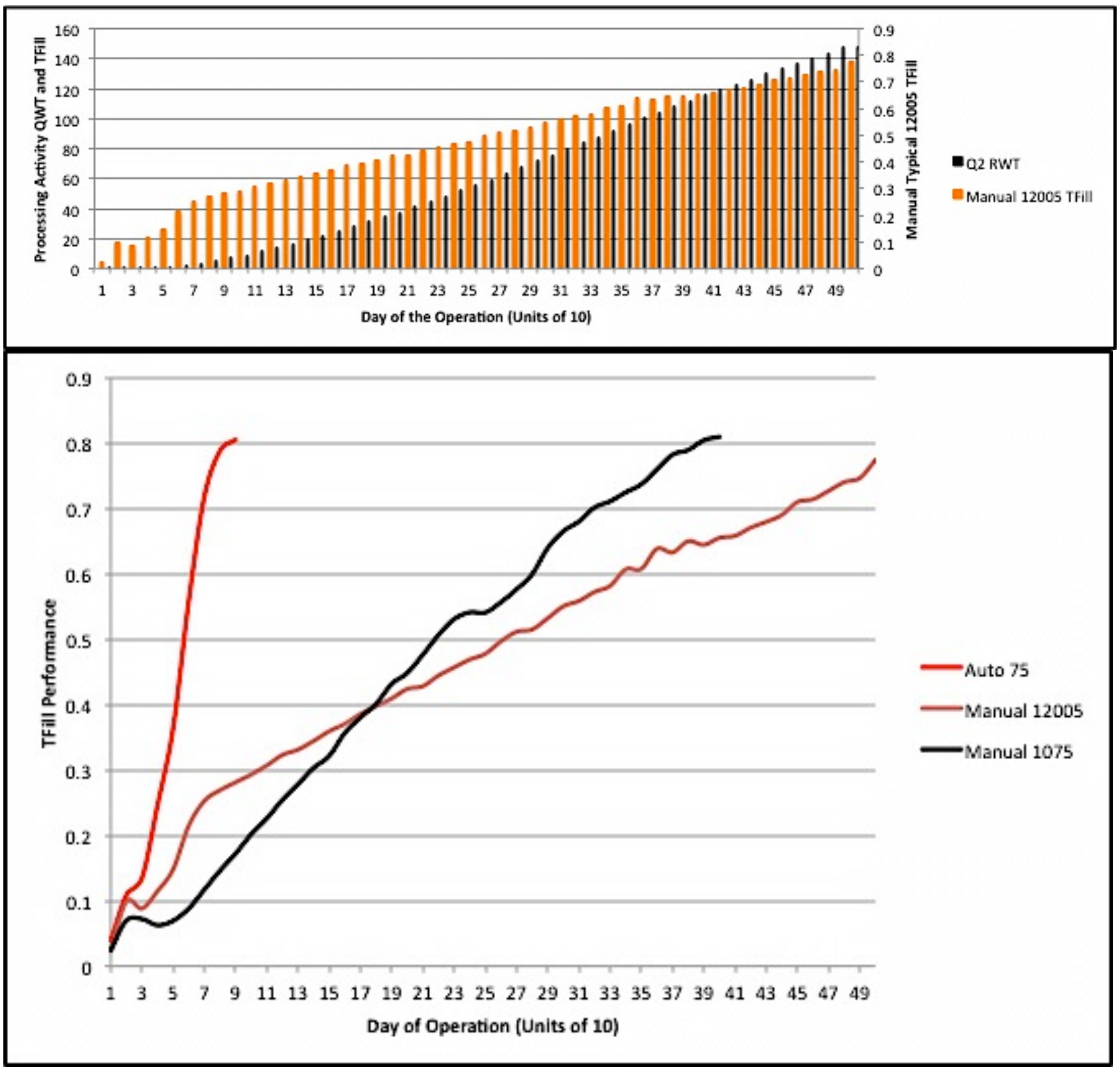


Figure 25. *Impact of Processing Activity Queue Backlog at Setting 12005 and Comparison of Manual System Typical TFill Performances at 1075 and 12005*

Adjusting the processing activity of the *automated system* results in a queue backlog which adversely effects TRWT and TFill performance in a similar manner. As the processing activity capacity for the automated system decreases, the processing activity queue wait time (Q3 RWT) increases and more of the automated requisition wait time (TRWT) is comprised of queue wait time. Figure 26 demonstrates the impact of processing queue backlog on the TRWT performance of the automated system. The top half shows the TRWT performance and queue wait time for the automated system at its typical base processing activity setting of 75. The bottom half shows the automated TRWT performance and queue wait time for the adjusted typical processing activity of 5. While there is no queue backlog at the 75 setting, there is significant queue backlog at the 5 setting. Additionally, these patterns of cumulative queue wait time and RWT resemble the results in Figure 22.

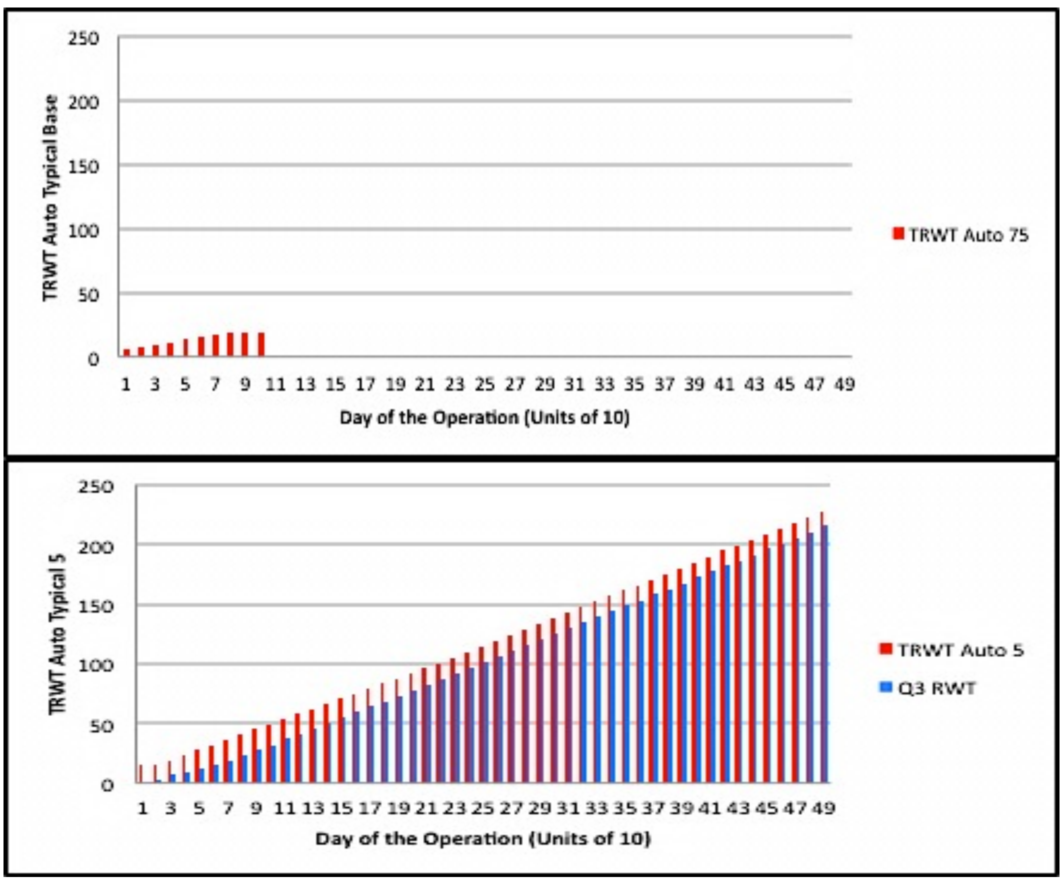


Figure 26. *TRWT and Queue 3 Requisition Wait Time at Typical Automated Base and 5 Settings*

Conclusion

This chapter presents findings towards Contribution #1: The Overall Impact of the Automated System and #2: The Optimal Range to Deploy the Automated System. These findings show that at the base settings for both systems, the automated system closes total requisitions faster, possess lower Total Requisition Wait Time (TRWT) and greater fill of total requisitions (TFill) in a shorter amount of time. Similar results were found among the performance measures for readiness driver requisitions (RRWT and RFill). The difference between the TFill and RFill performances of automated and manual systems was found to be statistically significant ($p<=0.01$) at interval 1-6. With the automated system producing a higher TFill and RFill performance, these findings suggest that establishing the automated system in this range contributes to better performance. Conversely, these results show the impact of not deploying the automated system within this range; if the automated system is not deployed or established, the performance difference averages a 200 day difference in total closure time, and a 113 day difference in TRWT at the time of closure. Within the 81-100 day range, a likely window for expeditions to end, the automated typical performance closes all requisitions while the manual performance achieves 21.92% TFill.

Contributing to the performance differences between the automated and manual systems is the capacity of the manual system's search activity. At its base setting, this queue accumulates backlog as demand increases around days 18-22; this queue wait time accounts for the majority of TRWT time and negatively impacts TRWT and TFill performance. Once the capacity of this search activity increases to 150, the manual system achieves a performance comparable with the automated system. Conversely, if the automated system's processing activity is decreased, the automated system produces a performance that resembles the manual system.

Once the manual system's search capacity is increased to 120, the probability of search success and manual system lead time contribute to improving performance, as the assumed manual lead time averages a shorter lead time than the lead time from the wholesale supply system.

These findings provide approaches on how to examine an existing military requisitioning system and evaluate methods to sustain supply chain performance while transitioning from a manual to automated system in an expeditionary setting. Ideally, the deployed retail location would be able to establish and operate an automated system at the onset of the deployment. However, it is more realistic that the deployed retail location will have to operate with a manual system for some period of time as it transitions from a home station to a deployed environment. Therefore, upon notification of deployment, the search activity capacity, search success probability and manual system lead time should be assessed or estimated. If the probability of search success is low, or the manual system lead time is higher than the average of the wholesale system, or both, then one method to improve overall effectiveness is to eliminate the local search activity and establish a dedicated sponsoring activity at home station early, even prior to the deployment if possible. This method would eliminate the backlog that accompanies the local search activity and would enter requisitions into the wholesale supply system much quicker. Figure 27 depicts this method.

Another method would be to increase the search process capacity to keep pace with demand, as seen in the sensitivity analysis discussion. While this is a considerable required increase (150 from 10), it would accommodate the increase in demand and would eliminate the backlog, enabling higher headquarters to locate items earlier, or the sponsor activity to enter requisition information into the wholesale systems earlier.

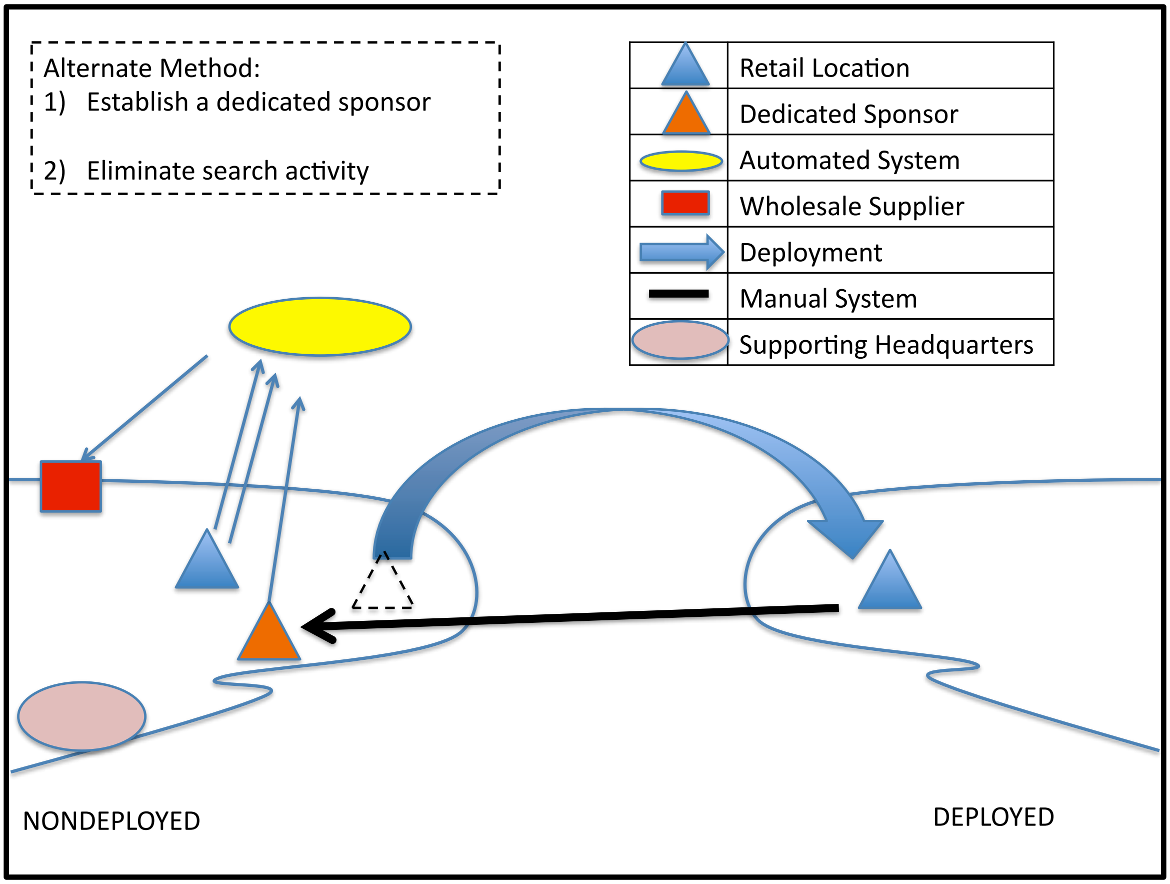


Figure 27. *Alternate Method for Improving Manual System Performance*

Finally, another method would be to either increase the breadth of the Authorized Stockage List, either in its pre-deployment state, or by deploying a supplementary ASL. It may not be feasible to increase the breadth prior to the deployment, as some of these items may not be demanded in the home station environment; this is discussed further in Chapter 5. However, simulations such as these could be used to identify potential supplementary ASL packages for shipment shortly after an expeditionary unit's deployment; these packages could reduce the amount of requisitions within the manual pipeline while the automated system is being established. The breadth of the ASL, combined with the impact the manual system has on overall fill rate, will be examined in Chapter 5.

CHAPTER 5. DECOUPLING POINT RESULTS AND ANALYSIS

This chapter presents the results and analysis on the performance of the automated and manual systems' ability to respond to demand that cannot be met from on-hand stocks. This chapter supports Contribution #3, Knowledge about the Decoupling Point.

The literature defines the decoupling point as the point at which specific market demand diverges from the previous strategic forecast. Decoupling points are defined as "the point at which the preponderance of demand is met from wholesale stocks (Oloruntoba & Gray, 2006)" and therefore reflect a particular supply system's ability to respond to this divergence. This research implemented the decoupling point concept by capturing the point at which fill rate from Authorized Stockage List (ASL fill rate) is exceeded by the fill rate from the respective manual or automated system. The system that could reach this point earlier responded to the difference between forecast and actual demand requirements, achieved a higher total fill rate and therefore was more effective.

For this research, four leading categories of commodities were used to examine the automated and manual system's abilities to respond to deployed demand requirements. The automated system was able to respond to demand not met by on-hand stocks more effectively than the manual system. The automated system attained decoupling points for the four leading groups of requisitions within 30-44 days at a Total Fill Range of 0.3591 - 0.5492; this was inside the expeditionary window of 60 days. The manual system attained decoupling points for these groups with 74-143 days at a Total Fill Range of 0.3965 - 0.6105; this was outside the expeditionary window of 60 days.

These findings complement the findings in Chapter 4, which suggest that establishing the automated system early is most optimal. These findings are also valuable in understanding how the weaknesses of the manual system, when combined with the limitations of Authorized Stockage Lists (ASL), may result in vulnerability that degrades effectiveness. This chapter also provides ideas on how to mitigate the limitations of ASL and improve the manual system's ability to respond to demand that cannot be met from on-hand stocks.

This chapter is organized in the following manner: background on how ASL is evolved in a non-deployed environment, background and definition on the decoupling point concept, the method to identify decoupling points and the responsiveness of the automated and manual systems, results of the four decoupling points, analysis of the ASL shortcomings and alternative methods to addressing manual system performance and ASL limitations. The chapter concludes with suggestions for future study and research.

Background

Before exploring the contributions of ASL to fill rate with the manual or automated system, it is necessary to provide several key points and background information. This section will cover total fill rate, how ASL is developed and evolved, and the Dollar Cost Banding Algorithm (DCB). This chapter will also use terms that were previously defined in Chapter 3.

The Role of Authorized Stockage Lists

As described in Chapter 2, when Army units deploy for contingency operations, they deploy ASL as well to meet demand requirements. However, ASL inevitably cannot meet all demand that arises, so the unit must rely on a complementary supply system—a connection with a wholesale supplier—to meet demand that exceeds the quantities or types that are available through ASL. Described another way, demand that cannot be met through ASL must be met through the manual or automated system. Figure 28 describes this process of encountering demand, determining if it is available through ASL and issuing the item from ASL or sending the requisition to a higher source. For the manual system, this higher source of supply could either be the deployed unit's home station higher headquarters or the wholesale system; for the automated system, this higher source of supply is the wholesale system.

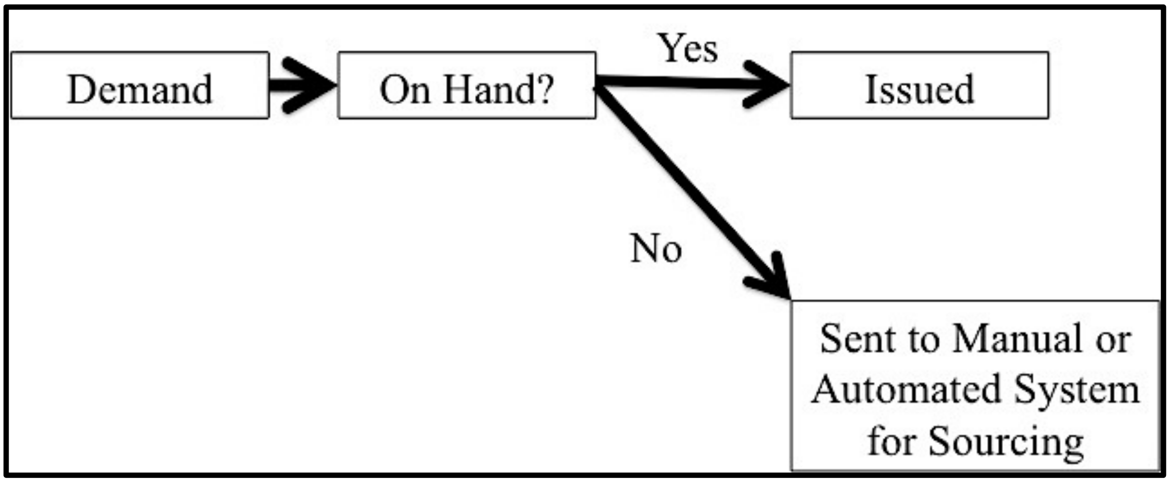


Figure 28. *Initial Demand Flow within Military Supply Chain*

'Total Fill Rate', as used in this chapter, is different from the TFill performance measure used in Chapters 3 and 4. TFill describes the fill rate achieved by the respective automated or manual system, based on those requisitions that could not be filled by ASL and must be filled by a higher source of supply. Total Fill Rate is sum of the fill rate met from ASL and the fill rate (TFill) provided by the respective manual or automated system used. Fill rate from ASL is determined by dividing the sum of requisitions closed to date that were filled by ASL by the sum of total requisitions opened to date. The equation for Total Fill Rate is computed using Equation 9.

$$Total\ Fill\ Rate = \ (ASL\ fill\ rate)\ + TFill\ (from\ manual\ or\ automated\ system) \qquad (9)$$

Factors Causing Differences between Non-deployed and Deployed Demand Patterns

Ideally, the ASL would possess sufficient depth and breadth to meet all demand during a contingency operation; this would eliminate the dependency on a wholesale supplier and the need to re-establish the automated system. However, Army Materiel Command (AMC) evolves and manages all Army Supply Support Activities based on past demand history, not a forecast of where the unit may deploy. Therefore, units deploy with ASL that previously met the DCB criteria for stocking. However, while deployed, the unit may experience a different demand pattern and may have limitations in meeting demand through ASL alone. Factors that may cause a difference between non-deployed and deployed demand patterns and requirements can be categorized as operational factors, environmental factors, and utilization factors.

--*Operational factors* refer to differences within missions a unit is performing. For example, an mission requiring a higher amount of night operations may translate into an increased or new requirement for repair parts supporting night vision and illumination capability. In other circumstances, a mission dependent on a higher usage of encrypted and sensitive communications devices could require different and unique communications repair parts. A third example is a mission in a permissive, stable environment when the unit takes advantage of the situation's predictability to address backlogs of vehicle services. This scenario would increase the demand for vehicle service parts.

--*Environmental factors* refer to physical aspects of the operation's geographic area. For example, a hot and polluted environment could result in an increased need for filters, while operating in extreme cold weather may causes gauges to freeze and crack at an accelerated rate.

--*Utilization* refers to the frequency, rate and tempo in which equipment is employed. Utilization factors are largely driven by the difference between non-deployed and deployed operations. In a home station/non-deployed training status, a unit generally functions within a "normal duty day" which lasts 8-9 hours, 5 days a week. Periodically during the non-deployed setting, the unit will conduct training exercises, during which it extends the duty day to a 24 hour period. The duration of training exercises vary; a unit may conduct training exercises at its home station, or may deploy to a training center. However, the preponderance of the unit's time non-deployed is spent following the "normal duty day". In contrast, in the deployed setting, the unit uses its equipment to conduct and sustain missions 24 hours a day, 7 days a week.

In addition to the operational and environmental impacts on utilization, utilization may also vary based on the available architecture within the deployment setting. In the non-deployed setting, the unit operates from garrison facilities, such as fixed buildings, computers, power and communications, using its organic military equipment, such as tents, radios, vehicles, and generators during training only. In contrast, during a deployment, a unit leaves its fixed garrison facilities and uses a greater portion of its military equipment to sustain operations. A vehicle, generator or radio may be used weekly in a non-deployed setting, but may be required daily in a deployed setting.

The Dollar Cost Banding Algorithm

AMC uses the Dollar Cost Banding Algorithm (DCB) to develop and evolve ASLs for over 100 Army Supply Support Activities (SSAs) while they are in a non-deployed status. AMC also uses the DCB algorithm to review the ASLs of SSAs while they are deployed. The algorithm was developed by the Rand Corporation in 2002 to replace the previous velocity management method of managing inventory and to provide more flexibility by looking at demand instead of a Days of Supply (DOS) concept. The goal of the DCB algorithm was to expand breadth and depth of deployable inventories while holding down costs and size for a deployable ASL. The Army G-4, the directorate of Army-wide logistics plans and policy, approved DCB as a "policy option" on October 12, 2000; two years later the Army G4 made DCB mandatory for ASL reviews. DCB generally leads to the inclusion of more small, low-cost items with at least one high-priority demand in an SSA's ASL (Girandini et al, 2004).

The DCB algorithm categorizes items under review by their individual price and priority. Within this research, all requisitions were high priority, as the unit examined was deployed for Operation Unified Response (OUR) to provide hurricane relief support in Haiti; therefore, the low priority requisition criteria have been removed. Based on price, the item's demand history determines whether or not it becomes a candidate to be stocked.

Table 9 provides the specific algorithm for high priority items. Items are first categorized by price: items less than $10, between $10.01 and $100, between $100.01 and $1000, and greater than $1000. Next, the quantity of demands within a year is assessed. The notation within the 'DCB Criteria to Stock Item' row refers to the number of demands that must occur within a year for the item to be considered as a candidate. For example, the notation '2/1' refers to two demands in a one-year period. If the prerequisite quantity of demands for a particular item is met within the review period, the item becomes a candidate for stocking. For example, at the time of the ASL review, Item X prices at $5.71 and has had 4 demands within one year. Therefore, Item X becomes a candidate for stocking.

Table 9
Dollar Cost Banding (DCB) Algorithm

Dollar Cost Banding (DCB) Algorithm				
Price of Item	<$10	$10.01 - $100	$100.01 - $1000	>$1000
DCB Criteria to Stock Item	2/1	3/1	6/3	9/3

Items that become candidates may or may not ultimately be stocked. The DCB provides specific rules for items that should not be added to ASL: non-essential, bulky (glass, furniture, computer cases), items approaching obsolescence, oversized items, restricted items (fuel, petroleum, terminal items), structural shapes (iron and steel) and cosmetic items (vehicle hoods, cushion assemblies). Further, the unit's budget could be a constraint; it may not be affordable toadd the desired items, regardless of a demand history that supports doing so.

The Decoupling Point Concept

Chapter 1 introduced how several researchers have used the decoupling point concept to describe how a particular supply chain responds to demand. Hoekstra & Romme (1992) identified the decoupling point as a point of separating a supply chain's ability from precision in planning from its ability to actually satisfy customer orders. Martin & Towell (2000) described two decoupling points, the *information decoupling point* and the *inventory decoupling point*. The *information decoupling point* identifies how far and fast information concerning specific market demand moves upstream. The *inventory decoupling point* is associated with the concept of postponement and identifies how far downstream generic inventory can be reconfigured to meet specific demand. Oloruntoba & Gray (2006) highlighted the role of these decoupling points in assessing the effectiveness of the humanitarian assistance supply chain.

While the military supply chain is currently not built to perform postponement at the SSA level, examining the speed at which demand is realized upstream is a relevant method to assess the effectiveness of the automated and manual systems. Specifically, applying the concept of the information decoupling point can assist in determining strengths and weaknesses of the ASL during a military expedition and how the respective wholesale system used addresses these strengths or weaknesses. An ASL that contributes to a higher Total Fill Rate for a longer period of deployment time is a better forecast than an ASL that results in a lower Total Fill Rate. At the same time, a wholesale supply system's fill rate is also an indicator of a supply chain's ability to sense and respond to demand. If wholesale supply system A meets deployed demand faster than wholesale supply system B, then wholesale supply system A is more effective.

To apply this concept while examining the data, three points (D1, D2 and D3) were defined for identification and comparison:

--D1: Depending on the quality of the forecast and the evolution of ASL, there may occur a point at which ASL fill rate begins to decrease and requisitions being passed to wholesale begin to increase. This point was defined as D1, the highest point of ASL fill rate. This point indicates a separation from the ability to forecast true demand through ASL from those requisitions that must be passed to a wholesale source. This point also signifies the point at which the supply chain's dependency on the wholesale level begins. From this point, the rate at which the slope of the ASL fill rate line becomes negative indicates the degree of this dependency.

--D2: The point at which automated or manual fill rate percentage surpasses the ASL fill rate percentage was identified as D2. This point also describes the system's responsiveness to demand that was not addressed or accommodated through the ASL. A system that achieves this point earlier than another system would indicate a more responsive system.

--D3: The point at which the wholesale supply system fill rate surpasses the original highest point of ASL fill rate (D1) was identified as D3.

Figure 29 depicts an example of how D1, D2, and D3 could appear graphically. The blue bars depict ASL fill rate and red bars depict fill rate from the respective system used (automated or manual). In this example, D1 occurs on day 8 with the highest ASL Fill achieved throughout the graph at 0.3153. D2 occurs on day 41, when the automated fill of 0.2729 surpassed the ASL Fill of 0.2615. D3 occurs on day 46 when the automated fill of 0.3204 surpasses D1, the high point of ASL fill rate at 0.3153.

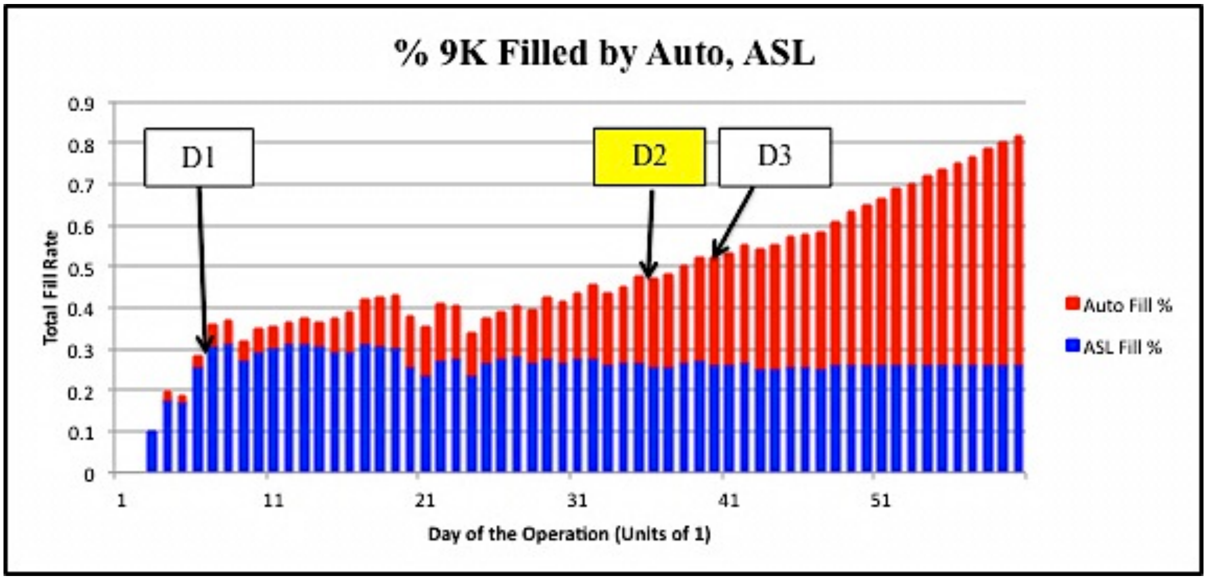


Figure 29. *Graphic Example of D1, D2 and D3 Decoupling Points*

It is important to note that although requisitions end on day 48 in this simulation, the achievement of D3 is not dependent on the time requisitions end. ASL contributions to fill rate do cease shortly after the end of requisitions, as ASL requisition processing time is much less than the wholesale system lead time. Wholesale system fill rate percentage continues to increase beyond day 48, as requisitions previously passed to the respective wholesale system continue to close and contribute to TFill. It is also important to note that those requisitions received prior to the expedition's end at day 60 are more relevant to the operation's success.

Method to Identify Decoupling Points

To generate data for decoupling point analysis, 60 runs were conducted at both the automated and manual system base settings (75 and 1075, respectively). For each set of 60 runs, the runs were put in order by the day of the closing total fill rate. Based on this order, runs 1-6 were collected as the "early" group, runs 27-32 as the "typical" group and runs 55-60 as the "late" group. This method of organizing the data into early, typical and late groups is the method used in Chapter 4.

The requisitions within the typical groups were examined for their characteristics. The total requisitions were found to be composed of 16 different commodity groups. Four commodity groups were found to possess 75.37 – 76.93% of the total requisitions. These groups were Sets, Kits and Outfits (i.e. Tools) (9B), Communications and Electronics Repair Parts (9G), Tactical Vehicle Repair Parts (9K) and Fabrication Items (9T). Of these four groups, commodity group 9K possessed the highest percentage with 28.04 - 28.62%. Table 10 depicts the respective percentages of these four commodity groups.

Table 10
Composition of Typical Group Requisitions by Commodity Type

Commodity Type	Description	% Manual Total Requisitions	% Automated Total Requisitions
9B	Sets, Kits, Outfits (i.e. tools)	14.83%	14.67%
9G	Communications & Electronics Repair Parts	18.36%	18.48%
9K	Tactical Vehicle Repair Parts	28.04%	28.62%
9T	Fabrication Items & Hardware	14.13%	15.16%
Subtotal		75.37%	76.93%

9B, 9G, 9K and 9T decoupling points D1, D2, and D3 were computed and graphed for manual and automated systems. These results were each graphed within the 1- 60 day range due to the length of the operation. These results were then compared. Because it contained the most requisitions, 9K is highlighted individually in the results and analysis section.

Decoupling Point Results

Overall, the automated system reached decoupling points earlier than the manual system, enabling a higher overall fill rate.

--The base automated typical system reached decoupling points for the four leading commodities for requisitions within the 30-44 day range and Total Fill range of 0.3591 - 0.5492.

--The base manual typical system reached decoupling points for these commodities within the 74-143 day range and a Total Fill range of 0.3965 - 0.6105.

--All of the decoupling points reached by the automated system occurred within the 60-day timeline of the expedition.

--All of the decoupling points reached by the manual system occurred beyond the 60-day timeline of the expedition.

Table 11 depicts the performance of the automated and manual systems for the commodities 9G, 9B, 9K and 9T. The left half of the table lists the days the automated system reached D2 for the four commodities, the right half lists the manual system's performance for D2 for these commodities. The far right column of the table lists the difference between the two systems by decoupling point.

Table 11
Four Leading Commodity Decoupling Points

Commodity	Automated System Day D2 Achieved	Total Fill Rate at D2	Manual System Day D2 Achieved	Total Fill Rate at D2	Difference in Days
9G	30	0.3708	74	0.3965	44
9B	34	0.3591	106	0.4412	72
9K	41	0.5344	139	0.6105	98
9T	44	0.5462	143	0.5951	99
				Average Difference	78.75

This section demonstrates the 9K decoupling point results to provide an example of how individual decoupling point results were computed. (The 9K decoupling point results will also be used later in this chapter when exploring methods to supplement ASL).

--The base automated typical system reached D1 at day 8 when ASL fill rate reached 0.3153. It reached D2 on day 41 when the base automated system fill rate reached 0.2729, surpassing the ASL fill rate of 0.2615. It reached D3 on day 46 when the automated system fill rate reached 0.3204 and surpassed D1.

--The base manual typical system reached D1 at day 18 when ASL fill rate reached 0.3051. The base manual typical system did not reach a D2 or D3 in the 1-60 day range. The base manual typical system reached a 0.1052 fill rate on day 60.

The 9K decoupling point results are depicted in Figure 30. The top half of the figure depicts D1, D2 and D3 for the 9K base typical automated system. The bottom half depicts D1 for the 9K base typical manual system. The base typical manual system did not achieve D2 or D3 within the 1- 60 day range.

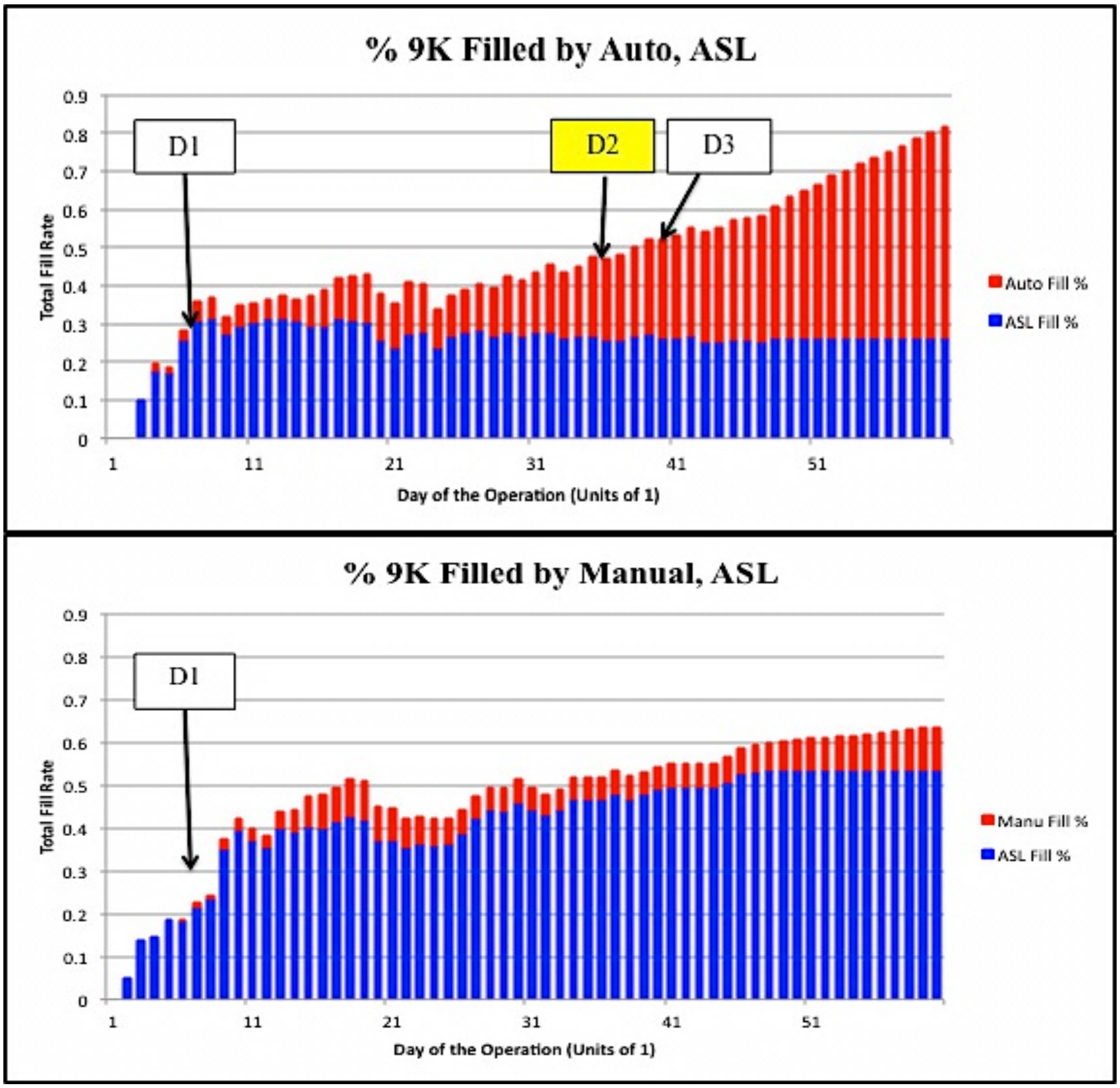


Figure 30. *Total 9K Fill Rates for Automated and Manual Systems*

9B, 9G, 9K and 9T Demand Analysis

Prior to analyzing the rate and order of the decoupling points, it is important to describe the demand patterns for these commodities. From the beginning of the operation, 9G (Communications and Electronics Repair Parts) and 9K (Vehicle Repair Parts) were in high demand. Figure 31 depicts the demand slopes of the categories 9G, 9B, 9K and 9T. During days 1-19, 9G experienced a growth slope of 17.78 and 9K experienced a growth slope of 20.22 with 9T and 9B at 5.72 and 5.44 respectively. These demand slopes can be explained by the system they support. 9G repair parts sustain communications and night vision devices, which are often individual items within the Infantry Brigade Combat Team. A high number of users deploy with communications and night vision devices and use them immediately; this suggests why 9G demand was high. This also suggests why the 9G slope changed the least between days 1-19 and days 20-39; these systems were deployed and used early. 9K supported the unit's fleet of vehicles and rolling stock (eg, trailers, generators, forklifts). Approximately 40% of the unit's vehicle fleet deployed by air and arrived within the 1-14 day range; the remainder arrived by ship with the 15-25 day range. This may have contributed to 9K's high demand pattern early with even larger growth beginning in the 18-22 day range. 9B (Tools) and 9T (Fabrication Items and Equipment) experienced a similar but lower demand pattern. The increase in 9B and 9T requisitions may be related to increase in 9K demand; 9B and 9T items support the performance of maintenance on vehicles, rolling stock and other ground support items.

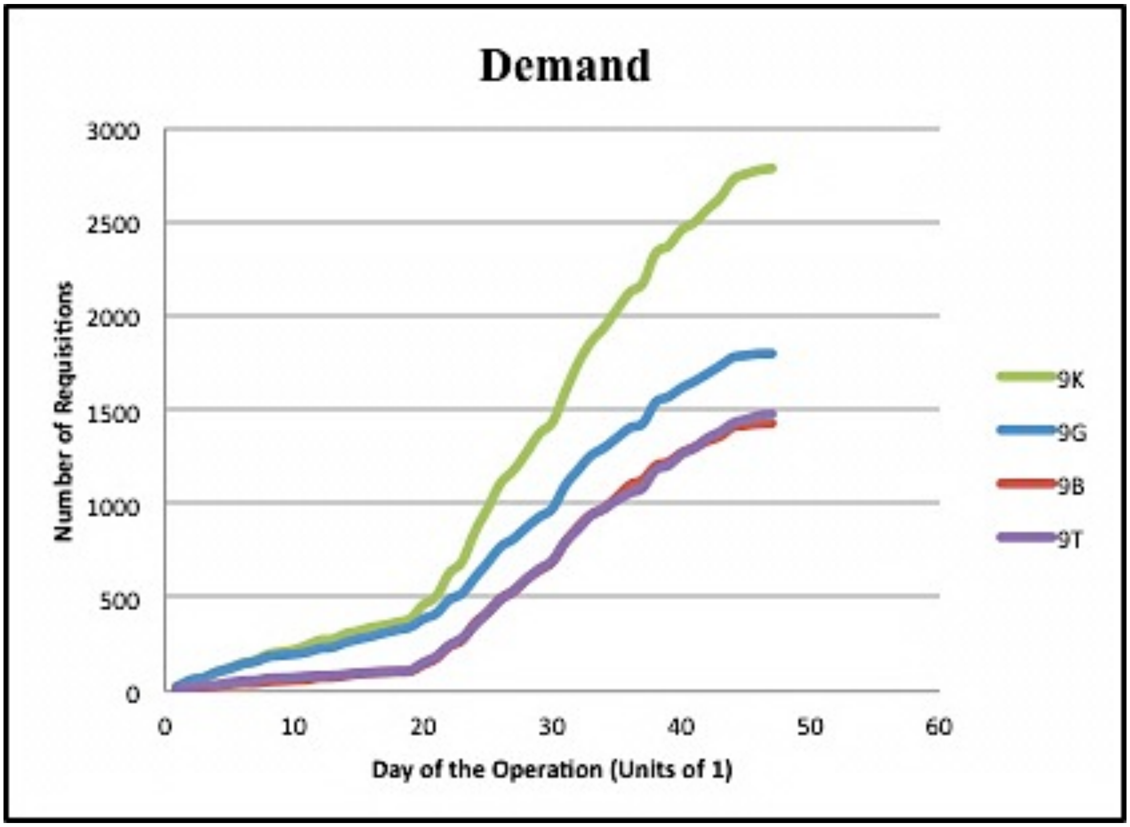


Figure 31. *9B, 9G, 9K and 9T Demand Patterns*

Decoupling Point Analysis

The rate at which a particular commodity realizes its decoupling point is primarily influenced by the ASL's ability to meet demand as it increases. Figure 32 depicts the effect ASL fill rate has on the decoupling point order. This figure depicts the ASL fill rate for the categories 9K, 9T, 9B and 9G over the 1-60 day range. Respective increases of demand cause 9B, 9T and 9K ASL fill rates to decrease within the range of days 20-27. Past day 27, the bottom to top order in which the lines appear is the sequence in which the decoupling points occur: 9G, 9B, 9K and 9T. Although 9T appears on the figure before 9K, the 9K decoupling point occurs before 9T, separated by one day in the automated system and four days in the manual system.

This section provides an analysis of each category's ASL limitations and provides possible factors to understand the pattern of the four decoupling points.

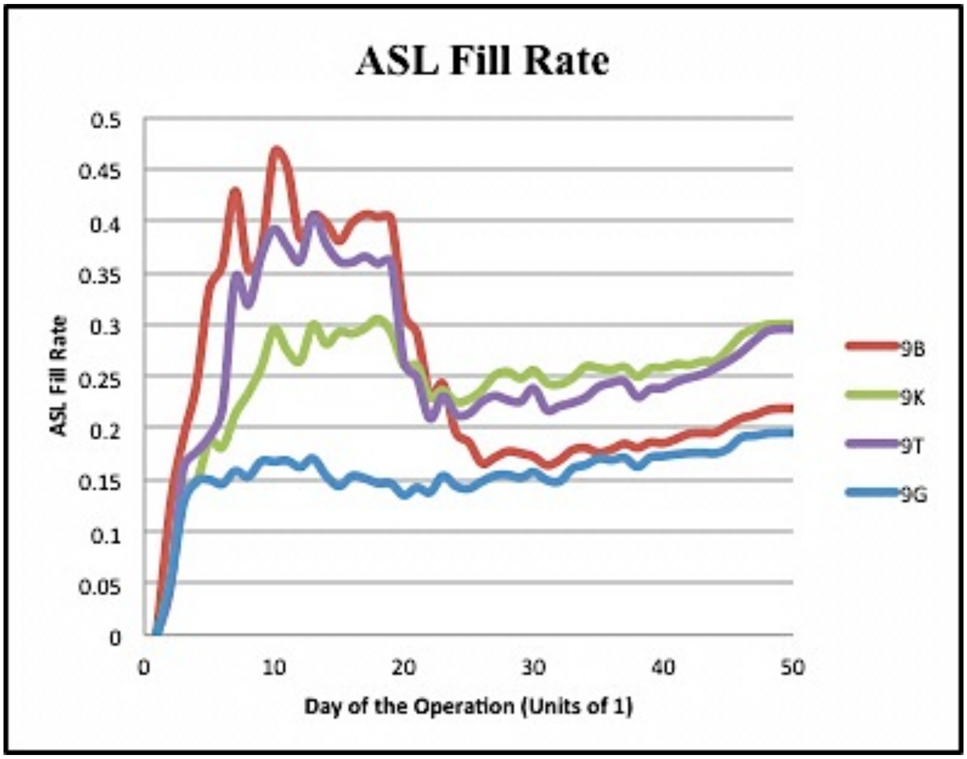


Figure 32. *ASL Fill Rates for 9K, 9T, 9B and 9G*

<u>9G (Communications and Electronics):</u> 9G experienced the lowest ASL fill rate throughout the simulation. The ASL could not fill 9G repair parts for night vision and communications: antennas, antenna mounts, batteries, relays, electrical testing devices and switches.

With a high amount of users, Infantry Brigade Combat Teams deploy and use these systems rapidly upon operations, incurring an immediate increase in utilization. 9G's low ASL fill rate may have been caused by the tendency of non-deployed units to focus on vehicle and major equipment services versus individual radios and night vision devices. This tendency would affect the readiness of these latter systems and would inhibit building the necessary demand history required to build the ASL. Due to its early demand and ASL limitations, more 9G requisitions were passed to wholesale within the 1-19 day range than the other categories. 9G passed 16.88% of its total requisitions within this range, compared to 13.26%, 7.41% and 6.89%

for 9K, 9B and 9T respectively. This early passing of requisitions resulted in 9G realizing its decoupling point earlier than the other categories.

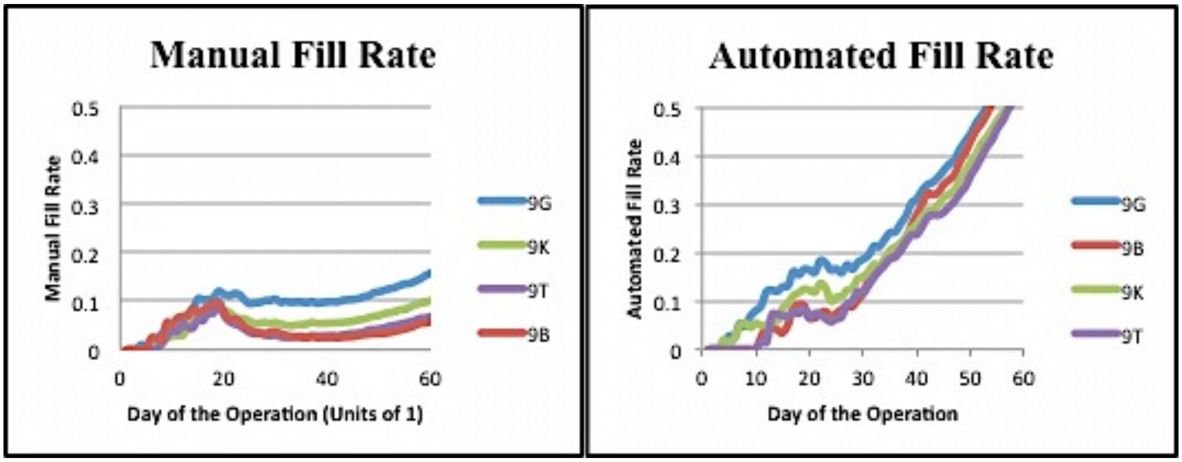
9B (Tools) and 9T (Fabrication Items): Categories 9B and 9T experienced high ASL sensitivity as demand increased. With both categories experiencing the same volume of demand, 9B experienced greater sensitivity; its ASL fill rate decreased to a level similar to 9G's ASL fill rate, causing it to be the second decoupling point realized. 9B's ASL shortcomings were likely driven by a higher amount of maintenance operations on all types of equipment. Of the demand 9B ASL could not fill, 31.74% was due to 17 different types of hoses, hand tools, lighting and motion detectors, equipment required to perform maintenance functions.

9T's ASL fill rate was less sensitive to demand, dropping to resemble 9K's fill rate. Of the demand 9T ASL could not fill, 35.40% was due to 11 different types of packing and gasket materials. This reflects the increase of breadth in fabrication from non-deployed to deployed operations. Fabrication allows units to adapt to deployed environments by producing items such as security gates, weapon mounts and equipment racks. Fabrication also enables units to sustain equipment readiness by producing items that are unavailable and have long lead times. Between categories 9B and 9T, the need to perform maintenance and repair functions is likely greater than the need for fabrication operations. This would contribute to 9B's greater ASL sensitivity to increased demand compared to 9T.

9K (Vehicle Parts): 9K's lesser amount of sensitivity may be due to vehicle operations being the focus of non-deployed readiness, which would cause demand history to be more robust. 9K ASL shortcomings were from vehicle systems failures, such as engine electrical and fuel systems, power transmissions and brakes, that may have been caused by increased utilization and Haiti's hot weather. Because 9K requisitions represent the highest volume of all requisitions, this demand possesses the greatest potential for generalizability.

The respective ASL limitations contributed to the order of the decoupling points, regardless of the automated or manual system. However, the automated system responds to the ASL limitations more rapidly than the manual system. While ASL limitations determined the order in which the decoupling points were realized, the manual or automated system determined the rate and dispersion at which the decoupling points were reached. Figure 33 demonstrates this. The left portion of the graph depicts the manual system fill rate for the four categories for days 1-60. The right portion shows the automated system fill rate for the four categories in the same range. Within both systems, 9G fill rate grows more rapidly the other categories due to its low ASL fill rate. As discussed earlier, 9G's low ASL fill rate passes more requisitions to the wholesale system (automated or manual) in the early days of the operation and therefore achieves the highest fill rate within both the manual and automated systems. The blue line in each portion indicates 9G's growth in fill rate compared to the other categories.

Figure 33 also demonstrates how the respective system used affects the rate and dispersion of the decoupling points. Within the automated system, the fill rates of all categories decrease with the surge of demand around day 20. The categories recover around day 27 and continue their increase, achieving steeper fill rate slopes. Within the manual system, the fill rate of the four commodities decrease during the 20-50 day range due to the queue backlog impact on processing time. 9G is affected the least by this queue backlog, as it passes the most requisitions to the manual system early. As demand increases, more of these requisitions are caught in the manual system's search activity backlog. Once the queue backlog begins to clear, these categories' manual fill increase at similar rates and realize decoupling points based on their ASL fill rate. While the order of the decoupling points does not change, the search activity's limitations in processing requisitions, combined with the increased demand, causes the decoupling points to be realized later, across a longer range.



	Manual	Automated
9G	74	30
9B	106	34
9K	139	41
9T	143	44

Figure 33. *Manual and Automated System Fill Rates for 9G, 9K, 9T and 9B*

It is significant to note that the manual system's search activity functions in a first in, first out manner. Future research could assign the search activity a priority method of processing based on attribute.   Assigning priority to 9G, 9K or other categories of requisitions could be modeled to evaluate change in the manual system's ability to realize the respective decoupling points.

ASL Depth and Breadth Analysis

The previous section analyzes 9B, 9G, 9K and 9T ASL limitations in terms of fill rate. This section examines the 9B, 9G, 9K and 9T ASL characteristics by breadth and depth. *Depth* refers to an item carried on the ASL but was not on hand at the time the requisition was submitted to the SSA. *Breadth* refers to an item not carried on the ASL at the time the requisition was submitted to the SSA. Table 12 depicts the results of the depth and breadth analysis. Depth and breadth shortfalls were identified for the manual and automated systems. Within each system, total and 9K shortfalls were further identified. The top portion of this table lists depth shortfalls, the bottom portion lists breadth shortfalls. The columns identify the respective system (manual vs. automated) and the rows identify the population examined (total vs. 9K). For example, 35.72% of the manual system's total shortfalls were due to depth.

Table 12
Depth and Breadth Analysis of Requisitions Not on Hand at Time Required

	Manual	Automated
Depth		
Total	35.72%	33.83%
9K	38.39%	35.25%
Breadth		
Total	64.28%	66.17%
9K	61.61%	64.75%

Breadth shortfalls demand history was further analyzed against the Dollar Cost Banding (DCB) criteria. For the total amount of breadth shortfalls, 86.68% - 88.29% met DCB criteria. For the total amount of 9K breadth shortfalls, 85.95% - 86.05% met DCB criteria. These findings indicate that either the deployed demand pattern differed from the non-deployed demand pattern, or that some items, although they qualified as candidates to be stocked, were not stocked by exception after the 407th Brigade Support Battalion's review in June 2009. A review of the breadth shortfalls shows they did not fall into the DCB exceptional non-stocking criteria of oversize, obsolete, cosmetic or hazardous, discussed earlier in this chapter. One possibility for non-stocking could be unit budgetary constraints at the time of the ASL review. Another possibility could be that items were demanded in the past, but at a lesser priority. Under DCB, items requisitioned at a lesser priority require more demands in the evaluated period to qualify for stocking. A full review of the 407th BSB's past demand history from several years prior to the deployment would be required to confirm these assumptions. However, if the items were required previously but at a lower priority, this would still indicate a difference in demand pattern between their non-deployed and deployed settings.

The price distribution of breadth shortfalls was also examined to assess the range of prices for items that met DCB criteria. Table 13 describes this distribution. For each price range, total and 9K breadth shortfalls for manual and automated systems were examined. In this table, the column cells list the number of requisitions that met the DCB within the respective price range, with the percentage of the total requisitions listed in parentheses. For example, within the less than $10 range, 209 breadth shortfalls met DCB criteria for stocking which accounted for 94.57% of the total breadth shortfalls within this price range.

Table 13
Price Distribution of Breadth Shortfalls Meeting DCB Criteria

	<$10	$10.01 - $100	$100.01 - $1000	>$1000
Manual Total	209 (94.57%)	212 (87.96%)	97 (69.28%)	22 (73.33%)
Auto Total	166 (100%)	182 (94.30%)	66 (67.34%)	16 (53.33%)
Manual 9K	46 (93.87%)	91 (89.21%)	32 (78.04%)	10 (62.50%)
Auto 9K	42 (100%)	73 (92.40%)	30 (75.00%)	8 (47.05%)

Breadth shortfalls were also analyzed for common characteristics. Throughout the total breadth shortfalls, six categories of items each possessed at least ten different item types. These six categories accounted for 21.58% - 21.72% of the total types and 23.02% - 23.65% of the total breadth requisition shortfalls. Four of these item categories—filter elements, gaskets, hoses and seals—could possibly be manufactured by units as they are needed. Units equipped with fabrication trailers manufactured small items, such as 782nd Brigade Support Battalion during Operation Enduring Freedom in Afghanistan (Nelsen, 2010). Future research could explore the cost-benefit analysis of equipping expeditionary logistics units with additive manufacturing ('3D printing') to address the difference between non-deployed ASL limitations and deployed demand requirements. The average price range of $14.42 - $134.02 for these four item categories initially suggests that the cost of adding manufacturing capability at the unit may be less expensive than the cost of shipping low-cost items depending on the volume of demand. Producing closer to the point of need may also increase responsiveness in an emergency situation. Table 14 depicts the common characteristics of breadth shortfalls across the leading commodity types of 9B, 9G, 9K and 9T; these common characteristics could serve as a starting point for such a future area of study.

Table 14

Common Characteristics of Breadth Shortfalls

Item	# of Manual Types	# of Automated Types	Manual Requisitions	Automated Requisitions	Price Average
Filter Element	39	39	345	392	42.55
Gasket	14	14	134	143	14.42
Hose	19	20	173	186	146.84
Light	10	10	71	72	69.76
Seal	14	14	129	167	134.02
Switch	20	20	218	232	93.5
Subtotal	106	106	999	1120	65.28
% of Overall Total	21.72%	21.58%	23.02%	23.65%	

9K Breadth Shortfalls Requisition Wait Time/Readiness Driver Analysis

The 9K breadth shortfalls were also analyzed to determine the cost and feasibility of delivering a supplementary ASL that would offset the vulnerability of the manual system and the limitations of existing ASL. This supplementary ASL would deliver a package of readiness driver requisitions to the deployed Supply Support Activity prior to their being demanded with the overall purpose of increasing Total Fill Rate.

For this analysis, 9K breadth shortfalls that were both readiness drivers and required more than 30 days of Requisition Wait Time (RWT) were first identified. Table 15 describes the distribution of these requisitions. Within this population, the requisitions exceeding 30 days accounted for 92.40% of the 9K total requisitions. This amounted to 580 requisitions at a total price of $177,419.13. This price does not include costs of storage, shipping and transportation. For feasibility, it was assumed that Army Materiel Command would centrally maintain this supplementary ASL and would require 7 days for shipping to the deployed unit. Items within this supplementary ASL were coded as ASL for computation purposes. The results of receiving the supplementary ASL on day 7 were graphed and compared with previous manual and automated performances to determine the impact on Total Fill Rate.

Table 15
RWT Distribution for 9K Readiness Driver/Breadth Shortfalls

RWT	Requisitions	% 9K Total
201-300	134	22.15%
101-200	265	43.80%
91-100	15	2.48%
81-90	22	3.64%
71-80	14	2.31%
61-70	25	4.13%
51-60	27	4.46%
41-50	29	4.79%
31-40	28	4.63%
21-30	21	3.47%
11-20	22	3.64%
<10	3	0.50%

Figure 34 compares the Total Fill Rate of the typical manual 9K system at the base settings (depicted in the top graph) with the Total Fill Rate of the typical manual 9K system with the supplementary ASL (depicted in the bottom graph). Both charts depict results within the 1-60 day range due to the relevancy of fill rate attained during the length of the expedition. For the manual system at the base settings, the highest points of total fill rate occur at day 19 (0.3954) and day 60 (0.4009). For the manual system with the supplementary ASL, the total fill rate achieves 0.5104 on day 19 and 0.6348 on day 60. This is a difference of 0.1115 and 0.2324 between the respective points. It should be noted that the manual system fill rate, depicted by the red bars, do not change between top to bottom. However, the ASL fill rate, depicted by the blue bars, does change based on the delivery of the supplementary ASL.

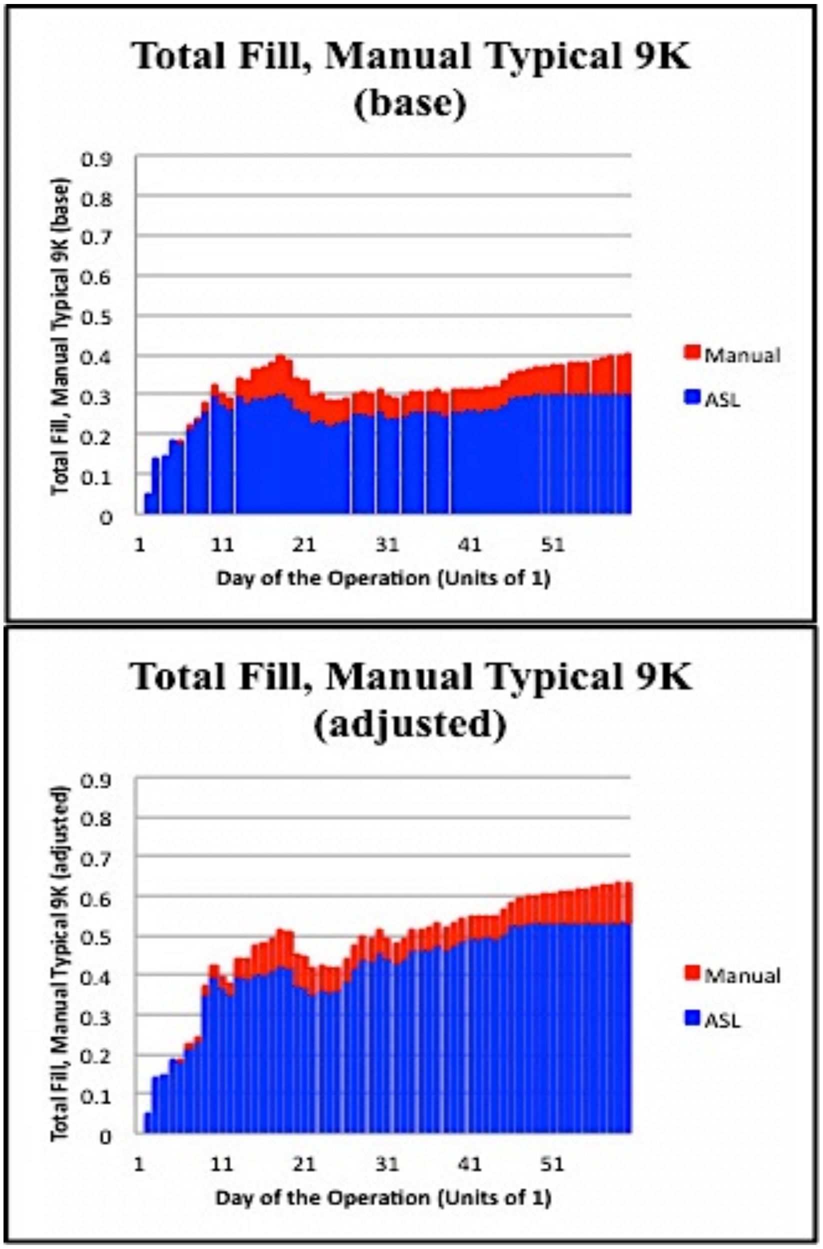


Figure 34. *Comparison of Total Fill, Manual Typical 9K (base) with Total Fill, Manual Typical 9K (adjusted)*

Figure 35 compares the Total Fill Rate of the typical manual 9K system with the supplementary ASL (depicted in the top graph) with the Total Fill Rate of the typical automated

9K system at the base settings (depicted in the bottom graph). For the manual system with the supplementary ASL, the Total Fill Rate highest points occurred on day 19 and day 60 at 0.5104 and 0.6348 respectively. For the automated system at the base settings, the Total Fill Rates on day 19 and day 60 were 0.1240 and 0.8105 respectively. The manual typical adjusted 9K system achieves a higher Total Fill Rate until day 47. From days 48-60, the automated typical unadjusted 9K achieves a higher Total Fill Rate.

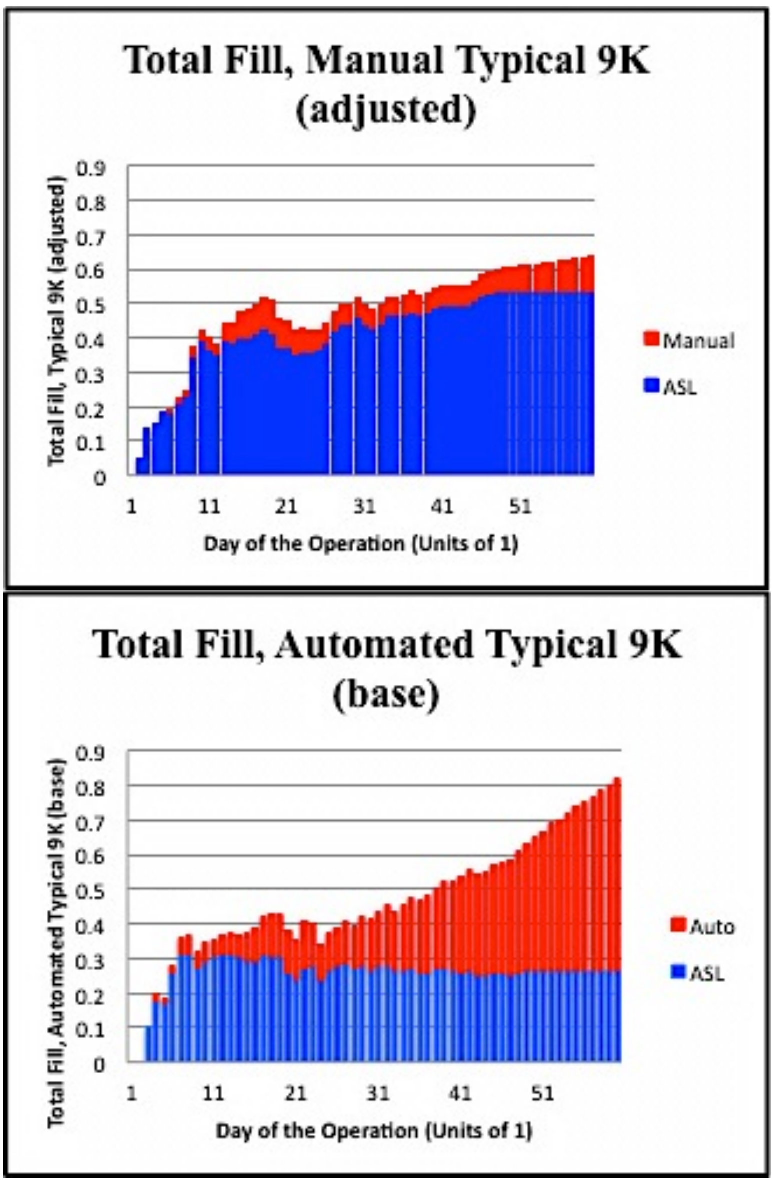


Figure 35. *Comparison of Total Fill, Manual Typical 9K (adjusted) with Total Fill, Manual Typical 9K (base)*

The significance of these results is the supplementary ASL's ability to improve performance in the short range and make up for the manual system's shortcomings. However, in the longer range, the automated system continues to perform at a higher Total Fill Rate than the manual system, even when the manual system receives a supplementary ASL. These findings are related to the TFill findings and analysis in Chapter 4. The manual system, due to its limitations in search activity processing, has a much slower improvement in TFill over time compared to the automated system. While the supplementary ASL mitigates these limitations in the short range, it does not in the long run. Adjustments to the manual system's base settings, in conjunction with receiving supplementary ASL, may result in a manual system performance that resembles the automated system; this may be an area for future research.

Conclusion

This chapter presents the results and analysis on the performance of the automated and manual systems' ability to respond to demand that cannot be met from on-hand stocks. In doing so, this chapter presents findings toward Contribution #1 (The Overall Impact of the Automated System), Contribution #2 (The Optimal Range to deploy the automated system), and #3 (Knowledge concerning Decoupling Points). These findings show that at base settings, the automated system was able to respond to demand not met by on-hand stocks more effectively than the manual system in the four leading categories of requisitions. This equated to a higher Total Fill Rate among these groups for the automated system within the expeditionary operational window of 60 days. These findings complement the findings in Chapter 4, which suggest that establishing the automated system early is most optimal. These findings are also valuable in understanding how the weaknesses of the manual system, combined with the limitations of Authorized Stockage Lists (ASL), may result in vulnerability that degrades effectiveness.

This chapter also provides ideas on how to mitigate the limitations of ASL. These include using increased utilization rates and simulation to further explore differences between non-deployed and deployed demand patterns. Further study on this difference could support cost benefit analysis of maintaining centralized contingency stocks of repair parts, and equipping expeditionary sustainment forces with increased manufacturing capability or additive (3D) printing capability.

Finally, this chapter also provides contributions towards areas of generalizability, in terms of the difference between non-deployment and deployed demand patterns and characteristics, and potential factors impacting these patterns and characteristics. These areas of generalizability will be further discussed in Chapter 6.

CHAPTER 6. AREAS OF GENERALIZABILITY

This chapter provides the potential generalizability of this research towards other military operations and NGO disaster relief operations. In doing so, it combines knowledge how the existing model functions and performs, as described in Chapters 3, 4, and 5 with the literature review and framework of disaster relief provided in this chapter. For future military operations, the existing model was found to be generalizable in terms of process structure, general knowledge of the effectiveness of the automated system, general knowledge of the repair parts makeup of demand and general knowledge of Authorized Stockage List (ASL) limitations. Less generalizable for future military operations were specific demand characteristics, which will be impacted by operational, environmental and utilization factors, as well as the type of unit deployed. For disaster relief operations, the existing model was found to be generalizable in terms of general knowledge of the effectiveness of the automated system, process structure of the warehouse, Authorized Stockage List and search activities. Less generalizable for disaster relief operations were the upstream process structure and specific demand characteristics.

This chapter is organized in the following manner: an explanation of the critical definitions within disaster relief, a discussion of the framework for disaster relief operations, literature review, a discussion of the similarities between military emergency and disaster relief supply chains and a discussion on the potential generalizability of this study.

Definitions

Disaster Relief Cycle

It is relevant to understand that relief and recovery efforts, while providing different functions, may occur simultaneously. On the other hand, reconstitution efforts begin later, based on conditions that must be set through assessment, political decision-making and budgeting.

Within research, disaster management is organized to four phases: preparedness, response, recovery and mitigation (Natarajarathinam et al; Howden, 2009). These four phases are depicted in Figure 36. The relationship of relief to recovery and reconstitution operations is captured in Figure 37. In short, relief is a subcomponent of the response phase and reconstitution is a subset of the recovery phase. It should also be noted that response and recovery phases can overlap; this overlap is referred to as the transition period.

The response phase focuses on saving lives and stopping further damage for those affected by the disaster. Recovery differs by involving the community and adopting a farther outlook. Relief operations may last days or months; recovery operations may last years. While logistics are critical throughout all phases, they are more critical during the response phase, as lives are at stake. Figure 38 depicts the relative duration of each phase and the criticality of commodities and supply chain performance (Howden, 2009).

Reconstitution involves the formal rebuilding and reestablishment of infrastructure to include housing areas. Similar to the nature of recovery operations, it has a much longer timeframe (Howden, 2009).

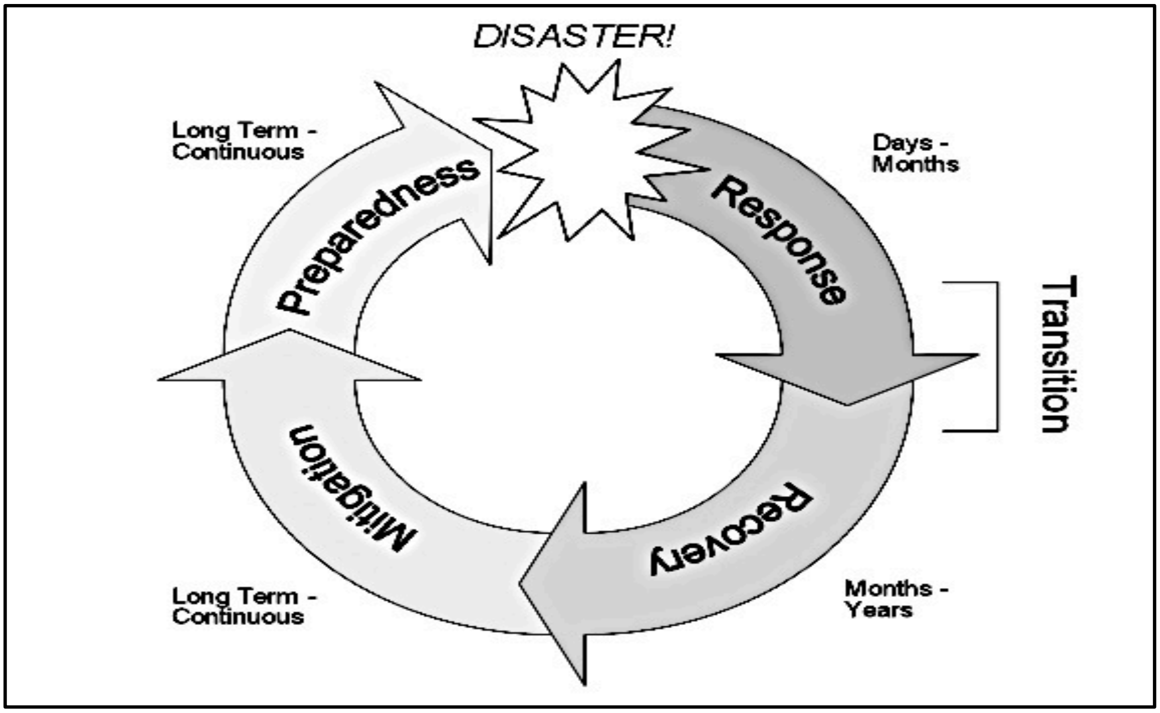


Figure 36. *Phases of Disaster Management (Howden, 2009)*

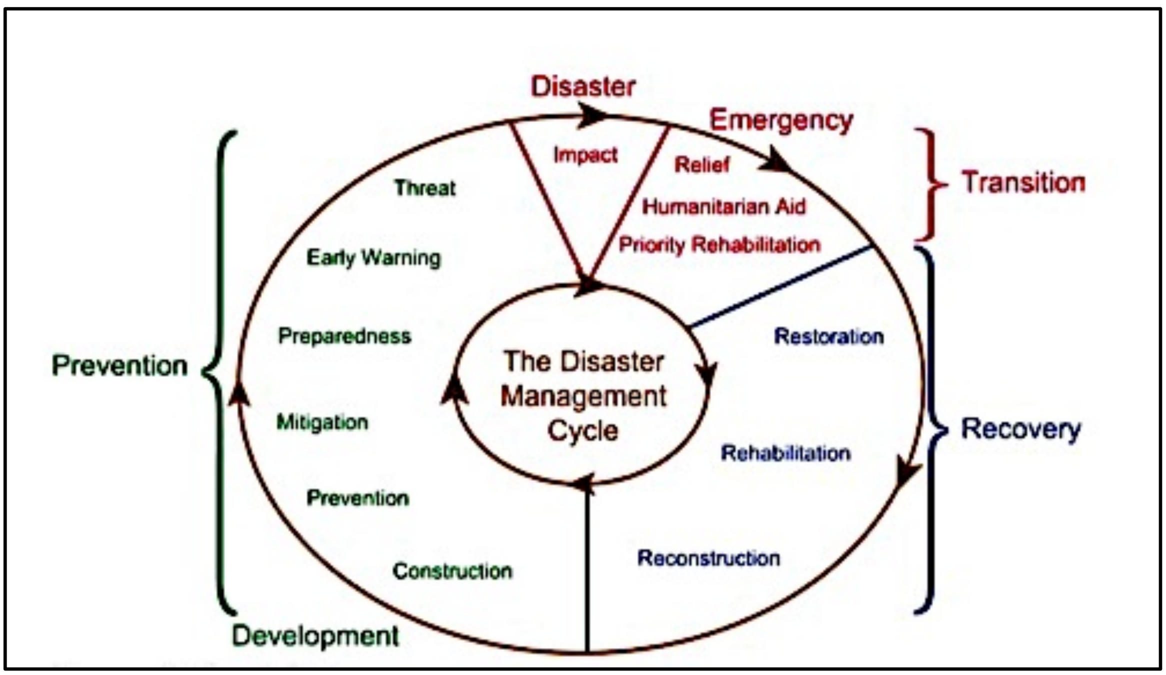


Figure 37. *Disaster Management Cycle (Tatham, 2009)*

<table>
<tr><td colspan="7">Summary</td></tr>
<tr><th>Phase</th><th>Preparedness</th><th>Response</th><th colspan="2">Transition</th><th>Recovery</th><th>Mitigation</th></tr>
<tr><td>Period</td><td>Long Term - Continuous</td><td colspan="2">Days – Months</td><td colspan="2">Months – Years</td><td>Long Term - Continuous</td></tr>
<tr><td>Logistics Volume</td><td>Low</td><td colspan="2">High</td><td colspan="2">Medium</td><td>Low</td></tr>
<tr><td>Supplies Required</td><td>Specific standard supplies pre-positioned for disaster response</td><td colspan="2">Specific standard supplies: Food, medical supplies, water and sanitation equipment, shelter, household kits, etc.</td><td colspan="2">Varied supplies depending on the context of the disaster: reconstruction material, livelihoods equipment</td><td>Varied supplies</td></tr>
<tr><td>Urgency</td><td>Low</td><td colspan="2">High:
Lead times for supplies can make the difference between life and death.</td><td colspan="2">Medium:
There may be government and donor pressure to complete recovery activities</td><td>Low</td></tr>
<tr><td>Procurement of Supplies</td><td>Local</td><td colspan="2">International</td><td colspan="2">Local-International</td><td>Local</td></tr>
<tr><td colspan="7">Table 1. Humanitarian Logistics Throughout the Disaster Management Cycle</td></tr>
</table>

Figure 38. *Humanitarian Logistics Throughout the Disaster Management Cycle (Howden, 2009)*

NonGovernmental Organizations

The term NGO addresses a wide scope of structure, focus and competence. A Non-Governmental Organization, or NGO, is generally defined as a "voluntary association independent of government control that seeks to realize human rights and to provide humanitarian assistance according to need." (Bynam, 2009). Within this definition, NGOs vary in terms of size and formal structure. The size of NGOs can vary from thousands of members with a formal organizational structure to a few friends working together. Organized structure facilitates an NGO's ability to gain governmental funding, which affects the need to garner donations from private companies (Bynam, 2009). While there is not a unifying structure or chain of command that ties all NGOs together, the United Nations (UN) Family of NGOs maintains an informal hierarchy over other NGOs. The UN Family of NGOs refers to higher-level NGOs that are associated with the United Nations. These include the UNHCR (United

Nations Humanitarian Commissioner for Refugees), the World Food Programme (WFP), the World Health Organization (Health issues), the Food and Agricultural Organization (FAO), and UNICEF (United Nations Children's Fund). These NGOs focus primarily on resourcing smaller NGOs, as well as enhancing inter-NGO collaboration (Bynam, 2009).

Literature Review of Disaster Relief

This Literature Review is organized in the following manner: literature on disaster relief supply chains, literature on past and current use of automated requisitioning systems within such chains, literature that promotes the use of technology with such chains, and cognate research performed on the relationship of NGOs and military forces during disaster relief operations.

Literature On Disaster Relief Supply Chain Performance

Stemming from a desire to understand a perceived lack of responsiveness in past disaster relief scenarios when the aid is available (Elsevier, 2010), much study has examined the challenges humanitarian assistance supply chains face and how operations could be improved.

Several higher-level international organizations, such as the International Federation of the Red Cross (IFRC), have conducted thorough analyses of their processes (Katruud, Samii & Van Wassenhowe, 2003). Researchers have identified several reasons for suboptimal performance in disaster relief supply chains:

--Low qualifications of NGO logisticians (Kovacs and Tatham, 2009)

--High personnel turnover, large number of stakeholders and a failure to recognize the significance of logistics (Gad el-Hak 2008).

--Narrow depth and speed of information-sharing required within the disaster relief supply chain as a challenge to effective distribution (Van Wassenhowe, 2006; Oloruntoba & Gray, 2006; Oloruntoba, 2007; Kovacs & Tatham, 2009).

Literature on The Use of Automated Requisitioning in Disaster Relief Supply Chains

Current disaster relief logistics systems are largely manual processes, unlike the electronic techniques used by civilian industry (Long, 1997; Gustavson, 2003; Rickard, 2003; Tabbara, 2008). Most of the emphasis on utilizing information technology within the disaster relief community has been for coordinating upstream suppliers, not for automated requisitioning downstream.

Call for Technology

Researchers provide several reasons for a lack of automated requisitioning technology:

--Logisticians supporting disaster relief efforts largely do not understand what systems are available (Gustavson, 2003)

--The multitude of diverse and constantly changing stakeholders makes enterprise solutions nearly infeasible.

--The competitive environment for lower-level NGOs promotes independent operations (Gad el-Hak, 2008).

--The belief among NGOs and donors that logistics technology systems are long-term projects with little media appeal, thus they do not merit funding (Gustavsson, 2003; Murray, 2005; Oloruntoba & Gray, 2006; Gad el-Hak, 2008; Petit & Beresford, 2005).

Tabbara (2008) identifies shortcomings of manual information systems used in humanitarian assistance operations. Some of these shortcomings may be characteristic of manual requisitioning procedures:

--Double handling of data through transferring from one to multiple forms and formats, increasing the potential for error

--Difficulty to control the budget and potential of overspending

--Lack of an audit trail, which increases the difficulty of reconciling requisitions

--Lack of a universal database to analyze distributions or demand patterns

--During manual processes, data is not captured, hindering future performance analysis

In light of the issues with integration and funding, researchers continue to call for information technology as a means to improve supply chain performance (Murray, 2005; Long & Wood, 1995; Oloruntoba & Gray, 2006). Similar to Oloruntoba & Gray (2006), Davidson suggests that a requisitioning system that could discern priorities among requests could potentially increase responsiveness. Whybark (2007) recommends scholarly exploration of the tradeoff between inventory and information technology to improve the effectiveness of the disaster relief supply chain.

Conversely, Balick et al have approached the issue from a supplier-managed inventory perspective, proposing that while technology supporting a Vendor Managed Inventory (VMI) would offer time savings, suppliers are most likely reluctant to guarantee performance, incur inventory holding costs or address the erratic demand patterns that characterize disaster relief scenarios. Additionally, personnel in the field may not have confidence in single suppliers across strategic supply distances and may prefer less expensive alternatives.

Major international organizations in the disaster supply chain have invested in information technology to improve operations (Oloruntoba & Gray, 2006). Since 2003, the IFRC has also worked to improve upon past manual methods to reconcile incoming cargo by implementing Humanitarian Logistics Software (HLS) in all of their major operations (Davidson, 2006). HLS, developed by the Fritz Institute, enables customers to order on-line from suppliers. It also increases requirements visibility throughout the entire supply chain (Davidson, 2006; Gatigon, Van Wassenhowe & Charles, 2010). However, while evidence exists to support that the IFRC did reduce their response time by decentralizing operations, it is uncertain if HLS contributed to this reduction (Gatigon, Van Wassenhowe & Charles, 2010). Further, HLS is an information-sharing tool, designed to facilitate operations among headquarters personnel and capture data for tracking movement. It is not a requisitioning tool (Davidson, 2006; Kopczak & Johnson, 2004).

Notably, other U.N. Family NGOs have logistics information systems in development. The U.N. has developed the International Emergency Network (UNIENET) to organize and exchange information and the World Food Program has developed the international food aid information system (INTERFAIS) to track the movement of food aid (Murray, 2005).

Research has also demonstrated an increased interest in establishing and studying performance metrics for disaster relief supply chains (Davidson, 2006; Beresford, 2005; Beiser, 2010). Davidson (2006) proposes measuring Requisition Wait Time (RWT) through automation to help humanitarian relief organizations identify the warehouses that are experiencing the greatest delays. Tabbarra (2008) suggests that Non Governmental Organizations can use benchmarked performance in logistics as an advantage to secure donations in the long run.

Others have modeled portions of the disaster relief supply chain, such as the donations process, optimal locations for storage, or best structure for tactical distribution (Petit & Beresford, 2005; Barbaraso & Arda, 2004; Onur, Mete & Zavinsky, 2006; Ozbay & Ozguven, 2006; Elsevier, 2010). Elsevier discusses the merits of modeling and simulation, but also points to a lack of logistics technology that would assist disaster supply chain operators during execution (Elsevier, 2010).

The Relationship between Military Forces and NGOs in Disaster Relief Operations

Whereas NGOs are continually involved in disaster relief support, the level of military involvement in such operations varies based on politics, range of missions, time and other factors. Several studies have explored these factors to capture the relationship between military and NGO forces in disaster relief operations.

As military forces are a means to achieving political ends, politics determine the involvement of military forces in disaster relief situations. In some instances, political considerations may restrict the use of military forces. On the other hand, NGOs are not as constrained by politics or bureaucracy (Petit & Beresford, 2005). Therefore, while disaster relief assistance is the essence of an NGO's existence, military forces are involved at a much lower frequency.

Military involvement in disaster relief spans a range of potential missions. Bynam (2009) outlines that U.S. military forces may be employed in complex contingencies to provide humanitarian assistance, protect humanitarian assistance, assist refugees and displaced people, enforce peace agreements and restore order. Petit and Beresford (2005) outline a similar range of missions for United Kingdom military involvement. The United Kingdom is even more explicit within their doctrine, stating that military forces will only be used for distribution when NGOs cannot perform the task.

The most likely role for military forces is to secure and protect relief efforts rather than to conduct them. To protect disaster relief operations, military forces may safeguard actual distribution points, as well as airports, seaports, warehouses, and other logistics activities to stabilize situations so that Non Governmental Organizations can perform distribution operations without disruption. Particularly, military forces are often used to secure operations involving food distribution, as such operations carry the highest threat of theft and looting (Petit and Beresford, 2005).

However, in certain cases, military forces may be used to conduct distribution operations. Such instances may stem from a temporary lack of NGO capability or responsiveness and often occur in the initial stages of disaster relief (Petit & Beresford, 2005; Bynam, 2009; Balick et al, 2010; Oloruntoba, 2010). Military forces may fill shortfalls when local capability is overwhelmed (Bynam, 2009), provide logistics capabilities prior to humanitarian systems being established, or gain access to damaged areas NGOs cannot (Petit and Beresford, 2005; Bynam, 2009). Military forces may provide airflow, ground transportation or airdrop of humanitarian supplies (Bynam, 2009).

Time may also impact the degree of military involvement. Petit and Beresford (2005) demonstrate that military forces may have a high degree of involvement in the beginning of the disaster, while NGOs are more involved as the disaster relief period continues. Accordingly, each supply chain has a different time horizon. Military supply chains are much shorter; NGO time horizons are longer as they extend into relief and reconstruction efforts (Bynam, 2009). It is common for military involvement to be high at the beginning of a disaster response, then to taper over time as NGOs arrive. At some point "there will be a shift in the balance of effort being provided by the various organizations (Petit and Beresford, 2005)."

Disaster Relief Framework

A framework is necessary to understand the nature of a disaster relief supply chain and examine the potential generalizability of the results presented in Chapters 4 and 5. Similar to the framework and sequence used to describe the military expedition supply chain, this framework describes the initial evolution of disaster relief supply chains, to include the combination of push and pull methods and the critical factors which impact distribution.

This framework was developed through a literature review of disaster relief operations. It is organized in two general sections: a discussion of the disaster relief supply chain's characteristics, then a description of the supply chain's sequence of events.

Disaster Relief Supply Chain Characteristics

General Need for Speed & Accuracy

Disaster relief environments are characterized by an extreme need for urgency and speed, with an overwhelming emphasis on results over cost-savings efforts (Van Wassenhowe, 2006). It seems a common feeling that an employing an efficient approach during the early days of relief support will significantly hinder progress (Oloruntoba, 2010). As an example, supplies are often flown during the initial stages of relief (Oloruntoba, 2007) despite the considerable financial expense to do so. Although the first 72 hours of logistics response are the most critical, attempts to improve the supply chain's economic procedures usually do not occur until much later, around the 90-100 day mark of operations (Van Wassenhowe, 2006).

Additionally, the disaster relief chain is characterized by considerable complexity across all stages (Balik & Beamon, 2008). This complexity manifests in generating donations, combating price wars, eliminating unneeded donations, and coordinating strategic transportation, customs clearance, local procurement and tactical distribution. Notably, all of these challenges must be overcome to meet demand with little to no lead time (Balik & Beamon, 2008).

Volume of Organizations Participating

The amount of agencies participating in disaster relief support potentially complicates the supply chain (Long & Wood, 1995; Kovacs & Tatham, 2009; Balcik & Beamon, 2008). Unlike a military expedition, it is rare that only one NGO possesses the resources necessary to singularly support and execute disaster relief. As examples, 300 NGOs and the Red Cross provided relief following a 2001 earthquake in Gujarat (Tabbara, 2010) and 700 NGOs provided support following the 2004 Asian Tsunami (Balcik et al). It is estimated there are over 20,000 aid-related organizations worldwide (Kovacs & Tatham, 2009). Figure 39 demonstrates the vast amount of organizations that are usually involved in supporting disaster relief.

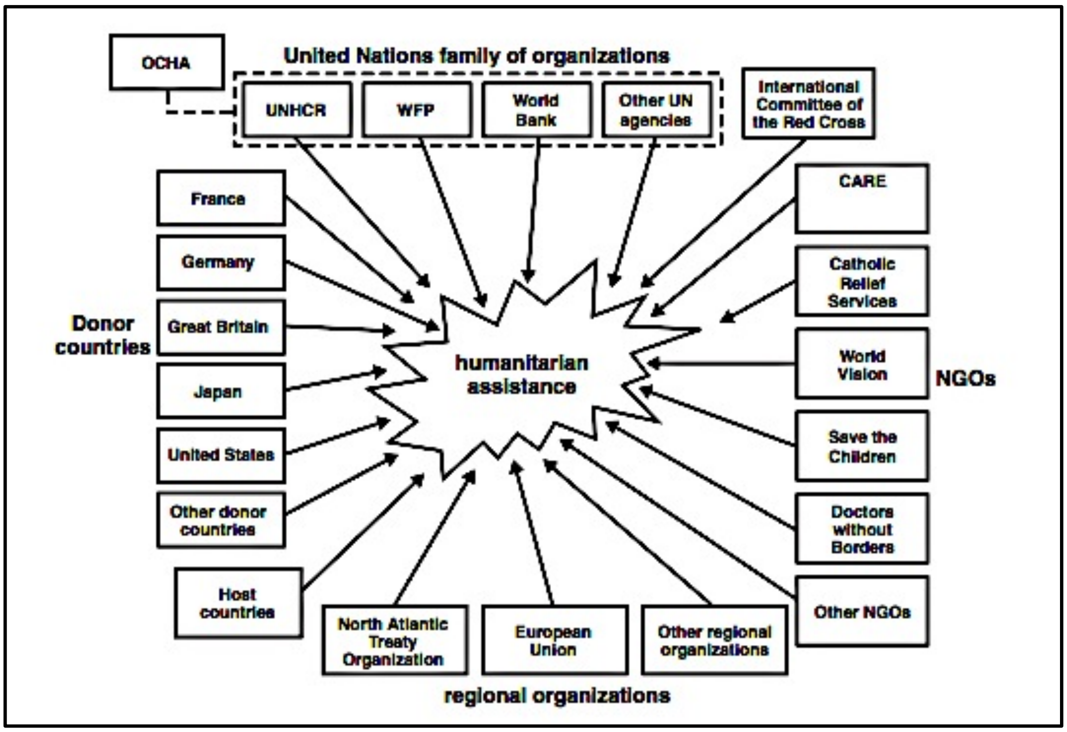


Figure 39. *Organizations Typically Involved in Disaster Relief (Bynam, 2009)*

Bringing these stakeholders together in an organized fashion immediately following adisaster is a considerable challenge (Elsevier, 2010), as stakeholders are rarely the same from one operation to the next (Oloruntoba, 2007). While civilian and military supply chains gain strength in emergency situations through known suppliers and established relationships, NGOs' enduring desire to remain impartial and disconnected from state actors complicates the disaster relief network (Katruud, Samii, & Van Wassenhowe, 2003). NGOs may constrain their allowable percentage of donations from a single state source; some organizations restrict their single source donations to 30% of the overall total (Spearin, 2008).

Pressure of Agility Appeal

Causing further complexity and strain on coordination is the competition among NGOs in gaining donations (Stevenson, 2005; Kovacs & Tatham, 2009; Elsevier, 2010). If donors do not believe their contributions are being used wisely and quickly, they will choose another NGO to support; the large number of NGOs supporting most disasters makes this possible (Oloruntoba & Gray, 2006; Kovacs & Tatham, 2009). During Hurricane Mitch, because the International Federation of the Red Cross (IFRC) took two weeks to respond, they found donations had already been passed to other organizations for distribution (Katruud, Samii & Van Wassenhowe, 2003).

As a result, NGOs regard donors as a customer equal to people in need (Gad el-Hak, 2008). Oloruntoba & Gray (2006) propose that the "agility appeal" of certain NGOs over others to push supplies quickly creates conflict in the supply chain. NGOs lacking "agility appeal" lose funding and become ineffective; therefore NGOs are very sensitive to funding and donor desires (Gad el-Hak, 2008; Oloruntoba & Gray, 2006). While supplies move quickly upstream, they may outrun the downstream demand, leading to overabundance or scarcity (Oloruntoba & Gray, 2006; Thevenaz & Resodihardjo, 2010). The pressure from self-induced restrictions on donations, combined with satisfying donor needs, creates considerable challenges to execute distribution at multiple levels (Stevenson, 2005).

Upstream portions of the supply chain may also encounter other challenges to responsiveness. Unneeded donations cause additional problems with supply chain performance (Murray, 2005; Oloruntoba, 2007). Operators at transportation nodes must spend time sorting and eliminating unnecessary goods, and an overabundance of supplies can contribute to congestion (Balcik et al, 2010). The evolving upstream disaster relief supply chain may also experience time delays due to competitive price bidding for required goods that have not been donated, international customs clearance, and transportation availability to move bulk shipments of supplies (Balcik & Beamon, 2008; Balcik et al).

Downstream Challenges

The preferred method is to purchase supplies locally and immediately use them for distribution, as this reduces the need for strategic transportation and local storage (Murray, 2005). Some NGOs have invested in pre-stocking supplies downstream in the supply chain to increase responsiveness (Olortunoba, 2010). Following Hurricane Mitch relief, the International Federation of the Red Cross and United Nations decentralized operations by establishing regional logistics hubs (Katruud, Samii, & Van Wassenhowe, 2003). From these hubs, Regional Logistics Units (RLUs) were able to deploy to disaster relief zones, identify needs, use prepositioned stocks and procure goods available locally (Kovacs & Tatham, 2009; Gatigon, Van Wassenhowe & Charles, 2010). In contrast, smaller NGOs have not pre-positioned stocks due to the cost of dedicated inventory. While the majority of distribution centers are temporary, determining warehousing and distribution center locations in the disaster area is challenging due to damaged infrastructure, cost and security (Whybark, 2007).

Disaster relief supply operations are also hindered by damaged or limited infrastructure; damage to air and seaports may degrade an area's capacity to respond (Blecken, 2010; Balcik et al) and NGOs may compete with military forces for throughput processing at the same aerial port (Shatzkin, 2011). Limited aerial ports may become overwhelmed trying to receive, store and issue an abundance of rapidly incoming cargo while maintaining throughput and trafficability

(Tabbara, 2008; Oloruntoba, 2007). Damaged seaports with limited material handling equipment may be challenged to throughput the surge influx of relief items (Long & Wood, 1995; Besier, 2010). Countries without seaport access are significantly challenged (Petit and Beresford, 2005), as are countries with limited architecture prior to disaster (Beiser, 2010). Such conditions result in midstream bottlenecks within the supply chain (Beiser, 2010).

The final leg of distribution presents the greatest challenge in meeting demand in disaster relief operations (Murray, 2005). This challenge is caused by the speed of demand requirements often exceeding the supply chain's capacity to complete distribution. The chain's capacity is hampered by slowness of assessment, damaged infrastructure, limited distribution assets, cultural considerations and security (Beiser, 2010).

Challenge in Assessment: Determining Accuracy of Requirements

Even with demand data for forecasting, many researchers and former disaster relief operators have commented on the unique unpredictability and fluctuation of disaster relief requirements (Kovacs & Spens, 2007; Beamon & Kotleba, 2006; Murray, 2005; Balcik & Beamon, 2008; Tabbara, 2008). The required commodities for relief may differ widely in size and scope, particularly when compared to established industrial and military supply chains (Long, 1997; Egan, 2010; Elsevier, 2010). For example, affected populations may need water, bulk grain, or refrigerated medicine in vastly different quantities. Demand may also vary based on outbreaks of warfare and physical conflict, displaced population shifts and adverse weather (Beamon & Kotleba, 2006).

Cultural food norms potentially present problems in meeting demand. Generically pushed food stocks may not comply with the cultural norms, rules or beliefs of the supported population; more specific food items may have to be requested through a pull system (Long &

Wood, 1995). Determining the exact needs of the population involves understanding cultural norms along with time to assess the actual needs.

Additionally, environmental considerations may make certain pushed goods unsuitable, necessitating a pull system (Besier, 2010; Barakrat, 2003). Assessing these relief requirements requires more time than demand situations will allow. Methods of sharing assessment information across agencies are fragmented and slow (Son, Aziz & Pena-Mora, 2007), which often contribute to initial assessed needs being understated (Davidson, 2006). To overcome the lack of information of concerning demand, supplies are initially pushed to the disaster area (Kovacs & Spens, 2007; Long & Wood, 1995).

Lack of transportation assets also contributes to difficulty meeting demand downstream. NGOs usually do not deploy organic vehicles (Long & Wood, 1995). Leasing and renting opportunities may be limited, making receiving supplies from the aerial port of departure or delivery to distribution points difficult (Balcik et al, 2010). Vehicles available for rent may be at a high price due to limited availability (Tabbara, 2008) and commercial vehicles may also experience difficulty moving along damaged road conditions (Long & Wood, 1995; Beiser, 2010; Shatzkin, 2011). While a decentralized method of distribution is preferred (Long & Wood, 1995), it becomes difficult to achieve with limited assets.

Disaster Relief Requisition Flow

This section describes the flow of the manual requisitioning process that characterizes most disaster relief situations. These steps refer to Figure 40, which captures the network sequence and structure.

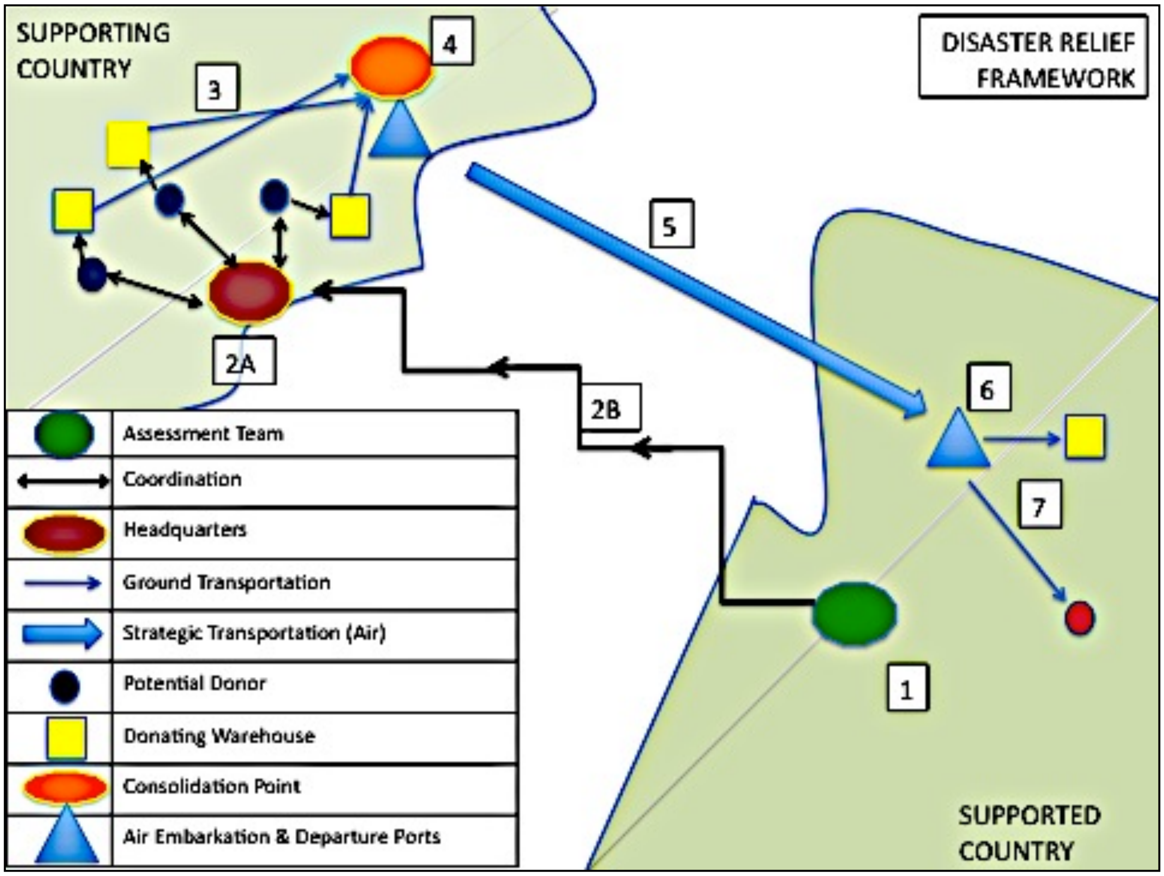


Figure 40. *Disaster Relief Requisitioning Process*

(1A) An NGO assessment team deploys to determine needs within the affected area.

(1B) Simultaneously, a home-station based headquarters solicits donations.

(2A) The headquarters finishes the initial request for donations and coordinates transportation to an embarkation processing point.

(2B) The assessment team manually submits their initial request for items they cannot fill from prepositioned stocks or locally purchased supplies.

(3) The headquarters mobilizes supplies. This may occur before the assessment team requests them.

(4) At the embarkation processing point, unnecessary items are segregated and all items are prepared for strategic shipment.

(5) Strategic movement occurs.

(6) Items are received at the Aerial Port of Debarkation (APOD).

(7) Items are moved to a storage facility or directly to a distribution site (Kopczak & Jones, 2004).

Areas of Generalizability

This section first discusses the areas of generalizability of this research's model to other military expeditions, then to NGO-led disaster relief operations through identifying areas of generalizability and areas that are less generalizable. The literature review and framework of military expeditions provided in Chapter 2 was complemented with how the model is constructed (Chapter 3) and how the model performs (Chapter 4 and 5) to construct the analysis of generalizability of the existing model to other military operations. The literature review and framework of NGO-led Disaster Relief provided in this chapter was combined with Chapters 3, 4 and 5 to construct the analysis of generalizability of the existing model to NGO-led disaster relief operations.

In describing these areas, this section uses several terms:

--*Process Structure* refers to how a model is physically structured in terms of activities and events that occur.

--*Demand Requirements* refers to the overall nature of demand, to include probabilities of occurrence, demand characteristics and demand patterns.

--*System Parameters* refers to the specifications on how the system performs, such as throughput in activities or activity cycle time.

--The *existing model* is the model constructed in Chapter 3 and discussed in Chapters 4 and 5.

Overall, the existing model is generalizable to other military operations in terms of overall process structure, effectiveness of the automated system, the preponderance of repair parts as demand and the general knowledge of ASL limitations. It is less generalizable in its specific demand characteristics, which will be subject to operational, environmental and utilization impacts in future missions. In comparison, the existing model is less generalizable to NGO-led operations, as it possesses more upstream inputs to lead time variance, as well as different demand characteristics. The existing model possesses areas of generalizability to NGO-led operations in the effectiveness of the automated system, warehouse functionality, pre-positioned and locally purchased stocks and upstream search activities.

Areas of Generalizability of Existing Model to other Military Operations

--The process structure of the military model will not change from one operation to the next. While a deployment location may change the depot locations that are used, the existing model's structure of a warehouse, a manual search activity and a wholesale supply system will not change. Similarly, while the model's parameters may change based on invalid assumptions or active measures to improve an activity's throughput, the existing model's sequence of activities is generalizable to other military operations.

--Because this process flow will remain unchanged, the knowledge of the automated system's effectiveness in comparison to the manual's system's performance is also generalizable. Factors such as different depot lead times, decreased volume of demand, increased search activity capacity, higher probability of home station search and decreased lead time from home station may lessen the differences between manual and automated system performance. However, the process is generalizable to modeling and understanding manual and automated system performance. While the automated system process is widely known, the manual system is not; therefore, the manual system process described in this research may serve as a framework to further understand, model and evaluate the manual system in supporting other deployments and environments.

--In terms of demand characteristics, 80.55% of the demand was composed of ten different commodities of repair parts with 75.14% of the demand composed of four different commodities of repair parts. Changes in environment or mission may incur a change in the specific repair parts required, but the knowledge of repair parts comprising the preponderance of military requisitions is generalizable to other military operations.

--The knowledge that ASL will have some limitations is also generalizable to other military operations. The specificity of limitations are dependent on the new operation's demand characteristics, but this research provides the differences between non-deployed and deployed demand characteristics and quantities along with potential causes of these differences.

Areas of Non-Generalizability of Existing Model to other Military Operations

--The demand characteristics, listed in the form of probability of occurrence, are not generalizable to future operations, as these characteristics and probabilities are specific to the operation performed in Haiti. Factors impacting demand requirements in military operations can be categorized as operational, environmental and utilization. These factors are described in Chapter 5. A different operation may very likely cause these demand characteristics to change. Continued research could improve upon the existing model by examining how these factors affect requisition probabilities and incorporating these new probabilities into a simulation model for further analysis.

It is also important to note that within disaster relief operations, the specific type of disaster will have less impact on military demand requirements than NGO-led demand requirements. This is because the military mission in disaster relief remains largely the same: to provide support and stability to the affected population while facilitating humanitarian relief and evacuation. The military supply chain in such situations supports the military units conducting these missions. Conversely, the NGO-led disaster relief supply chains directly address the demand requirements of personnel affected by the disaster and are therefore more dependent on the type of disaster.

--The existing model's demand characteristics address the requirements of an Infantry Brigade Combat Team (BCT), one of three BCTs within the U.S. Army. For example, the analysis in Chapter 5 highlights the Infantry BCT's dependency on night vision devices and radios by their immediate demand for communications and electronics repair parts. A Heavy or Stryker BCT would possess different demand characteristics, based on the greater densities of armored vehicles and heavy equipment within these units. These units would require less support for individually operated systems and more support for vehicle dependent systems. For these reasons, repair parts would most likely comprise the majority of requisitions for these units, but the categories and volume of repair parts would be different based on the equipment these brigades possess. Additionally, the manner in which these brigades deploy may also cause differences in the demand growth patterns. While Infantry BCTs deploy personnel and some equipment by air early, Heavy and Stryker BCTs are more dependent on ships to deploy their equipment. Although personnel within these units are deployed by air, their arrival occurs closer to the ship's arrival. This different method of deployment could result in a demand growth pattern different from those discussed in Chapter 5.

Generalizability of Existing Model to NGO-led Disaster Relief Operations

Overall, the knowledge regarding the effectiveness of automated system and adverse impact of the manual system on fill rate and responsiveness is generalizable from the existing model to disaster relief operations, although modeling automated and manual disaster relief operations may require modelers to assume additional parameters due to a lack of automated and manual data to research.

Areas of Generalizability

--The existing model operates with a centralized warehouse structure to process incoming requisitions. These processes are based on standard rules concerning requisition objectives, reorder points and backorders. The emerging trend is for disaster relief supply chains to centralize receiving and issuing functions in a warehouse operation. Assuming supplies are brought to a consolidation or clustering point for issue, the existing model's downstream warehouse process structure could be generalized to support disaster relief warehousing operations.

Compared to the existing model, the disaster relief warehouse experiences some added adverse impacts to downstream warehouse processing capability. Due to the pressure of upstream donation pressure, the disaster relief warehouse may receive some items that were not requested and may require additional time to sort these items. The disaster relief warehouse may also experience a lack of transportation assets to move requisitions from the aerial port, limitations to aerial port throughput due to competition with military forces, or disaster-induced damage to the port's capability to throughput cargo. These three sources of variation could be addressed in the warehouse's processing time parameters.

--The existing model operates with an Authorized Stockage List (ASL) as stocks the military warehouse has deployed. The purpose of these stocks is to decrease overall lead time by minimizing the amount of requisitions that must be sourced from higher sources of supply. The disaster relief supply chain attempts to decrease lead time in the same manner through the use of stocks that are pre-positioned or purchased locally. In the existing model, if a requisition is on hand through ASL, it is issued in accordance with the processing time standards of the Supply Support Activity (SSA). The disaster relief model could reference the prepositioned and locally purchased stocks in the same manner. Adjustments could be made to the warehouse processing time's variability to address the variability of the delivery of these items, or the model could be expanded to address the variability of these sources individually. Figure 41 depicts the generalizability between the existing model and the disaster relief model. The top portion of the diagram shows how the existing model references the ASL activity. The bottom portion of the diagram shows how the existing model could be altered to reference prepositioned and locally procured stocks within the disaster relief process while addressing these sources' variability in lead time.

--Disaster relief networks are dependent on an upstream search activity to locate demand requirements. The existing model's search activity could be generalized to replicate an interim NGO search activity that manually locates stocks at known warehouses and coordinates shipments for delivery.

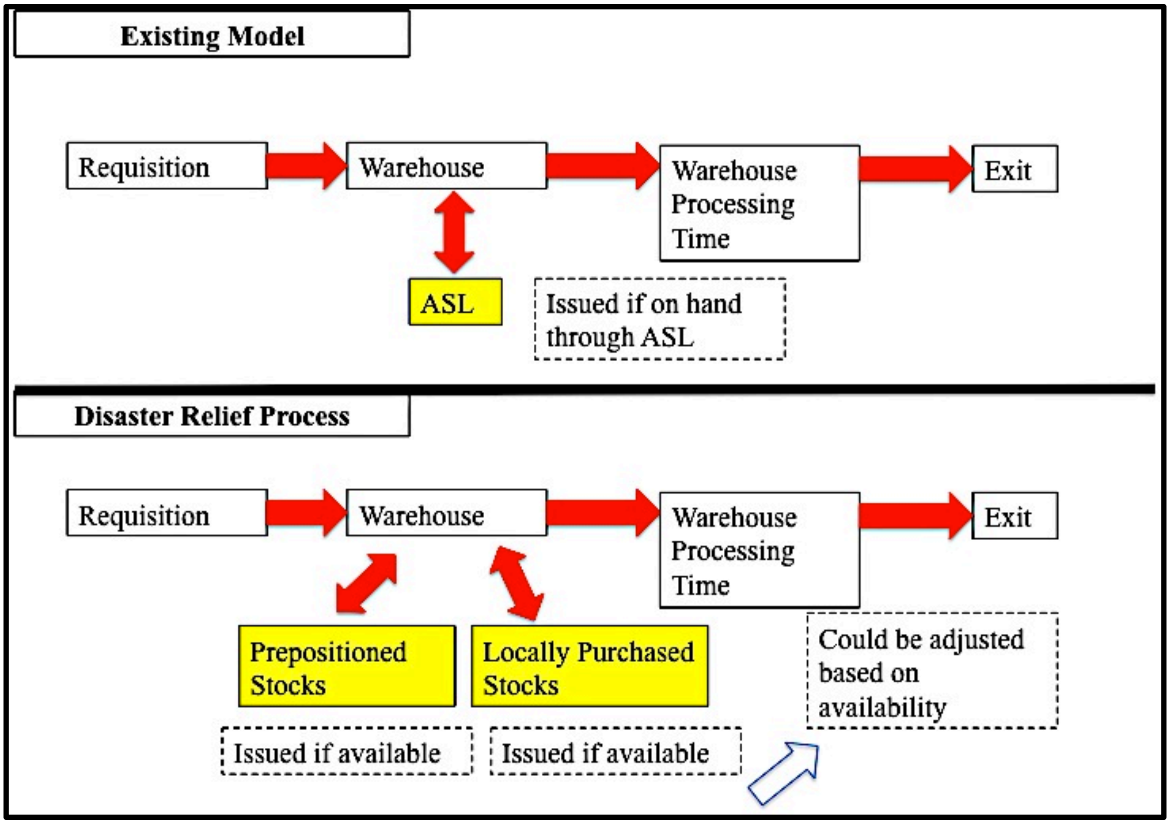


Figure 41. *Generalizability of Existing Model's Authorized Stockage List (ASL) Activity*

Areas of Non-Generalizability

--The upstream disaster relief process has more factors impacting lead time variability than the existing model addresses. Because the military supply chain possesses a stable depot structure, the existing model's upstream process is largely constant from one operation to the next. Conversely, the stakeholders and sources of supply in the disaster relief process change constantly. Factors such as time required to generate donations, time required to conduct price wars, time spent eliminating unwanted donations and time spent coordinating strategic transportation impact lead time variance.

Figure 42 depicts the difference between the upstream lead time activity of the existing model and the factors impacting lead time variance within the disaster relief supply chain. On the left of the figure, the existing model is depicted. It encompasses wholesale logistics functions

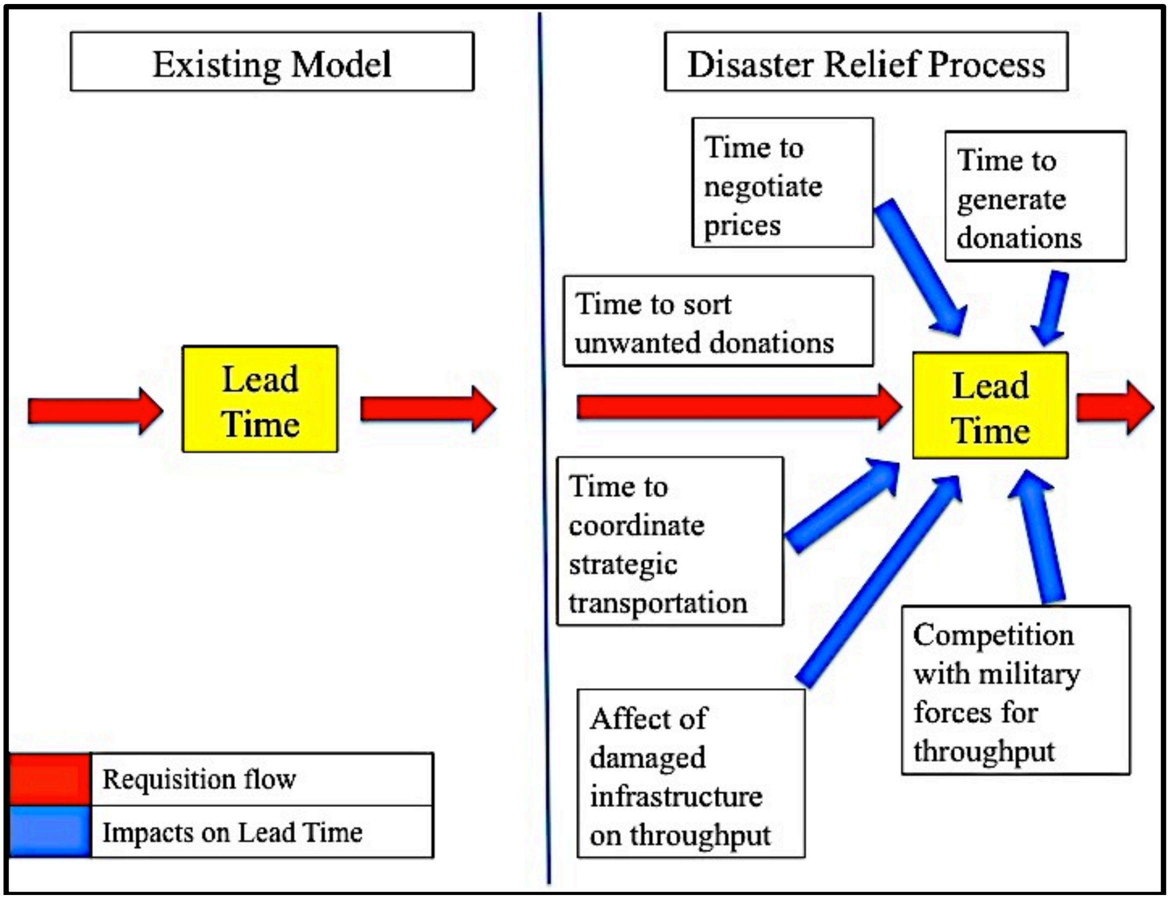


Figure 42. *Comparison of Factors Impacting Variance Between the Existing Model and the Disaster Relief Process*

into one processing activity. This processing activity uses a discrete probability table to assign lead time based on the depot from which the requisition can be sourced. This lead time encompasses the variance of the logistics functions comprising the distribution of items from depot to the deployed warehouse. While the existing model's lead time parameters could be adjusted to possess more variance, this method may not best reflect the factors impacting lead time within the disaster relief framework. These factors are depicted on the figure's right side. The existing model would need to address the probability of these occurrences and their adverse impact on the model's activities.

--Demand characteristics would require the most change from the existing model. The demand pattern would be different, based on the comparatively slower speed of disaster relief assessment. Also, the disaster relief phase would drive both the demand pattern and item characteristics. During the initial relief phase, requisitions would occur farther apart, but with sporadic spikes in quantity. Item types would occur more in depth than breadth. While the type of disaster would have some effect on items required, relief items such as medical aid, temporary shelter and water would remain common from one disaster to the next. Food items could be variable dependent on the population. During the recovery phase, the demand pattern would potentially begin to stabilize, although it may become volatile during the transition between phases. During the recovery phase, both depth and breadth requirements would increase, as they would during the reconstruction phase. The reconstruction phase would likely produce the most stable demand pattern as more deliberate projects are launched. This phase would possess the greatest breadth due to the vast amount of commodities required.

--The method of evaluating of decoupling points described in Chapter 5 could assist in evaluating a disaster relief supply chain's ability to respond to demand differences across the phases of relief, recovery and reconstitution. This method would assist in evaluating the use of prepositioned or locally procured stocks to address decoupling points, which may signal the change from one phase to another. Oloruntoba & Gray (2006) describe a necessary upstream leanness within the disaster relief supply chain due to the constantly changing suppliers and lack of fixed overhead. If the existing model were expanded to address the multiple sources of upstream lead time variation, the concept of the upstream "penetrating" decoupling point would provide a relevant framework for evaluating the leanness of the supply chain. Using this method would require identifying multiple D1, D2 and D3 decoupling points over an extended timeline.

Conclusion

This chapter provides this research's potential generalizability to other military operations and NGO disaster relief operations. For future military operations, the existing model was found to be generalizable in terms of process structure, general knowledge of the effectiveness of the automated system, general knowledge of the repair parts makeup of demand and general knowledge of Authorized Stockage List (ASL) limitations. Less generalizable for future military operations were specific demand characteristics, which will be impacted by operational, environmental and utilization factors, along with the type of units deployed. For disaster relief operations, the existing model was found to be generalizable in terms of general knowledge of the effectiveness of the automated system, process structure of the warehouse, Authorized Stockage List and search activity. Less generalizable for disaster relief operations were the upstream process structure and specific demand characteristics.

This chapter identifies several areas for future research. These areas will be further discussed in Chapter 7 along with an overall summary and conclusion.

CHAPTER 7. CONCLUSION

This chapter summarizes the major findings of this research and recommendations for future study. It is organized in the following manner: a reviewed statement of the problem, a review of the research methodology, a summary of the findings categorized by contribution, future study recommendations and an overall conclusion.

Statement of the Problem

Emergency supply chains, defined by military expeditions and disaster relief operations, are often defined by manual requisitioning systems, involving phone calls, text messaging and other similar means. While military doctrine describes the use of automated requisitioning systems, history indicates manual means is most common to sustain emergency support operations. This research examines the impact automated requisitioning methods may have on improving the emergency supply chain's effectiveness.

Research Methodology

Literature reviews of both the military and disaster relief requisitioning processes were performed to serve as the basis for modeling automated and manual systems. Simulation lengths of 600 days were run to allow all requisitions to close and exit the system. To establish the parameters for the manual and automated processes, data was gained from the U.S. Logistics Support Activity (LOGSA) Logistics Information Database (LIDB). The data selected was from the 407th Brigade Support Battalion (BSB)'s earthquake relief support during Operation Unified Response in Haiti from January – March 2010. This data included the 407th BSB's requisition history and the Authorized Stockage List (ASL) used at the time. The ExtendSim8 program was then used to build a discrete-event simulation depicting both the automated and manual systems.

Measurements of total and readiness driver fill rate and requisition wait time were used to evaluate the effectiveness of the automated and manual systems.

Findings

<u>Overall Effectiveness of an Automated Requisitioning System</u>

The automated system was found to be more effective than the manual system in terms of fill rate, responsiveness and closure rate. The automated and manual systems averaged a 200 day difference in total closure time and a difference of 113 in requisition wait time (RWT) at the time of closure. At the 81-100 day range, which is a likely window for expeditions to end, the automated typical performance closed all requisitions, while the manual performance achieved 21.92% TFill. When demand increases around the 18-22 day range, the manual system's search activity incurs a processing backlog, which adversely impacts the manual system's fill rate, responsiveness and ability to close requisitions. These overall findings suggest that establishing the automated system contributes to more effective performance.

Sensitivity analysis was conducted to assess the adjustments necessary for the manual system to improve performance. To achieve a responsiveness rate comparable to the automated system, the manual system's search activity must perform at a processing rate 12 times its assumed rate. Additionally, the manual system requires increases in search success probability and decreases in home station lead time to perform at a rate comparable to the automated system. Reducing the automated system's processing activity 15 times from its assumed rate resulted in requisition wait time and fill rate typical performances that were less effective than the manual system.

Optimal Time Ranges to Establish the Automated Requisitioning System

These findings also suggest that establishing the automated system early is most optimal. A contingency table chi squared comparison was conducted of the two systems' performance measures. A statistically significant difference ($p<=0.01$) in automated and manual fill rates was found at interval 1-6 for the two fill rate performance measures. For the two requisition wait time performance measures, there was a significant statistical difference between the manual and automated systems across the broader interval of days 1-45.

Development of the Decoupling Point Concept

The decoupling point within a supply chain is described as the point in which the strategic forecast diverges from demand requirements. This research specifically defined the decoupling point as the day manual or automated system fill rate exceeded ASL fill rate. Four leading categories of commodities were used to examine the automated and manual system's abilities to respond to deployed demand requirements**.** The automated system was able to respond to demand not met by on-hand stocks more effectively than the manual system. The automated system attained decoupling points for the four leading groups within 30-44 days at a Total Fill Range of 0.3591 - 0.5492 inside the expeditionary window of 60 days. The manual system required an average difference of 78.75 days to achieve decoupling points for these four groups at a Total Fill Range of 0.3965 - 0.6105. This occurred at the 74-143 day range and outside the expeditionary window of 60 days. The automated system was more effective in addressing the difference between demand and on-hand stocks than the manual system. These findings are also valuable in understanding how the weaknesses of the manual system, when combined with the limitations of Authorized Stockage Lists (ASL), may result in vulnerability that degrades effectiveness.

Generalizability of Automated Requisitioning Systems to Disaster Relief Environments

For future military operations, the existing model was found to be generalizable in terms of process structure, general knowledge of the effectiveness of the automated system, general knowledge of the repair parts makeup of demand and general knowledge of Authorized Stockage List (ASL) limitations. Less generalizable for future military operations were specific demand characteristics, which will be impacted by operational, environmental and utilization factors, as well as the type of unit deployed. For disaster relief operations, the existing model was found to be generalizable in terms of general knowledge of the effectiveness of the automated system, process structure of the warehouse, Authorized Stockage List and search activities. Less generalizable for disaster relief operations were the upstream process structure and specific demand characteristics.

Areas for Future Study

Development of a Strategic Decision Criteria Framework for Reestablishing the Automated System

A recommended area for future research is developing a framework for the strategic decision criteria to remain on the manual system or reestablish the automated system in the deployed environment. Such a framework could assist military units prior to operations in evaluating optimal courses of action, at the beginning of an operation, during operations as new information arises, or during the unit's redeployment to home station operations.

Such a framework would integrate the results and analysis of this research to produce a methodology for decision-making, involving the following criteria:

Anticipated Length of the Operation

Refers to the duration of the operation in terms of time, with the assumption that the longer the operation, the greater the likelihood that deployed demand volume will increase. This increased volume may result in breadth shortfalls that cannot be accommodated through ASL, as well as manual search activity backlog. A shorter anticipated length would support remaining on the manual system; a longer length would support reestablishing the automated system.

Anticipated Volume of Demand

Refers to the required quantity of requisitions that will be necessary to support the operation, knowing the potential impact that demand volume may have on the search and processing activities within a manual system (as outlined in Chapter 4). Evaluating this criterion would require an estimate of the operation's demand volume. A lower volume would result in less queue backlog for the manual search and processing activities and would therefore support remaining on the manual system. A higher volume would potentially present more of an impact on these activities and would support reestablishing the automated system.

Time Required to Deploy ASL and the Equipment Required to Establish the Automated System

Refers to the time required to deploy the physical stocks, terminals, satellites and other equipment necessary to establish the ability to independently process requisitions from the deployed environment. This time is affected by the competing priorities for deployment, such as distribution assets, water purification, or medical capabilities. This does not refer to the time required to change systems parameters, which are addressed separately below. A longer time required would support remaining on the manual system; a shorter time would support reestablishing the automated system.

ASL's Ability to Accommodate Anticipated Demand

Refers to the ASL's ability to meet demand during the operation, in terms of breadth and depth, as defined in Chapter 5. Evaluating this criterion would require an estimate of the operation's demand characteristics. A stronger ability of the ASL to meet anticipated demand would lessen the dependency on the wholesale system used and would support remaining on the manual system. A lesser ability of the ASL to meet anticipated demand would increase the dependency on the wholesale system used, and therefore supports reestablishing the automated system due to its assumed better effectiveness.

Time Required to Change Parameters in System (Addressing, Financial)

Refers to the time required for stakeholders at multiple levels within the supply chain to change the necessary parameters that affect where requisitions are delivered (addressing), how requisitions are managed, and how they are accounted for (financial). A longer time required supports remaining on the manual system; a shorter time supports reestablishing the automated system.

Ability of Higher Headquarters to Designate a Sponsoring Activity

Refers to the ability to identify a non-deployed retail activity that will process requisitions in support of the deployed unit using the manual system, as described in Chapter 4. As a sponsoring activity may improve the effectiveness of the manual system, an ability to designate such an activity supports remaining on the manual system; an inability to do supports reestablishing the automated system.

Ability of Sponsoring Activity (if one is designated) to Accommodate Anticipated Demand (in terms of fill and processing activity)

Refers to the ability of the sponsoring activity, if one is designated, to meet the demand anticipated in the deployed environment, in terms of breadth and depth. As with evaluating the unit ASL's ability to accommodate anticipated demand described above, evaluating this criterion would require an estimate of the operation's demand characteristics. A stronger ability supports remaining on the manual system; a lesser ability supports reestablishing the automated system.

Manual System Lead Time

Refers to the lead time from the unit's home station to its deployed location, as described in Chapter 4. A shorter lead time supports remaining on the manual system; a longer lead time supports reestablishing the automated system.

Volume Currently Due in to SSA's Non-Deployed Address

Refers to the amount of requisitions that are inbound to the unit that would possibly require re-directing to arrive at the unit's new address. A high amount of inbound requisitions supports remaining on the manual system due to the required amount of address changes and increased probability that items will be shipped to the wrong location. A low amount supports reestablishing the automated system.

Anticipated Recovery Time Following the Deployment

Refers to the amount of time required for the unit to return from the emergency operation to its non-deployed state. While this criterion is low in the priority for evaluation, a lower amount of time would support remaining on the manual system and may be driven by the requirement to quickly transition from the deployment to an operation that was planned before the deployment, or a follow-on operation that becomes a requirement during the operation. A higher amount of recovery time would better facilitate the system's return to its non-deployed state and would therefore support reestablishing the automated system.

Table 16 provides an example of how these criteria could be organized into a framework for assessment. This table lists the criteria described above. With this example, each criterion is assessed with a rating of low/high (for volume and quality) or short/ long (for time required). (While this example initially captures these assessments in a qualitative manner, future research would seek to define them quantitatively). The criterion assessment then indicates the system method (manual or automated) best supported, which is entered in the 'System Best Supported' cell. For example, if the assessment for the first criterion, length of the operation, was evaluated as 'short', the manual system would be best supported and 'manual' would be entered in the 'System Best Supported' cell.

Table 16
Example Framework for Strategic Decision Criteria

Evaluation Criteria	Criterion Assessment	Remain on Manual	Reestablish Automated System	System Best Supported
Length of Operation	Short or Long?	Short	Long	
Anticipated Demand Volume	Low or High?	Low	High	
ASL's Ability to Meet Demand	Low or High?	High	Low	
Time Required to Establish Automated System	Short or Long?	Long	Short	
Time Required to Change System Parameters	Short or Long?	Long	Short	
Ability to Designate Sponsoring Activity	Low or High?	High	Low	
Ability of Sponsoring Activity to Meet Anticipated Demand	Low or High?	High	Low	
Manual System Lead Time	Short or Long?	Short	Long	
Availability of Supplementary ASL	Low or High?	High	Low	
Volume Currently Due in to SSA's Non-deployed Address	Low or High?	High	Low	
Anticipated Recovery Time Following Operation	Short or Long?	Short	Long	

Certain criterion may contribute more to a decision than others. For example, under certain conditions, if the anticipated length, demand volume and ASL ability support reestablishing the automated system, then the remaining criteria may become irrelevant. Future research would further develop the qualitative and quantitative means to evaluate these criteria in order to derive the overall decision supported.

Difference between Non-deployed ASL and Deployed Demand

The Rand Dollar Cost Banding (2004) study states: "empirical data of National Training Center (NTC) suggest that demand patterns, while increasing overall with increased tempo, do not shift dramatically in terms of composition. Further, a proportion of home station failures occur during field exercises." However, the results in Chapter 5 indicate that these patterns may shift in terms of composition, reflected by the number of breadth items not supported by past demand history. Further research may contribute to preserving the effectiveness of expeditionary supply chains by addressing the potential for these breadth shifts to occur. There are several options to address these shifts: use of a supplementary ASL as initially modeled in Chapter 5, increase of downstream manufacturing capabilities, or implementation of postponement by combining upstream generic inventory with increased downstream production capability. Brigade Combat Teams already have some downstream capability to manufacture which will increase with the Metal Working Machine Shop Set (MWMSS) fielding in 2015. Additive printing could potentially increase forward manufacturing capability. Future research could identify the breadth shortfalls of future operational environments, then analyze the downstream ability to manufacture these shortfalls. Priority could be assigned to higher volume requisition categories, such as vehicle and communication repair parts, tools, fabrication items and readiness drivers within these categories with longer lead times. Such research could influence the needs and direction of downstream additive printing within the military supply chain.

Use of Model to Evaluate Disaster Relief Decoupling Points

The method of evaluating of decoupling points described in Chapter 5 could assist in evaluating a disaster relief supply chain's ability to respond to demand differences across the phases of relief, recovery and reconstitution. This method would assist in evaluating the use of prepositioned or locally procured stocks to address decoupling points, which may signal the change from one phase to another. Oloruntoba and Gray (2006) describe a necessary upstream leanness within the disaster relief supply chain due to the constantly changing suppliers and lack of fixed overhead. If the existing model were expanded to address the multiple sources of upstream lead time variation, the concept of the upstream "penetrating" decoupling point would provide a relevant framework for evaluating the leanness of the supply chain. Using this method would require identifying multiple D1, D2 and D3 decoupling points over an extended timeline.

Methods to Improve Automated System Deployability or Manual System Effectiveness

Little data exists to understand the true performance of the manual system. Manual systems are usually employed in emergency environments which focus on results as opposed to data collection. An area of future study could collect data on the functioning of a manual system to better understand its limitations. This data could be used to better model the manual system for comparison with the automated system, particularly in the key assumed parameters of capacity, local search success and lead time. However, capturing this data is challenging, as a real world contingency is required to generate the demand. Some data could be collected in training environments; however, this may produce limited data, as users may requisition less in a training exercise due to its short duration.

Conclusion

The findings in this study are relevant to the world's future operating environment. After 10 years of prolonged deployments conducting counterinsurgency operations, the Army is returning to an expeditionary method for conducting operations. At the same time, because more of the world's population lives in zones highly vulnerable to tsunamis, typhoons, hurricanes, tornadoes, earthquakes and other natural catastrophes, responding to these natural disasters will continue to be a priority (U.S. Joint Forces Command, 2010). Research and publications within the Department of Defense have called for supply chains that can address these contingencies. "Operation of the Logistics Enterprise in Complex Emergencies" asserted that "the recognition that complex emergencies are an increasingly common feature of the 21st century landscape and that the role of logistics is a central part of their resolution." In conducting these operations, military forces will typically operate in conjunction with or in the same physical space with other US Government agencies, partner governments, including those at the state, local and municipal levels, intergovernmental organization (IGOs), or NGOs and private corporations during both domestic and overseas contingencies (Joint Staff, 2012). Lieutenant General (Retired) Claude Christianson, the director of the Center for Joint and Strategic Logistics at National Defense University, states that future success in sustaining operations in the future global conflict "demands that we build sensor networks from the customer back, not from the strategic level forward as we have done in the past (Christianson, 2012)." It is towards these challenges of sustaining future expeditionary conflict and disaster relief situations that this research seeks to provide value.

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APPENDIX. ADDITIONAL TABLES

Table A1
Warehouse Start Up Data

NSN	ASL	OH	RO	ROP	NSN	ASL	OH	RO	ROP
00-045-9769	1	60	60	44	01-246-1120	33	84	86	29
00-107-3925	2	118	102	69	01-246-1822	34	54	55	29
00-161-9066	3	44	42	28	01-255-0207	35	26	29	7
00-549-6581	4	44	75	33	01-257-7706	36	26	30	26
00-549-6583	5	44	75	33	01-263-8889	37	123	124	117
00-726-1916	6	52	56	41	01-270-5448	38	192	147	72
00-809-4085	7	24	34	19	01-293-5466	39	22	25	0
00-811-1848	8	56	43	27	01-314-1188	40	57	59	0
00-815-1458	9	56	43	27	01-333-6068	41	31	38	19
00-880-7744	10	24	21	4	01-337-7324	42	77	88	9
00-908-6292	11	38	40	32	01-353-5794	43	0	41	13
00-992-7292	12	7	10	4	01-364-4622	44	20	19	3
01-128-5613	13	50	52	18	01-365-8024	45	22	23	11
01-128-5641	14	109	86	4	01-375-1903	46	26	33	17
01-157-6757	15	24	24	9	01-375-3950	47	26	26	3
01-161-2136	16	27	43	4	01-375-7257	48	59	59	0
01-167-4298	17	27	66	37	01-377-1638	49	40	37	0
01-168-7912	18	43	56	41	01-377-3127	50	22	25	12
01-179-7590	19	35	36	28	01-378-9264	51	22	19	9
01-184-5544	20	24	34	19	01-379-0644	52	29	29	20
01-184-9821	21	34	34	13	01-383-5846	53	22	20	9
01-185-9651	22	20	30	15	01-385-9031	54	52	63	40
01-186-0822	23	33	33	12	01-386-8790	55	40	32	14
01-186-2358	24	201	266	179	01-387-4036	56	22	22	9
01-186-7764	25	56	107	36	01-394-8332	57	20	19	7
01-189-0897	26	24	24	8	01-395-9585	58	20	20	18
01-189-9738	27	42	44	0	01-406-7217	59	1	1	0
01-192-4469	28	27	24	12	01-412-4013	60	50	50	0
01-199-1498	29	23	26	3	01-417-2755	61	1	1	0
01-203-5746	30	23	30	8	01-419-0222	62	3	2	1
01-212-7634	31	26	43	24	01-419-2990	63	1	1	0
01-236-0238	32	46	100	50	01-419-2992	64	2	2	1

Table A1
Warehouse Start Up Data (Continued)

NSN	ASL	OH	RO	ROP	NSN	ASL	OH	RO	ROP
01-420-1229	65	3	2	1	01-192-5817	99	12	28	8
01-420-9968	66	9	9	7	01-192-7498	100	14	11	2
01-423-1947	67	3	4	2	01-203-0412	101	16	17	14
01-423-6537	68	3	2	1	01-203-6551	102	20	26	19
01-434-0822	69	22	22	11	01-249-3492	103	13	13	6
01-439-6664	70	21	30	24	01-314-1189	104	18	21	7
01-440-8651	71	100	130	61	01-361-2346	105	13	13	4
01-442-9413	72	101	122	89	01-361-8229	106	12	13	6
01-443-3284	73	21	33	18	01-367-8921	107	12	12	3
01-448-3346	74	25	25	20	01-368-2911	108	13	15	12
01-452-1161	75	25	57	12	01-376-2316	109	12	16	5
01-461-7078	76	30	199	69	01-376-3676	110	15	15	5
01-461-7150	77	30	199	69	01-381-7489	111	14	14	10
01-478-4782	78	46	49	24	01-382-8728	112	16	16	9
01-481-7663	79	20	31	18	01-429-9149	113	15	11	3
01-483-2291	80	52	56	41	01-446-9506	114	46	100	50
01-558-2138	81	38	56	4	01-456-3884	115	19	26	12
00-059-3528	82	178	6	5	01-457-3171	116	20	20	19
00-100-3541	83	15	15	11	01-490-6691	117	17	15	7
00-142-4355	84	14	12	8	01-507-7423	118	12	11	5
00-557-7409	85	14	17	12	00-044-6914	119	106	3	12
00-809-8541	86	19	28	11	00-227-7356	120	11	8	2
00-974-7628	87	13	13	7	00-722-7074	121	10	13	5
00-993-5546	88	17	23	11	01-033-3889	122	7	16	4
01-033-1523	89	13	20	9	01-038-6869	123	9	7	3
01-126-1042	90	16	36	12	01-128-5608	124	11	11	5
01-128-5607	91	19	45	11	01-148-7492	125	9	10	3
01-131-2551	92	14	21	10	01-148-8875	126	3	2	1
01-174-8146	93	18	26	8	01-150-5944	127	9	9	2
01-180-9037	94	19	20	7	01-157-0856	128	11	17	5
01-185-6712	95	16	16	7	01-164-7593	129	10	9	5
01-185-7071	96	19	16	8	01-186-0969	130	10	10	3
01-190-2193	97	18	20	8	01-188-1370	131	10	30	3
01-192-4622	98	15	17	0	01-191-8783	132	9	10	4

Table A1
Warehouse Start Up Data (Continued)

NSN	ASL	OH	RO	ROP	NSN	ASL	OH	RO	ROP
01-194-2049	133	11	22	9	01-186-3740	167	6	11	4
01-195-2146	134	10	10	3	01-212-5868	168	6	8	4
01-203-0183	135	9	14	6	01-233-8637	169	7	19	6
01-249-1577	136	10	10	3	01-253-2825	170	7	10	4
01-256-3616	137	10	10	0	01-256-5350	171	7	7	4
01-293-5355	138	10	12	9	01-313-0458	172	7	7	3
01-293-5356	139	9	12	5	01-321-4482	173	7	9	3
01-294-1997	140	10	10	4	01-360-6366	174	8	8	3
01-314-9379	141	10	66	4	01-360-7724	175	6	6	4
01-356-7137	142	10	10	6	01-360-7725	176	6	6	4
01-360-7105	143	9	13	5	01-361-2407	177	7	10	4
01-375-7321	144	9	11	2	01-362-3392	178	6	10	2
01-385-9000	145	11	12	6	01-368-1531	179	6	12	5
01-398-3777	146	10	10	1	01-369-6549	180	6	6	3
01-398-8484	147	2	21	16	01-375-0478	181	7	7	3
01-465-8386	148	10	10	4	01-379-1410	182	7	8	4
00-207-9422	149	4	8	9	01-447-4762	183	6	7	4
00-379-2815	150	8	8	0	01-458-8017	184	6	6	3
00-683-0598	151	8	8	5	00-223-7397	185	5	7	3
01-169-2437	152	8	11	3	01-033-8872	186	6	8	3
01-181-1757	153	8	9	4	01-088-7798	187	6	5	2
01-188-3685	154	9	11	4	01-122-9552	188	5	4	1
01-189-1007	155	8	8	3	01-187-3386	189	5	8	4
01-189-6748	156	9	14	4	01-189-2195	190	6	8	3
01-196-1636	157	8	10	6	01-340-5627	191	5	8	3
01-326-8021	158	8	8	4	01-422-4748	192	16	16	9
01-378-8577	159	8	15	6	01-424-4115	193	9	13	3
01-385-8931	160	8	9	3	00-082-6034	194	180	7	5
01-410-8789	161	7	6	3	01-128-3053	195	5	5	2
01-444-1208	162	0	50	0	01-298-0498	196	5	5	1
01-472-8179	163	8	10	2	01-466-9476	197	5	6	4
01-502-7312	164	8	32	0	01-046-3399	198	5	7	2
00-238-0033	165	6	12	8	01-144-1499	199	5	5	2
01-090-8050	166	6	6	4	01-147-9808	200	5	5	2

Table A1
Warehouse Start Up Data (Continued)

NSN	ASL	OH	RO	ROP	NSN	ASL	OH	RO	ROP
01-147-9808	200	5	5	2	01-422-4745	233	16	16	9
01-205-2864	201	5	5	1	01-444-9478	234	3	5	2
01-284-2709	202	5	5	4	01-472-7762	235	4	5	1
01-356-7173	203	8	10	6	01-477-0840	236	4	9	3
01-384-1441	204	5	6	4	01-496-1925	237	3	4	1
01-185-8328	205	5	5	4	01-505-1035	238	3	4	1
01-282-6968	206	5	5	1	01-128-5477	239	3	8	2
00-078-5706	207	10	3	4	01-395-4257	240	3	3	1
00-168-2186	208	10	3	2	01-549-4174	241	3	10	2
00-978-1025	209	5	6	4	00-017-9547	242	228	13	3
00-992-6654	210	3	5	2	00-240-7080	243	2	6	1
00-992-6655	211	3	3	1	01-188-3684	244	2	5	1
00-992-7288	212	4	5	2	00-115-7149	245	15	2	3
01-128-5636	213	3	3	2	00-240-3720	246	2	2	0
01-128-5637	214	4	4	1	01-146-8006	247	2	2	1
01-136-5471	215	4	6	4	01-209-7843	248	2	7	1
01-147-9284	216	4	4	1	01-315-1609	249	2	2	1
01-186-6018	217	3	3	1	01-355-3686	250	2	3	1
01-188-0911	218	3	2	1	01-360-3099	251	2	2	1
01-189-0889	219	4	3	1	01-360-6118	252	2	4	1
01-190-3579	220	4	6	1	01-434-8611	253	40	32	14
01-200-0466	221	4	5	2	01-455-9287	254	2	2	1
01-206-0934	222	3	3	1	00-019-3093	255	242	17	2
01-213-1574	223	4	3	1	01-154-5127	256	2	1	0
01-237-7322	224	10	3	7	01-213-4185	257	2	1	0
01-251-1607	225	4	19	2	01-378-8572	258	2	4	3
01-279-5150	226	4	8	6	01-149-0874	259	2	3	1
01-303-7840	227	4	4	1	01-185-8329	260	1	10	0
01-326-4780	228	4	3	1	01-188-3863	261	2	2	1
01-358-9540	229	3	4	1	01-422-4747	262	38	38	19
01-362-9873	230	4	15	0	01-185-7048	263	1	6	1
01-382-8925	231	4	4	2	01-329-9151	264	1	8	4
01-420-8320	232	16	18	5	01-422-4743	265	53	53	34

Table A1

Warehouse Start Up Data (Continued)

NSN	ASL	OH	RO	ROP
01-422-4746	266	45	46	29
01-551-4525	267	1	1	0
00-099-5467	268	30	1	2
01-282-9316	269	1	2	0
01-310-6566	270	1	1	0
01-448-8513	271	1	2	0

Table A2

Time Between Requisitions Demanded

Day	Time Between Arrivals (TBA)	Day	Time Between Arrivals (TBA)	Day	Time Between Arrivals (TBA)	Day	Time Between Arrivals (TBA)
1	0.142	16	0.167	31	0.025	46	0
2	0.03	17	0	32	0.083	47	0
3	0.023	18	0.25	33	0.125	48	0
4	0.1	19	0.02	34	0.008	49	0
5	0	20	0.011	35	0.2	50	0
6	0	21	0.018	36	0.111	51	0
7	0.011	22	0.021	37	0.067	52	0
8	0	23	0.2	38	0.013	53	0
9	0	24	0.02	39	0.01	54	0
10	0.333	25	0.02	40	0.012	55	0
11	0	26	0.018	41	0.01	56	0
12	0	27	0.006	42	1	57	0
13	0	28	0.015	43	0.019	58	0
14	4	29	0.01	44	0.071	59	0
15	1	30	0.014	45	0		

Table A3

Probability of Specific Time Period 1 Priority 1 Demand by NSN

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
01-168-7912	0.015	18	01-256-5350	0.005	171	01-291-2975	0.005	384
01-179-7590	0.005	19	01-321-4482	0.005	173	01-315-7211	0.005	391
01-186-2358	0.005	24	01-447-4762	0.005	183	01-334-9858	0.005	399
01-212-7634	0.005	31	01-033-8872	0.015	186	01-335-1033	0.005	400
01-353-5794	0.005	43	01-466-9476	0.005	197	01-360-2380	0.005	409
01-375-1903	0.005	46	01-046-3399	0.005	198	01-364-1626	0.005	413
01-377-3127	0.005	50	01-282-6968	0.005	206	01-374-9147	0.005	422
01-420-9968	0.005	66	00-992-6654	0.005	210	01-381-6048	0.025	430
01-439-6664	0.005	70	00-992-6655	0.005	211	01-384-8597	0.013	433
01-461-7078	0.005	76	01-128-5636	0.005	213	01-434-1781	0.005	446
01-461-7150	0.005	77	01-128-5637	0.005	214	01-444-1231	0.005	457
01-192-7498	0.005	100	01-206-0934	0.005	222	01-455-9642	0.005	467
01-367-8921	0.005	107	01-213-1574	0.005	223	01-541-6816	0.01	507
01-382-8728	0.005	112	01-128-5477	0.005	239	00-132-8973	0.005	511
01-446-9506	0.032	114	01-549-4174	0.005	241	00-143-3159	0.005	512
01-456-3884	0.005	115	01-455-9287	0.005	254	00-619-8880	0.014	526
01-507-7423	0.005	118	00-019-3093	0.005	255	01-199-5423	0.005	549
00-044-6914	0.005	119	01-154-5127	0.005	256	01-326-1816	0.005	558
01-033-3889	0.005	122	01-378-8572	0.005	258	01-375-8087	0.005	586
01-148-7492	0.005	125	01-551-4525	0.042	267	01-428-6195	0.005	606
01-150-5944	0.005	127	00-099-5467	0.012	268	01-482-6107	0.005	615
01-188-1370	0.005	131	01-448-8513	0.005	271	01-526-5612	0.005	621
01-256-3616	0.005	137	00-068-0510	0.005	277	00-252-3384	0.005	626
01-293-5355	0.005	138	00-307-8856	0.005	296	00-724-7264	0.005	629
01-293-5356	0.005	139	01-012-9294	0.005	309	00-909-2483	0.025	633
01-465-8386	0.005	148	01-131-4932	0.005	318	01-294-1803	0.005	645
00-379-2815	0.012	150	01-184-1937	0.005	334	01-294-3260	0.005	646
01-188-3685	0.005	154	01-200-1995	0.005	351	01-413-1366	0.005	659
01-189-6748	0.005	156	01-200-6611	0.005	352	01-310-6780	0.005	679
01-502-7312	0.005	164	01-217-8184	0.005	366	01-372-3513	0.005	683
01-090-8050	0.005	166	01-246-6807	0.033	370	01-454-1148	0.005	693
01-233-8637	0.005	169	01-246-6810	0.085	371	01-463-9260	0.005	694

Table A3

Probability of Specific Time Period 1 Priority 1 Demand by NSN (Continued)

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
01-493-5859	0.015	701	00-926-5493	0.005	825	00-617-0991	0.005	923
00-177-5106	0.005	708	00-999-1509	0.005	826	00-934-7989	0.005	927
00-180-5922	0.005	710	01-116-7866	0.005	832	00-158-3805	0.005	933
00-205-1168	0.005	711	01-207-4167	0.005	839	01-188-3776	0.005	946
00-243-3407	0.005	718	01-335-2623	0.005	848	01-381-2219	0.005	953
00-281-5911	0.005	723	01-352-7321	0.005	849	01-196-0136	0.005	967
00-357-7386	0.005	725	01-386-2265	0.005	857	01-505-3661	0.005	976
01-334-7086	0.005	740	01-386-2329	0.005	859	01-456-7985	0.005	982
01-373-8849	0.005	744	01-547-9043	0.005	896	00-224-8663	0.005	983
01-386-2399	0.005	747	01-374-2243	0.005	901	01-310-4495	0.005	984
01-411-5266	0.005	749	01-360-5271	0.005	905	00-222-3521	0.005	987
00-057-2553	0.005	763	00-530-3770	0.005	910	00-266-9736	0.012	992
01-398-2473	0.005	771	01-178-5559	0.005	914	00-270-1587	0.005	996
01-168-7905	0.005	778	01-346-9148	0.005	919	00-921-5516	0.005	997
00-178-8315	0.012	785	01-376-5666	0.005	920	00-262-9914	0.005	998
00-162-6178	0.005	801	01-386-1609	0.005	921			

Table A4

Probability of Specific Time Period 2 Priority 1 Demand by NSN

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
00-045-9769	0.001	1	01-128-5641	0.001	14	01-199-1498	0.001	29
00-107-3925	0.001	2	01-157-6757	0.001	15	01-203-5746	0.002	30
00-161-9066	0.001	3	01-161-2136	0.001	16	01-236-0238	0.001	32
00-549-6581	0.001	4	01-167-4298	0.001	17	01-246-1120	0.002	33
00-549-6583	0.002	5	01-179-7590	0.001	19	01-246-1822	0.001	34
00-726-1916	0.001	6	01-184-5544	0.001	20	01-255-0207	0.001	35
00-809-4085	0.001	7	01-184-9821	0.001	21	01-257-7706	0.001	36
00-811-1848	0.001	8	01-185-9651	0.001	22	01-263-8889	0.001	37
00-815-1458	0.001	9	01-186-0822	0.001	23	01-270-5448	0.001	38
00-880-7744	0.001	10	01-186-7764	0.002	25	01-293-5466	0.001	39
00-908-6292	0.001	11	01-189-0897	0.001	26	01-314-1188	0.001	40
00-992-7292	0.001	12	01-189-9738	0.001	27	01-333-6068	0.001	41
01-128-5613	0.001	13	01-192-4469	0.001	28	01-337-7324	0.001	42

Table A4

Probability of Specific Time Period 2 Priority 1 Demand by NSN (Continued)

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
01-364-4622	0.001	44	01-481-7663	0.001	79	01-429-9149	0.001	113
01-365-8024	0.001	45	01-483-2291	0.004	80	01-446-9506	0.001	114
01-375-1903	0.001	46	01-558-2138	0.001	81	01-456-3884	0.002	115
01-375-3950	0.001	47	00-059-3528	0.001	82	01-457-3171	0.001	116
01-375-7257	0.001	48	00-100-3541	0.001	83	01-490-6691	0.001	117
01-377-1638	0.001	49	00-142-4355	0.001	84	01-507-7423	0.004	118
01-378-9264	0.001	51	00-557-7409	0.001	85	00-044-6914	0.006	119
01-379-0644	0.001	52	00-974-7628	0.001	87	00-227-7356	0.002	120
01-383-5846	0.001	53	00-993-5546	0.002	88	00-722-7074	0.001	121
01-385-9031	0.002	54	01-033-1523	0.001	89	01-038-6869	0.001	123
01-386-8790	0.001	55	01-126-1042	0.001	90	01-128-5608	0.001	124
01-387-4036	0.001	56	01-128-5607	0.001	91	01-148-7492	0.001	125
01-394-8332	0.001	57	01-131-2551	0.001	92	01-148-8875	0.001	126
01-395-9585	0.001	58	01-174-8146	0.001	93	01-150-5944	0.001	127
01-406-7217	0.001	59	01-180-9037	0.005	94	01-157-0856	0.001	128
01-412-4013	0.001	60	01-185-6712	0.002	95	01-164-7593	0.001	129
01-417-2755	0.001	61	01-185-7071	0.001	96	01-186-0969	0.001	130
01-419-0222	0.001	62	01-190-2193	0.001	97	01-188-1370	0.001	131
01-419-2990	0.001	63	01-192-4622	0.001	98	01-191-8783	0.001	132
01-419-2992	0.001	64	01-192-5817	0.001	99	01-194-2049	0.002	133
01-420-1229	0.001	65	01-192-7498	0.002	100	01-195-2146	0.001	134
01-420-9968	0.002	66	01-203-0412	0.001	101	01-203-0183	0.001	135
01-423-1947	0.001	67	01-203-6551	0.001	102	01-249-1577	0.001	136
01-423-6537	0.001	68	01-249-3492	0.001	103	01-256-3616	0.001	137
01-434-0822	0.001	69	01-314-1189	0.002	104	01-294-1997	0.001	140
01-439-6664	0.002	70	01-361-2346	0.001	105	01-314-9379	0.003	141
01-440-8651	0.001	71	01-361-8229	0.001	106	01-356-7137	0.001	142
01-442-9413	0.002	72	01-367-8921	0.003	107	01-360-7105	0.001	143
01-443-3284	0.001	73	01-368-2911	0.001	108	01-375-7321	0.001	144
01-448-3346	0.001	74	01-376-2316	0.001	109	01-385-9000	0.003	145
01-452-1161	0.001	75	01-376-3676	0.001	110	01-398-3777	0.001	146
01-461-7150	0.001	77	01-381-7489	0.001	111	01-398-8484	0.001	147
01-478-4782	0.002	78	01-382-8728	0.002	112	00-207-9422	0.001	149

Table A4
Probability of Specific Time Period 2 Priority 1 Demand by NSN (Continued)

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
00-379-2815	0.001	150	01-088-7798	0.001	187	01-251-1607	0.001	225
00-683-0598	0.001	151	01-122-9552	0.001	188	01-279-5150	0.002	226
01-169-2437	0.001	152	01-187-3386	0.001	189	01-303-7840	0.001	227
01-181-1757	0.001	153	01-189-2195	0.001	190	01-326-4780	0.001	228
01-188-3685	0.003	154	01-340-5627	0.001	191	01-358-9540	0.001	229
01-189-1007	0.001	155	01-422-4748	0.001	192	01-362-9873	0.001	230
01-326-8021	0.001	158	01-424-4115	0.001	193	01-382-8925	0.001	231
01-378-8577	0.001	159	00-082-6034	0.003	194	01-420-8320	0.001	232
01-385-8931	0.001	160	01-128-3053	0.001	195	01-422-4745	0.001	233
01-410-8789	0.001	161	01-298-0498	0.001	196	01-444-9478	0.001	234
01-444-1208	0.001	162	01-466-9476	0.001	197	01-472-7762	0.001	235
01-472-8179	0.001	163	01-046-3399	0.001	198	01-477-0840	0.001	236
01-502-7312	0.002	164	01-144-1499	0.001	199	01-496-1925	0.001	237
00-238-0033	0.001	165	01-147-9808	0.001	200	01-505-1035	0.001	238
01-186-3740	0.001	167	01-205-2864	0.001	201	01-395-4257	0.001	240
01-212-5868	0.002	168	01-284-2709	0.001	202	00-017-9547	0.001	242
01-233-8637	0.001	169	01-356-7173	0.001	203	00-240-7080	0.001	243
01-253-2825	0.001	170	01-384-1441	0.001	204	01-188-3684	0.003	244
01-256-5350	0.002	171	01-185-8328	0.001	205	00-115-7149	0.001	245
01-313-0458	0.001	172	01-282-6968	0.001	206	00-240-3720	0.001	246
01-321-4482	0.003	173	00-078-5706	0.001	207	01-146-8006	0.001	247
01-360-6366	0.003	174	00-168-2186	0.001	208	01-209-7843	0.001	248
01-360-7724	0.001	175	00-978-1025	0.001	209	01-315-1609	0.001	249
01-360-7725	0.001	176	00-992-7288	0.001	212	01-355-3686	0.001	250
01-361-2407	0.001	177	01-136-5471	0.001	215	01-360-3099	0.001	251
01-362-3392	0.001	178	01-147-9284	0.003	216	01-360-6118	0.001	252
01-368-1531	0.001	179	01-186-6018	0.001	217	01-434-8611	0.001	253
01-369-6549	0.001	180	01-188-0911	0.001	218	01-455-9287	0.002	254
01-375-0478	0.001	181	01-189-0889	0.003	219	00-019-3093	0.004	255
01-379-1410	0.001	182	01-190-3579	0.004	220	01-154-5127	0.001	256
01-458-8017	0.001	184	01-200-0466	0.001	221	01-213-4185	0.003	257
00-223-7397	0.003	185	01-213-1574	0.001	223	01-378-8572	0.001	258
01-033-8872	0.001	186	01-237-7322	0.001	224	01-149-0874	0.001	259

Table A4
Probability of Specific Time Period 2 Priority 1 Demand by NSN (Continued)

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
01-185-8329	0.001	260	00-307-8856	0.005	296	01-175-7219	0.001	331
01-188-3863	0.001	261	00-407-9566	0.001	297	01-178-7445	0.001	332
01-422-4747	0.001	262	00-498-2905	0.001	298	01-183-6757	0.001	333
01-185-7048	0.001	263	00-498-2920	0.001	299	01-184-5545	0.001	335
01-329-9151	0.001	264	00-543-2419	0.001	300	01-185-3757	0.001	336
01-422-4743	0.001	265	00-686-9151	0.001	301	01-185-7188	0.001	337
01-422-4746	0.001	266	00-705-6714	0.001	302	01-187-3485	0.001	339
00-099-5467	0.001	268	00-753-5242	0.001	303	01-187-6911	0.001	340
01-282-9316	0.001	269	00-765-8443	0.001	304	01-188-3229	0.001	341
01-310-6566	0.001	270	00-768-0318	0.001	305	01-190-7079	0.003	342
00-013-7228	0.001	272	00-777-3068	0.001	306	01-192-3673	0.001	343
00-018-2296	0.001	273	00-951-7209	0.001	307	01-194-0473	0.001	344
00-019-0877	0.001	274	00-992-7287	0.001	308	01-196-4937	0.001	345
00-051-8568	0.001	275	01-014-6856	0.001	310	01-196-5228	0.001	346
00-060-4707	0.001	276	01-025-1692	0.001	311	01-197-4900	0.001	347
00-081-9491	0.001	278	01-033-3900	0.001	312	01-197-7689	0.001	348
00-083-5009	0.001	279	01-046-5864	0.001	313	01-197-7690	0.001	349
00-106-7598	0.001	280	01-092-1904	0.002	314	01-199-2391	0.001	350
00-134-5036	0.001	281	01-108-6410	0.001	315	01-207-9004	0.001	353
00-151-6120	0.001	282	01-128-5490	0.001	316	01-208-7097	0.001	354
00-155-7790	0.001	283	01-129-0492	0.001	317	01-209-4590	0.001	355
00-155-8717	0.001	284	01-131-9693	0.001	319	01-209-5997	0.001	356
00-168-2187	0.001	285	01-139-4886	0.001	320	01-209-6008	0.001	357
00-197-1274	0.001	286	01-142-7498	0.001	321	01-209-7834	0.001	358
00-202-3639	0.001	287	01-147-8744	0.001	322	01-210-3504	0.001	359
00-243-1169	0.001	288	01-148-3686	0.001	323	01-210-5785	0.001	360
00-248-6974	0.001	289	01-149-6787	0.001	324	01-210-8868	0.001	361
00-250-0926	0.001	290	01-149-7859	0.001	325	01-211-7436	0.001	362
00-275-5012	0.001	291	01-151-4180	0.001	326	01-213-5545	0.001	364
00-278-4822	0.001	292	01-155-7784	0.001	327	01-214-1568	0.001	365
00-278-8575	0.001	293	01-159-5796	0.001	328	01-236-0319	0.001	368
00-294-0860	0.001	294	01-165-2363	0.001	329	01-236-0663	0.001	369
00-295-5757	0.002	295	01-172-1919	0.001	330	01-246-8281	0.001	372

Table A4
Probability of Specific Time Period 2 Priority 1 Demand by NSN (Continued)

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
01-252-8362	0.001	373	01-366-0193	0.001	415	01-443-9093	0.001	455
01-252-9214	0.001	374	01-366-2726	0.001	416	01-444-1218	0.001	456
01-253-4647	0.001	375	01-368-2539	0.001	417	01-444-4365	0.001	458
01-258-1536	0.001	376	01-368-7644	0.001	418	01-447-9655	0.001	459
01-261-5484	0.001	377	01-370-5483	0.001	419	01-450-5479	0.001	460
01-262-9520	0.001	378	01-370-5484	0.001	420	01-451-8114	0.001	461
01-266-1651	0.001	379	01-372-3883	0.001	421	01-452-8409	0.001	462
01-281-5201	0.001	381	01-375-6341	0.001	423	01-455-0665	0.001	464
01-288-8567	0.001	383	01-376-3744	0.001	424	01-455-1014	0.001	465
01-291-2975	0.001	384	01-377-1535	0.001	425	01-455-1017	0.001	466
01-291-4597	0.001	385	01-377-3121	0.001	426	01-456-1500	0.001	468
01-299-7699	0.001	386	01-377-4279	0.001	427	01-459-0050	0.001	469
01-313-3562	0.001	387	01-377-6607	0.001	428	01-461-0607	0.001	470
01-314-7834	0.001	388	01-378-1755	0.001	429	01-462-3596	0.001	471
01-314-7835	0.001	389	01-383-2387	0.003	431	01-465-5993	0.002	472
01-314-9378	0.001	390	01-384-5101	0.001	432	01-469-9893	0.001	473
01-315-7223	0.001	392	01-385-1139	0.003	434	01-470-3219	0.001	474
01-315-8649	0.001	393	01-385-5341	0.001	435	01-470-6230	0.001	475
01-319-5435	0.001	394	01-387-3987	0.001	436	01-471-5112	0.001	476
01-328-4878	0.001	395	01-388-4847	0.001	437	01-474-2072	0.001	477
01-332-1326	0.001	397	01-409-1662	0.001	439	01-476-8945	0.001	478
01-333-8263	0.001	398	01-411-2729	0.002	440	01-476-8981	0.001	479
01-342-6820	0.001	402	01-413-3713	0.001	441	01-477-0732	0.002	480
01-346-5341	0.001	403	01-415-9613	0.001	442	01-477-3650	0.001	481
01-353-7523	0.001	404	01-420-5986	0.001	443	01-477-3656	0.001	482
01-357-9708	0.001	406	01-421-4589	0.001	444	01-478-7862	0.001	483
01-358-3160	0.001	408	01-423-5549	0.001	445	01-479-5023	0.001	484
01-360-2380	0.001	409	01-438-4900	0.001	447	01-479-8859	0.002	485
01-361-1456	0.001	410	01-438-4901	0.001	448	01-480-0093	0.001	486
01-362-5229	0.001	411	01-438-7792	0.001	449	01-480-4890	0.001	487
01-363-2562	0.001	412	01-439-1154	0.001	450	01-491-0691	0.001	488
01-364-1626	0.001	413	01-439-2380	0.001	451	01-480-4890	0.001	487
01-365-7152	0.001	414	01-439-9700	0.002	452	01-491-0691	0.001	488

Table A4
Probability of Specific Time Period 2 Priority 1 Demand by NSN (Continued)

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
01-493-6643	0.006	489	00-643-5626	0.001	527	01-361-0616	0.001	564
01-495-0817	0.001	490	00-816-6892	0.001	528	01-361-5802	0.005	565
01-496-9879	0.004	491	00-837-7757	0.001	529	01-363-0492	0.001	566
01-498-0332	0.001	492	00-855-7478	0.001	530	01-363-0493	0.001	567
01-500-4619	0.002	493	00-869-3144	0.001	531	01-363-6833	0.001	568
01-502-9504	0.009	494	00-889-3494	0.001	532	01-364-1596	0.001	569
01-504-0680	0.001	495	00-892-9311	0.001	533	01-365-9614	0.002	570
01-506-7709	0.001	496	00-933-3600	0.001	534	01-365-9953	0.002	571
01-507-7938	0.002	498	01-038-2820	0.001	535	01-366-0735	0.001	572
01-515-2404	0.003	499	01-047-0258	0.001	536	01-366-2725	0.001	573
01-521-3187	0.001	500	01-073-1768	0.001	537	01-366-8983	0.001	574
01-526-2846	0.001	501	01-076-8659	0.001	538	01-367-9723	0.002	575
01-527-0464	0.001	502	01-107-6474	0.001	540	01-368-2891	0.001	576
01-527-4590	0.001	503	01-128-5601	0.001	541	01-368-5160	0.001	577
01-528-1903	0.003	504	01-145-3154	0.002	542	01-368-5430	0.001	578
01-529-7226	0.001	505	01-149-5061	0.001	543	01-368-7113	0.001	579
01-533-4172	0.001	506	01-167-1541	0.001	544	01-369-0021	0.001	580
12-176-7417	0.001	509	01-168-7891	0.001	545	01-369-0893	0.001	581
00-089-3031	0.001	510	01-172-6381	0.001	546	01-370-2868	0.001	582
00-143-3159	0.001	512	01-190-1969	0.001	547	01-372-3883	0.001	584
00-148-7961	0.001	513	01-198-5455	0.001	548	01-373-0526	0.001	585
00-224-1372	0.001	514	01-220-7105	0.001	550	01-375-8087	0.003	586
00-224-1390	0.001	515	01-227-9604	0.001	551	01-376-1613	0.001	587
00-247-9105	0.001	516	01-291-5072	0.001	553	01-376-5259	0.004	588
00-265-7462	0.001	517	01-301-5195	0.001	554	01-378-6025	0.001	589
00-285-0901	0.001	518	01-306-4622	0.001	555	01-378-6882	0.001	590
00-449-6775	0.001	519	01-308-8988	0.001	556	01-381-9950	0.001	591
00-528-3771	0.001	520	01-322-6986	0.001	557	01-382-5915	0.001	592
00-539-2573	0.001	521	01-331-3567	0.001	559	01-382-8782	0.001	593
00-539-6920	0.001	522	01-333-2151	0.001	560	01-384-5937	0.001	594
00-542-4668	0.001	523	01-333-2309	0.001	561	01-385-1102	0.001	595
00-551-1094	0.001	524	01-359-4770	0.001	562	01-385-1894	0.001	596
00-580-6304	0.001	525	01-360-4778	0.003	563	01-386-0543	0.001	597

Table A4
Probability of Specific Time Period 2 Priority 1 Demand by NSN (Continued)

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
01-389-0682	0.001	599	01-049-5263	0.001	638	01-244-9863	0.001	678
01-389-6028	0.001	600	01-148-3771	0.001	639	01-310-6780	0.002	679
01-391-6360	0.001	601	01-156-7296	0.002	640	01-317-6140	0.001	680
01-392-8821	0.001	602	01-255-0208	0.001	644	01-356-7138	0.001	681
01-395-6537	0.001	603	01-342-2739	0.001	647	01-359-4992	0.003	682
01-417-2228	0.001	604	01-355-6028	0.001	648	01-378-7172	0.002	684
01-421-1106	0.001	605	01-361-2173	0.001	649	01-382-3940	0.001	685
01-431-4558	0.001	607	01-368-2893	0.003	650	01-406-9542	0.001	686
01-444-7651	0.001	608	01-374-0532	0.001	651	01-416-7830	0.001	687
01-459-4985	0.002	609	01-375-7322	0.001	652	01-418-4404	0.001	688
01-461-9777	0.002	610	01-375-7805	0.001	653	01-424-7315	0.001	689
01-463-4490	0.003	611	01-378-6921	0.002	654	01-426-4425	0.001	690
01-463-9774	0.001	612	01-386-0360	0.001	655	01-444-9487	0.001	691
01-477-0855	0.002	613	01-386-4192	0.001	656	01-446-9498	0.004	692
01-480-5775	0.002	614	01-407-3977	0.001	657	01-463-9260	0.001	694
01-487-3587	0.001	616	01-408-7785	0.006	658	01-465-5999	0.002	695
01-490-4423	0.001	617	01-413-1366	0.001	659	01-476-8607	0.001	696
01-491-1339	0.001	618	01-421-5159	0.001	660	01-477-4194	0.001	697
01-498-9903	0.001	619	01-424-2495	0.001	661	01-486-9482	0.002	698
01-511-2578	0.001	620	01-460-7980	0.001	662	01-490-7254	0.003	699
01-526-5612	0.001	621	01-477-0634	0.001	663	01-493-4533	0.001	700
01-531-2976	0.001	622	12-342-1512	0.001	665	01-493-5859	0.001	701
01-531-2977	0.001	623	00-244-1319	0.001	666	01-502-1852	0.002	702
01-544-5905	0.001	624	00-288-6574	0.002	667	01-502-9507	0.009	703
00-243-3367	0.001	625	00-726-5165	0.001	668	01-527-0510	0.001	704
00-293-2336	0.002	628	00-772-4142	0.002	669	01-554-8288	0.001	705
00-837-7754	0.001	630	00-910-3065	0.001	670	99-301-6898	0.001	706
00-880-1624	0.002	631	00-965-1709	0.001	671	00-106-7478	0.001	707
00-892-4525	0.001	632	00-989-3388	0.001	672	00-177-6154	0.001	709
00-909-2483	0.002	633	01-036-6829	0.001	673	00-205-2795	0.001	712
00-940-0947	0.001	634	01-061-4426	0.001	674	00-221-1999	0.001	713
00-975-1156	0.001	635	01-174-9142	0.001	675	00-234-8912	0.001	714
01-003-9599	0.001	636	01-180-9099	0.001	676	00-240-5328	0.001	715
01-032-6042	0.001	637	01-196-1642	0.001	677	00-243-2395	0.001	716

Table A4

Probability of Specific Time Period 2 Priority 1 Demand by NSN (Continued)

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
00-243-2419	0.002	717	01-527-9584	0.001	761	00-197-1271	0.001	802
00-255-4571	0.001	719	01-546-2031	0.001	762	00-205-1421	0.001	803
00-263-0328	0.001	720	00-205-1711	0.001	765	00-223-7800	0.001	804
00-263-8504	0.001	721	00-234-8913	0.002	766	00-224-7446	0.001	805
00-264-8261	0.001	722	01-043-7488	0.001	767	00-237-6985	0.001	806
00-292-2306	0.001	724	01-364-8306	0.001	768	00-242-3435	0.001	807
00-359-6848	0.001	726	01-378-1130	0.004	769	00-248-1153	0.001	808
00-575-2243	0.001	727	01-386-2323	0.001	770	00-256-2158	0.001	809
00-596-9156	0.001	728	01-398-2473	0.001	771	00-264-3796	0.001	810
00-670-2459	0.001	729	01-416-8568	0.001	772	00-272-2489	0.001	811
00-900-6103	0.002	730	01-425-7305	0.001	773	00-287-1468	0.001	812
00-966-3831	0.004	731	01-470-7197	0.001	774	00-292-2307	0.001	813
01-038-6826	0.001	732	01-479-8945	0.001	775	00-316-9217	0.001	814
01-197-7692	0.001	733	00-007-4791	0.001	776	00-488-7939	0.001	815
01-199-6103	0.001	734	00-264-5368	0.001	777	00-488-7950	0.001	816
01-219-4697	0.001	735	01-174-8145	0.003	779	00-535-1217	0.001	817
01-219-8200	0.002	736	01-360-5929	0.001	780	00-616-0997	0.001	818
01-293-5345	0.001	738	01-374-9934	0.001	781	00-680-2635	0.001	819
01-353-8696	0.001	741	01-490-7301	0.002	782	00-752-9030	0.001	820
01-358-9532	0.001	742	01-525-7555	0.002	783	00-808-8019	0.001	821
01-366-2836	0.001	743	01-528-2989	0.001	784	00-809-5998	0.001	822
01-374-1764	0.001	745	00-972-8204	0.001	787	00-844-4456	0.001	823
01-407-0532	0.001	748	01-253-6439	0.001	788	00-880-4454	0.001	824
01-439-9698	0.001	750	01-314-1190	0.003	789	01-055-6094	0.001	827
01-439-9705	0.001	751	01-326-8017	0.001	790	01-072-4342	0.001	828
01-454-5502	0.001	752	01-326-8110	0.001	791	01-074-6684	0.001	829
01-459-1661	0.003	753	01-359-4971	0.001	792	01-085-1665	0.001	830
01-461-7547	0.001	754	01-360-7826	0.001	793	01-103-3267	0.001	831
01-474-0894	0.001	755	01-365-6535	0.001	794	01-128-3944	0.001	833
01-482-7542	0.001	756	01-372-0636	0.001	795	01-134-3630	0.001	834
01-508-1282	0.004	757	01-376-3674	0.001	796	01-139-4010	0.001	835
01-517-4151	0.001	758	01-527-5765	0.001	797	01-179-4106	0.001	836
01-523-6533	0.001	759	00-292-2363	0.002	798	01-189-1832	0.001	837
01-525-3095	0.013	760	00-044-9281	0.001	800	01-190-3862	0.001	838

Table A4

Probability of Specific Time Period 2 Priority 1 Demand by NSN (Continued)

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
01-210-5872	0.001	840	01-430-3051	0.001	876	00-899-3054	0.001	912
01-230-8601	0.001	841	01-430-3052	0.001	877	01-035-5393	0.001	913
01-251-5316	0.001	842	01-433-1894	0.001	878	01-178-5559	0.004	914
01-254-1492	0.001	843	01-444-1216	0.001	879	01-178-5560	0.003	915
01-324-3462	0.001	844	01-473-9274	0.001	880	01-197-2160	0.001	916
01-324-3463	0.001	845	01-479-1492	0.001	881	01-346-5339	0.001	918
01-326-5533	0.001	846	01-498-1876	0.001	882	01-376-5666	0.004	920
01-327-1448	0.001	847	01-507-9080	0.001	883	00-590-1878	0.001	922
01-335-2623	0.002	848	01-509-1467	0.001	884	00-266-5016	0.002	924
01-360-5987	0.001	850	01-513-6406	0.001	885	01-360-2925	0.001	925
01-360-6368	0.001	851	01-522-0835	0.001	886	01-375-5085	0.002	926
01-360-9653	0.001	852	01-525-7554	0.001	887	00-934-7989	0.004	927
01-362-7192	0.001	853	01-527-4594	0.001	888	01-227-7992	0.003	928
01-370-2999	0.001	854	01-544-9476	0.001	889	00-240-8703	0.001	929
01-373-3649	0.001	855	01-548-9077	0.001	890	01-395-0291	0.001	930
01-382-8214	0.001	856	01-549-6409	0.001	891	01-468-5390	0.002	931
01-386-2289	0.001	858	01-549-6419	0.001	892	00-029-0388	0.001	932
01-386-2329	0.002	859	01-550-0490	0.001	893	00-158-3805	0.003	933
01-394-6252	0.001	860	00-240-8898	0.001	894	00-172-1919	0.001	934
01-398-7946	0.001	861	01-103-3268	0.001	895	00-269-8463	0.003	935
01-398-7950	0.001	862	01-547-9043	0.002	896	00-395-8799	0.001	936
01-398-7951	0.001	863	00-835-7210	0.001	897	00-828-8639	0.001	937
01-398-7973	0.001	864	01-121-6350	0.001	898	00-930-7223	0.001	938
01-425-9120	0.001	865	01-260-3792	0.001	899	00-978-1022	0.001	939
01-430-2917	0.001	866	01-461-2084	0.001	900	00-978-1023	0.001	940
01-430-2919	0.001	867	01-374-2243	0.001	901	01-102-9455	0.001	941
01-430-2929	0.001	868	01-521-6438	0.002	902	01-179-4107	0.001	942
01-430-2938	0.001	869	01-527-0515	0.001	903	01-184-5503	0.001	943
01-430-2947	0.001	870	00-246-0688	0.001	904	01-185-9668	0.001	944
01-430-2966	0.001	871	01-385-7235	0.001	906	01-186-1016	0.001	945
01-430-2999	0.001	872	01-185-7218	0.002	907	01-195-9752	0.002	947
01-430-3003	0.001	873	00-199-8831	0.001	908	01-246-8273	0.001	948
01-430-3020	0.001	874	00-292-9946	0.001	909	01-287-2603	0.001	949
01-430-3023	0.001	875	00-826-4798	0.001	911	01-363-3089	0.003	950

Table A4

Probability of Specific Time Period 2 Priority 1 Demand by NSN (Continued)

NSN	Prob	ASL	NSN	Prob	ASL	NSN	Prob	ASL
01-346-5339	0.001	918	01-430-5045	0.001	956	01-039-3494	0.001	974
01-376-5666	0.004	920	01-435-4921	0.001	957	01-465-2096	0.001	975
00-590-1878	0.001	922	01-452-2215	0.001	958	01-510-2337	0.001	977
00-266-5016	0.002	924	01-456-5196	0.001	959	01-549-4203	0.001	978
01-360-2925	0.001	925	01-488-5606	0.001	960	00-089-3827	0.006	979
01-375-5085	0.002	926	01-491-0345	0.001	961	01-337-5269	0.001	980
00-934-7989	0.004	927	01-548-1183	0.001	962	01-456-7985	0.001	982
01-227-7992	0.003	928	01-247-0365	0.001	963	00-141-2942	0.001	985
00-240-8703	0.001	929	00-252-6383	0.001	964	01-085-1423	0.001	986
01-395-0291	0.001	930	01-464-9137	0.001	965	00-222-3521	0.001	987
01-468-5390	0.002	931	00-682-1508	0.002	966	00-418-8557	0.007	988
00-029-0388	0.001	932	01-196-0136	0.003	967	01-214-6441	0.001	989
00-158-3805	0.003	933	01-230-8597	0.001	968	01-498-2078	0.001	990
00-172-1919	0.001	934	01-369-9340	0.001	969	01-516-3225	0.001	991
01-363-4377	0.001	951	01-430-5037	0.001	970	01-505-3660	0.001	993
01-375-7624	0.001	952	01-516-3218	0.004	971	01-381-3292	0.001	994
01-424-3523	0.001	954	00-935-7135	0.004	972			
01-424-7906	0.001	955	00-247-0318	0.001	973			

Table A5

Probability of Sourcing and Depot Determination Passed to Higher Source of Supply, Time Period 1

TPSD	SOF-Depot	Probability
1111	WHSLBO	0.1139
1121	WHSLAN5	0.0094
1122	WHSLGN3	0.0284
1133	DVDBO	0.0633
1144	LATON	0.7848

Table A6

Probability of Sourcing and Depot Determination Passed to Higher Source of Supply, Time Period 2

TPSD	SOF-Depot	Probability
2111	WHSLBO	0.0699
2121	WHSL-AN5	0.4957
2122	WHSL-GN3	0.0970
2126	WHSL-AQ5	0.2688
2133	DVDBO	0.0755
2144	LATON	0.2617

Table A7

Lead Time Performance of Relevant Sourcing and Depot Combinations, Time Period 1

TPSD	Mean	Standard Deviation
1111	5	1
1121	11.2	7.7717
1122	44.74	5.1192
1133	37.692	11.8845
1144	20	10
1311	34	21.0932
1321	24.75	21.0931
1333	43	11
1344	20	10

Table A8

Lead Time Performance of Relevant Sourcing and Depot Combinations, Time Period 2

TPSD	Mean	Standard Deviation
2111	13.45	6.2616
2121	10.8201	5.0289
2122	20.6875	5.2519
2315	16	1
2321	16.7	7.2272
2326	20.2	0.4721
2333	15.5833	4.9259
2344	22	3.6742

Table A9

Probabilities for Replenishment Requisitions in Time Period 1

TPSD	SOF-Depot	Probability
1311	WHSLBO	0.1081
1321	WHSL-AN5	0.2972
1333	DVDBO	0.1081
1344	LATON	0.4864

Table A10
Probabilities for Replenishment Requisitions in Time Period 2

TPSD	SOF-Depot	Probability
2315	WHSLBO	0.0379
2326	WHSL-AQ5	0.0843
2344	LATON	0.5569

Table A11
Time Period 1 Source of Fill/Depot Lead Time Performance for Replenishment Requisitions

TPSD	Mean	Standard Deviation
1311	34	21.0932
1321	24.75	21.0931
1333	43	11
1344	20	10

Table A12
Time Period 2 Source of Fill/Depot Lead Time Performance for Replenishment Requisitions

TPSD	Mean	Standard Deviation
2315	16	1
2321	16.7	7.2272
2326	20.2	0.4721
2344	22	3.6742

Table A13
Lookup Table for Readiness Driver (RD), Quantity Required (QR) and Commodity Code (CC)

ASL	RD	QR	CC	ASL	RD	QR	CC	ASL	RD	QR	CC
1	0	1	9	31	1	1	10	61	0	1	10
2	0	1	9	32	0	1	12	62	0	1	10
3	0	1	5	33	0	1	10	63	0	1	10
4	1	1	9	34	1	1	13	64	0	1	10
5	1	1	9	35	0	1	13	65	0	1	10
6	0	1	8	36	0	1	13	66	0	1	10
7	1	1	13	37	0	1	13	67	0	1	10
8	0	1	8	38	0	1	13	68	0	1	10
9	0	1	1	39	0	1	15	69	0	1	10
10	0	1	13	40	0	1	10	70	1	1	10
11	1	1	8	41	1	1	10	71	0	1	13
12	0	1	13	42	0	1	8	72	1	1	8
13	1	1	12	43	1	1	10	73	0	1	8

Table A13

Lookup Table for Readiness Driver (RD), Quantity Required (QR) and Commodity Code (CC)(Continued)

ASL	RD	QR	CC	ASL	RD	QR	CC	ASL	RD	QR	CC
74	1	1	13	108	1	2	8	143	0	3	12
75	1	1	9	109	0	2	10	144	0	3	10
76	0	1	10	110	1	2	8	145	0	3	10
77	0	1	9	111	1	2	9	146	1	3	13
78	0	1	9	112	1	2	10	147	0	3	8
79	1	1	10	113	0	2	13	148	0	3	8
80	1	1	10	114	1	2	9	149	1	4	10
81	0	1	10	115	0	2	13	150	1	4	10
82	1	2	9	116	0	2	13	151	0	4	10
83	1	2	13	117	0	2	9	152	0	4	9
84	0	2	13	118	1	2	10	153	1	4	10
85	0	2	12	119	0	3	8	154	1	4	10
86	1	2	13	120	0	3	1	155	0	4	8
87	1	2	10	121	0	3	10	156	0	4	13
88	1	2	9	122	1	3	13	157	0	4	10
89	1	2	12	123	0	3	9	158	0	4	13
90	0	2	13	124	1	3	12	159	1	4	13
91	1	2	12	125	1	3	13	160	0	4	10
92	1	2	8	126	0	3	8	161	0	4	10
93	1	2	13	127	1	3	13	162	0	4	9
94	1	2	9	128	0	3	13	163	1	4	13
95	0	2	10	129	0	3	13	164	1	4	8
96	1	2	13	130	0	3	10	165	0	5	10
97	1	2	13	131	1	3	8	166	0	5	12
98	1	2	10	132	0	3	8	167	0	5	10
99	1	2	10	133	1	3	10	168	0	5	10
100	0	2	9	134	0	3	8	169	0	5	12
101	0	2	13	135	0	3	10	170	1	5	10
102	0	2	13	136	1	3	10	171	0	5	10
103	0	2	10	137	1	3	10	172	0	5	9
104	0	2	10	138	1	3	13	173	1	5	10
105	1	2	10	139	1	3	13	174	0	5	10
106	1	2	10	141	0	3	10	175	0	5	13
107	1	2	8	142	1	3	13	176	0	5	13

Table A13

Lookup Table for Readiness Driver (RD), Quantity Required (QR) and Commodity Code (CC)(Continued)

ASL	RD	QR	CC	ASL	RD	QR	CC	ASL	RD	QR	CC
177	0	5	10	211	1	10	13	245	0	15	9
178	1	5	13	212	0	10	12	246	0	15	9
179	0	5	9	213	0	10	12	247	1	15	9
180	1	5	9	214	0	10	12	248	0	15	13
181	0	5	9	215	0	10	13	249	0	15	13
182	0	5	9	216	0	10	8	250	0	15	13
183	0	5	13	217	1	10	8	251	1	15	9
184	0	5	10	218	0	10	13	252	1	15	9
185	0	6	1	219	0	10	8	253	1	15	13
186	0	6	12	220	0	10	8	254	0	15	9
187	0	6	8	221	0	10	13	255	0	17	8
188	1	6	12	222	0	10	12	256	1	17	10
189	1	6	8	223	1	10	10	257	0	18	13
190	0	6	10	224	0	10	9	258	1	18	13
191	0	6	13	225	0	10	13	259	0	20	13
192	0	6	9	226	0	10	8	260	1	20	8
193	0	6	13	227	1	10	8	261	0	20	10
194	1	7	10	228	0	10	13	262	0	20	9
195	1	7	9	229	0	10	13	263	0	25	13
196	0	7	8	230	0	10	13	264	0	25	8
197	0	7	10	231	1	10	9	265	0	25	9
198	0	8	8	232	0	10	10	266	0	25	9
199	0	8	12	233	0	10	9	267	0	25	9
200	1	8	13	234	0	10	9	268	0	30	10
201	0	8	13	235	0	10	9	269	0	144	13
202	0	8	8	236	1	10	10	270	0	40	10
203	0	8	13	237	0	10	8	271	0	30	12
204	0	8	8	238	0	10	12	272	1	1	13
205	1	9	8	239	0	12	12	273	0	1	8
206	0	9	10	240	0	12	12	274	0	1	8
207	0	10	1	241	0	12	8	275	0	1	8
208	0	10	10	242	0	13	12	276	1	1	10
209	0	10	13	243	0	14	1	277	0	1	13
210	0	10	12	244	1	14	10	278	1	1	10

Table A13
Lookup Table for Readiness Driver (RD), Quantity Required (QR) and Commodity Code (CC)(Continued)

ASL	RD	QR	CC	ASL	RD	QR	CC	ASL	RD	QR	CC
279	0	1	13	313	0	1	10	347	0	1	10
280	0	1	1	314	0	1	8	348	0	1	5
281	0	1	9	315	0	1	8	349	0	1	5
282	0	1	2	316	1	1	12	350	0	1	10
283	0	1	8	317	0	1	9	351	0	1	10
284	0	1	8	318	0	1	8	352	0	1	10
285	0	1	10	319	1	1	9	353	0	1	13
286	0	1	1	320	0	1	1	354	0	1	10
287	0	1	8	321	0	1	8	355	0	1	10
288	0	1	13	322	0	1	13	356	0	1	13
289	0	1	8	323	0	1	13	357	0	1	10
290	0	1	5	324	1	1	10	358	0	1	13
291	0	1	13	325	1	1	10	359	1	1	10
292	1	1	8	326	1	1	13	360	0	1	10
293	1	1	8	327	1	1	8	361	0	1	10
294	0	1	5	328	1	1	10	362	0	1	13
295	1	1	9	329	0	1	13	363	0	1	10
296	0	1	10	330	0	1	13	364	0	1	13
297	1	1	13	331	0	1	10	365	0	1	10
298	1	1	13	332	0	1	13	366	0	1	8
299	0	1	13	333	0	1	9	367	0	1	9
300	0	1	13	334	0	1	13	368	0	1	10
301	0	1	9	335	1	1	10	369	0	1	10
302	0	1	9	336	1	1	8	370	0	1	9
303	0	1	2	337	0	1	13	371	0	1	9
304	0	1	8	338	0	1	10	372	0	1	13
305	0	1	13	339	0	1	13	373	0	1	10
306	1	1	10	340	1	1	8	374	0	1	13
307	0	1	13	341	0	1	10	375	0	1	10
308	0	1	12	342	0	1	10	376	0	1	13
309	0	1	3	343	1	1	10	377	0	1	10
310	0	1	1	344	1	1	13	378	0	1	10
311	0	1	10	345	1	1	13	379	1	1	10
312	0	1	12	346	0	1	10	380	0	1	8

Table A13
Lookup Table for Readiness Driver (RD), Quantity Required (QR) and Commodity Code (CC)(Continued)

ASL	RD	QR	CC	ASL	RD	QR	CC	ASL	RD	QR	CC
381	0	1	13	415	0	1	9	449	1	1	10
382	0	1	10	416	0	1	9	450	1	1	13
383	0	1	10	417	1	1	9	451	0	1	8
384	1	1	10	418	1	1	10	452	0	1	8
385	0	1	10	419	0	1	10	453	0	1	10
386	0	1	13	420	0	1	10	454	1	1	8
387	0	1	13	421	0	1	10	455	0	1	9
388	0	1	10	422	0	1	8	456	0	1	9
389	0	1	10	423	1	1	10	457	1	1	9
390	0	1	10	424	1	1	9	458	0	1	10
391	0	1	13	425	0	1	13	459	0	1	13
392	0	1	13	426	0	1	10	460	0	1	10
393	0	1	13	427	0	1	10	461	0	1	10
394	0	1	10	428	0	1	10	462	1	1	10
395	0	1	8	429	1	1	13	463	0	1	10
396	0	1	10	430	1	1	9	464	0	1	8
397	0	1	10	431	1	1	10	465	0	1	8
398	1	1	10	432	1	1	8	466	0	1	8
399	0	1	1	433	0	1	10	467	1	1	9
400	0	1	1	434	1	1	8	468	0	1	13
401	1	1	9	435	0	1	10	469	0	1	10
402	1	1	10	436	0	1	10	470	0	1	10
403	0	1	1	437	0	1	10	471	1	1	8
404	0	1	10	438	0	1	9	472	1	1	8
405	0	1	10	439	0	1	13	473	1	1	10
406	0	1	10	440	0	1	10	474	1	1	8
407	0	1	9	441	0	1	13	475	1	1	8
408	1	1	10	442	0	1	13	476	1	1	10
409	0	1	8	443	0	1	10	477	0	1	13
410	0	1	13	444	0	1	10	478	1	1	9
411	0	1	9	445	0	1	9	479	1	1	9
412	0	1	10	446	1	1	3	480	0	1	9
413	1	1	10	447	0	1	10	481	0	1	8
414	1	1	10	448	0	1	10	482	0	1	9

Table A13

Lookup Table for Readiness Driver (RD), Quantity Required (QR) and Commodity Code (CC)(Continued)

ASL	RD	QR	CC	ASL	RD	QR	CC	ASL	RD	QR	CC
483	0	1	9	517	0	2	1	551	0	2	1
484	1	1	10	518	0	2	9	552	0	2	9
485	1	1	10	519	0	2	1	553	0	2	13
486	0	1	10	520	1	2	10	554	1	2	13
487	0	1	13	521	1	2	9	555	0	2	9
488	0	1	8	522	0	2	9	556	0	2	9
489	0	1	9	523	0	2	8	557	1	2	9
490	0	1	10	524	0	2	1	558	1	2	1
491	0	1	9	525	0	2	10	559	0	2	10
492	0	1	9	526	1	2	2	560	0	2	13
493	1	1	10	527	1	2	9	561	0	2	10
494	0	1	8	528	0	2	9	562	0	2	8
495	0	1	10	529	0	2	1	563	1	2	13
496	0	1	13	530	0	2	9	564	0	2	10
497	0	1	13	531	0	2	9	565	1	2	10
498	1	1	8	532	0	2	2	566	0	2	8
499	1	1	9	533	0	2	9	567	0	2	8
500	0	1	9	534	1	2	8	568	0	2	10
501	0	1	8	535	0	2	1	569	0	2	8
502	0	1	5	536	0	2	1	570	0	2	9
503	0	1	9	537	0	2	9	571	0	2	9
504	0	1	10	538	0	2	9	572	0	2	10
505	0	1	9	539	0	2	11	573	0	2	9
506	0	1	13	540	1	2	9	574	0	2	10
507	0	1	10	541	0	2	12	575	0	2	9
508	0	1	2	542	0	2	13	576	1	2	9
509	0	1	13	543	1	2	10	577	1	2	9
510	1	2	9	544	0	2	1	578	1	2	8
511	0	2	1	545	0	2	10	579	1	2	9
512	0	2	8	546	1	2	13	580	0	2	8
513	0	2	4	547	0	2	13	581	0	2	13
514	0	2	1	548	0	2	13	582	0	2	10
515	0	2	1	549	0	2	10	583	0	2	13
516	0	2	8	550	0	2	10	584	0	2	10

Table A13
Lookup Table for Readiness Driver (RD), Quantity Required (QR) and Commodity Code (CC)(Continued)

ASL	RD	QR	CC	ASL	RD	QR	CC	ASL	RD	QR	CC
585	0	2	8	619	1	2	9	653	0	3	13
586	1	2	10	620	0	2	9	654	1	3	9
587	0	2	9	621	1	2	9	655	0	3	9
588	1	2	13	622	1	2	9	656	0	3	8
589	1	2	10	623	0	2	9	657	0	3	10
590	0	2	9	624	0	2	8	658	0	3	8
591	0	2	13	625	0	3	1	659	0	3	10
592	0	2	13	626	1	3	16	660	0	3	10
593	1	2	10	627	0	3	5	661	0	3	5
594	0	2	10	628	0	3	1	662	0	3	8
595	0	2	8	629	1	3	13	663	0	3	9
596	1	2	9	630	0	3	1	664	0	3	3
597	0	2	9	631	0	3	10	665	0	3	10
598	0	2	10	632	0	3	1	666	0	4	10
599	0	2	8	633	0	3	10	667	0	4	1
600	0	2	13	634	0	3	8	668	1	4	10
601	0	2	10	635	0	3	9	669	0	4	1
602	1	2	8	636	0	3	1	670	0	4	10
603	0	2	9	637	0	3	1	671	0	4	2
604	0	2	8	638	0	3	5	672	0	4	10
605	0	2	10	639	0	3	10	673	0	4	7
606	0	2	10	640	0	3	1	674	0	4	10
607	1	2	9	641	0	3	9	675	0	4	10
608	0	2	10	642	0	3	9	676	0	4	13
609	0	2	9	643	0	3	9	677	0	4	8
610	0	2	9	644	0	3	13	678	0	4	10
611	0	2	13	645	0	3	10	679	1	4	13
612	1	2	10	646	1	3	10	680	0	4	2
613	1	2	9	647	0	3	13	681	0	4	13
614	0	2	10	648	0	3	10	682	0	4	10
615	0	2	8	649	1	3	10	683	1	4	13
616	1	2	10	650	1	3	9	684	1	4	9
617	0	2	10	651	0	3	1	685	1	4	9
618	0	2	10	652	0	3	10	686	0	4	10

Table A13

Lookup Table for Readiness Driver (RD), Quantity Required (QR) and Commodity Code (CC)(Continued)

ASL	RD	QR	CC	ASL	RD	QR	CC	ASL	RD	QR	CC
687	0	4	1	721	0	5	1	755	0	5	1
688	0	4	9	722	0	5	1	756	0	5	9
689	0	4	10	723	0	5	2	757	0	5	9
690	0	4	10	724	0	5	1	758	0	5	12
691	0	4	10	725	0	5	2	759	0	5	12
692	1	4	9	726	0	5	1	760	0	5	1
693	0	4	9	727	0	5	1	761	1	5	14
694	0	4	10	728	0	5	1	762	0	5	12
695	1	4	10	729	0	5	1	763	1	6	9
696	1	4	8	730	0	5	1	764	0	6	9
697	0	4	10	731	0	5	8	765	0	6	2
698	0	4	3	732	0	5	9	766	0	6	1
699	0	4	9	733	0	5	5	767	0	6	12
700	0	4	10	734	0	5	13	768	0	6	10
701	1	4	10	735	0	5	9	769	0	6	8
702	1	4	8	736	0	5	9	770	0	6	1
703	0	4	8	737	0	5	10	771	0	6	2
704	0	4	9	738	0	5	13	772	0	6	1
705	0	4	10	739	0	5	9	773	0	6	9
706	1	4	10	740	0	5	1	774	0	6	10
707	0	5	1	741	0	5	9	775	0	6	13
708	1	5	1	742	0	5	13	776	0	7	10
709	0	5	1	743	1	5	13	777	0	7	1
710	1	5	1	744	1	5	2	778	1	7	10
711	0	5	2	745	0	5	10	779	1	7	13
712	0	5	8	746	0	5	9	780	1	7	13
713	0	5	1	747	1	5	1	781	0	7	9
714	0	5	1	748	0	5	10	782	0	7	9
715	0	5	1	749	1	5	1	783	0	7	1
716	1	5	1	750	0	5	8	784	0	7	1
717	0	5	1	751	0	5	8	785	1	8	2
718	0	5	2	752	0	5	8	786	0	8	12
719	0	5	2	753	1	5	8	787	1	8	13
720	0	5	1	754	0	5	9	788	0	8	13

Table A13

Lookup Table for Readiness Driver (RD), Quantity Required (QR) and Commodity Code (CC)(Continued)

ASL	RD	QR	CC	ASL	RD	QR	CC	ASL	RD	QR	CC
789	0	8	10	823	1	10	10	856	1	10	9
791	0	8	2	824	0	10	2	857	0	10	9
792	0	8	10	825	0	10	2	858	0	10	1
793	1	8	13	826	1	10	12	859	0	10	1
794	0	8	10	827	0	10	1	860	0	10	1
795	0	8	13	828	0	10	9	861	0	10	1
796	0	8	13	829	0	10	9	862	0	10	1
797	0	8	1	830	0	10	9	863	0	10	1
798	0	9	2	831	0	10	10	864	0	10	1
799	0	10	9	832	0	10	2	865	0	10	1
800	0	10	2	833	0	10	9	866	0	10	1
801	1	10	2	834	0	10	12	867	0	10	1
802	0	10	1	835	0	10	10	868	0	10	1
803	0	10	1	836	0	10	13	869	0	10	1
804	0	10	1	837	1	10	10	870	0	10	1
805	0	10	1	838	0	10	10	871	0	10	1
806	0	10	1	839	0	10	2	872	0	10	1
807	0	10	1	840	0	10	10	873	0	10	1
808	0	10	1	841	0	10	1	874	0	10	1
809	0	10	1	842	0	10	10	875	0	10	1
810	0	10	1	843	0	10	13	876	0	10	1
811	0	10	1	844	0	10	9	877	0	10	1
812	0	10	8	845	0	10	9	878	0	10	8
813	0	10	1	846	0	10	9	879	0	10	9
814	0	10	1	847	0	10	9	880	0	10	1
815	0	10	1	848	0	10	2	881	0	10	13
816	0	10	1	849	1	10	2	882	0	10	2
817	0	10	1	850	1	10	13	883	0	10	9
818	0	10	1	851	0	10	10	884	1	10	9
819	0	10	1	852	0	10	9	885	1	10	9
820	0	10	1	853	0	10	9	886	1	10	9
821	0	10	13	854	0	10	8	887	0	10	1
822	1	10	13	855	0	10	13	888	1	10	9

Table A13

Lookup Table for Readiness Driver (RD), Quantity Required (QR) and Commodity Code (CC)(Continued)

ASL	RD	QR	CC	ASL	RD	QR	CC	ASL	RD	QR	CC
889	0	10	2	923	1	16	8	957	0	20	8
890	1	10	1	924	1	17	2	958	0	20	1
891	1	10	8	925	1	17	13	959	0	20	13
892	1	10	8	926	1	17	9	960	1	20	10
893	1	10	8	927	1	18	10	961	0	20	8
894	1	11	1	928	1	18	1	962	0	20	10
895	1	11	10	929	1	19	1	963	0	23	1
896	1	11	10	930	1	19	1	964	0	24	5
897	0	12	9	931	1	19	1	965	0	24	9
898	1	12	10	932	1	20	10	966	0	25	5
899	1	12	9	933	0	20	5	967	0	25	1
900	1	12	9	934	1	20	13	968	0	25	1
901	1	12	9	935	0	20	1	969	0	25	1
902	1	12	3	936	0	20	9	970	0	25	1
903	0	12	9	937	0	20	13	971	0	25	1
904	1	13	5	938	0	20	9	972	0	28	2
905	0	13	13	939	0	20	12	973	0	30	2
906	1	13	1	940	0	20	13	974	0	30	8
907	1	14	13	941	0	20	5	975	0	30	3
908	0	15	9	942	1	20	13	976	0	30	2
909	1	15	1	943	0	20	10	977	0	30	12
910	1	15	1	944	1	20	8	978	0	30	8
911	1	15	8	945	1	20	10	979	0	31	1
912	1	15	1	946	0	20	10	980	0	32	1
913	1	15	5	947	0	20	1	981	1	35	12
914	1	15	1	948	0	20	9	982	0	36	13
915	1	15	1	949	0	20	12	983	1	40	6
916	1	15	10	950	0	20	10	984	0	40	10
917	1	15	9	951	0	20	10	985	0	41	5
918	1	15	1	952	0	20	10	986	0	48	5
919	1	15	2	953	1	20	2	987	0	50	2
920	1	15	10	954	0	20	13	988	0	50	12
921	1	15	2	955	0	20	13	989	0	50	8
922	1	16	2	956	0	20	1	990	0	50	2

Table A13
Lookup Table for Readiness Driver (RD), Quantity Required (QR) and Commodity Code (CC)(Continued)

ASL	RD	QR	CC
991	0	50	1
992	0	58	3
993	0	75	2
994	0	80	1
995	1	100	13
996	0	1000	6
997	1	1000	6
998	0	3000	6

Table A14
TRWT Chi Squared Comparison Results

Interval ---------	P Value ----------	Significance ---------	Action
1-6	0.1523	***	Combined
1-9	0.8299	***	Combined
1-12	0.6689	***	Combined
1-15	0.6586	***	Combined
1-18	0.8519	***	Combined
1-21	0.1751	***	Combined
1-24	0.2871	***	Combined
1-27	0.3000	***	Combined
1-30	0.2147	***	Combined
1-33	0.0712	***	Combined
1-36	0.0308	**	Combined
1-39	0.0178	**	Combined
1-42	0.0104	**	Combined
1-45	0.0015	*	---------
46-48	0.2562	***	Combined
46-51	0.1266	***	Combined
46-54	0.0679	***	Combined
46-57	0.0313	**	Combined
46-60	0.0252	**	Combined

Table A15

TFill Chi Squared Comparison Results

Interval	P Value	Significance	Action
1-3	0.1164	*	---------
4-6	0.0000	*	---------
7-9	0.0001	*	---------
10-12	0.0001	*	---------
13-15	0.0001	*	---------
16-18	0.0001	*	---------
19-21	0.0001	*	---------
22-24	0.0001	*	---------
25-27	0.0001	*	---------
28-30	0.0001	*	---------
31-33	0.0001	*	---------
34-36	0.0001	*	---------
37-39	0.0001	*	---------
40-42	0.0001	*	---------
43-45	0.0001	*	---------
46-48	0.0001	*	---------
49-51	0.0001	*	---------
52-54	0.0001	*	---------
55-57	0.0001	*	---------
58-60	0.0001	*	---------

Table A16
RRWT Chi Squared Comparison Results

Interval	P Value	Significance	Action
1-3	NA	***	Combined
1-6	0.1491	***	Combined
1-9	0.1769	***	Combined
1-12	0.9306	***	Combined
1-15	0.0647	***	Combined
1-18	0.0001	*	---------
19-21	0.1277	***	Combined
19-24	0.0001	*	---------
25-27	0.0001	*	---------
28-30	0.0001	*	---------
31-33	0.0001	*	---------
34-36	0.0001	*	---------
37-39	0.0001	*	---------
40-42	0.0001	*	---------
43-45	0.0001	*	---------
46-48	0.0001	*	---------
49-51	0.8553	***	Combined
49-54	0.9254	***	Combined
55-57	0.9379	***	Combined
58-60	0.7517	***	Combined

Table A17

RFill Chi Squared Comparison Results

Interval	P Value	Significance	Action
1-3	0.0001	*	---------
4-6	0.0009	*	---------
7-9	0.1823	***	Combined
7-12	0.1138	***	Combined
7-15	0.5899	***	Combined
7-18	0.6638	***	Combined
7-21	0.0003	*	---------
22-24	0.0000	*	---------
25-27	0.0001	*	---------
28-30	0.0001	*	---------
31-33	0.0002	*	---------
34-36	0.0001	*	---------
37-39	0.0001	*	---------
40-42	0.0001	*	---------
43-45	0.0001	*	---------
46-48	0.0001	*	---------
49-51	0.5696	***	Combined
49-54	0.4635	***	Combined
49-57	0.0110	**	Combined
49-60	0.2810	***	Combined