AIRLIFT CARGO HUB PORT HOLD TIMES: CONTROLLING VARIATIONS IN DEFENSE SUPPLY CHAIN DELIVERY

GRADUATE RESEARCH PAPER

Brandon A. Casey, Major, USAF
AFIT/IMO/ENS/10-03

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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Brandon A. Casey, BS, MS

Major, USAF

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Brandon A. Casey, MA
Major, USAF

Approved:

___________//SIGNED// _________ 10 June 2010
James T. Moore (Chairman) Date

AFIT/IMO/ENS/10-03

Abstract

Air Mobility Command uses hub and spoke operations to move a significant portion of cargo around the world as efficiently as possible. High system demand, limited cargo capacity, and desired cost efficiencies drive significant portions of even the highest priority wartime cargo into a hub and spoke delivery system. However, additional efficiencies afforded through hub and spoke delivery come at the cost of longer delivery times and greater delivery time variations. Leaders require an expanded understanding of those costs to make informed decisions with respect to Air Mobility Command operations.

This study examines the relationship between port hold time and total time enroute, the division of port hold time attributable to port tasks and command and control functions, and potential causes for port hold time variations. It was completed at the request of AMC Directorate of Analyses, Assessments, and Lessons Learned in response to ancillary findings of high correlation between port hold time and total time enroute at Incirlik Air Base (AB), Turkey in a previous study. This study expands on the scope of the previous study, focusing on port hold time, and tracking 10,541 pallets transiting Air Mobility Command's (AMC) six largest transload airports throughout the world during a four month period from 1 July to 31 October 2009.

Using regression analysis and descriptive statistics, this study verifies the correlation between port hold time and total time enroute, characterizes the portion of port hold time attributable to port processing and cargo awaiting lift functions, explores the relationship between port hold time and potential causes of variation, and makes leadership recommendations to improve AMC's delivery performance and customer satisfaction.

To my wife and daughters

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I would like to thank my sponsor, Mr. Don Anderson from the Air Mobility Command Directorate of Analyses, Assessments, and Lessons Learned, for asking the questions about port hold time patterns that formed the basis for this study. Without his shared expert knowledge of the mobility system and his assistance accessing historical movement records, I could not have completed this research.

I would also like to thank my advisor, Dr. James Moore, for helping to scope the research topic, providing guidance on research sources, and for ensuring the appropriateness and completeness of the final content. His thoroughness, responsiveness, and counsel were integral to my successful completion of the project.

Air Force Expeditionary Center Librarian Pamela Bennett Bardot helped to locate initial research material and saved me countless hours of struggling through academic databases. Her ability to locate literature based on partial references or loosely formed ideas improved the comprehensiveness of the research and final report.

Most importantly, I would like to thank my family for their support and understanding. To my daughters, thank you for your sacrificed daddy-time as I endeavored to complete this project. Finally, to my wife, I owe you endless thanks for your direct assistance as my editor and your strength and understanding in handling everything else in life when this paper prevented my participation. I could not have completed such a time-intensive study without you.

Brandon Casey

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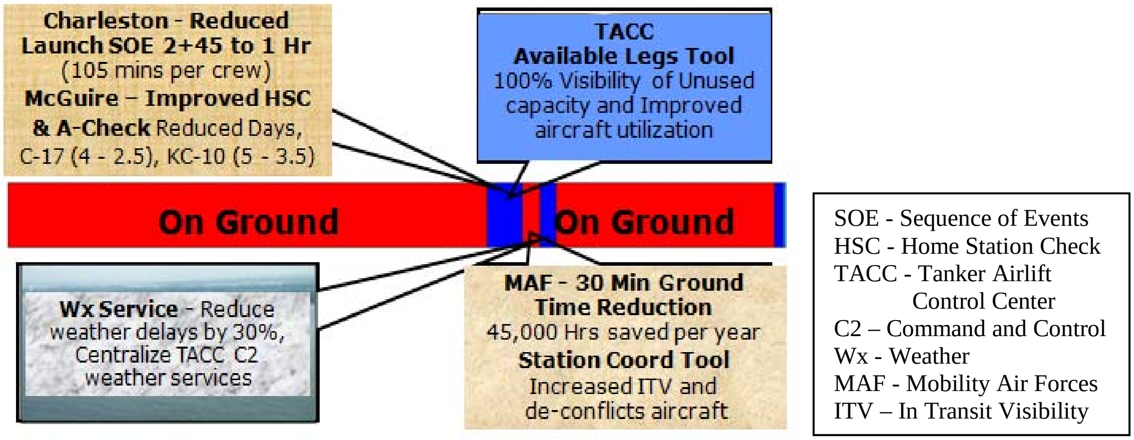
"The line between disorder and order lies in Logistics" -Sun Tzu

I. Introduction

United States Transportation Command (TRANSCOM) airlift customers desire rapid and dependable delivery. Extensive delivery times and unpredictable delivery intervals lower customer satisfaction and create supply chain difficulties for end customers. These difficulties may result in larger order quantities to create localized stockpiles capable of reducing the effects of delivery variation on mission accomplishment. A Defense Logistics Agency customer satisfaction study found that "discrepancies between the required and estimated delivery dates are a source of considerable impact upon customer perceived quality/satisfaction" (Mentzer, Bienstock, & Kahn, 1993). Faster and/or more predictable delivery times can therefore improve customer satisfaction and may reduce total delivery volume demanded by customers. "There are costs associated with an unpredictable transportation system, such as increased ordering costs because of duplicate orders, increased inventory, and increased inventory holding costs" (Condon & Patterson, Summer 2004). However, TRANSCOM is struggling to achieve predictable delivery times given limited assets to fulfill surging wartime demand. Unfortunately, only 60% of cargo destined for Afghanistan is currently meeting the negotiated 15-day delivery timeline (USTRANSCOM, August 9 2009).

AMC has completed studies and created initiatives to minimize portions of the total time enroute and improve customer service. Figure 1 shows a selection of recent improvement efforts overlaid on a typical pallet's transportation timeline, with red depicting time spent waiting on the ground and blue depicting pallet air movement. Even though most of a pallet's delivery time is spent waiting on the ground, these studies and initiatives historically focus on flight time or activities adjacent to the aircraft movement steps in the total transit process [Figure 1] (Anderson D. , 2009). Although related, effective use of aircraft does not directly equate to effective movement of cargo. In some circumstances, the difference between the two may lead to sub-optimization of the airlift process at the expense of cargo delivery.

Figure 1 AMC Velocity Efforts



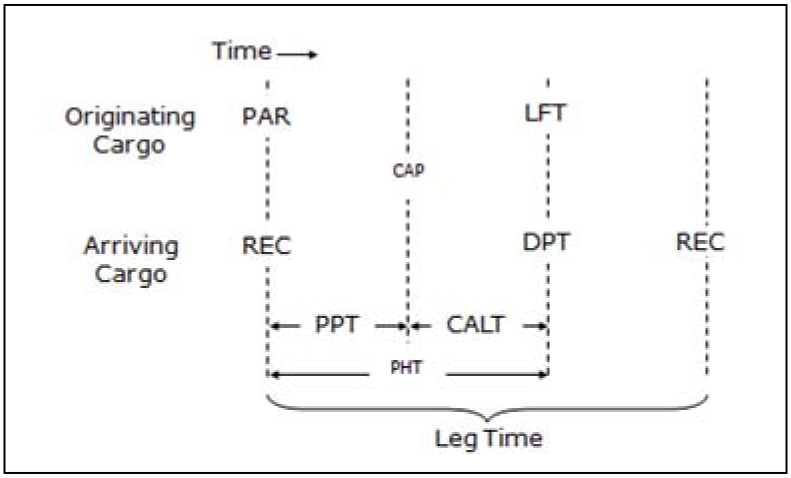
(Anderson D. , 2009)

In an effort to monitor cargo delivery progress, AMC leadership routinely views pallet inventory and port hold time metrics. Leadership interprets rising port hold times as an indicator of transportation system problems and looks to aerial port improvements to correct the problems. Research is needed to quantify the relevance of port hold time impact on total delivery time and establish areas leadership should address to assuage concerns over rising Port Hold Times (PHT). Leadership's selection of metrics is vital, given that metrics influence the decisions and behavior of subordinates as they seek to maximize results.

A second source of contention in military logistics stems from the often-conflicting goals of efficiency and effectiveness. Unfortunately, velocity goals best supported by rapid direct delivery compete with operational limitations and efficiency goals resulting in hub-and-spoke delivery for considerable amounts of airlift cargo. The mobility community attempts to maximize cargo flow through the system to achieve the greatest systematic customer satisfaction for delivery. The aggregated view of maximum cargo throughput contends with delivery reliability, as cargo delays to achieve full airplanes necessary for greater throughput. The definition of Defense Transportation System (DTS) customers complicates the conflict between efficiency and effectiveness. In addition to serving warfighters as the direct end-user customers, the Defense Transportation System must remain accountable to indirect customers in the form of taxpayers (Mentzer, Bienstock, & Kahn, 1993). Thus, meeting the Army's "effectiveness" goals can conflict with cost-efficient use of aircraft.

As a precursor to weighing the advantages of effectiveness versus efficiency, decision makers must first understand the impact of efficiency decisions on total delivery time. A 2009 research study targeted at supply chain velocity from Susquehanna to Iraq identified a high correlation between port hold time and total time enroute. The study identified a need for further research into the portion of total delivery time attributable to intermediate node or "hub" port hold time and the makeup and causes of that port hold time (Lanier, 2009). This research endeavors to determine intermediate node port hold time (PHT) impact on variations in airlift cargo total time enroute (TTE) and to identify significant sources of PHT variations. Specifically, the research divides PHT into two components, port processing time (PPT) and cargo awaiting lift time (CALT), and through regression analysis attempts to determine the indicators of PHT variation [Figure 2]. An understanding of port hold time impact on customer delivery time will allow the mobility community to improve its processes systematically within the context of the complete factory to foxhole supply chain and establish metrics that monitor the DTS effectiveness at satisfying the warfighter.

Figure 2 Port Hold Time key data points



(Anderson D. , 2009)

The remainder of this paper attempts to define PHT, frame PHT within the DTS, analyze the composition and impact of PHT at key transload locations, and provide leadership recommendations to use an expanded knowledge of PHT to improve support to DTS customers. The literature review in Chapter II provides a look at the current Defense Supply Chain, analyzes the supply of and demand for airlift within the DTS, and concludes with a look at the debate between Effectiveness versus Efficiency that generates the AMC hub and spoke delivery system and the need to study Port Hold Times within that system. Chapter III lays out this study's methodology for analyzing Port Hold Time, the statistical justification for analysis, and study limitations. Chapter IV provides the results and analysis of the statistical procedures while Chapter V presents recommendations and conclusions.

II. Literature Review

Defense Supply Chain

Efforts to optimize the cargo mobility process must first begin with an understanding of current theories of supply chain management (SCM). The definition of SCM is "the integration of business processes from end user through original suppliers that provides products, services and information that add value for the customer" (Cooper, Lambert, & Pagh, 1997). Supply chains are concerned with the entire end to end logistics process. More importantly, supply chains look for the value added from a customer point of view. Keeping the final customer as the focus is essential to avoid the pitfalls of sub-optimization that occur if each organization in the supply chain attempts to optimize its own results. The key difference between current studies into supply chain management and more traditional logistics management theory is the focus on value added from the customer point of view (Cooper, Lambert, & Pagh, 1997). Finally, SCM seeks to establish a flow of goods and information across the chain in order to generate system efficiencies. By establishing a flow of goods, managers can eliminate bottlenecks and waste from the process. The continuous improvement process of eliminating waste drives up system efficiency while maintaining customer service expectations (Womack & Jones, 2003). Within supply chains, Information Technology serves as the "key enabler," establishing the flow of information that allows managers to monitor, examine, and improve the flow of goods (Hammer & Champy, 2006). The commercial concepts of supply chain management, including end-to-end logistics, customer focus, and flow of information and goods, create a lens for improvement within military logistics.

The concept of military supply chain management spans from factory to foxhole. The Defense Logistics Agency (DLA) is the primary supplier for military consumable items. The

Agency sources and provides nearly 100 percent of the consumable items America's military forces need to operate, including food, fuel, uniforms, medical supplies, and construction and barrier equipment. The DLA also supplies approximately 84 percent of the military's spare parts (Defense Logistics Agency Website). United States Transportation Command (TRANSCOM) is the military distribution process owner ultimately responsible for managing the defense supply chain. TRANSCOM manages a 52 billion dollar fleet including 87 ships, 1269 aircraft 2,150 rail cars, and additional infrastructure necessary to provide transportation, sustainment, and distribution to U.S. warfighters (TRANSCOM). TRANSCOM manages the overall defense supply chain, managing business and logistics enterprise responsibilities in its role as Distribution Process Owner (DPO) (McNabb, 2009). As the air component of TRANSCOM, Air Mobility Command (AMC) provides rapid global deployment and sustainment to U.S. military forces.

Defense Supply Chain Customers

The Defense Supply Chain must contend with two competing customers: the warfighters who use the transportation services and the taxpayers who pay for the services. The primary customer in the defense supply chain is the warfighter. The Army and Marine Corps in Iraq and Afghanistan are the consumers of vast amounts of theater delivered cargo. Walden notes that the Defense Transportation System delivered the equivalent of 150 Wal-Mart superstores to Kuwait to support 250,000 soldiers, sailors, airmen, and marines during Operation Iraqi Freedom (Walden, 2003).

Defense logistics customers differ from traditional industry customers because they are a captive audience not capable of purchasing from competitors. TRANSCOM has a monopoly on DoD transportation as the sole defense transportation service provider; regulations appoint

TRANSCOM as the single manager for all DoD transportation (AMCI65-602, 27 Jul 2006). Unless military units are capable of repositioning cargo with organic resources, they must work through TRANSCOM for transportation. Because of the lack of customer choice in suppliers, researchers hypothesize that the "behavioral intention from customer dissatisfaction is relatively insensitive over the short range" (Mentzer, Bienstock, & Kahn, 1993). Customers will continue to procure through the defense supply chain despite customer dissatisfaction.

The defense supply chain experiences customer ambiguity because taxpayers that are the purchasers of transportation serve as indirect customers. Researchers found that participants in the defense supply chain are concerned with "providing value, in the form of missions accomplished at a minimum of cost, to the taxpayer" (Mentzer, Bienstock, & Kahn, 1993). By focusing on taxpayer value, decision makers may opt for the cheaper solution over the solution that best satisfies the warfighter. Because the customers are ill-defined and cannot immediately switch to a competitor, military transportation service providers are prone to minimize the importance of customer satisfaction in the military supply chain. On the contrary, because transportation is a service, USTRANSCOM's output should be thought of as customer service, elevating the importance of foxhole customers in line with SCM theory (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 334).

What do Defense Logistics (DL) customers want? Defense logistics customers desire demand-responsive supply chains that yield reliable and transparent delivery. The military's reduction in forward positioned forces elevates its need for rapid global mobility. Planners cannot easily forecast demand associated with this mobility. The unpredictable yet nationally vital military mission dictates a demand-responsive supply chain (Wang, 2006). Furthermore, research into physical distribution service quality found that the low level of interaction between the DL service provider and the customer decreases the importance of the process and increases the importance of responsiveness (Mentzer, Bienstock, & Kahn, 1993). Military supply chain customers may establish their responsiveness expectations based on personal civilian experiences in a society where customers are more empowered and expectant of personalized treatment (Hammer & Champy, 2006). Individual and corporate experiences with express service providers, such as FedEx and UPS, create expectations of fast and time definite delivery. Faster delivery times allow customers to achieve savings through reduced working stock and inventory carrying costs for items in transit. A 1999 AFIT study found that a day of pipeline costs saved for all DoD customers translates into nearly $100 million less in inventory stock the DoD must purchase (Condon, Cunningham, Moore, & Patterson, 1999).

Even more important than fast delivery is reliable time definite delivery. Surveys of traffic managers and travelers indicate that a later but reliable arrival time is preferred to a faster less reliable time (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 336). Customers that lack reliable delivery times must compensate with expensive and unproductive safety stocks. “Discounting the need for fast, emergency shipment service, the cost of reliable but longer service time often is perceived as less than that of shorter but unreliable service time” (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 336). The cost associated with stockout for a military operation can be unacceptable, often incurring life-or-death consequences. To guard against such consequences, deployed commanders are likely to saturate the defense transportation system with orders for far more supplies than they need. “Efforts to avoid shortages in war have been directed towards establishing stockpiles of material and supplies across the combat zone…this practice has become unofficially known as “Just in Case” logistics

(Walden, 2003). Evidence of such behavior was apparent after Operation DESERT STORM, where 27,000 ISO containers lay unopened on the ground in Kuwait (Walden, 2003).

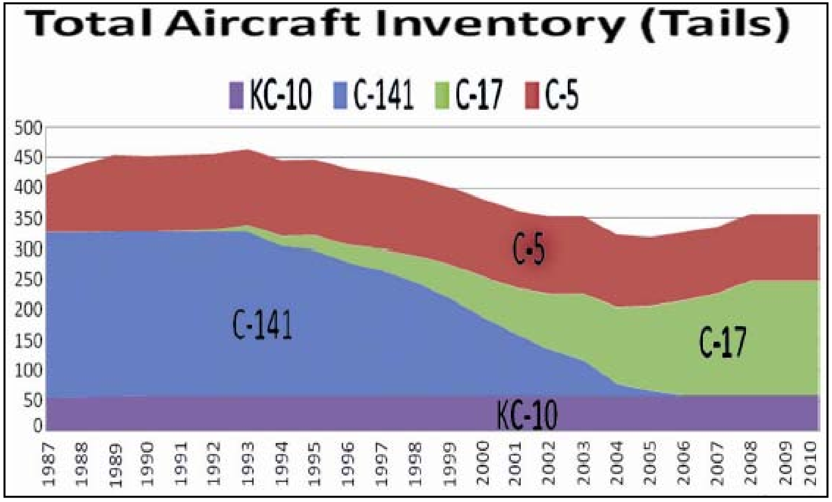
Finally, customers have expectations of in-transit-visibility, similar to package tracking web pages available to FedEx and UPS customers. Researchers have found that without timely and accurate updates on the status of late orders, customers become dissatisfied and confused (Lee & Billington, 1992). While TRANSCOM provides an RFID tracking website and has mandated RFID tags on all DTS shipments, the responsibility for tagging and updating tag information falls on individual task-saturated customers leading to inconsistent and unreliable tracking capability.

Failure to correctly identify customers and identify their needs creates occasions for sub-optimization at the expense of greater supply chain efficiency. “Carriers that stress operations are more likely to optimize their existing system at the expense of customer satisfaction” (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 335). Lee and Billington found that incomplete views of supply chains and final customers generate inefficiencies, citing an automobile dealership’s demand for spare parts. “Dealers have their own inventory control systems. For them, an 85 percent fill rate, with highly variant delays for the remaining 15 percent, would be worse than a 0 percent off-the-shelf fill rate with a reliable resupply time of one week” (Lee & Billington, 1992). Similarly, DoD supply chain customers that maintain their own inventory are likely to be better served by consistent deliveries than faster deliveries. To achieve fast, time definite delivery to the warfighter, the defense transportation system must provide airlift supply that meets or exceeds war-time surge demand.

Military Airlift Supply

According to the 2006 Quadrennial Defense Review (QDR), extensive investment in cargo transportability, strategic lift, and prepositioned stock have “yielded military forces capable of responding to a broad spectrum of security challenges worldwide” (DoD, 2006, p. 54). The Department of Defense is working to modernize and recapitalize its strategic airlift fleet to ensure airlift supply viability. The 2006 QDR called for an organic fleet of 292 inter-theater airlifters, comprised of 180 C-17s and 112 modernized and reliability enhanced C-5s. This organic strategic lift fleet is smaller in numbers than the 346 C-5s and C-141s employed during Operation DESERT SHIELD/DESERT STORM (ODS) [Figure 3] (CLR, 2008). Since completion of the QDR, Congress has awarded further procurement of C-17s with a total purchase of 223 (Boeing, 2009). The QDR quotes the military capability study (MCS) which assessed the programmed mobility fleet as capable of deploying and sustaining forces in support of two major overlapping wars as outlined in the Joint Staff led Operational Availability (OA) studies (DoD, 2006). While current military airlift supply is substantial, it is also inflexible in response to changing demand given long lead times for ordering aircraft and the bureaucratic defense procurement system. Meeting military transportation needs has become more difficult as the U.S. has diminished overseas troop presence by 80,000 (CLR, 2008). It is estimated that approximately 60 million ton-miles/day (MTM/D) are required to deploy and sustain two major overlapping wars (IDA, 2008). To achieve this massive throughput level and to compensate for differences in peacetime and wartime demand levels, the DoD uses a mix of organic military and commercial airlifters.

Figure 3: Organic Military Fleet

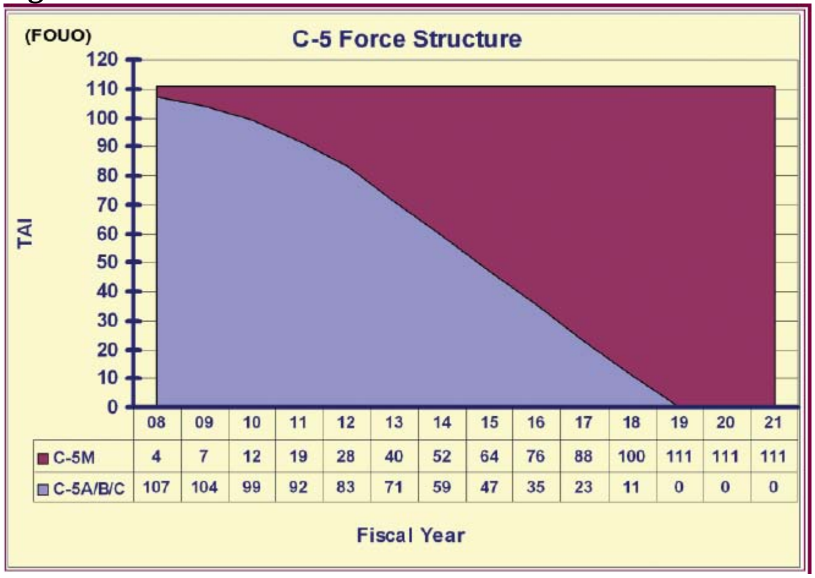


(CLR, 2008)

Organic Airlift

C-5s and C-17s act in a primary strategic airlift capacity, providing approximately 40 MTM/D (IDA, 2008). The C-5 is the Air Force's largest organic airlifter. It can fly 3,200 miles with 180,000 pounds of cargo, and carries a maximum of 36 pallets. Unfortunately, age and maintenance characteristics offset the substantial carrying capacity of the C-5. The C-5A has an average fleet age of 32 years and carries 0.1019 MTM/D. The C-5B average fleet age is 20 years, with each aircraft carrying 0.1209 MTM/D. Mission capable rates of 49 percent for the C-5A and 66 percent for the C-5B fall far below the AMC goal of 75 percent (AMC, 2008). To address the age and reliability problem, AMC is upgrading the C-5s with two programs: the Avionics Modernization Program (AMP) and the Reliability Enhancement and Re-engining Program (RERP). The modernized aircraft, re-designated as the C-5M, will enter the force between 2008 and 2019 and should raise reliability rates above the 75 percent AMC goal [Figure 4]. Increased reliability and lift capacity should increase C-5M throughput to 0.1378 MTM/D. Defensive systems and aircraft armor are also programmed for installation on 61 C-5M aircraft between 2013 and 2017, allowing the aircraft to operate in a more capable direct delivery role to forward operating bases (FOB), bypassing intermediate nodes and reducing hub and spoke congestion (AMC, 2008). The current Air Mobility Master Plan calls for a C-5M fleet size of 111.

Figure 4: C-5 Fleet



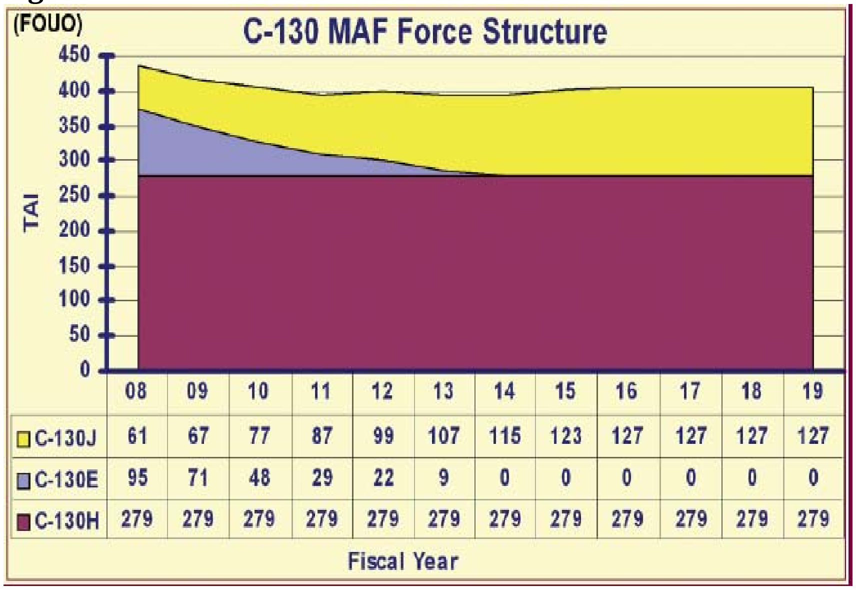
	08	09	10	11	12	13	14	15	16	17	18	19	20	21
■ C-5M	4	7	12	19	28	40	52	64	76	88	100	111	111	111
■ C-5A/B/C	107	104	99	92	83	71	59	47	35	23	11	0	0	0

(AMC, 2008)

The C-17 is the nation’s core military airlifter. It is capable of carrying 18 pallets, and can fly for 3,200 miles with 110,000 pounds of cargo. All C-17s are equipped with defensive systems and are air refuelable, allowing them to bypass hubs and operate in a direct delivery role to FOBs (AMC, 2008). However, C-17s also participate in hub operations to achieve higher aircraft utilization rates. The newer C-17, which achieved initial operational capability in 1995, routinely maintains an 85 percent or higher mission capable rate with throughput of 0.1245 MTM/D (Boeing, 2009). The additional payload capacity, outsized cargo capability, and forward-based austere airfield ability of the C-17 allows AMC to increase throughput significantly during contingency operations (AMC, 2008). Even with this additional organic capability, the DoD requires substantial commercial airlift augmentation to achieve logistics goals.

C-130s augmented by C-17s provide intra-theater lift, the spoke portion of AMCs hub and spoke operations. AMC maintains a fleet of over 400 C-130 tactical airlifters. The C-130 has 6 pallet positions and can carry 25,000 pounds of cargo 2,500 miles (AMC, 2008). C-130s are equipped with defensive systems and are capable of operating into small austere airfields. C-130s first entered service in 1955, and have seen several revisions and modification. The average aircraft is 30 years old with a mission capable rate of 75 percent. However, new C-130J models are entering the fleet as older E models retire, improving reliability rates and raising capacity by two pallet positions per aircraft in the process [Figure 5]. C-130s are incapable of carrying outsized cargo, requiring augmentation by C-17s operating in an intra-theater role to increase spoke capacity and provide outsized cargo capability.

Figure 5: C-130 Fleet



	08	09	10	11	12	13	14	15	16	17	18	19
🟨 C-130J	61	67	77	87	99	107	115	123	127	127	127	127
🟪 C-130E	95	71	48	29	22	9	0	0	0	0	0	0
🟥 C-130H	279	279	279	279	279	279	279	279	279	279	279	279

(AMC, 2008)

Civil Reserve Air Fleet (CRAF)

The DoD relies heavily on commercial partners to reach target airlift capabilities at reduced operational cost. General Duncan McNabb, Commander of USTRANSCOM, testified before congress that “CRAF significantly enhances our ability to succeed anywhere in the world by providing unmatched strategic lift – a capability no other Nation can provide" (McNabb, 2009, p. 1). His tribute is not an exaggeration. CRAF deployed more than 60 percent of the passengers and 27 percent of the air cargo, and redeployed 84 percent of the passengers and 40 percent of the cargo during Operations DESERT SHIELD/DESERT STORM (McNabb, 2009). Currently, 34 separate carriers participate in the program, committing almost 1,100 aircraft, providing 40.6 (MTM/D) in bulk cargo capacity and nearly 200 million passenger miles/day (MPM/D) (McNabb, 2009). The DoD typically plans for CRAF carriers to move about 40 percent of the cargo and 90 percent of the passengers, during peacetime and war (McNabb, 2009). DoD target capacity for CRAF is 20.5 MTM/D to meet major contingency scenarios (IDA, 2008). This capacity comes at significant cost savings over organic airlift. A 1994 RAND study found that replacing CRAF capacity with military aircraft would cost the DoD between $1 billion and $3 billion annually. The program generates cumulative cost avoidance in 2009 dollars of between $43 billion and $128 billion (McNabb, 2009). However, the CRAF airlift fleet does not provide identical capability to the military fleet. CRAF aircraft are not equipped with defensive systems, lack the ability to operate at austere airfields, and do not train or equip their aircrews to operate in direct combat environments. These differences prevent direct delivery of cargo by CRAF to dangerous FOBs, requiring hub and spoke transfer of cargo to combat-capable C-17 or C-130 aircraft.

Additional Airlift Options

Additional military aircraft, commercial tenders, and the World Wide Express programs offer limited augmentation options to airlift cargo that lacks strategic airlift or CRAF options. The AMC fleet includes 59 KC-10 tanker aircraft capable of carrying 23 pallets each [Figure 3]. However, the DoD does not include this capacity in planning scenarios because high demand for air refueling capability limits asset availability for dedicated cargo missions. KC-10s also lack defensive systems and austere airfield capability, limiting their direct delivery potential (AMC, 2008). To augment delivery to FOBs in Iraq and Afghanistan, the military has instituted a commercial tender program. This program places cargo that CRAF cannot carry, due to aircraft availability, cargo dimensions, or location restrictions, up for bid. Potential commercial carriers price cargo delivery between individual city pairs by the pound. Foreign owned aircraft including AN-124 and IL-76 dedicated cargo aircraft provide substantial additional airlift in support of Operations IRAQI FREEDOM/ENDURING FREEDOM. While successful and economical to date, the commercial tender program is not included in planning scenarios due to questionable availability and reliability in future political or economic scenarios (Carter, 2009). The military also makes use of Worldwide Express (WWX) carriers, such as FedEx and UPS, to provide door-to-door logistics service for small packages up to 150 pounds (AMCI 24-101 V11, 7 April 2006). WWX delivery has proven extremely efficient for this limited segment. A 1999 AFIT study compared organic and World Wide Express delivery times for high priority cargo moving from the CONUS to Spangdahlem, Germany. Total transit time for organic airlift displayed a mean of 6.86 days with a standard deviation of 6.21 in contrast to FedEx total transit time of 2.77 with a standard deviation of 1.11 (Condon, Cunningham, Moore, & Patterson, 1999) Although WWX provides quick and cost effective transportation capability, hazardous delivery locations and small package size requirements limit WWX utility in contingency scenarios. Despite the extensive military and commercial airlift options, airlift demand in support of OEF and OIF exceeds AMC capacity, creating longer and more variable delivery times.

Military Airlift Demand

Although military airlift capacity exceeds DoD-stated requirement levels, the nature of counterinsurgency warfare in Iraq and Afghanistan, availability of wartime funding, and transportation priority system inflation create excess demand that leads to airlift system saturation. Demand Management is the supply chain management process that balances the customers’ requirements with the capabilities of the supply chain. Demand management focuses on finding ways to reduce demand variability and to improve operational flexibility (Croxton, Lambert, Garcia-Dastugue, & Rogers, 2002).

Traditional transportation theory advocates moving the majority of cargo by sea or land because of increased capacity and decreased cost. A single ship is capable of moving 300 C-17 equivalents of cargo. The cost per mile of sealift or ground transportation is substantially less than airlift. Because Afghanistan is land-locked and possesses poor transportation infrastructure, TRANSCOM sends the majority of critical wartime cargo by air, regardless of efficiency. Ground lines of communication (G-LOCs) exist through Pakistan and Kazakhstan; however, political consideration and theft concerns limit these routes to carrying non-critical supplies. Once reaching the Afghanistan border through either route, the limited highway infrastructure and danger associated with convoy operations presents further logistical challenges for ground transportation options, driving more cargo to air delivery. While Iraq is accessible through sealift, the Improvised Explosive Device (IED) risk to convoy operations leads to airlifting supplies that would otherwise travel through higher capacity ground transportation options (Nelson, 2004).

Counterinsurgency operations and wartime funding structures further elevate airlift demand. Normal deployment and sustainment projections focus on transporting unit equipment and with resupplying food, water, ammunition, and other critical needs by air [Appendix B]. In the prolonged counterinsurgency environment of Iraq and Afghanistan, these traditionally critical needs compete with airlift requests for infrastructure and building supplies, comfort and entertainment items, and non-combat related in-garrison supplies. Wartime supplemental funding from Congress provides commanders with virtually unlimited transportation budgets. Furthermore, leaders do not rank or reward units based on fiscal achievements as they do in business. Instead, Congress collects unspent money without rewarding those responsible for the savings (GAO, 2008). Because units pay for contingency transportation with separate wartime funding that they cannot easily save or use for other purposes, transportation is essentially free. Items that normally would not be a wartime priority, such as building materials, mail, or office supplies, can become a commander's top priority and identified as an Urgent Need in a prolonged counterinsurgency conflict. Former DIRMOBFOR Brigadier General Timothy Zadalis noted that at one point during Operation IRAQI FREEDOM, leadership considered mail the highest priority cargo in theater (Zadalis, 2009).

Finally, priority inflation saturates airlift transportation capacity by negating the system's ability to segment customers. TP-1 999 represents the highest priority requirement for the Defense Transportation System. DoD regulations reserve Transportation Priority 1 (TP-1) for items designated as Urgent Need by deployed commanders (DoD 4140.1-R, May 23, 2003, p. AP 8.4). The 999 required delivery date suffix indicates "Expedited handling for Non-Mission Capable Status (NMCS) overseas customer" (DTR 4500.9-R, 25 September 2009). Despite strict requirements, unmanageable amounts of cargo receive the TP-1 999 designator. Research has shown mail, construction materials, computer items, office and school supplies makeup 40-50% of the TP-1 999 cargo, despite the requirement for commanders to authorize Urgent Need shipments personally (AFLMA, Mar 2004, p. 19). A study by the Air Force Logistics Management Agency found that cargo coded TP-1 999 represented 30 percent of shipments during OEF and OIF. Priority inflation removes the ability to prioritize shipments effectively, leading to system saturation, backlogs, and delays. System delays paired with poor visibility lead many customers to reorder items, further saturating the airlift system (AFLMA, Mar 2004). Airlift demand is outpacing airlift supply in OEF and OIF. Striving to improve operational flexibility to the unquenchable demand on airlift, AMC has focused on optimization efforts to expand the throughput of airlift channels.

Transportation System Optimization

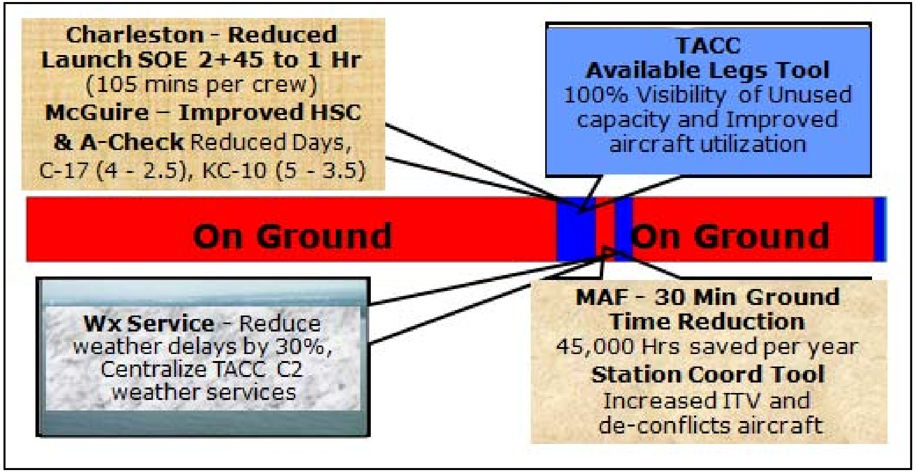
Air transportation industry optimization efforts focus on increasing aircraft load factors, decreasing aircraft turn times, and achieving synchronization of operations. For a commercial route to be profitable airlines must sell enough seats to cover fixed and variable costs associated with operations. Filling a greater number of seats divides fixed costs over a broader customer base, allowing airlines to decrease ticket price or increase profits. Airlines typically operate with load factors of 65-70 percent (Coyle, Bardi, & Novack, Transportation 6e, 2006). If airlines fill planes to capacity, per mile costs decrease. Economies of scale for aircraft relate to the inability to inventory an unused seat. Air transportation is a service. Once an aircraft departs, any unused capacity is lost forever, in contrast to unsold physical products that can be stored, maintaining some value. To avoid lost capacity and achieve economies of scale, transportation providers alter routes or schedules to achieve higher utilization rates. Managers often delay runs to accumulate more freight for the long haul given the relatively high fixed costs incurred for each run (Coyle, Bardi, & Novack, Transportation 6e, 2006). Following deregulation in 1978, airlines evolved a hub and spoke system to consolidate passengers from various destinations onto a common follow-on connection, thereby increasing load factors. Transportation providers subscribe to consolidation and break-bulk activities to achieve full capacity for long-haul moves. Furthermore, they attempt to minimize empty mileage traveling between routes as it has an effective load factor of zero (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 329).

A second source of transportation industry optimization focuses on increasing equipment utilization. For aircraft, that means reducing ground time between flights. General McNabb highlighted this concept and its application to the military in testimony before Congress. “The airline business model is at its best when aircraft spend minimum time on the ground – we are implementing initiatives like concurrent servicing at Air Mobility Command bases to reduce ground times and keep CRAF aircraft airborne, spending less time on the ground and more time moving cargo” (McNabb, 2009).

Finally, commercial transportation providers seek synchronization of operations to facilitate higher equipment utilization while garnering competitive advantage through speed of service. Airlines work to synchronize flights at their hubs, concentrating the flights together in time blocks known as “hub waves,” to allow customers to transition quickly between connecting flights (Alderighi, Cento, Nijkamp, & Rietveld, 2005). Shorter total travel times are a source of competitive advantage for airlines. Similarly, FedEx synchronizes the arrival and departure of approximately 150 aircraft each evening into their primary hub in Memphis. This synchronization allows them to sort all packages onto connecting flights in minimum time, maintaining velocity and achieving unmatched customer service (FedEx, 2009).

The military has aimed optimization efforts at each of these areas: load factors, turn times, and synchronization. The Tanker Airlift Control Center (TACC) uses hub and spoke operations, targets minimum cargo levels for each aircraft type, and attempts to avoid empty legs to improve aircraft load factors. To increase aircraft time aloft, AMC has initiated a number of recent improvement events including a Reduced Launch Sequence of Events, centralized weather service to reduce weather delays, a 30 minute ground time reduction during en-route stops, and faster maintenance checks to keep aircraft in service [Figure 6]. Recently, the Inbound Logistics Lean event (21-25 July 2008) aimed to increase synchronization of cargo movement. The event scheduled trucks inbound to the Aerial Port of Embarkation (APOE) from DLA while coordinating with the aerial port process for a seamless flow of cargo onto the aircraft segment (AMC and DDC, 24 Sep 08).

Figure 6 AMC Velocity Efforts



(Anderson D. , 2009)

While the military should continue to benchmark successful civilian optimization initiatives, implementers must consider that military airlift differs substantially from civilian transportation providers. Military logistics require massive surge capability in times of war or conflict. Infrequent events of enormous magnitude drive military requirements while the airlines face demands that, over time, are considerably less variable (Baker, Morton, Rosenthal, & Williams, 2002). Furthermore, airlines can choose which markets to serve. Airline leadership assesses available infrastructure, competition, demand, and profitability before choosing to enter a route. In contrast, DoD leadership compels military transportation providers to serve customer demand globally, often to areas possessing insufficient or war-damaged infrastructure. Small customer bases created by limited operations must receive timely service, even if demand does not allow for efficient aircraft load factors. At times, the urgency of need for military cargo justifies extremely inefficient operations such as mid-air refueling in order to achieve an effect through rapid delivery. Using air refueling to support a large deployment results in additional costs, but often substantially shortens the overall time to complete the delivery (Baker, Morton, Rosenthal, & Williams, 2002).

Goals of synchronization and high load factors will conflict in some cases, requiring leadership to weigh advantages of each goal. Lean Thinking, a well-known business process improvement (BPI) theory, advocates the continuous flow of work enabled through synchronization and right sized operations (Womack & Jones, 2003). Aligning workflow steps to achieve continual uninterrupted progress achieves the greatest possible work velocity for a given product or service. This system achieves continual, reliable delivery, creating a reduction in associated cost by reducing or eliminating working inventory, safety stocks, and work in progress inventory (Womack & Jones, 2003). Transportation principles such as operational synchronization, direct delivery, and smaller aircraft align with principles of Lean Thinking. Decision makers should measure performance against economies of scale achieved through hub and spoke operations, large aircraft, and operational delays aimed at higher aircraft load factors. Given that demand exceeds airlift supply for current sustainment operations in Iraq and Afghanistan, the military uses a hub and spoke network to increase aircraft utilization and total system throughput.

Hub and Spoke Networks

Military Hub and Spoke operations can draw parallels to airline hub and spoke operations, limited cargo hub and spoke examples, and cargo cross docking. Airline hubs developed in 1987 following deregulation. With the end of regulated fares, airlines had to increase load factors to remain competitively viable. "Grouping passengers with the same travel origin but different destinations allows the realization of economies of density on both feeder flights and connecting flights to the final destinations." (Alderighi, Cento, Nijkamp, & Rietveld, 2005). As airlines funneled a greater number of passengers across their hubs, efficiency and profitability increased. Toh and Higgins (1985) found a positive relationship between the extent of hubbing and airline profitability. Costs reduce by 0.1 percent for every 1 percent increase in hub-and-spoke routing (McShan & Windle, 1989). Hub operations also allow airlines to serve smaller markets profitably. Hub and Spoke strategy targets passengers travelling between origins and destinations for which traffic volume is not sufficient for frequent non-stop flights (McShan & Windle, 1989). While airlines are the most common example of hub activities, many commercial cargo carriers successfully employ hub concepts.

Cargo processed through hubs offers similar economy of density and network efficiencies. The Hub is similar to the motor carrier's break-bulk terminal. In break bulk facilities, cargo is efficiently transported longer distances in cost-efficient Full Truck Load (FTL) volumes. Near the destination, the FTL shipments are broken down into Less than Truck Load (LTL) shipments that travel shorter distances to their individual destinations (Coyle, Bardi, & Novack, Transportation 6e, 2006). Cost leader Wal-Mart uses a hub and spoke network to distribute products to its retail outlets (Apte & Viswanathan, 2000). In air transportation, FedEx's cargo hub at Memphis processes over 3 million packages daily, routing them efficiently to global destinations overnight; a feat that would be economically unviable with direct delivery service (FedEx, 2009).

A related concept to hub and spoke operations is cross docking. “Cross docking is a warehousing strategy that involves movement of material directly from the receiving dock to the shipping dock with a minimum dwell time in between” (Apte & Viswanathan, 2000). Similar to a commercial mixed warehouse, input shipments from several vendors arrive as FTL shipments to the warehouse, are broken up, and then consolidated again to create several multi-product shipments. The key to cross docking is the concept of shipment velocity. By keeping the shipment dwell time to a minimum, employers of cross docking seek to benefit from the cost efficiencies of transportation economies of scale while minimizing the expenses of increased total travel time and inventory carrying costs. “Cross docking offers reduced transportation cost while maintaining customer service and reduction of order cycle time improving flexibility and responsiveness of the distribution network” (Apte & Viswanathan, 2000).

Leadership must weigh the negative ramifications of hub and spoke/cross docking operations against the generated economies of density and network flexibility. Because transportation can no longer travel in a straight line to the destination, people or items entered into a hub and spoke network will experience longer travel times. They will incur additional delays related to handling and processing at the intermediate node or hub. Finally, delivery time variability will increase based on the cumulative effects of multi-segment travel times coupled with hub processing time. Given that items in transit incur inventory hold costs related to total travel time, and that customers incur expenses for safety stock held to guard against delivery time variability, economies of scale and network flexibility may not be worth the added expense (Womack & Jones, 2003). “The receiver may increase inventory levels and incur higher inventory carrying costs to guard against damaged cargo and stockouts" (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 325). Industry studies have found that increased inventory costs accrued to ship full container loads of products more than offset the savings of "economical" shipments (Lee & Billington, 1992). Leaders must examine the time value of a given product before pursuing hub and spoke/cross docking efficiencies. "Cross-docking can ideally be implemented for products that enjoy a steady and stable demand rate and a low unit stock-out cost" (Apte & Viswanathan, 2000). Air Force doctrine summarizes that "direct delivery is the method of choice for timely, effective delivery of cargo and passengers. However, there is a planning, flexibility, and resource bill to pay for this effectiveness" (AFDD 2-6, 1 Mar 2006).

Port Processing

At the heart of effective hub activity is terminal or port operations. A terminal is "any point in a carrier's network where the movement of freight or passengers is stopped so some type of value-adding activity can be performed" (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 339). The most fundamental port activity is physically handling the goods efficiently: rapidly unloading, storing, and reloading shipments [Table 1]. Because aircraft only earn revenue when they are moving, firms strive to operate with a minimum of down time or loading and unloading time (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 330). Terminals can use proper equipment and planning to improve port velocity. In a pure cross-docking warehouse, shippers complete all the unit labeling and packing activities before the products enter the warehouse (Apte & Viswanathan, 2000). Terminals also strive to use full vehicle shipments effectively by employing consolidation and break-bulk activities. Planning and management activities at terminals allow for aircraft scheduling, aircraft maintenance, and crew changes to leverage aircraft and aircrew assets fully. Finally, terminals deploy information technology to enable local management and centralized leadership to pursue increased effectiveness and efficiency (Coyle, Bardi, & Novack, Transportation 6e, 2006).

Table 1: Fundamental Port Requirements

Fundamental Port Requirements
(1) Effective handling of physical flow of goods
(2) Effective use of Full vehicle shipments
(3) Effective use of proper planning and management tools
(4) Effective deployment of advanced information technology

(Apte & Viswanathan, 2000)

To achieve rapid loading and unloading of aircraft, terminals must possess trained and capable personnel, sufficient and capable ground support/mission handling equipment (MHE), and an efficient port layout. "Success in moving the product through the system depends on both equipment and manpower" (Apte & Viswanathan, 2000). Trained personnel are the most valuable asset to any operation, but these personnel must be appropriately equipped for their tasks. Although expensive, MHE will often define the throughput and therefore efficiency and profitability of a terminal. Cost of adequate ground support equipment is less than the lost revenue that would result from not having the large vehicle itself in operation (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 330). Coupled with MHE is the facility layout for processing cargo. Inefficient layouts that generate long travel times between transportation assets and storage locations will limit operational throughput, especially given safety considerations and the slow travel speed of MHE. Efficient hub and cross docking requires well-equipped and well-designed docks (Apte & Viswanathan, 2000). The Air Force maintains units with personnel trained to employ MHE and to establish and control efficient aerial ports.

In the Air Force, Global Air Mobility Support System (GAMSS) units establish and operate air mobility terminals. GAMSS is a compilation of units based at key permanent global mobility installations and rapidly deployable units capable of setting up and maintaining operations anywhere in the world. Aerial port experts provide expertise to establish marshalling yards and traffic routing for cargo, aircraft servicing, air terminal operations center services, and loading and unloading aircraft (AFDD 2-6, 1 Mar 2006). The mobility community often views port hold time as an indicator of aerial port efficiency. Consequently, the aerial port community responsible for measuring and recording port-hold time endeavors to limit the definition and thereby limit their implied culpability for system delays.

In terminal operations, it is important to manage the flow of information as adeptly as the flow of goods. Centralized command and control authorities use the flow of information through IT systems to allocate and route aircraft. Within the port, port planning requires advance information to forecast and plan for in-transit and incoming goods. Managers use this information as the basis of cross docking and terminal decisions, allowing them to minimize dwell time and maximize load factors (Apte & Viswanathan, 2000). Port personnel transfer information into the system using container markings, barcodes and scanning of products. "Cross docking is as much an information handling system as it is a material handling system" (Apte & Viswanathan, 2000). The Defense Transportation System operates a robust suite of information systems to enable rapid efficient global mobility, including GATES and GTN. These interlinked systems provide real-time information of cargo location along with key information about each item within the global transportation network. These systems provide the core information used by GAMSS personnel at each port and centralized command and control planners at TACC and TRANSCOM.

Mobility Metrics

In addition to real-time information system access, commercial transportation system decision-makers employ metrics to measure performance and plan future operations. Performance measurement provides the ability to track outcomes in a timely manner and allows for real-time adjustment and productivity improvement (Berman, 2002). The simple act of measuring performance affects human behavior and motivation, creating intrinsic and extrinsic benefits. The adage "what gets measured gets done" refers to the concept that attention paid to a particular behavior will motivate individuals to place their effort on that behavior. Robson (2004) notes that measurement creates "intrinsic motivation to take control and eliminate the perceived deficiency." It also creates "extrinsic motivation by connecting a reward or punishment to a measurable level of performance" (Robson, 2004). The relationship between measurements and performance follows Campbell's Expectancy Theory. Campbell states that an individual's motivation stems from their perceived probability of achieving a first-level reward, with the valence of the reward corresponding to the instrumentality of that reward achieving a second-level outcome (Campbell, 1970). The perceived strength of the link between measurement and reward will then dictate the level of effort to achieve the desired performance or behavior.

Paired with the prevalent belief that "what gets measured gets done" are the cautionary tales of misalignment between measurements and desired behavior. Individuals can make a number of errors in selecting metrics. Many managers seek simple, quantifiable standards to measure and reward performance. The quest for simplicity may lead to goal displacement when the behavior that optimizes that measurement is not the same as management's desired behavior. Additional causes of disparity between measurements and desired performance include an overemphasis on highly visible behaviors, hypocrisy between goals and desired behavior, and an emphasis on morality or equity over efficiency (Kerr, 1995). Therefore, “what gets measured gets done” may support attainment of desired behavior, or explain a lack of achievement of desired behavior, depending on the appropriateness of the selected metric.

Commercial transportation literature advocates maintaining a customer focus to performance metrics to ensure metric-maximizing behavior supports optimization of the supply chain. “If what you are measuring is not important to the customer and to customer support, it should not be important to the company and therefore, should not be measured” (Walden, 2003). Commercial transportation service performance measures include time, consistency, and damage (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 325). Metrics must appropriately measure value to the customer. “Consistently producing a desired transit time, free of damage, is a value to a carrier because it provides a value to the shipper in the form of reduced inventory and stockout costs” (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 325). Leadership must maintain a supply-chain spanning customer focus when designing metrics to avoid the pitfall of sub-optimization. “Without specific service performance systems measuring their tasks, individual operating personnel can lose sight of the need to maintain the company service standard or the assurances made to the customer by the salesperson” (Coyle, Bardi, & Novack, Transportation 6e, 2006, p. 338). Metrics can have unintended behavioral consequences if they do not properly align with desired behavior. The DTS employs metrics at all levels of leadership to provide decision makers with tools to pursue effective and efficient airlift.

DoD staffs in the defense transportation system use metrics to monitor performance and exert control of the airlift channel. The complex bureaucratic system that defines the prioritizing and movement of DoD cargo could not function without sufficient leadership oversight. Responsibility for the DoD airlift system is shared by the 618th Tanker Airlift Control Center (TACC), 18th Air Force (18AF), AMC, and TRANSCOM, with each level responsible for appropriate portions of the process. The AMC Directorate of Intelligence, Surveillance, and Reconnaissance prepares a Daily Operations Brief of airlift performance metrics which the commands each use to control their tactical, operational, or strategic aspect of the airlift channel. The classified metrics include sortie counts and cancellations, total passengers and cargo tons moved, number of committed aircraft along with maintenance issues, a 30-day forecast of upcoming deployments and redeployment with passengers and cargo tons, and upcoming VIP missions. A detailed breakdown of channel cargo shows cargo tons planned, lifted, and inventory levels at Dover AFB, McGuire AFB, Travis AFB, and Incirlik AB. The inventory levels, commonly referred to as backlog, further disaggregates into cargo with less than or greater than 3 days port hold time (PHT). Finally, a summary of past performance shows AMC force package movements over the last 30 days broken down into 1, 2, or more than 2 days late (AMC, 2009). In addition to the AMC Daily Operations Brief, TRANSCOM prepares a briefing of Integrated Distribution Lanes for Airlift and Sealift lanes which shows a one year history of supplier, long range transporter, and intra-theater delivery times measured against TRANSCOMs negotiated delivery times (USTRANSCOM, August 9 2009). A detailed study of Port Hold Time and its effect on cargo delivery times will facilitate and validate leadership metric development.

III. Methodology

Scope

This study examined the composition and impact of Port Hold Times at major AMC transload locations. Defense supply chain management (SCM) seeks to optimize the delivery of goods to the warfighter. The DoD supply chain services warfighting customers' orders, which are processed and filled by the Defense Logistics Agency (DLA) or outside vendors, moved to a port of embarkation, transported by airlift or sealift to a port of debarkation, and moved by follow-on intra-theater airlift and/or ground transportation to a supply depot for final delivery to the customer. The all-encompassing factory-to-foxhole viewpoint of defense SCM aims at optimizing the entire process without falling victim to sub-optimization. However, the broad viewpoint of supply chains is incompatible with thorough study. To provide sufficient depth of analysis, this research focuses on the intermediate node port process associated with major AMC airlift hubs.

During delivery, items may stop at intermediate nodes for trans-load, consolidation or break-bulk activities before continuing through the supply chain. These intermediate nodes can improve transportation system efficiency, but incur a cost to overall delivery time. An expanded understanding of the characteristics that influence port hold time can enable leadership to manage the delivery time cost when pursuing transportation system efficiencies. This research focuses on the port hold time for intermediate airlift nodes within the Defense Transportation System, beginning with cargo arrival at the airfield and terminating with cargo departure from the airfield.

Port hold time is one target metric used by mobility leadership to assess transportation system performance. Leadership often views increases in Port Hold Time as a precursor to cargo delivery delays. Previous research found that total enroute time correlated extremely closely to port hold time, with an adjusted R square total of 0.793 (Lanier, 2009, p. 46). AMC/A9 indicates that decision-makers view extended Port Hold Times as an indicator of over-tasked aerial ports. This research examines PHT impact on total time enroute to determine those areas that may cause changes in PHT. Within this context, several investigative questions arise:

1: What is the PHT correlation to variations in Total Time Enroute (TTE) at major transload locations?

2: What percentage of PHT is made up of Port Processing Time (PPT) and Cargo Awaiting Lift Time (CALT)?

3: How do mission and transportation priority codes, cargo size, throughput, aircraft types, theater destination, and mission delay relate to PHT?

The purpose of these questions is first to validate previous research conclusions that PHT represents a significant portion of TTE and has a high correlation to variations in TTE. The previous study looked only at one channel segment from DLA Susquehanna to Iraq. This study tests the validity of the PHT correlation to TTE across a broad sample of missions and a greater time period. Second, this research seeks to show that port processing time remains consistent at a given port, and that the variations in Cargo Awaiting Lift Time indicate that overall PHT variations are based on command and control factors versus performance of aerial ports. Finally, the research intends to explore potential factors which influence PHT. Based on discussion with AMC/A9 and personal operational experience, the researcher suspects that transload type combined with port throughput may be used to accurately predict PHT.

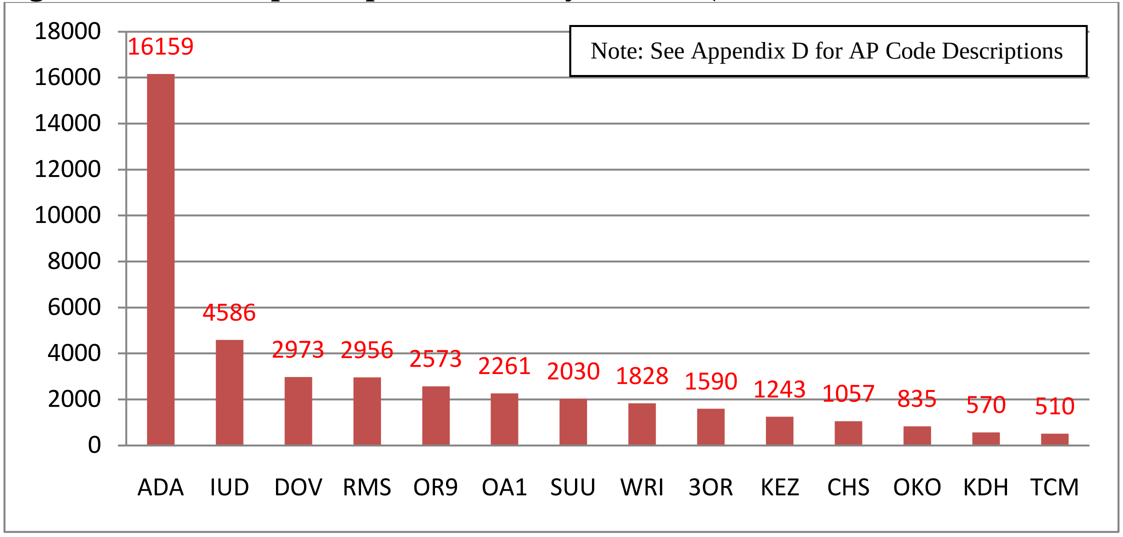
Data Set

To select the airfields for study, the research began with analysis of AMC hub and spoke operations using Global Air Transportation Execution System (GATES) data. GATES is “Air

Mobility Command's aerial port operations and management information system designed to support automated cargo and passenger processing, the reporting of in-transit visibility data to the Global Transportation Network, and billing to Air Mobility Command's financial management directorate" (DoD, 2003, p. GL9). GATES provides a robust collection of data suitable to extensive airlift system analysis.

The research identified major transload locations using GATES pallet throughput counts calculated in Excel. The GATES data spanned all AMC-tracked pallet movements worldwide from 1 Jan 09 to 31 Oct 09 to provide a wide dataset while preserving applicability to recent operations. The data included 246,997 individual pallet movement legs to 401 different destination airfields. 202,272 of the legs, or 81.9%, landed at the final pallet APOD. The remaining 44,769 legs, or 18.1%, landed at an intermediate node other than the final pallet APOD. The majority of hub operations occurred at a small set of airfields [Figure 7].

Figure 7: Trans-Shipment pallet counts by location (GATES data 1 Jan - 31 Oct 09)

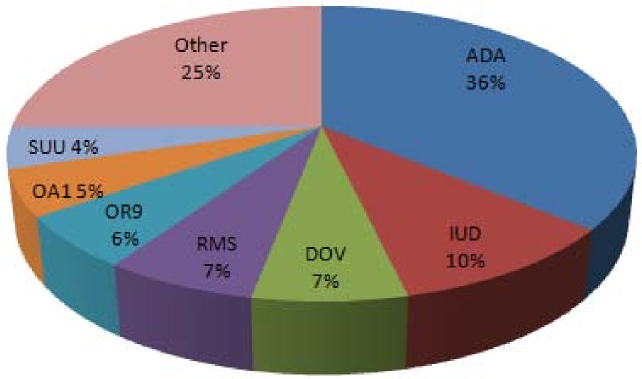


Over 36 percent of intermediate stops occurred at Incirlik AB, Turkey, consistent with DLA trans-shipment tables for Dover cargo bound to Iraq [Appendix C]. Al Udeid AB, Qatar, was the second most common destination, serving Afghanistan and Persian Gulf locations from

McGuire AFB in the DLA trans-shipment table. The third most common location is Dover, acting as a hub for wartime backhaul cargo with a primary cargo origin of Kuwait City, Kuwait. Ramstein AB, Germany (RMS) serves as a major crew and aircraft-staging base between the continental United States and CENTCOM locations. Balad AB, Iraq (OR9) is the largest airlift cargo hub within Iraq while Bagram AB is the largest airlift cargo hub in Afghanistan. Collectively, these 6 airfields capture more than 70 percent of AMC cargo hub operations globally [Figure 8].

Figure 8 Percent of Hub Cargo by Location

(GATES data 1 Jan – 31 Oct 09)



Note: See Appendix D for AP Code Descriptions

AMC/A9 provided data from several GATES database queries. GATES data was combined in Excel to calculate PHT, PPT, CALT and TTE for all pallets transiting major transload locations over a four-month period from 1 July 2009 through 31 October 2009. Data was limited to a four-month period based on query limitations of the Global Transportation Network (GTN) website, the anticipated source of CAP times. CAP time indicates that aerial port personnel have marked a pallet shipment-ready within the AMC system. AMC/A9 later discovered an alternate method of drawing CAP times from GATES. The data was filtered further to view the target airfields, with removal of pallets with the target field as their port of debarkation.

While the research sought inclusion of all data points for completeness of study, a significant number of datapoints had to be eliminated because of incomplete or inaccurate database information. 16,333 records remained fitting the criteria of transloading at Incirlik AB, Al Udeid AB, Dover AFB, Balad AB, Ramstein AB, and Bagram AB between 1 July 2009 and 31 October 2009. However, 3,593 pallets that landed at other than their final destination lacked follow-on leg information in GATES. The majority of these occurred at Dover AFB, where pallets arriving by air were likely switched to ground transportation modes that are not included in GATES. A further 2,199 pallets had pallet dates after their first departure time, and were eliminated as invalid. 10,541 records were included in the final study.

Using Excel, descriptive statistics and regression analysis were completed with reference to *Statistics for Business and Economics, 10E* (Anderson et al., 2008) to determine PHT correlation to TTE and portions of PHT attributable to PPT and CALT. Further descriptive statistics and regression analysis examined aircraft/transload type, throughput, priority, cargo size, destination, and delay code impact on PHT. Resulting correlations are used to recommend appropriate leadership metrics and advantageous areas for future velocity research and initiatives.

Statistical Analysis

Data from the four-month period is analyzed with statistics to gain insight into the research questions. Excel descriptive statistics determined the mean, median, and standard deviation of PHT, PPT, CALT, and TTE for each individual airfield and for the data set as a whole. Scatter plots are used to gain a basic understanding of the relationship between PHT and TTE, PPT and PHT, and CALT and PHT. Simple linear regressions are completed, beginning with PHT as the independent variable and treating TTE as the dependant variable to address research question 1. To address question 2, descriptive statistics are completed to determine the percentage of PHT attributable to PPT and CALT. Finally, descriptive statistics and multiple linear regression analysis was completed to determine if mission or transportation priority codes, cargo size, airfield throughput, aircraft types, theater destination, or mission delay correlate to PHT.

Assumptions/Limitations

Although airlift transloading occurs at many airfields throughout the world, this research is scoped to look at the 6 most common trans-load locations to allow sufficient depth of analysis. Although these 6 locations include the majority of air cargo given the concentration of airlift supporting Operations IRAQI FREEDOM/ENDURING FREEDOM, conclusions from this paper should not be directly generalized to other locations without analyzing the unique factors of each location.

Cargo originating or terminating at the 6 selected locations is not included in the study, because it is intended to focus on intermediate nodes in the delivery process. Cargo remaining on an aircraft without being handled and processed by the port is excluded based on data availability. Because they are not handled at the port, these items lack CAP times in GATES. Significant amounts of unprocessed through-load cargo during hub stopovers could alter the conclusions associated with this paper.

This research is limited to analysis of GATES data, which the research assumes to be accurate and not manipulated. Efforts were made to remove erroneous and incomplete data from the study as described above to gain accurate results. Further erroneous system inputs, intentional or unintentional, would change the resulting analysis and conclusions. Although port personnel interviews, surveys, or direct monitoring of operations could counteract data inaccuracies and would yield additional insight into port hold times, the scope of this research precludes their inclusion.

In 2009, the majority of DTS activity focused on transporting cargo to the Middle East in support of Operations ENDURING FREEDOM and IRAQI FREEDOM. Conclusions from this study may not apply to the drastically different defense supply chain that will develop at the conclusion of these operations or during future conflicts.

Finally, the researcher chose to analyze potential factors that influence PHT based on discussions with AMC/A9, associated research uncovered during the literature review, and personal experience. Additional factors that the research does not analyze could prove more influential on port hold time changing associated conclusions.

Implications

This research builds upon an earlier study which identified port hold time as highly correlated to variations in total time enroute. It tests the correlation within the broader AMC system using data from diverse airfields and over a greater time period. A high correlation between PHT and TTE confirms the importance of the PHT metric for DTS leadership. Given the established importance of PHT on TTE, the research separates the time allocated to cargo processing from time spent awaiting lift by dividing port hold time into PPT and CALT. This division indicates how leadership should allocate additional resources between aerial ports and command and control assets when addressing rising PHT metrics. Finally, the research explores potential contributing factors to PHT with the goal of identifying correlations worthy of future research. Airlift customers require reliable delivery times to facilitate streamlined military supply chains. Awareness and understanding of PHT impact on achieving dependable delivery times should enable mobility decision-makers to pursue greater functional fulfillment of warfighter transportation needs.

IV. Results and Analysis

The Excel 2007 statistical analysis package was used to obtain the results of the PHT research study. Table 2 lists and explains the key variables analyzed during the project.

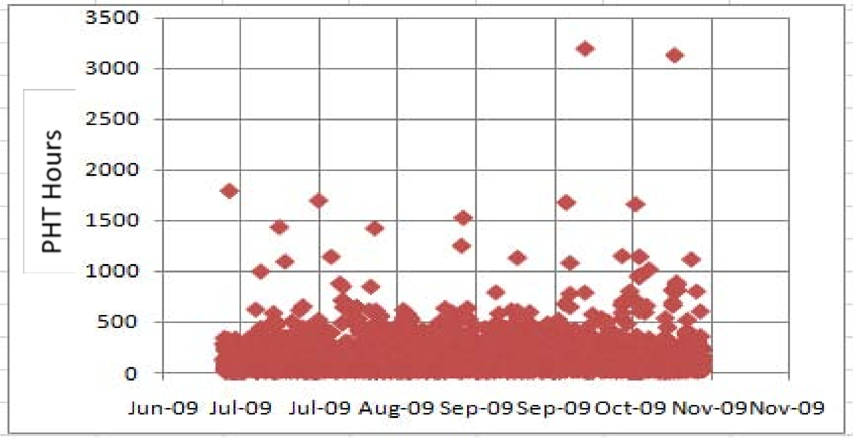
Table 2: Key Variables

Variable Name	Description
Port Hold Time (PHT)	Number of hours from cargo arrival to departure at the port
Total Time Enroute (TTE)	Total Time from pallet date (creation) until arrival at APOD
Cargo Awaiting Lift Time (CALT)	Number of hours from "capped" and ready for airlift until departure
Port Processing Time (PPT)	Number of hours from cargo arrival at intermediate node until "capped" and ready for airlift
Mission Priority (MP)	A scaled number representing the mission priority of the departing aircraft; 1A3 =5, 1B1 = 4, 1B3 = 3, 3A3 =2, 3B1 =1
Transportation Priority (TP)	A scaled number representing the transportation priority code of the pallet; TP1/999 =5, TP1 = 4, TP2 = 3, TP3 =2, TP4 =1
Cargo Size	Measured in equivalent pallet positions
Throughput	Number of transloading pallets at a given airfield for a given calendar date
Aircraft Type: Arrive 747?	A binary variable indicating if a pallet arrived at the transloading airfield on a Boeing 747 airframe.
Aircraft Type: Depart C-17?	A binary variable indicating if a pallet departed from the transloading airfield on a C-17.
Theater Destination?	A binary variable indicating if a pallet APOD is located in Iraq or Afghanistan
Delay	Binary variable (1 if departure mission received a delay code, 0 if no delay)
Location	5 binary dummy variables used to denote DOV, IUD, OA1, OR9, and RMS. ADA was the default location.
Additional Stops	Count of additional intermediate stops excluding the studied transload stop

Question 1: PHT

A scatter-plot was created in Excel to develop a basic understanding of PHT during the four-month window [Figure 9]. The plot shows the date and PHT hours for each of the 10,541 pallets in the study. This preliminary look shows that PHT remained stable over the four-month period, clustering at less than 300 hours. A few large outliers were present, taking times of 3000+ hours. No obvious cyclical pattern emerged in the data.

Figure 9: PHT Scatter Plot (July through October 2009)



Descriptive statistics for Port Hold Time, Port Processing Time, Cargo Awaiting Lift Time, and Total Time Enroute are provided in Table 3. All four key variables displayed a wide range of values as can be seen in the difference between the minimum and maximum values.

Table 3: Descriptive Statistics - PHT, PPT, CALT, and TTE

Variable	Min	Max	Average	Median	Mode	Variance	STDEV	N
PHT	1.0	1791.0	71.0	53.0	31.0	4390.9	66.3	10541
PPT	0.0	1658.0	15.3	3.0	2.0	1204.4	34.7	10541
CALT	0.0	1687.0	55.6	42.0	29.0	2401.6	49.0	10541
TTE	8.9	3494.2	166.4	131.5	85.9	19504.8	139.7	10541

Note: Values rounded to one decimal place

Pallets spent an average of 71 hours in the port at transload locations, of which 15.3 hours was Port Processing Time while the remaining 55.6 was spent as a ready pallet awaiting airlift (CALT). Total delivery times averaged 166.4 hours, or just less than 7 days. Of note is that all four variables displayed a median (50th percentile) value less than the average, and a mode (most prevalent value) significantly less than the average. This positive skew shows that a smaller number of pallets with longer PHT are driving the average times up. Also of note are the high standard deviations for all four variables, showing large inconsistencies in times. Table 4 provides a similarly-formatted look at PHT broken down by individual airfield.

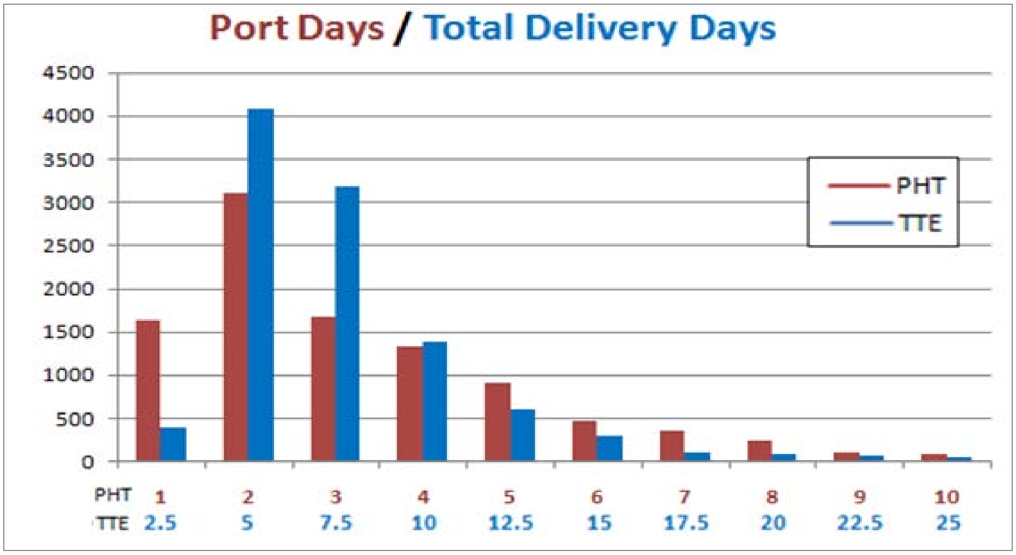
Table 4: Descriptive Statistics - PHT by Airfield

Field	Min	Max	Average	Median	Mode	Variance	STDEV	N
ADA	1.0	785.0	68.8	53.0	31.0	2794.0	52.9	7785
DOV	10.0	589.0	151.4	117.0	43.0	13753.8	117.3	90
IUD	4.0	1791.0	75.0	38.0	25.0	22621.3	150.4	528
OA1	2.0	610.0	75.3	58.0	32.0	4599.8	67.8	1012
OR9	1.0	570.0	89.7	73.0	32.0	5465.4	73.9	423
RMS	2.0	619.0	63.8	38.0	23.0	5123.9	71.6	703
Total	**1.0**	**1791.0**	**71.0**	**53.0**	**31.0**	**4390.9**	**66.3**	**10541**

Note: Values rounded to one decimal place

While it was hoped that variations between the ports would explain some of the high variance in collective PHT, Table 4 shows that PHT remains highly variable within each of the 6 individual ports. Incirlik showed the lowest standard deviation at 52.9 hours, which may be explained by the consistency of missions with 747 contract carriers moving standard pallets from CONUS to Incirlik, with follow on C-17 intra-theater lift to final destination. The significantly larger volume of transloading pallets may also serve to decrease the standard deviation in PHT. In contrast, Al Udeid AB and Dover AFB experienced the highest standard deviations at150.4 and 117.3 hours, respectively. Al Udeid's mission diversity and Dover's primarily backhaul role as an intermediate node, paired with their smaller volume of transloading pallets may add to their PHT variability. Despite these differences, the general trend of highly variable, positive-skewed times remained consistent across the ports. This general distribution of Port Hold Times is very similar to the distribution of Total Time Enroute, as can be easily seen in the histogram in Figure 10.

Figure 10: PHT and TTE Histogram



While the time scale differs, with PHT shown with 1-day increments and TTE shown with 2.5-day increments, the general distribution is the same. A small number of pallets moves unusually quickly in the first increment, the bulk of the pallets move in the second and third increments, but a significant portion possess unusually long PHT and TTE times. Looking at PHT specifically, 1185 pallets (11 percent) experienced PHT greater than 1 sigma above normal (>137 hours). 378 pallets (4 percent) experienced PHT greater than 2 sigma above average (>203 hours). Although PHT and TTE display very similar distributions, this does not indicate that PHT for a given pallet is a strong indicator of that particular pallet's TTE. To answer this aspect of the research question, regression analysis was completed in Excel, using PHT as the independent variable, and TTE as the dependant variable. Table 5 provides the results of PHT/TTE regression analysis for individual airfields and for the collective group. The coefficient of determination (R-Squared) provides a measure of goodness of fit for the estimated regression equation. It can be interpreted as the proportion of the variability in the dependant variable that is explained by the estimated regression equation (Anderson, Sweeney, & Williams, 2008, p. 605).

Table 5: PHT/TTE Regression Analysis

Independent Variable (s)	Dependent Variable	R^2	R^2 Adjusted	Standard Error
ADA PHT	TTE	0.533	0.533	44.0
DOV PHT	TTE	0.539	0.534	215.3
IUD PHT	TTE	0.492	0.491	206.3
OA1 PHT	TTE	0.201	0.200	154.4
OR9 PHT	TTE	0.367	0.365	149.3
RMS PHT	TTE	0.097	0.096	243.5
PHT	**TTE**	**0.297**	**0.297**	**117.1**
PHT Dummy Vars, Addl Stops	**TTE**	**0.464**	**0.464**	**102.3**

Results vary between airfields, with Incirlik generating the best coefficient of determination at 0.533. Ramstein AB had the lowest R-Squared at 0.097. Collectively, all 6 airfields grouped together created an R-Squared just under 0.3. Setting Incirlik as the default field, and adding 5 binary dummy variables to identify the remaining 5 fields allowed for a Regression Analysis accounting for differences in individual airfields. The inclusion of location dummy variables and an additional stops count yielded an R-Squared of 0.464. The Adjusted R-Squared corrects for chance improvements of an additional variable when using a small sample size. Given the relatively large number of samples in each regression, Adjusted R-Squared for this study is nearly the same as R-Squared. The standard error shows the estimate of the standard deviation in the error component of the regression equation (Anderson, Sweeney, & Williams, 2008, p. 605). A 0.464 Adjusted R-Squared value should be considered highly significant given the noise inherent to a natural system. All tests yielded P-values less than 0.01 for all variables, indicating a high confidence that the PHT and TTE are highly correlated. The improved results associated with the inclusion of an additional stops counter, which accounts for the PHT at additional intermediate locations, only elevates the importance of PHT on TTE. While R-Squared of 0.464 is lower than the 0.79 listed in Lanier's Susquehanna-Incirlik study, it still serves to validate a high correlation between PHT and TTE across a much broader sampling of cargo. Given the high correlation of PHT and TTE, it is important to understand the composition of PHT.

Question 2: PPT/CALT

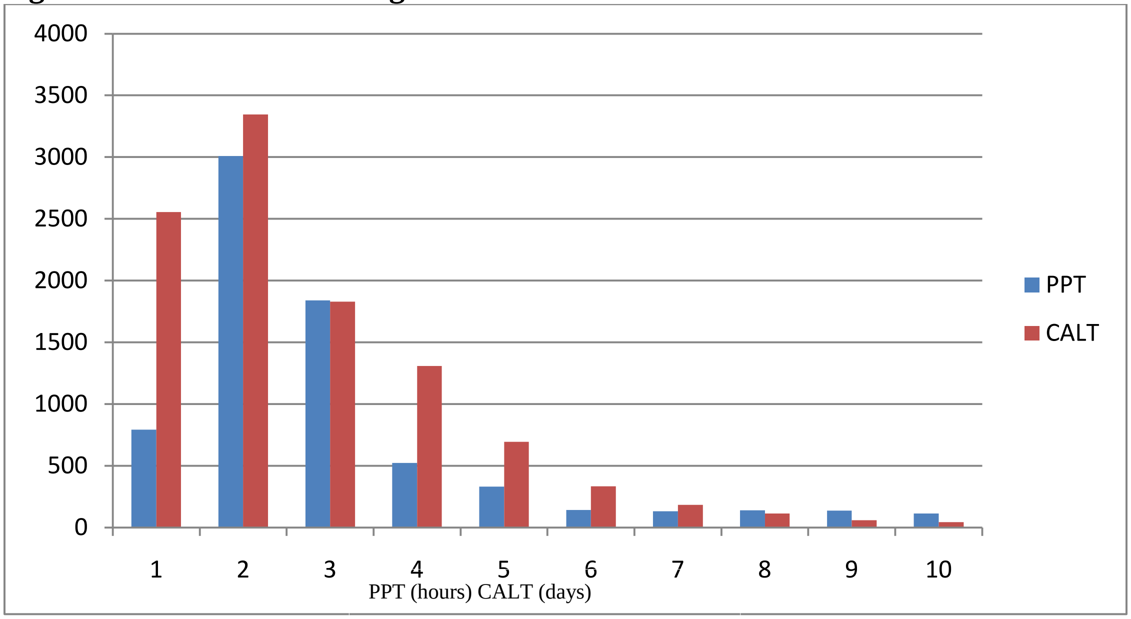
Dividing Port Hold Time into two components, Port Processing Time and Cargo Awaiting Lift Time, allows for an understanding of time allocation among the activities occurring between airfield arrival and departure. Descriptive statistics available in Table 6 show that pallets spend on average 15.3 hours or 18 percent of their time in aerial port pallet processing activities. Pallets spend the remaining 55.6 hours or 82 percent of their time awaiting airlift to the next destination.

Table 6: Descriptive Statistics - Port Processing/Cargo Awaiting Lift Times

	PPT Average		CALT Average		MEDIAN	
Field	Hours	% Time	Hours	% Time	PPT	CALT
ADA	13.9	16.4%	54.9	83.6%	3.0	43.0
DOV	23.5	19.9%	127.9	80.1%	11.5	84.0
IUD	24.2	25.3%	50.8	74.7%	5.0	28.0
OA1	18.9	26.0%	56.4	74.1%	8.0	40.0
OR9	21.2	19.0%	68.5	81.0%	4.0	53.5
RMS	14.7	17.7%	49.1	82.3%	2.0	29.0
Total	**15.3**	**18.0%**	**55.6**	**82.0%**	**3.0**	**42.0**

While some variation existed between airfields, the roughly 80/20 split holds true across the examined data set. Of note again is the large disparity between median times and average times. The significantly shorter median times indicate that large variations in the times drive the average up considerably higher than the more commonly experienced times. This was especially apparent in Port Processing Times where average times were 200 to 400 percent higher than the median. A histogram of PPT and CALT values shown in Figure 11 depicts a distribution similar to the PHT histogram, with PPT displayed in hours and CALT overlaid in days. From the histogram it can be seen that the majority of pallets experienced shorter acceptable times while a smaller but significant portion of pallets experienced much longer times in violation of negotiated standards.

Figure 11: PPT/CALT Histogram



Given the established relevance of PHT on TTE, and the composition of PHT shown through the PPT and CALT calculations, the research turns to potential factors of PHT variations.

Question 3: PHT Factors

Based on AMC/A9 suggestions and the author's personal experience, the following variables were examined as potential indicators of PHT: departing aircraft Mission Priority, pallet Transportation Priority (TP) code, pallet size, throughput, arriving/departing aircraft type, theater destination, and departure mission delay. To begin, the percentage of pallets and corresponding average PHT are presented by mission priority in Table 7.

Table 7: Mission Priority Statistics

Mission Priority			
Code	Count	%	Avg PHT
1	33	0.3%	85
1A3	21	0.2%	127
1B1	10214	96.9%	71
1B3	260	2.5%	69
3A3	4	0.0%	17
3B1	9	0.1%	297
Total	10541	100.0%	71

As expected in time of war, nearly 97 percent of pallets transloading at the chosen 6 ports departed on 1B1 missions. The small number of pallets departing on non-1B1 missions showed inconsistent changes to PHT. Higher priority 1A3 missions averaged 56 additional hours PHT. Lower priority missions varied from as short as 17 hours average PHT for 3A3 to 297 hours PHT for 3B1. The deficient code "1," which showed up 33 times in GATES, was included for completeness. Given no pattern for aircraft mission priority, we turn to pallet Transportation Codes in Table 8.

Table 8: TP Code Statistics

Transportation Priority Code			
Code	Count	%	Avg PHT
1/999	6523	61.9%	73
1	1729	16.4%	63
2	728	6.9%	56
3	243	2.3%	59
4	142	1.3%	59
#N/A	1176	11.2%	83
Total	10541	100.0%	71

Pallet transportation codes should be a key determinant of PHT, as this corresponds directly to the commercial expedited shipment concept. As expected from the literature review, a large number of pallets (61.9 percent) received the highest available expedited priority code TP 1/999 at the 6 transload locations. However, these highest-priority pallets actually averaged 2 additional hours PHT above the average. In fact, they averaged 10 hours longer than TP 1. Also of note, TP 2, 3, and 4 pallets averaged measurably shorter PHT than TP 1/999 and TP 1. The 11.2 percent coded “#N/A” had no corresponding TP code in GATES, and were included for completeness. After analyzing priorities, the research next looked at potential deterministic characteristics of the pallets, beginning with pallet size in Table 9.

Table 9: Pallet Size Statistics

Equivalent Pallet Positions			
Pallets	**Count**	**%**	**Avg PHT**
<1.0	**37**	**0.4%**	**48**
1.0	**9695**	**92.0%**	**71**
<=2.0	**515**	**4.9%**	**78**
<=3.0	**245**	**2.3%**	**68**
<=4.0	**38**	**0.4%**	**62**
4.0+	**11**	**0.1%**	**69**
Total	**10541**	**100.0%**	**71**

The pallet positions shown in Table 9 reflect 463L (88” x 108”) pallet positions used for each cargo “pallet” or item. 92 percent of transloaded “pallets” used 1 standard pallet position on the aircraft. A small number of items used less than a full pallet position while 7.6 percent used more than one position. Large items, representing vehicles or linked-together “pallet trains” used for transporting oversized items such as helicopter rotor blades, would intuitively be more difficult to fit in the remaining space on a given aircraft. Small items less than a full pallet position traveled much faster at 48 hours average PHT. While items requiring 2 pallet positions averaged 7 additional hours PHT, larger items actually showed shorter average PHT. After looking at pallet size, the research next examined arriving and departing airframe characteristics in Table 10.

Table 10: Airframe Statistics

		Departure Airframe			
		C-17	C-130	Other	TOTAL
Arrival Airframe	747	70.2%	3.5%	4.8%	78.5%
	C-5	4.8%	0.4%	1.3%	6.4%
	C-17	4.9%	2.0%	3.9%	10.8%
	Other	1.4%	1.3%	1.6%	4.3%
	TOTAL	81.2%	7.2%	11.6%	100.0%

Nearly 80 percent of transloading pallets arrived by 747, while a little over 80 percent of transloading pallets departed by C-17. This gives the two logical discriminating questions to be examined in the regression analysis:

1. Did the pallet arrive on a 747 airframe?
2. Did the pallet depart on a C-17?

These questions were included in the subsequent regression analysis by introducing binary variables for each question. The final binary variable, Theater Destination, separated logically higher priority war-support cargo from intuitively lower-priority backhaul cargo by delineating cargo destined for Iraq or Afghanistan. Before running the final regression, a Pearson Product Moment Correlation Coefficient table was computed in Excel to ensure multi-collinearity did not artificially decrease the influence of related variables [Table 11].

Table 11: PHT Factor Correlation Coefficients

VARIABLE	PHT2	Priority Index	TP Index	Pallet Pos	Through-put	Arrive 747?	Depart C-17?	Theater?	Delay?
PHT2	1.000								
Mission Priority	0.001	1.000							
TP	-0.018	0.147	1.000						
Pallet Pos	-0.003	-0.001	0.014	1.000					
Throughput	0.008	-0.053	0.254	-0.297	1.000				
Arrive 747?	0.027	0.139	0.126	-0.185	0.009	1.000			
Depart C-17?	0.012	0.239	0.398	0.006	-0.036	0.403	1.000		
Theater Dest.?	-0.024	-0.034	0.062	0.005	0.100	-0.001	-0.016	1.000	
Delay?	0.032	-0.008	-0.054	0.046	-0.114	-0.016	-0.021	-0.018	1.000

In general, if the absolute value of the correlation coefficient exceeds 0.7 for any two of the independent variables, one of those variables should be excluded to avoid multi-collinearity problems (Anderson, Sweeney, & Williams, 2008). From Table 11 it can be seen that the potential PHT factor variables have correlations less than 0.7, allowing all variables to be tested without high concern for multi-collinearity. The three variables with the highest correlation to PHT from Table 11 were selected for individual regression analysis in Table 12. The table also includes regression analysis results for all chosen variables and a final regression with Dummy location variables included.

Table 12: PHT Factors Regression Results

Independent Variable (s)	Dependent Variable	R^2	R^2 Adjusted	Standard Error
Delay?	PHT	0.001	0.001	66.2
Theater?	PHT	0.001	0.000	66.2
Airframes?	PHT	0.001	0.001	66.2
TP Code, Mission Priority, Pallet Size, Throughput, Airframes, Delay Codes, Theater Destination	PHT	0.003	0.003	66.2
All plus Location Dummy Variables	PHT	0.006	0.005	66.1

As expected from the non-linear resulting changes to PHT depicted in the above tables, R-squared results were very low for all PHT factor regressions. From these results, no suitable model exists for predicting PHT from the chosen variables. Alternatively expressed, the generic average presents a better model. This randomness is consistent with first-in-first-out (FIFO), the expected current treatment of pallets in theater. It shows that transportation priorities and mission priorities do not significantly speed up delivery time. The coefficient associated with each variable provides some insight on the average trends [Table 13].

Table 13: PHT Factor Coefficients

Variable	Coefficients	Std Err	P-value
Intercept	67.96	15.1	0.000
Priority Index	-0.22	3.8	0.953
TP Index	-1.23	0.5	0.007
EVQ_PAL_PS	0.16	0.2	0.435
Throughput	0.02	0.0	0.024
Arr 747?	4.29	1.8	0.015
Dep C-17?	2.50	2.0	0.211
Theater?	-3.52	1.4	0.014
Delay?	22.83	6.7	0.001

Coefficients with low standard errors and correspondingly low P-values display the average trends. On average, cargo arriving on a 747 spends 4 hours additional PHT, consistent with 747 download times. Going to theater averaged 3.5 hours less than alternate destinations, consistent with the greater flow of missions provided by intra-theater assets. Finally, departure missions with delay codes average 22.8 additional hours PHT, consistent with AMC's 24-hour mission slip policy. Delayed missions generated PHT of 93 versus 71 for non-delayed missions. However, none of these factors provided sufficient explanation for PHT variations to justify a model other than the simple average.

V. Conclusion and Recommendations

Data Conclusions

The results of the research on cause and effects of PHT indicate that PHT is characterized by high variability at the 6 most common transload airfields. The PHT standard deviations displayed in Table 4, which were of similar magnitude to the PHT averages, indicate that many customer orders are delayed in hubs for twice as long as the average time. Current TRANSCOM negotiated time standards for the transporter segment of the defense supply chain is 6-8 days for CENTCOM locations. However, only 87 percent of OIF cargo and 65 percent of OEF cargo is meeting negotiated delivery timelines. (USTRANSCOM, August 9 2009). Figure 10 shows that the positive skew generates a larger average time, and more importantly, violates customer contracts and expectations. Port Hold Times average 3 days with a standard deviation of almost 3 days, contributing to total delivery times of 7 days with a standard deviation of 6 days [Table 3]. These longer delivery times are too common to be an annomoly, and generate large variance. Large variance, in turn, leads to greater customer safety stocks and causes TRANSCOM to fail to meet customer expectations.

Research also indicates that PHT is a significant indicator of variations in overall customer delivery time. Paired with location dummy variables and an additional stop count, which accounts for PHT at other locations, PHT generated a significant 0.464 Adjusted R-Squared value to Total Time Enroute. The results validate the high correlation between PHT and TTE discovered in Lanier's earlier research (Lanier, 2009, p. 35). The correlation was even higher at the busiest transload ports of Incirlik AB, Dover AFB, and Al Udeid AB. In order for TRANSCOM to leverage the efficiency benefits of a Hub and Spoke delivery network without failing to meet negotiated customer delivery times, TRANSCOM, AMC, and TACC leadership should focus on managing PHT. As described above, the research shows that managing PHT means addressing variations in PHT, and subsequently TTE.

Furthermore, Table 6 showed that greater than 80 percent of PHT is composed of Cargo Awaiting Lift Time. Both PPT and CALT were highly variable, with standard deviations in excess of the average component times. The approximate 4-to-1 ratio of CALT to PPT and high component variability remained consistent across all six examined airfields. While this would initially indicate that efforts should address CALT instead of PPT, looking at the variability of each component shows them to be equally responsible for total PHT variability. If it can be assumed that pallets are not scheduled for airlift until CAP time, approximately 12 hours or half a day can be saved on average delivery time by striving to have all pallet CAP times approach the median times for a given airfield. The DTS could potentially save an average of 12 hours by achieving CALT closer to median times [Table 6]. The positive-skewed distribution histogram, shaped similar to the PHT and TTE histograms, shows that a significant portion of cargo falls into the right side tail at greater than one standard deviation above the mean. Reducing the standard deviation in PPT/CALT times by targeting pallets with times greater than one standard deviation (sigma) above the mean would reduce average time, compress variability, and better meet customer delivery expectations.

Finally, the research showed no significant correlation between PHT and mission priority, transportation priority, pallet size, airfield throughput, arrival or departure aircraft type, destination, or mission delay. The lack of correlation with any of these potential indicators, especially the priority indicators that are designed to create delivery time variations based upon importance to the warfighter, indicate that cargo port hold times are random for any given pallet. Port personnel are surprised by calculated average PHT. They commonly reference median/mode times based on personal experience, as the vast amount of pallets visibly follow these timelines. These results are consistent with a first-in-first-out (FIFO) processing system, indicating that priority codes are not driving delivery timelines. Predictably, customers saturate the Defense Transportation System in time of war. Transportation demand consistently outpaces supply. It is tempting to place emphasis on moving the greatest possible volume of cargo in a given time period to satisfy the greatest possible number of customers and achieve faster average delivery times. However, as shown in the literature review, reliability can be more important to customers than speed of delivery. Achieving reliable and consistent delivery times can increase customer satisfaction by allowing them to plan accordingly. Consistent delivery timelines can also serve to reduce demand and avoid saturation by reducing safety stocks and customer reorders.

The research's conclusions about the causes and effects of PHT are consistent with previous studies while providing new information to DTS leadership and key participants in the transportation process. PHT correlates closely to total delivery time for hub-and-spoke cargo. PHT, and therefore TTE, is highly variable, with a large standard deviation and heavy positive skew to the distribution. While CALT makes up the majority of PHT, PPT and CALT contribute equally to PHT variability. Finally, none of the selected potential indicators of PHT, including transportation and mission priorities, is an accurate predictor of PHT. Instead, PHT appears to be random, consistent with a FIFO selection method for moving cargo. These data conclusions, when paired with the background research garnered in the literature review, allow for improvement recommendations to the Defense Transportation System.

System Recommendations

This paper's research recommendations include addressing PHT and TTE variation, reinstituting an effective transportation priority system, establishing metrics aligned with customer expectations, and achieving improved data integrity to empower decision-making. As shown in Chapter IV, large time variations contribute to missed leadership goals, misunderstandings between leadership and port personnel on system performance, and ultimately inadequate transportation customer service. TRANSCOM's metrics on Integrated Distribution Lanes show that AMC delivers only 78 percent of CENTCOM cargo within negotiated timelines, 87 percent on time to Iraq and 65 percent on time to Afghanistan (USTRANSCOM, August 9 2009). Paired with supplier and theater delivery, the Defense Supply Chain delivers only 71 percent of pallets on time to theater, with an abysmal 60 percent on time to Afghanistan. As explained in Chapter II, delivery variations have a greater impact on customers than average delivery time, thwarting their efforts to plan accordingly, and driving up safety stock requirements that ultimately saturate the system. To begin reform, TRANSCOM and CENTCOM must negotiate attainable delivery timelines to theater, relaxing the average delivery time in pursuit of reliable delivery times. If warfighters order supplies with an expected 30-day delivery standard, and reliably receive 99 percent of their deliveries on time, customers can establish appropriate working stocks with minimal safety stocks.

While AMC cannot hope to achieve FedEx's performance levels given diverse, unpredictable, hostile and austere locations, leadership can benchmark some concepts from successful commercial transportation providers. FedEx customers would not tolerate packages delivered on average by 10 AM the next day, with a standard deviation of 12 additional hours. Shortening FedEx's average delivery time to 8 AM with 12 hours variability would still not satisfy customers.   Transportation customers want all packages delivered by the negotiated timeline. Similarly, the DTS needs to shift the focus from maximizing cargo throughput to achieving reliable customer delivery times. System efficiency should not be at odds with effectiveness; instead, the DTS must establish a firm attainable delivery timeline, pursuing efficiency within that effective timeline. Given a consistent delivery timeline, customers will be less likely to reorder shipments that miss delivery standards or to inflate shipments priorities in pursuit of reliable delivery times.

The second recommendation is to reestablish an effective Transportation Priority system. Customers routinely over-prioritize shipments, likely out of frustration at inconsistent delivery times. Consistent with previous research highlighted in Chapter II, Table 8 showed that 61.9 percent of all shipments in this study were coded TP-1/999, the highest possible shipment priority reserved for commander certified Non-Mission Capable Status (NMCS) for an overseas customer. To address the over-inflation, TRANSCOM leadership could advocate a redesigned Transportation Working Capital Fund (TWCF) that charges customers more for higher priority shipments, similar to commercial tiered pricing structures for expedited shipment. Additionally, TRANSCOM could highlight customers that order exceptional percentages of TP-1/999 to raise commander awareness or examine de-weighting the priority of customers that routinely order TP-1/999. However, fault with the Transportation Priority system does not rest solely with customers.   As shown in Table 8, AMC is not honoring TP codes, routinely shipping lower priority items at an equivalent or faster rate. Higher priority shipments should routinely move ahead of lower priority shipments. Given sufficiently differentiated negotiated timelines for each Transportation Priority, lower priority pallets should wait while higher priority pallets move first. In a saturated wartime environment, this may require eventual priority upgrade within a port once lower-priority pallets approach or exceed negotiated timelines. To help assist in creating an effective TP system, leadership must redesign metrics which currently do not differentiate performance by TP code.

Current mobility metrics focus on aggregated delivery times, with multiple exceptions that hide true delivery performance. AMC needs to publish negotiated delivery times to customers and DTS participants, and then honor those commitments by aligning metrics with customer promise fulfillment. Metrics drive behavior; what gets measured gets done. Leaders must deliberately institute metrics that generate desired behaviors as a component of their overarching management strategy. By recognizing the power of measurement to influence behavior and performance, leadership can leverage that power to support desired behaviors and avoid the common pitfalls that lead to misaligned metrics and preclude attainment of organizational goals. The Daily Operations brief prepared by TACC shows inventory levels (backlog) and the number of pallets with greater than 3 days PHT at key mobility locations including Dover AFB, McGuire AFB, Travis AFB, and Incirlik AB. Because current mobility metrics focus on averaged delivery times, not differentiated by TP code, DTS participants strive to minimize average delivery time, regardless of TP code. Leadership should de-emphasize backlog as a key metric. The backlog or pallet count metric influences port personnel to move as many pallets as possible, instead of focusing on moving the correct pallets. It also implies poor performance from ports that experience demand surges. The PHT metric of 3 days addresses the key PHT variable, but aggregates all pallets together regardless of TP code and ignores pallets that are frustrated or allocated to commercial carriers. To maintain a customer focus, all pallets in the port should be included, regardless of status. If PHT were elevated to the key port metric, with PHT times differentiated by TP code, port personnel decisions would be aligned with

TRANSCOM negotiated delivery timelines and customer expectations as they pursued improved metric performance.

Finally, this study highlights the need for improved data collection and data integrity to enable decision-making. Of 16,333 records matching study criteria in the chosen time period, only 10,541 were ultimately included in the study. This equates to 35 percent of records that were dismissed for incomplete or implausible information, such as pallets with creation dates after initial mission departure time. Of the included records, 33 had an invalid mission priority code (Table 7) and 11 percent lacked valid TP codes (Table 8). While record keeping is certainly challenging in a dynamic global environment, it is crucial to create accurate and actionable metrics for TRANSCOM, AMC, and TACC decision-makers. Leadership emphasis of accurate GATES information would improve the validity of leadership metrics, and therefore operational decisions, while simultaneously improving future strategic DTS research studies.

Recommendations for Future Research

The focus of this research was to use GATES data to quantitatively study and evaluate PHT, creating a foundation of research in a currently understudied highly-important area. A qualitative study of PHT, interviewing port personnel, DTS customers, and TRANSCOM, AMC, and TACC leadership, would help to develop a more robust understanding of PHT causes and effects.

Another area for future research involves quantitative and qualitative research into Transportation Priorities. As identified in Table 8, the TP system is overinflated by customers and underutilized by providers. An improved understanding of the customer importance attached to TP codes, transportation provider view of TP codes, and the over inflation of the current system, offers potential improvements in customer satisfaction and system effectiveness.

Finally, a research study dedicated to mobility metrics could assist in developing standardized metrics for DTS participants and associated leadership levels. Current metrics vary greatly between leadership levels, are contended by system participants, and lack customer focus. Given the influence of metrics on organizational behavior, optimized metric selection could offer systematic improvement in the cohesiveness of the Defense Supply Chain.

Final Thoughts

Achieving customer satisfaction is difficult in a supply chain where demand surges unpredictably to unexpected, austere, dangerous locations and supply is legislatively limited. The DTS pursuit of efficient use of all resources, intended to satisfy as many customers as possible, introduces high delivery time variability that decreases customer effectiveness and customer satisfaction. Establishing an achievable level of effectiveness in customer delivery time, and reliably meeting that level of effectiveness, is of paramount importance to meeting customer requirements. Furthermore, it should bring additional benefits of reduced reorders and safety stock ultimately decreasing system demand. This study showed PHT as a key indicator of total customer delivery time. It showed high variability in PHT, translating into high variability in TTE, which the DTS must correct to achieve acceptable customer effectiveness and satisfaction. The study showed that while the majority of PHT consists of CALT, PPT and CALT equally contribute to PHT variability. Finally, it identified no correlation between suspected PHT indicators and the actual PHT, including the mission and transportation priority codes designed to segment delivery performance.

To improve the system performance and customer satisfaction, the DTS needs to honor priorities. Metrics should focus on the right-side tail of the time distributions, not on the average times. They should address not the number of pallets in port (demand), or average PHT (system capacity), but instead focus on reducing variations to provide predictable customer delivery times. Currently, extreme times in the right-side tail of the time distributions generate customers' perceptions. Paired with a well-known and upheld priority system, meeting customer expectations with reliable delivery times will reduce system demand, improve USAF customer image, meet warfighter demands and ultimately win wars.

Appendix A: Definitions

CAP Time: the time that aerial port personnel certify a pallet movement-ready within the AMC system

Cargo Awaiting Lift Time (CALT): the time difference between capped time and departure time

Port Hold Time (PHT): the time difference between arrival and departure time at the airfield

Port Processing Time (PPT): the time difference between arrival time and capped time

Total Time Enroute (TTE): the time difference between pallet creation time and destination airfield arrival time

Appendix B: FY09 JP 4 Supply Classes

CLASSES AND SUBCLASSES OF SUPPLY

Symbols	Subclasses
CLASS I Subsistence	A - Nonperishable C - Combat Rations R - Refrigerated S - Nonrefrigerated W -Water
CLASS II Clothing individual equip., tools, admin, supplies	A - Air B - Ground Support Materiel E - General Supplies F - Clothing G - Electronics M - Weapons T - Industrial Supplies
CLASS III Petroleum, oils, lubricants	A - POL for Aircraft W -POL for Surface Vehicles P - Packaged POL
CLASS IV Construction materiel	A - Construction B - Barrier
CLASS V Ammunition	A - Air Delivery W -Ground
CLASS VI Personal demand items	A - Personal Demand Items M - Personal and Official Mail P - Ration Supplemental Sundry Pack
CLASS VII Major end items: racks, pylons, tracked vehicles, etc.	A - Air B - Ground Support Materiel D - Admin. Vehicles J - Tanks, Racks, Adapters, and Pylons (USAF only) L - Missiles M - Weapons N - Special Weapons T - Industrial Materiel X - Aircraft Engines
CLASS VIII Medical materiels	A - Medical Materiel B - Blood/Fluids
CLASS IX Repairs parts	A - Air B - Ground Support Materiel D - Admin. Vehicles G - Electronics K - Tactical Vehicles L - Missiles M - Weapons N - Special Weapons T - Industrial Materiel
CLASS X Materiel for nonmilitary programs	

Appendix C: DLA Trans-Ship Table

Trans-Ship Table provided to Susquehanna DDC Personnel; a second sheet for Charleston AFB was also a part of the table but has been excluded for brevity.

Inbound Logistics Trans-Ship Table

McGuire

OA1: OA1 (*Bagram AB, Afghanistan*) / KBL (*Kabul, Afghanistan*) / JAA (*Jalalabad, Afghanistan*) / OA4 (*Salam, Afghanistan*) / ASB (*Ashgabat, Turkmenistan*) / AZ1 (*Camp Bastion LZ, Afghanistan*) / AZ2 (*Deh Dadi LZ, Afghanistan*) / AZ3 (*Sharana LZ, Afghanistan*) / AZ4 / BIN (*Bamyan, Afghanistan*) / CCN (*Chakhcharan, Afghanistan*) / FAH (*Farah, Afghanistan*) / FBD (*Faizabad, Afghanistan*) / HEA (*Herat, Afghanistan*) / ISB (*Islamabad, Pakistan*) / MZR (*Mazar I Sharif, Afghanistan*) / OA2 (*Shindand, Afghanistan*) / PEW (*Peshawar, Pakistan*) / TE2 (*Tereen, Afghanistan*) / UND (*Kunduz, Afghanistan*) / FRU (*Bishkek, Kyrgyzstan*)

IUD: IUD (*Al Udeid AB, Qatar*) / DHF (*Al Dhafra AB, UAE*) / RUH (*Riyadh, Saudi Arabia*) / TTH (*Thumrait, Oman*) / JIB (*Djibouti, Djibouti*) / KDH (*Kandahar, Afghanistan*)

KWI: KWI (*Kuwait City, Kuwait*) / KEZ (*Ali Al Salem, Kuwait*) / IZE

RMS: RMS (*Ramstein AB, Germany*) / MHZ (*RAF Mildenhall, England*) / ADA (*Adana AB, Turkey*) / TLV (*Tel Aviv, Israel*) / CAI (*Cairo, Egypt*) / AKT (*Akrotiri, Cyprus*) / SPM (*Spangdahlem AB, Germany*) / LKZ (*RAF Lakenheath, United Kingdom*) / ESB (*Ankara, Turkey*)

LGS: LGS (*Lajes AB, Azores*)

THU: THU (*Thule AB, Greenland*)

Dover

ADA: SDA (*Baghdad, Iraq*) / OR9 (*Balad, Iraq*) / O6R (*Qayyarah West, Iraq*) / O8R (*Tall Afar, Iraq*) / KIK (*Kirkuk, Iraq*) / TA8 (*Ali (Tallil), Iraq*) / OSM (*Mosul, Iraq*) / O2R (*Al Sahra, Iraq*)
(see note 1)

SDA: SDA (*Baghdad, Iraq*)

OR9: SDA (*Baghdad, Iraq*) / KIK (*Kirkuk, Iraq*) / O6R (*Qayyarah West, Iraq*) / OR9 (*Balad, Iraq*) / TA8 (*Ali (Tallil), Iraq*) / OSM (*Mosul, Iraq*) / O8R (*Tall Afar, Iraq*) / O2R (*Al Sahra, Iraq*)
(see note 2)

3OR: 3OR (*Al Asad, Iraq*) / OR5 (*Al Taqaddum, Iraq*)

OR5: OR5 (*Al Taqaddum, Iraq*)

Note 1: For all Commodity Code: 2 and 3 cargo, utilize the OR9 (*Balad, Iraq*) channel

Note 2: No more than ten non-OR9 (*Balad, Iraq*) pallets per aircraft

Appendix D: Aerial Port Code / Airfield ICAO Location Table

AP	ICAO	Base Name	State/Country
ADA	LTAG	Incirlik AB	Turkey
IUD	OTBH	Al Udeid AB	Qatar
DOV	KDOV	Dover AFB	Delaware
RMS	ETAR	Ramstein AB	Germany
OR9	ORBD	Balad AB	Iraq
OA1	OAIX	Bagram AB	Afghanistan
SUU	KSUU	Travis AFB	California
WRI	KWRI	McGuire AFB	New Jersey
3OR	ORAA	Al Asad AB	Iraq
KEZ	OKAS	Ali Al Salem	Kuwait
CHS	KCHS	Charleston AFB	S. Carolina
OKO	RJTY	Yokota AB	Japan
KDH	OAKN	Kandahar AB	Afghanistan
TCM	KTCM	McChord AFB	Washington

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14. ABSTRACT

Air Mobility Command uses hub and spoke operations to move a significant portion of cargo around the world as efficiently as possible. However, additional efficiencies afforded through hub and spoke delivery come at the cost of longer delivery times and greater delivery time variations. Leaders require an expanded understanding of those costs to make informed decisions with respect to Air Mobility Command operations. This study examines the relationship between port hold time and total time enroute, the division of port hold time attributable to port tasks and command and control functions, and potential causes for port hold time variations. It was completed in response to ancillary findings of high correlation between port hold time and total time enroute at Incirlik Air Base (AB), Turkey in a previous study. Using regression analysis and descriptive statistics, this study verifies the correlation between port hold time and total time enroute, characterizes the portion of port hold time attributable to port processing and cargo awaiting lift functions, explores the relationship between port hold time and logical causes of variation, and makes leadership recommendations to improve AMC's delivery performance and customer satisfaction.

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