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**14. ABSTRACT**

The purpose of this study is to examine the degree of influence supply chain factors exert on wait times for medical supplies to the Operation Enduring Freedom and Operation Iraqi Freedom theaters. A multivariate, regression analysis was used to test five hypotheses involving sixteen predictors of wait times. This research is important because reductions in wait times facilitate Army transformation and the Army's ability to win wars. Twelve months of scores were collected and means, standard deviations, and correlations were and examined for each variable. A regression analysis revealed beta coefficients, f scores, and probability scores for the hypotheses tested. The descriptive statistics for the dependant variables indicate that intransit time is the source of variation in both customer wait time and requisition wait time. ANOVA tests for each hypothesis revealed identical significance test scores; f (11,0) = 0, p. > .05. The null hypothesis for each test was accepted and alternate hypotheses were rejected. Colinearity among the independent variables reduced the error score for each analysis causing low f scores.

**15. SUBJECT TERMS**

Customer Wait Time, Healthcare Logistics, Logistics, Operation Iraqi Freedom, Operation Enduring Freedom, Supply Chain, Supply Chain Management, Supply Chain Performance.

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**Running Head: Customer Wait Time Analysis**

# A Customer Wait Time Analysis of Medical Supplies and Equipment for Operations Enduring and Iraqi Freedom

**Graduate Management Project**

**15 June 2005**

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**Abstract**

The purpose of this study is to examine the degree of influence supply chain factors exert on wait times for medical supplies to the Operation Enduring Freedom and Operation Iraqi Freedom theaters. A hierarchical, multivariate, regression analysis was used to test five hypotheses involving sixteen predictors of wait times. This research is important because reductions in wait times facilitate Army transformation goals and, subsequently, the Army's ability to win wars.

Twelve months of scores were collected and means, standard deviations, and correlations were calculated and examined for each variable. A regression analysis revealed beta coefficients, $f$ scores, and probability scores for each hypothesis tested. The descriptive statistics for the dependant variables indicate that intransit time is the source of variation in both customer wait time and requisition wait time. ANOVA tests for each hypothesis revealed identical significance test scores; $f(11,0) = 0$, $p. > .05$. The null hypothesis for each test was accepted and alternate hypotheses were rejected. Colinearity among the independent variables significantly reduced the error score for each analysis leading to the low $f$ scores. The dependant variables are not functions of the sixteen independent variables.

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The purpose of this study is to examine the degree of influence supply chain factors exert on customer wait times for medical supplies and equipment to the Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) theaters. Factors specific to this analysis include sixteen variables that reflect supply chain performance in customer support, transportation, inventory management, storage management, capacity & utilization, processing time, and supply chain flexibility. The unit of analysis for this research is customer wait times from a supporting theater distribution perspective. This research is important because significant reductions in customer wait times facilitate the combat service support (CSS) transformation goals and ultimately support the Army's ability to conduct ongoing military operations.

The Army must continually adapt to meet the demands of disparate missions. The Army's logistics systems must also change, in order to make the Army more agile and flexible. The inability of a logistics system to replenish mission critical supplies significantly detracts from the operational capabilities of the Army's combat units (Peltz, Halliday, & Hartman, 2003). Accurately measuring supply chain performance and implementing process improvements enables a logistics system to support battle-ready units and increase the Army's readiness.

Many after action reports (AAR) from units involved in OEF and OIF are filled with commentary on the quality of healthcare logistics support during the war efforts. Much of the AAR commentary speaks to the hard work and dedication of the logisticians involved. Often, however, commentary is geared toward healthcare logistics shortfalls that center on issues of customer wait time. The following quote from the 703rd Main Support Battalion (MSB) serves as an example of such logistics shortfalls.

> "The laboratory was not functional the entire war. Several shortages in expendable supplies caused the section to be non-operational. The company was given I-

Stat readers while in Kuwait (force modernization), however, the cartridges required for use were not included. The cartridges were placed on order, but did not arrive in time to contribute to the fight" (Center for Army Lessons Learned (B), 2003).

Laboratories throughout both the OEF and OIF theatres experienced similar shortages in critical expendable supplies like the reagent cartridges referred to by the 703rd MSB's AAR. The effect of non-operational laboratories is both severe and unambiguous. Doctors' ability to diagnose and subsequently treat patients is impaired. The 703rd MSB commentary illustrates logistics systems failures on the part of the Army medical department. Specifically, failures in deploying equipment that is supportable by developing supply chains. The issues surrounding the statement, "The cartridges were placed on order, but did not arrive in time to contribute to the fight" (Center for Army Lessons Learned (B), 2003) are particularly germane to this study. The statement implies that the I-Stat Analyzers, with which the MSB deployed, could be supported if the supply chain established to move the cartridges from supply depots to the laboratories was adequate. In the 703rd MSB's case, the chain was inadequate because the time between the generation of their supply request and the delivery of that cartridge to their laboratory was too long. The customer wait time (CWT), therefore, rendered the I-Stat machines and, therefore the laboratory, non-operational for the duration of combat operations. Although this example is specific to the 703rd MSB's laboratory operation, it is not mutually exclusive to either the 703rd MSB or laboratory operations during the war. Similar, less crippling examples of long CWT for medical supplies are prevalent in many OIF and OEF reports. The purpose of this study is to examine the degree of influence supply chain factors exert on customer wait times for medical supplies and equipment to the OEF and OIF theaters.

**Literature review**

Effective supply chain management is paramount to an organization's success. Understanding the flow of materials and information throughout the supply chain enables faster logistical response time, increases satisfaction with logistics operations, reduces costs and inventory, and results in the maximum use of logistical resources (Handfield and Nichols, 2002). Over the last several decades the Army has made continuous improvements in supply chain management that coincide with changes in the strategic objectives of the Army.

In the years following World War II, the Army evolved according to the preeminent threat of the Cold War, a Soviet Union invasion of Europe. The evolution resulted in two very distinct fighting forces. The first being a light, reactionary force made up of wheeled, lightly armored vehicles, and light infantry capable of moving very quickly into and around the battlefield. The second being a heavy, powerful force made up of tracked, heavily armored vehicles (i.e. M1A2 tanks, and Bradley Fighting Vehicles), slow to move into and around the battlefield, but deadly powerful once employed. The light and heavy force structure was instrumental in winning the Cold War but was flawed in the post Cold War geopolitical environment. Operations Desert Shield and Desert Storm illustrated a fundamental weakness of the heavy and light force structure. Light forces were able to move swiftly into Saudi Arabia but with limited power to repel Iraqi forces. The months it took for the heavy forces to reach the theater left the light forces vulnerable to being overrun by Iraqi mechanized units. This perceived weakness in power projection needed to be addressed, and spurred an Army modernization process that we know today as "Army Transformation" (Peltz, Halliday, & Hartman, 2003).

In the early 1990's, as a reaction to the notion that the Army's logistics systems were cumbersome and unreliable, the Army began to initiate supply chain process improvements. The

Army adopted the velocity management concept in 1995 and was able to substantially improve and transform the flow of goods and services into a world-class operation. The focus of velocity management was to change the supply strategy away from large stockpiles of supplies and equipment toward reliable and timely physical distribution systems emphasizing quality over quantity (Edwards & Eden, 1999). The primary goal of velocity management remains centered on improving the flow of goods, resources, and information from the supplier to the customer (Office of the Undersecretary of Defense, 2003).

In 1999, the Army initiated an organizational transformation to redesign its structure into both a dominant and rapidly deployable force. The goal of the transformation was to design a power projection force capable of meeting a variety of worldwide missions. Such a force must be capable of global, rapid deployment with sufficient power to execute a broad spectrum of missions associated with the development of fourth generation warfare. The development of fourth generation warfare pits nation states, like the United States, against non-state affiliated opponents, like al Quaeda and Hamas. Engagements between opponents regress from linear and maneuver tactics to terror and guerilla tactics (Hammes, 1994). The transformation from a heavy/light force structure to a maneuverable and powerful force structure requires enterprise level change reaching the most fundamental systems in the Army, to include logistics. Developing logistics systems capable of supporting this new objective force structure fell on the Army's Deputy Chief of Staff, G4, who oversees the CSS functions of the Army (Peltz, Halliday, & Hartman, 2003).

CSS organizations within the Army sustain combat power by providing the mission essential people and equipment needed to meet all assigned missions. It is through these elements that CSS influences mobility both into (strategic) and around (operational) combat zones. Without CSS units, combat units cannot shoot, move, or communicate. When CSS units provide efficient support, combat forces operate more effectively. Three important CSS goals were established to facilitate the transformation to the new objective force: 1) reduce the footprint of CSS assets in the combat zone, 2) reduce deployment timelines, and 3) reduce the cost of logistics while maintaining war fighting capability (Peltz, Halliday, & Hartman, 2003, Steele, 2000, and RB-3040-A, 2003). Reducing the footprint of CSS assets in the combat zone improves mobility of combat units both into and around the combat zone. Given a fixed deployment capacity, reducing the number of supporting assets required in a combat zone, increases the number of combat assets available. The second goal, reducing deployment timelines, focuses on improving strategic mobility. The faster an effective combat force can be deployed, the more flexible that force becomes to national decision makers. The final goal, reduce the cost of logistics while maintaining war-fighting capability, is a business process transformation focused on freeing current resources to pay for new capabilities (Peltz, Halliday, & Hartman, 2003).

The Army adopted five strategies to achieve the CSS transformation goals. The first strategy, demand reduction, reduces the need for support elements by reducing the requirements of the units being supported. For example, improving combat vehicle fuel efficiency reduces the total requirement for fuel in the combat zone. The second strategy, modular support, limits organic support to those capabilities always essential during combat operations. Personnel and equipment not essential to combat operations are removed from the combat units. The third strategy, distribution-based logistics, aims to provide equal or better support capability with fewer resources and supplies by leveraging better distribution technologies and systems. The fourth strategy, improved deployment capabilities, focuses on reducing deployment timelines.

This strategy attempts to increase the total capacity for moving personnel and equipment by improving the infrastructure and processes associated with deploying combat units. The final strategy, forward positioning of CSS assets, attempts to move equipment closer to anticipated deployment destinations (Peltz, Halliday, & Hartman, 2003). Figure 1 illustrates how each CSS strategy compliments Army transformation goals.

| | Army Transformation Strategy | | Transformation Result | |
|---|---|---|---|---|
| CSS Strategy | Footprint Reduction | Faster Deployment | Operational Mobility | Strategic Mobility |
| Demand Reduction | ★ | | ★ | ★ |
| Modular Support | ★ | | ★ | ★ |
| Distribution Based Logistics | ★ | | ★ | ★ |
| Improved Deployment Capabilities | | ★ | | ★ |
| Forward Positioning | | ★ | | ★ |

*Figure 1.* Combat service support strategies and their ties to Army transformation

The two strategies especially germane to the study of supply chain management and improvements are modular support and distribution-based logistics. Modular support eliminates the "just-in-case" capabilities and focuses on mission essential capabilities necessary for combat. The intent is for military units to be combat ready and loaded with only the essentials needed to enter into combat immediately. Inventories must be minimized and appropriate supplies must be ordered or maintained on hand. An example of modular support is the creation of a "shallow, yet broad authorized stockage list (ASL)" for a unit (Peltz, Halliday, & Hartman, 2003). Such an ASL would contain relatively small quantities of all the supplies and equipment necessary for combat operations. Little redundancy would be built into the ASL causing a greater reliance on physical distribution systems to deliver replenishment materiel in a timely manner. To effectively support this concept, ASLs must be tightly scrutinized to ensure that the appropriate items and quantities are selected. In order to successfully employ this concept, units must integrate newly developed ASLs in with their supply support activities (SSA). Distribution based logistics focuses on activities that improve CSS capabilities through better distribution mechanisms. Large warehouse inventories are replaced by smaller, more frequent, and consistent supply flows. Figure 2 illustrates the contrast between logistics based on massive stockpiles and logistics based on efficient distribution techniques. This strategy complements modular support by enhancing consistent replenishment with faster, reliable supply processes (Peltz, Halliday, & Hartman, 2003, and RB-3042-A, 2003).

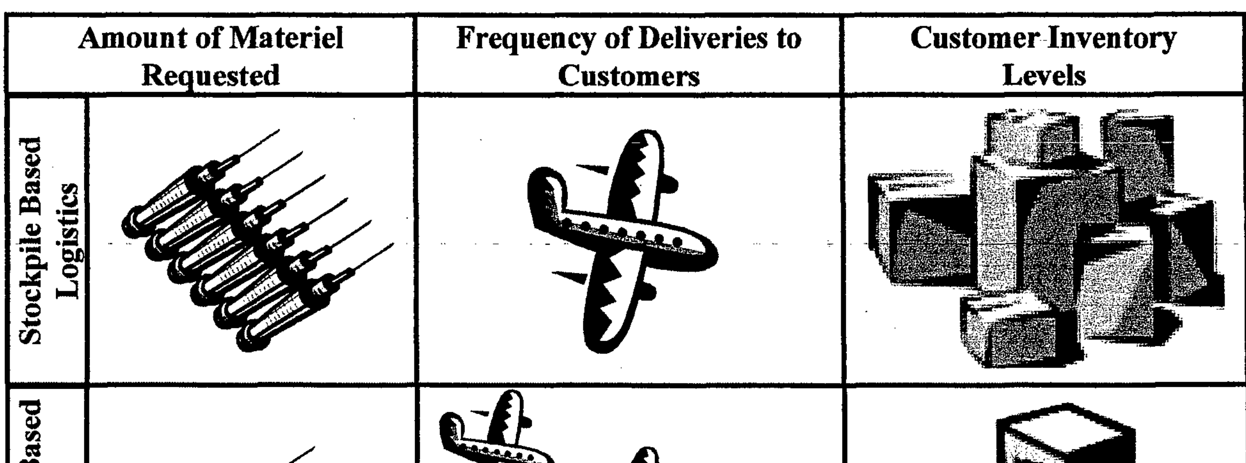


*Figure 2.* Contrast in stockpile logistics and distribution based logistics

The Army's goals and strategies for CSS transformation are based on supply chain management concepts. Supply chains are the means by which goods and information are moved between organizations. Supply chains encompass all organizations and activities associated with the flow and transformation of goods from the raw material stage, through to the end user, as well as with the associated information flows. Material and information flows both up and down the supply chain (Handfield & Nichols, 2002). Supply chain management, therefore, is both key and essential to influencing customer wait times. Supply chain management is the integration and management of supply chain organizations and activities through cooperative organizational relationships, effective business processes, and high levels of information sharing to create high performing value systems that provide member organizations a sustainable competitive advantage (Handfield & Nichols, 2002). The organizations involved in the medical, supply chain for units deployed in OIF and OEF range from materiel suppliers, to pharmaceutical developers, to storage sites, to distributors, and finally to front line military units (Waters, 2003). Figure 3 depicts USAMMCE's multi-tiered supply chain relative to the OIF and OEF theaters of operation.

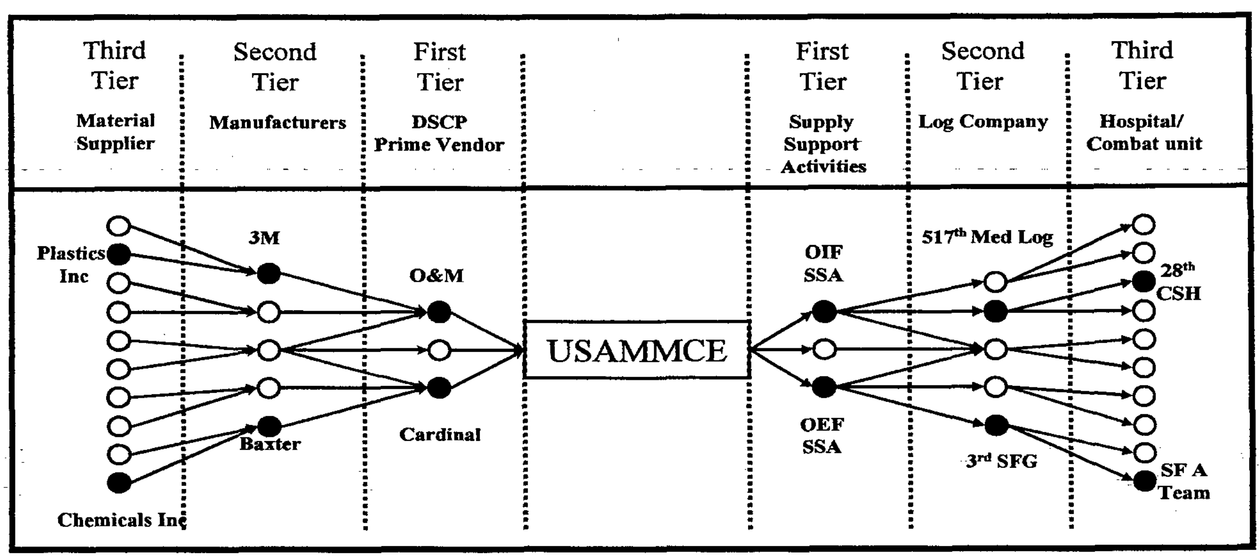


*Figure 3.* USAMMCE's OIF/OEF Supply Chain (Waters, 2003)

An exploration of the performance of the entire supply chain for OIF and OEF is beyond the scope of this study. The unit of analysis for this research is customer wait times from the supporting theater distribution perspective. The United States Army Medical Materiel Center, Europe (USAMMCE), located in Pirmasens, Germany, serves as the supporting theatre distribution center for both OEF and OIF. USAMMCE, therefore, is the focal point of the study. USAMMCE employs over 300 people and specializes in medical inventory management, medical supply distribution, medical assembly management, clinical engineering, and optical fabrication. While supporting OIF and OEF, USAMMCE is also responsible for providing support to the Balkans theater of operations and the European region consisting of five hospitals, numerous health clinics, and many individual units (Vaughan, 2003). USAMMCE interfaces with the United States Army Medical Materiel Center, South West Asia (USAMMC-SWA), located in Camp As Sayliyah, Qatar, in support of OIF, and Joint Task Force 180, located in Kharshi, Uzbekistan in support of OEF. USAMMC-SWA employs over 80 personnel and specializes in medical inventory management, medical supply distribution, clinical engineering, and blood product distribution. USAMMC-SWA is responsible for providing medical materiel for several deployed hospitals and a multitude of other units engaged in support of OIF (Showe, 2004). The OEF SSA is a team of about 10 people specializing in medical inventory management, medical supply distribution, and clinical engineering. This SSA is responsible for providing support for two hospitals and a myriad of brigade-sized and smaller units operating in Afghanistan (VanVactor, 2004). Figure 4 illustrates the narrow focus of this research relative to USAMMCE's entire supply chain.

The initiation of OEF in October 2001 and OIF in March 2003 allowed for an analysis of wartime logistics processes (War on Terror Timeline, 2003). Deploying units stressed the current CSS system. Reports indicate that the distribution systems worked well in support of OEF. CSS units provided reliable, continuous support without compromising service to other non-deployed military customers (RB-3020, 2000). AARs from OIF indicate that the supply system had to work overtime to help deployed forces achieve operational success. According to the 3rd Infantry Division's OIF AAR, "...Victory was accomplished through brute force logistics...with numerous logistical challenges throughout the operation...many units operated dangerously low on ammunition, fuel, water, and other sustainment items.... Similar to vehicle repair parts, combat losses and scrounging kept units functional for the short term." (Center for Army Lessons Learned (B), 2003) The 212th Mobile Army Surgical Hospital's OIF AAR noted other areas, "...the 591st Medical Logistics Company was not able to provide adequate distribution of supplies because of lack of warehouse space to house the supplies." (Center for Army Lessons Learned (A), 2003)

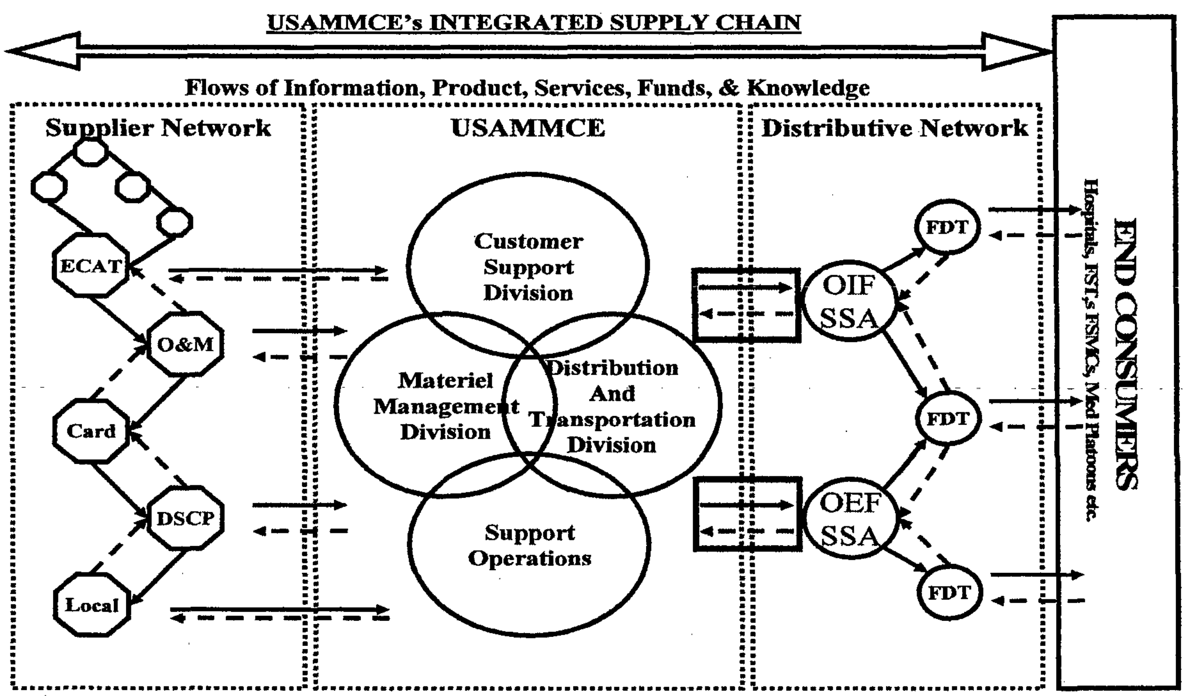


*Figure 4.* Alternative depiction of the USAMMCE supply chain highlighting the relationship that serves as the focus of this study (Handfield & Nichols, 2003).

**Purpose**

Focusing on the USAMMCE to OIF and OEF SSA supply chain relationships , this study attempts to quantify the effects of supply chain factors on CWT and requisition wait time

(RWT), as well as their subcomponents, customer processing time (CPT), depot processing time (DPT), and in transit time (ITT). Measuring customer wait times is an essential element toward determining overall CSS supply performance. Empirical studies of customer wait times are not very common because the DoD adopted the metric in 2001. To date, no benchmarks or objectives are established for CWT at the DoD level. Still, CWT serves as the premier supply chain performance measure because it encompasses the entirety of supply chain performance. It is the amount of time needed for a supply request to be generated, submitted, processed, transported, and received by the requesting activity. It is the single best measure of the flow of information, the transformation of goods, and the flow of materiel.

Table 1.
*Dependant Variables*

| **Variable** | **Variable SPSS Name** | **Description** | **Data Source** | **Literature Reference** |
|---|---|---|---|---|
| Customer Wait Time | CWT | The amount of time from the inception of a supply request to the satisfaction of that supply request | USAMMCE CWT Reports | Brauner & Lackey (2003) |
| Requisition Wait Time | RWT | The amount of time from the inception of an supply request, for a USAMMCE stocked item, to the satisfaction of that supply request. Backorders not included. | USAMMCE CWT Reports | Brauner & Lackey (2003) |
| Customer Processing Time | CPT | The amount of time from the inception of a supply request to the acceptance of that request in the USAMMCE ordering system | USAMMCE CWT Reports | Handfield & Nichols (2002) |
| Depot Processing Time | DPT | The amount of time from the acceptance of a supply request in the USAMMCE ordering system to the USAMMCE release of materiel satisfying that supply request | USAMMCE CWT Reports | Handfield & Nichols (2002) |
| In Transit Time | ITT | The amount of time materiel, associated with a supply request, spends in transit from USAMMCE to an SSA | USAMMCE CWT Reports | Handfield & Nichols (2002) |

Because CWT is such an all-inclusive and complex measure, subcomponents and variations of CWT are also measured to determine the performance of various parameters of a supply chain. Such secondary supply chain measures include, RWT, CPT, DPT, and ITT (RB 3020, 2000 and RB-3035-A, 2003). These five wait time measures, CWT, RWT, CPT, DPT, and ITT, serve as the dependant variables of this study and are operationally defined in Table 1.

The complex nature of supply chain management requires a multifactor analysis of customer wait times. A total of sixty-five potential independent variables present themselves in the literature as relevant precedents for wait times. Some potential variables overlap one another as performance measures and others are not relevant as measures in a government organization. Each of the potential independent variables fell into one of seven categories or constructs: customer support, transportation, inventory management, storage management, capacity & utilization, processing time, and supply chain flexibility. These seven constructs join wait times, as an eighth construct, to create a model of supply chain performance. The supply chain performance model developed to illustrate the relationship between the many constructs and variables is depicted in Figure 5. The eight constructs illustrate the strength of the supply chain relationship between two organizations and are further operationalized into a total of twenty-one variables that can be measured (Bachrach, 1989).

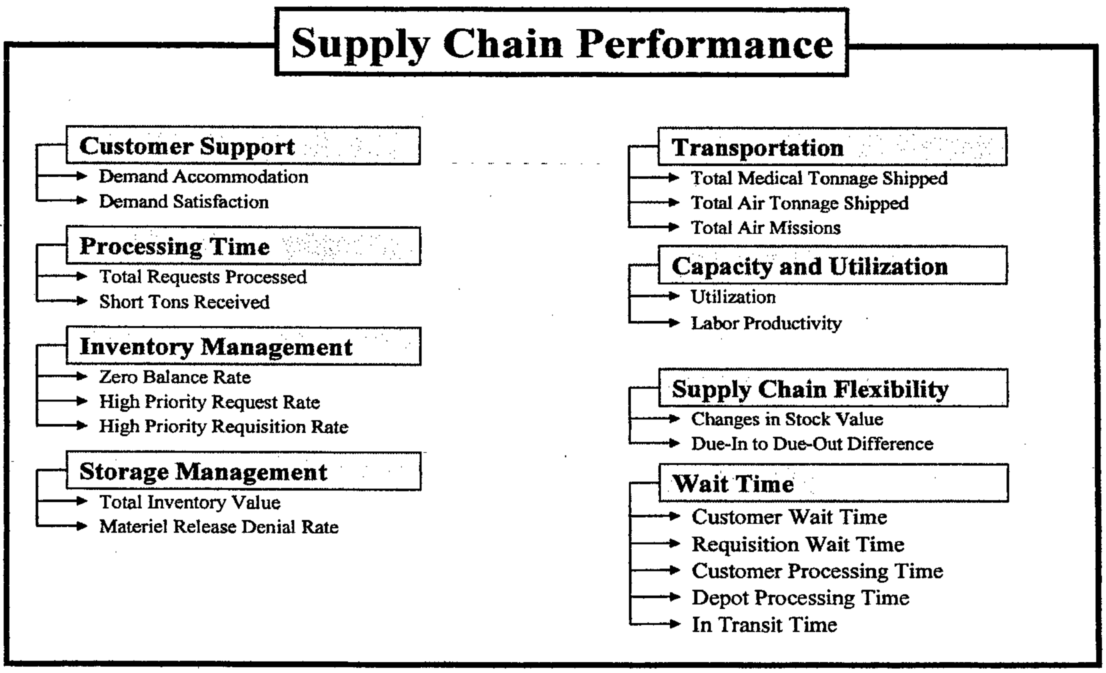

*Figure 5*. Model of the construct to variable relationship for supply chain performance

The following seven constructs are comprised of the independent variables for this study. The discussion of the constructs gives some insight into what the variables are theoretically intended to measure. Table 2 operationally defines each variable offering the specifics of each measure and how they are applied to the unit of analysis for this research.

The first construct is customer support. This construct attempts to illustrate the quality of support provided by a supplier organization to a customer (AR 40-61, 1995). The construct is operationalized into two variables: demand accommodation and demand satisfaction. Demand accommodation measures how well a supplier supports the type of items required by a customer. Demand satisfaction measures how well a supplier supports the volume of items required by a customer.

The second construct is processing time. Processing time seeks to illustrate the efficiency of a supply organization in maintaining the flow of both information and materiel (AR 40-61, 1995). This construct is operationalized into two variables: short tons received and total orders processed. Short tons received measures the flow of materiel into a supplier organization. Total orders processed illustrates the volume of customer requests being processed.

The third construct is inventory management. This construct attempts to illustrate the ability of the supplier organization to effectively manage inventory levels (AR 40-61, 1995). Inventory management performance is operationalized into three variables: zero balance rate, high priority request rate, and high priority requisition rate. Zero balance rate measures how well a supplier maintains inventory levels for items that are clearly needed by customers. Both high priority request and requisition rates measure what percent of orders are submitted as emergency requests. The request rate is from the customer perspective and the requisition rate is from the supplier perspective.

The fourth construct is storage management. This construct illustrates the ability of a supplier organization to effectively manage warehousing operations (AR 40-61, 1995). The construct is operationalized into two variables: total inventory value and materiel release order (MRO) denial rate. Total inventory value illustrates the volume of materiel being managed in a supplier's inventory. MRO denial rate measures the accuracy of information flow between a supplier's storage management systems and inventory management systems.

The fifth construct, transportation, attempts to illustrate both the efficiency and the effectiveness of the supplier organization's delivery mechanisms (Waters, 2003). The construct is operationalized into three variables: medical short tons shipped, air missions flown by AMC, and total tons shipped by AMC. Medical short tones shipped measures the volume of outbound, medical materiel leaving the supplier's distribution system. Air missions flown illustrates the workload of the supplier's distribution system. Total tons shipped by AMC also illustrates the workload of the supplier's distribution system.

The sixth construct, capacity and utilization, illustrates the efficiency in which the supplier organization is able to throughput materiel (Waters, 2003). The construct is operationalized into two variables: utilization and labor productivity. Utilization is an index that illustrates the overall efficiency of a supplier's materiel flow. Labor productivity is also an index and measures efficiency in a supplier's workforce.

The seventh construct is supply chain flexibility. This construct is designed to illustrate the degree to which a supply chain can react to random fluctuations in the demand pattern (Chan et al., 2003) Supply chain flexibility is operationalized into two variables: change in stock value and due in to due out difference. The change in stock value measures how quickly supplier inventory management systems can react to changing trends in customer requirements. Due in to due out difference illustrates how efficiently a supplier reacts to spikes and lulls in customer ordering.

Table 2.
*Independent Variables* *

| Variable | Variable SPSS Name | Description | Data Source** | Literature Reference |
|---|---|---|---|---|
| | | **Customer Support** | | |
| Demand Accommodation | DemAcc | Percent of total demands received from OIF/OEF for items stocked by USAMMCE | TAMMIS Reports | AR 40-61 (1995) |
| Demand Satisfaction | DemSat | Percent of total demands for stocked items from OIF/OEF issued at 100% of total quantity demanded | TAMMIS Reports | AR 40-61 (1995) |
| | | **Processing Time** | | |
| Total Orders Processed | TotOrdPro | Total number of orders processed from OIF/OEF customers | TAMMIS Reports | Waters (2003) |
| Short Tons Received | STRec | Total weight in short tons received from USAMMCE's suppliers. | Workload Reports | AR 40-61 (1995) |
| | | **Inventory Management** | | |
| Zero Balance Rates | ZerBalRat | Percent of Stocked lines with no on hand balance | TAMMIS Reports | AR 40-61 (1995) |
| Hi Priority Request Rate | CusPriReq | Percent of customer requests with issue priority designator of 1-8 | TAMMIS Reports | AR 40-61 (1995) |
| Hi Priority Requisition Rate | DepPriReq | Percent of depot requisitions with issue priority designator of 1-8 | TAMMIS Reports | AR 40-61 (1995) |
| | | **Storage Management** | | |
| Total Inventory Value | InvVal | Total dollar value of inventory | TAMMIS Reports | Waters (2003) |
| Materiel Release Denial Rate | MroDenRat | Percentage of Materiel Release Orders erroneously released from inventory. | TAMMIS Reports | AR 40-61 (1995) |
| | | **Transportation** | | |
| Medical Tonnage Shipped | MedSTShp | Total weight in short tons of medical materiel delivered to OIF/OEF | Workload Reports | Waters (2003) |
| Air Missions Flown | AirMis | Total number of flights flown by Air Mobility Command to OIF/OEF | AMC PAO | Waters (2003) |
| Air Tonnage Shipped | AirTonShp | Total weight in tons of all materiel delivered by Air Mobility Command to OIF/OEF | AMC PAO | Waters (2003) |
| | | **Capacity and Utilization** | | |
| Utilization | Utiliz | Number of OEF/OIF MROs processed for the month divided by number of possible MROs for the month. Reported as a percentage. | Workload Reports | Waters (2003) |
| Labor Productivity | LabPro | Weight in pounds of materiel delivered to OIF & OEF divided by the total # of FTE hours. Reported as Lbs per hour. | Workload Reports | Waters (2003) |
| | | **Supply Chain Flexibility** | | |
| Changes in Stock Value | ChgStoVal | Changes in Average stock value between time periods. Reported in dollars. | TAMMIS Reports | Waters (2003) |
| Due-In to Due-Out Dollar Difference | DiDoDif | Difference between the Dollar value of inventory due-in to USAMMCE from supplier and inventory due-out of USAMMCE to Customers. Reported in dollars. | TAMMIS Reports | Chan et al. (2003) |

*All data are collected by month from January 2004 to December 2004

** All data are collected from USAMMCE, except AirMis and AirTonShp

**Assumptions and Limitations**

Several assumptions are made in conducting this study. The key assumption of this research is that USAMMCE, serving as the supporting theatre distribution center, plays a key role in the medical supply chain for OIF and OEF. USAMMCE, therefore, is capable of influencing CWT to the OIF/OEF SSAs through organizational performance. A second, and similar, assumption is that USAMMCE has the ability to implement performance improvement initiatives focused on CWT improvements. A major limitation to this study is the focus of the research. The focus of this study purposefully holds constant key segments of the supply chain that affect customer wait time. Both the supplier network and the bulk of the distributive network are held constant. Also, and especially noteworthy, is the absence of the end consumer. The end consumer in this medical supply chain represents the healthcare providers that employ the medical supplies and equipment in the course of patient care. End consumers, in any supply chain, are a driving force for the entire chain because they create the demand that feeds the entire chain. Healthcare providers potentially exhibit the greatest influence on CWT as their ordering patterns begin the process cycle. In the OIF and OEF supply chains, many end consumers are two or three tiers removed from the SSA being analyzed for this research. Because of their distance from the SSAs, CWT is only tracked as far as the materiel delivery to the SSA supporting the end consumer. While this measure of time is sufficient for the purpose of this study, it is a notable limitation to this research.

## Methods and Procedures

This research is a retrospective and longitudinal study. The research proposes a link between the wait time construct and the remaining constructs of customer support, processing time, inventory management, storage management, transportation, capacity and utilization, and supply chain flexibility (Cooper, & Schindler, 2002). Figure 6 illustrates the independent to dependant variable relationships that create the links between the 23 variables within the eight constructs.

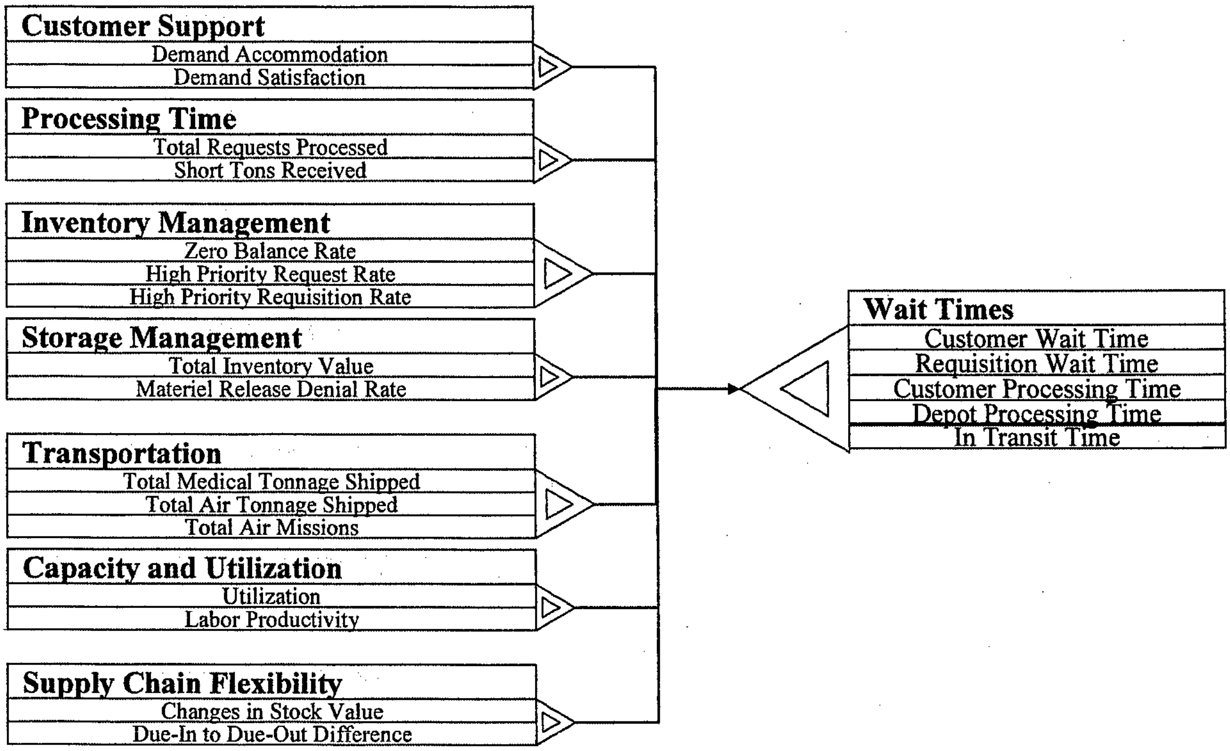


*Figure 6.* Graphic of the dependant variable to independent variable relationships for this study

Five hypotheses are tested in this study to quantify the factors that influence wait times. These hypotheses are generated from the proposition that wait times are influenced by the other seven constructs representative of supply chain performance. The five hypotheses tested in this study are:

$Ha_1$: CWT varies as a function of DemAcc, DemSat, TotOrdPro, STRec, ZerBalRat, CusPriReq, DepPriReq, InvVal, MroDenRat, MedSTShp, AirMis, AirTonShp, Utiliz, LabPro, ChgStoVal, DiDoDif.

$Ha_2$: RWT varies as a function of DemAcc, DemSat, TotOrdPro, STRec, ZerBalRat, CusPriReq, DepPriReq, InvVal, MroDenRat, MedSTShp, AirMis, AirTonShp, Utiliz, LabPro, ChgStoVal, DiDoDif.

$Ha_3$: CPT varies as a function of DemAcc, DemSat, TotOrdPro, STRec, ZerBalRat, CusPriReq, DepPriReq, InvVal, MroDenRat, MedSTShp, AirMis, AirTonShp, Utiliz, LabPro, ChgStoVal, DiDoDif

$Ha_4$: DPT varies as a function of DemAcc, DemSat, TotOrdPro, STRec, ZerBalRat, CusPriReq, DepPriReq, InvVal, MroDenRat, MedSTShp, AirMis, AirTonShp, Utiliz, LabPro, ChgStoVal, DiDoDif

$Ha_5$: ITT varies as a function of DemAcc, DemSat, TotOrdPro, STRec, ZerBalRat, CusPriReq, DepPriReq, InvVal, MroDenRat, MedSTShp, AirMis, AirTonShp, Utiliz, LabPro, ChgStoVal, DiDoDif

The null hypotheses are that none of the five dependant variables vary as functions of the sixteen independent variables.

Scores for the dependant variables were obtained from USAMMCE. All receipt transactions processed by OIF and OEF SSAs between January of 2004 and December of 2004 were obtained for this study. Receipt transactions processed by the SSAs were compared against USAMMCE's databases to ascertain the scores for the dependant variables. The data were collected through the electronic data interface (EDI) common to the medical supply (MEDSUP) module of the Theatre Army Medical Materiel Information System (TAMMIS), which is used by all three organizations for medical inventory management (TAMMIS Project Office, 2003). Data collected was subject to DoD Directive 4000.25-1 "Military Standard Requisitioning and Issue Procedures," May 1987 ensuring reliability. All receipt actions for the relevant time-periods were transmitted to USAMMCE during the closing days of each month. Receipt transactions were then filtered through the demand history and transportation databases common to the TAMMIS system maintained at USAMMCE producing scores for the dependant variables.

Scores for independent variables were obtained from periodic reports maintained at USAMMCE. Specifically, the end-of-month cycle reports associated with TAMMIS inventory management. These reports include the monthly performance reports (RZS-S65), stock status summary overall recaps (RZS-SB1), and USAMMCE's monthly OIF/OEF workload reports. In addition, transportation performance data was provided by the public affairs office for the Air Mobility Command (AMC) in Scott Air Force Base, Indiana. AMC provides the primary means of transportation for materiel moving from USAMMCE to the OIF/OEF theaters.

A hierarchical, multivariate, linear regression was used to analyze and test the five hypotheses. Descriptive statistics such as means, standard deviations, and beta weights were examined for all variables. The strength and direction of the relationships between the dependant variables and the independent variables were also evaluated using a Pearson's "r" coefficient of correlation. Additionally, the amount of variance in the dependant variables accounted for by each independent variable was examined through an ANOVA analysis. Finally the ANOVAs were conducted to test for significance in variation among and between the variables at alpha level .05 for each test (Sander, & Smidt, 2000).

No people or confidential information was used in this research. Additionally, the results of this research are in no way intended to provide a means of comparing organizations within the logistics community, healthcare related or otherwise. This research is conducted in support of continuous quality improvement initiatives. No punitive actions are intended as a result of this research.

## Results

Descriptive statistics that summarize pertinent characteristics of the variables examined in this study are shown in Table 3, Dependant Variable Descriptive Statistics, Table 4, Independent Variable Descriptive Statistics, and Table 5, beta coefficients. The characteristics shown in Table 3 summarize the data of the dependant variables by way of the mean and standard deviation. In addition, the correlation coefficients (*r*) show the degree and the direction of association between the dependant variables. The characteristics shown in Table 4 summarize the data of the independent variables by way of the mean and standard deviation. This table, however, provides correlation coefficient (*r*) characteristics between dependant and independent variables, unlike Table 3. Table 5 shows the degree of change found in each independent variable given a one degree change in the dependant variable.

Table 3
*Dependant Variable Descriptive Statistics*

| Variable | Mean | Standard Deviation | *r* Correlation with CWT | *r* Correlation with DPT | *r* Correlation with CPT | *r* Correlation with ITT | *r* Correlation with RWT |
|---|---|---|---|---|---|---|---|
| Customer Wait Time (CWT) | 42.75 | 21.17 | 1.000 | 0.292 | 0.170 | .896** | .998** |
| Depot Processing Time (DPT) | 11.58 | 2.97 | 0.292 | 1.000 | 0.309 | 0.104 | 0.263 |
| Customer Processing Time (CPT) | 4.75 | 0.87 | 0.170 | 0.309 | 1.000 | 0.212 | 0.162 |
| Intansit Time (ITT) | 23.33 | 20.82 | .896** | 0.104 | 0.212 | 1.000 | .903** |
| Requisition Wait Time (RWT) | 40.25 | 20.56 | .998** | 0.263 | 0.162 | .903** | 1.000 |

Note: N = 12 Months, ** = p > .01

Dependant variable descriptive statistics are shown in Table 3. In 2004, medical items ordered from USAMMCE took, on average, 43 days to reach the OEF or OIF theaters from the creation of the request as shown by the CWT mean. On average, materiel spent 23 days within the transportation system, 12 days being processed by USAMMCE, and 5 days being processed by the requesting units. Medical items stocked by USAMMCE took, on average, 40 days to reach the theaters as shown by the RWT mean. CWT, ITT, and RWT all have extremely high standard deviations indicating considerable variation and instability. These three variables also share a strong association illustrated by their high correlation with one another. DPT and CPT are very stable but only somewhat correlated with one another and less so with the other three dependant variables. All variables are directly correlated, though to varying degrees, indicating as any one variable increases the others will increase as well.

Table 4
Independant Variable Descriptive Statistics

| Variable | Mean | Standard Deviation | *r* Correlation with CWT | *r* Correlation with DPT | *r* Correlation with CPT | *r* Correlation with ITT | *r* Correlation with RWT |
|---|---|---|---|---|---|---|---|
| Customer Support | | | | | | | |
| Demand Accomodation | 0.86 | 0.04 | -0.367 | 0.346 | 0.375 | -0.606* | -0.390 |
| Demand Satisfaction | 0.75 | 0.09 | 0.009 | -0.197 | 0.097 | -0.066 | -0.004 |
| Processing Time | | | | | | | |
| Total Orders Processed | 40721.92 | 5933.99 | 0.090 | 0.174 | -0.260 | -0.146 | 0.082 |
| StRec | 524.83 | 128.69 | -0.193 | 0.013 | -0.300 | -0.103 | -0.170 |
| Inventory Management | | | | | | | |
| ZerBal | 0.08 | 0.02 | -0.223 | 0.294 | -0.069 | -0.159 | -0.224 |
| CusPriReq | 0.18 | 0.02 | 0.089 | 0.018 | 0.090 | 0.086 | 0.075 |
| DepPriReq | 0.05 | 0.02 | 0.144 | 0.317 | -0.393 | -0.223 | 0.146 |
| Storage Management | | | | | | | |
| InvVal | 28737668.51 | 2452195.22 | -0.266 | 0.025 | 0.441 | -0.368 | -0.271 |
| MRODen | 0.01 | 0.00 | 0.123 | -0.049 | -0.459 | 0.191 | 0.115 |
| Transportation | | | | | | | |
| MedSTShp | 340.09 | 105.50 | 0.253 | 0.103 | -0.117 | 0.310 | 0.279 |
| AirMis | 133930.60 | 340759.31 | 0.256 | 0.407 | -0.257 | -0.161 | 0.247 |
| AirTonShp | 4385.30 | 10958.49 | 0.258 | 0.400 | -0.256 | -0.159 | 0.249 |
| Capacity and Utilization | | | | | | | |
| Utiliz | 0.63 | 0.06 | -0.030 | -0.397 | -0.416 | 0.186 | 0.003 |
| LabProd | 0.29 | 0.09 | 0.198 | 0.385 | 0.060 | 0.020 | 0.209 |
| Supply Chain Flexibility | | | | | | | |
| InvValChg | -86230.22 | 2588988.01 | -0.372 | 0.026 | 0.392 | -0.337 | -0.371 |
| DinDouDif | 5990930.04 | 1902718.20 | -0.311 | -0.098 | -0.355 | -0.213 | -0.317 |

Note: N = 12 Months, * = p > .05

Independent variable descriptive statistics are shown in Table 4. The customer support construct attempts to illustrate the quality of support provided by USAMMCE to the OIF and OEF medical supply support activities. Within the construct, we find that, on average, 86% of the OIF/OEF requests were stocked at USAMMCE as shown by the demand accommodation mean. The demand satisfaction mean shows that 75% of the time USAMMCE was able to immediately fill the full quantity of requests for stocked items. Demand accommodation maintains some association with each of the dependant variables but maintains a strong association with ITT. The direct correlation with DPT and CPT implies that increasing the percentage of USAMMCE stocked lines would increase the amount of time it takes customers and USAMMCE to process orders. Conversely, the same increase in demand accommodation would decrease CWT, RWT, and ITT because of their inverse correlations with demand accommodation. The inverse correlation between demand accommodation and ITT is noticeably the strongest relationship in the model. Demand Satisfaction maintains very weak correlations with all the dependant variables.

The processing time construct illustrates efficiency in maintaining the flow of information and materiel through USAMMCE. On average, USAMMCE processes 40,722 orders per month and receives 525 short tons of materiel per month. The standard deviations for each variable indicate some instability and variation within the variables. Neither total orders processed nor short tons received show more than a weak correlation with any of the dependant variables.

The inventory management construct attempts to illustrate the ability of USAMMCE to effectively manage inventory levels. Within this construct we see that, on average, USAMMCE maintains no inventory on 8% of the lines they stock. In addition, 18% of the requests USAMMCE receives from OIF/OEF are of a priority nature while 5% of the requests USAMMCE makes to its suppliers are of a priority nature. Standard deviations for each of these variables are very low. With the exception of a moderately strong direct correlation between DPT and depot priority requisitions, only very weak correlations exist between these variables and the dependant variables.

The storage management construct illustrates USAMMCE's ability to manage warehouse operations. The results show that USAMMCE maintains $28.7 million in inventory (InvVal) and erroneously issues materiel from inventory (MroDenRat) 1% of the time. The standard deviations for both variables are extremely low. The MRO denial rate maintains nothing more than weak correlations with each dependant variable. Inventory value shows a moderate direct correlation with CPT and a moderate indirect correlation with ITT. Therefore, as the USAMMCE inventory value increases, CPT increases and ITT decreases.

The transportation construct attempts to illustrate both the efficiency and the effectiveness of USAMMCE's delivery mechanisms. Within this construct we see that, on average, USAMMCE shipped 340 short tons (680,000 lbs.) of medical materiel into OEF/OIF per month. Air Mobility Command (AMC), USAMMCE's primary delivery mechanism, shipped on average, 4,385 long tons (9,647,000 lbs) of materiel, to include medical, into OEF/OIF per month. Finally, we see that AMC flew 25,000 air missions per month in support of OEF/OIF. Standard deviations for these variables are very high indicating great variation in air missions, overall tonnage shipped, and medical tonnage shipped occurring month to month. The AMC variables, air missions flown and air tonnage shipped are moderately and directly correlated with DPT. The relationship indicated that the more air missions and tons of general supplies being shipped, the longer it takes USAMMCE to process orders. Medical tonnage shipped is moderately and directly correlated with ITT; indicating the more medical materiel shipped, the greater the ITT.

The capacity and utilization constructs illustrates the efficiency in which USAMMCE processes materiel. USAMMCE averaged a 63% utilization rate with a low standard deviation and a 29% labor productivity rate with a high standard deviation. The utilization rate is moderately and inversely correlated to both CPT and DPT. This relationship implies that as the utilization rate increases, both CPT and DPT will decrease. The labor productivity rate is moderately and directly correlated to DPT. The relationship indicates that as labor productivity increases, depot processing time will also increase.

The supply chain flexibility construct illustrates the degree to which USAMMCE can react to random fluctuations in the demand pattern. Within this construct we see that USAMMCE decreased inventory value by $86,230 per month, on average and maintained an average difference between due-in inventory and due-out inventory of $6 million. Both variables show very high standard deviation indicating great month to month variation. The inventory value change is moderately and indirectly correlated with CWT, ITT, and RWT. This indicates that as the change in USAMMCE's inventory value increases, CWT, ITT, and RWT will decrease. Conversely, as USAMMCE's inventory value increases, CPT will actually increase due to the moderate and direct correlation between inventory value change and CPT. The due-in to due-out difference variable is moderately and inversely correlated with CWT, CPT, and RWT. The relationship indicates that as the difference in due-in's to due-out's increases, CWT, CPT, and RWT decreases.

Table 5.
*Beta Coefficients*

| | CWT $\beta$ *Coefficients* | DPT $\beta$ *Coefficients* | CPT $\beta$ *Coefficients* | ITT $\beta$ *Coefficients* | RWT $\beta$ *Coefficients* |
|---|---|---|---|---|---|
| Intercept | -140.98184884 | -211.71175225 | -20.63550832 | 467.46089217 | -206.05454606 |
| DEMACC | 115.45087222 | 147.07463050 | 20.24371500 | -433.49546043 | 152.39855867 |
| DEMSAT | 172.50101570 | -23.01004639 | 19.15321530 | 319.16493210 | 127.19394949 |
| TotOrdPro | 0.00154356 | 0.00073835 | -0.00013355 | -0.00116361 | 0.00167361 |
| MedStRec | -0.19665632 | 0.05975398 | -0.01065242 | -0.40873573 | -0.16314401 |
| ZerBal | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| CusPriReq | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| DepPriReq | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| InvVal | -0.00000564 | 0.00000030 | -0.00000022 | -0.00000500 | -0.00000462 |
| MRODEN | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| MedStShp | 0.32690456 | -0.01980636 | 0.01415264 | 0.37044394 | 0.31532332 |
| AirMis | 0.00149433 | -0.00010608 | 0.00028254 | 0.00688317 | 0.00045843 |
| AirStShp | 0.01785903 | 0.05091337 | -0.00611057 | -0.21585503 | 0.05341707 |
| Utiliz | 37.53655705 | 34.56628313 | 8.93965469 | -34.47796548 | 58.56039256 |
| LabProd | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 | 0.00000000 |
| InvValChge | -0.00000017 | -0.00000173 | 0.00000029 | 0.00000453 | -0.00000082 |
| DinDoutdiff | -0.00000532 | -0.00000246 | -0.00000017 | 0.00000192 | -0.00000574 |

Note: *t* scores and significance levels not calculable

Table 5, Independent variable Beta coefficients, shows the degree of change within the independent variable, given a 1 unit change in the dependant variable. For example, for each 1 day increase in CWT there will be corresponding 20% decrease in the amount of medical short tons received at USAMMCE. Given the Beta coefficients found in Table 5 the regression equations for each of the dependant variables can be determined. All variables with a Beta coefficient of less than .0000 are removed from the equation for lack of influence on the dependant variable. Half of the independent variables are removed from the equation for lack of influence. Figure 7 shows each of the regression equations for the hypotheses tested.

$$CWT = -140.98 + 115.45(\text{DEMACC}) + 172.5(\text{DEMSAT}) + .002(\text{TotOrdPro}) + -.20(\text{MedStRec}) + .33(\text{MedStShp}) + .001(\text{AirMis}) + .18(\text{AirStShp}) + 37.53(\text{Utiliz}) + 0$$

$$DPT = -211.71 + 147.07(\text{DEMACC}) + -23.01(\text{DEMSAT}) + .001(\text{TotOrdPro}) + .059(\text{MedStRec}) + -.019(\text{MedStShp}) + -.0001(\text{AirMis}) + .051(\text{AirStShp}) + 34.57(\text{Utiliz}) + 0$$

$$CPT = -20.64 + 20.24(\text{DEMACC}) + 19.15(\text{DEMSAT}) + .0001(\text{TotOrdPro}) + -.01(\text{MedStRec}) + .014(\text{MedStShp}) + .0003(\text{AirMis}) + -.006(\text{AirStShp}) + 8.94(\text{Utiliz}) + 0$$

$$ITT = 467.46 + -433.46(\text{DEMACC}) + 319.16(\text{DEMSAT}) + -.002(\text{TotOrdPro}) + -.41(\text{MedStRec}) + .37(\text{MedStShp}) + .007(\text{AirMis}) + -.22(\text{AirStShp}) + -34.48(\text{Utiliz}) + 0$$

$$RWT = -206.05 + 152.40(\text{DEMACC}) + 127.19(\text{DEMSAT}) + .002(\text{TotOrdPro}) + -.16(\text{MedStRec}) + .32(\text{MedStShp}) + .0004(\text{AirMis}) + .05(\text{AirStShp}) + 58.56(\text{Utiliz}) + 0$$

*Figure 7.* Dependant Variable Regression Equations

Having summarized the individual variables and their strengths and directions of association and influence, we now turn to the utility of the model as a whole. Table 6, inferential statistics, summarizes the model by showing the degree and direction of correlation ($R$) between the independent variables, as a whole, and the dependant variables. It also shows the amount of variation within the dependant variable that is accounted for by the independent variables ($R^2$). Finally, Table 6 shows key information from the ANOVAs ran for each hypothesis.

Table 6.
*Inferential Statistics*

| | Model Summary | | ANOVA | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hypothesis | *R* | *R Square* | *ESS reg* | *df* | *ESS res* | *df* | *EMS reg* | *EMS res* | *f* | *sig* |
| CWT | 1.00 | 1.00 | 4930.250 | 11 | 0 | 0 | 448.205 | 0 | - | - |
| DPT | 1.00 | 1.00 | 96.917 | 11 | 0 | 0 | 8.811 | 0 | - | - |
| CPT | 1.00 | 1.00 | 8.250 | 11 | 0 | 0 | 0.750 | 0 | - | - |
| ITT | 1.00 | 1.00 | 4766.667 | 11 | 0 | 0 | 433.333 | 0 | - | - |
| RWT | 1.00 | 1.00 | 4648.25 | 11 | 0 | 0 | 422.568 | 0 | - | - |

Note: ESS = Error Sum Square, EMS = Error Mean Square

The perfect *R* and $R^2$ scores attained for each hypothesis tested initially indicate that the independent variables perfectly predict the dependant variables and that all variation within the dependant variables is accounted for by the dependant variables. The ANOVA's conducted for each hypothesis reveal no *f* scores and subsequently no significance levels for any of the hypotheses tested. *f* scores and significance levels cannot be calculated because no error is identified in the model. The absence of error is indicative of the extremely high intercorrelations between many of the independent variables, as shown in Table 7, and illustrated in the 0 error score found in the regression equations of each hypothesis (see Figure 7). The ANOVA conducted for each hypothesis reveals $f(11, 0) = 0$, $p > .05$ for each hypothesis tested. The discussion section of this study will address the interpretation of these results.

Table 7.
Independent Variable Correlations

| | r | r | r | r | r | r | r | r |
|---|---|---|---|---|---|---|---|---|
| Variable | Correlation AirMis | Correlation AirStShp | Correlation CusPriReq | Correlation DEMACC | Correlation DEMSAT | Correlation DepPriReq | Correlation DinDouDif | Correlation InvVal |
| AirMis | 1 | | | | | | | |
| AirStShp | 0.511 | 1 | | | | | | |
| CusPriReq | 0.244 | -0.082 | 1 | | | | | |
| DEMACC | -0.170 | -0.348 | 0.022 | 1 | | | | |
| DEMSAT | -0.425 | 0.472 | -0.343 | -0.016 | 1 | | | |
| DepPriReq | -0.437 | -0.414 | -0.253 | 0.208 | -0.039 | 1 | | |
| DinDouDif | 0.295 | -0.019 | 0.358 | 0.007 | -0.260 | -0.369 | 1 | |
| InvVal | -0.447 | -0.088 | -0.515 | 0.537 | 0.562 | 0.102 | -0.472 | 1 |
| InvValChg | 0.160 | -0.012 | 0.061 | 0.356 | -0.060 | -0.120 | -0.115 | 0.476 |
| LabProd | -0.189 | -0.803** | 0.034 | 0.396 | -0.557 | 0.471 | -0.146 | 0.053 |
| MRODen | 0.409 | -0.011 | 0.609* | -0.368 | -0.604* | -0.049 | 0.393 | -0.858** |
| StRec | 0.139 | -0.674* | 0.360 | -0.093 | -0.811** | 0.054 | 0.389 | -0.433 |
| TotOrdPro | -0.409 | -0.623* | 0.014 | 0.308 | -0.056 | 0.430 | 0.111 | 0.260 |
| TotStShp | 0.176 | -0.602* | 0.326 | -0.178 | -0.845** | 0.074 | 0.208 | -0.499 |
| Utiliz | -0.033 | -0.374 | 0.169 | -0.548 | -0.393 | -0.265 | 0.453 | -0.453 |
| ZerBal | 0.485 | -0.425 | 0.402 | 0.168 | -0.910** | -0.026 | 0.352 | -0.437 |

Table 7 (continued).
Independent Variable Correlations

| Variable | r Correlation InvValChg | r Correlation LabProd | r Correlation MRODen | r Correlation StRec | r Correlation TotOrdPro | r Correlation TotStShp | r Correlation Utiliz | r Correlation ZerBal |
|---|---|---|---|---|---|---|---|---|
| InvValChg | 1 | | | | | | | |
| LabProd | -0.083 | 1 | | | | | | |
| MRODen | -0.094 | -0.071 | 1 | | | | | |
| StRec | 0.069 | 0.549 | 0.448 | 1 | | | | |
| TotOrdPro | 0.257 | 0.494 | -0.030 | 0.303 | 1 | | | |
| TotStShp | -0.094 | 0.694* | 0.421 | 0.873** | 0.263 | 1 | | |
| Utiliz | -0.172 | 0.092 | 0.336 | 0.704* | 0.194 | 0.637* | 1 | |
| ZerBal | 0.288 | 0.407 | 0.604* | 0.770** | 0.162 | 0.660* | 0.333 | 1 |

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

## Discussion

The results realized in this study are not as expected. They are neither statistically significant nor useful in the priority application of scarce resources at USAMMCE. Although the primary purpose of this study is not achieved through the analysis, the results are not entirely without merit. This discussion section will focus on the implications of the statistical analysis and how they fit into the Army's logistics strategies.

For each of the five hypotheses tested, the null hypothesis is accepted and the alternate hypothesis is rejected. CWT, DPT, CPT, ITT, and RWT are revealed to not be functions of the sixteen independent variables shown in Figure 6. The ANOVAs conducted for the 5 hypotheses revealed the same statistical test result for each hypothesis; $f(11,0) = 0, p > .05$. The lack of statistical significance, illustrated by the low $f$ score and probability score, gives cause to accept the null hypotheses.

As noted in the results section, the low $f$ score is caused by a 0 error coefficient in the regression equations for each hypothesis tested. No error implies that all possible influences are accounted for in the regression equations. This cannot be the case because it is contrary to the model development. In the literature review, I identified over sixty possible variables that could affect wait times. Sixteen of those variables were considered in the model I developed for this study, see Figure 6. Clearly there are more influences on wait times than the few I chose to examine. The 0 error score in the regression is not a result of accounting for all possible error, but rather some other factor has affected the amount of error identified in the equation.

Colinearity is the factor affecting error in the regression equations. The high intercorrelations between independent variables in the regression experiments make the analysis of individual impact on the dependent variables difficult to estimate. An example of the high intercorrelations is seen in the strong correlations between DemSat and four other independent variables to include TotStShp. TotStShp, in turn, is strongly correlated with three other independent variables, see Table 7. The colinearity amongst these seven variables is very high which significantly reduces the amount of error identified in the regression equation. The colinearity within the independent variables is a fundamental flaw in the model used for this study. This fundamental flaw, carried through the entire analysis, eventually leads us to accept the null hypotheses and reject the alternate hypotheses.

By accepting the null hypotheses in our study we determine that this model, as shown in Figure 6, is a poor predictor of wait times from USAMMCE to the OIF and OEF theatres. The statistical analysis conducted does not provide the intended, useful information to leadership and managers at USAMMCE in their endeavor to decrease wait times and allocate scarce resources. Although the results of the multivariate regression analysis are disappointing, the study is not entirely without value.

The descriptive statistics, found in Table 3, provide valuable information on USAMMCE's support to both the OIF and OEF theaters. The stable and short cycle time for both CPT and DPT contrasts sharply with the long and variable cycle times for CWT, RWT, and ITT. Mean cycle times of more than 40 days for CWT and RWT do not support the logistics strategies of distribution based logistics or modular support. An average of 40 ± 20 days lead time to request materiel forces units to stockpile inventory forward in order to cover the long lead time. Units are required to plan for the worst and maintain 60 days worth of supplies on hand in order to prevent shortages of materiel. Units unable to maintain inventory levels at 60 days of supply will horde materiel acquired due to their mistrust in an extremely variable supply chain. The ± 20 days variability means units can expect their materiel to arrive within a 40 day window. Though most units can adapt to this long and variable lead time for routine ordering, it becomes very difficult to compensate for any fluctuations in their routine ordering patterns. Fluctuations, in turn, occur constantly.

The focus for improving supply chain cycle time variability can be found in the dependant variable correlations. CWT is the sum of ITT, CPT, and DPT. RWT is the sum of ITT, CPT, and DPT for stocked items at USAMMCE. ITT is very highly and directly correlated with CWT and RWT. ITT is also extremely variable at 23 ± 21 days on average. CPT and DPT are only somewhat directly correlated with CWT and RWT and very stable at 5 ± 1 day and 12 ± 3 days respectively. Because the majority of the variation in CWT and RWT can be found in ITT and because ITT is very highly correlated with CWT and RWT, improvements in either the stability or length of ITT will likely be directly reflected in CWT and RWT. Conversely, similar improvements in DPT and CPT may not be reflected in CWT and RWT because they are already stable and because they are only somewhat correlated with CWT and RWT.

The descriptive statistics for the independent variables provide little useful information in improving wait times from USAMMCE to the OIF and OEF theaters. See Table 4 for independent variable descriptive statistics. Most of the independent variables focus on depot operations at USAMMCE. Like DPT, these variables are generally stable. The mean scores for these variables do not indicate serious problems with depot operations. None of the independent variables maintain strong correlations with CWT or RWT. Among all the variables, only DemAcc and ITT share a moderately strong correlation. The inverse nature of the relationship implies that by improving DemAcc, ITT might be reduced somewhat. Improving DemAcc can be accomplished by adopting a more liberal stockage policy that allows more of the items being requested to be stocked at USAMMCE. The 86% ± 4% average DemAcc is well within Department of the Army (DA) standards and might prove more costly, in time, effort, and dollars, to improve upon than other strategies more directly focused on ITT. Even the independent variables intended to reflect the performance of transportation functions in the supply chain (MedStShp, AirMis, AirTonShp) are weakly correlated with ITT. Although they are weakly correlated with ITT, these variables do exhibit extreme instability like ITT. The only apparent useful information within these variables is the MedStShp to AirTonShp ratio. After standardizing MedStShp to long tons like AirTonShp, we find that USAMMCE's medical shipments account for 7% of AMC's tonnage flown into the OIF and OEF theaters.

The descriptive statistics in this study reveal that USAMMCE's role in the supply chain appears both efficient and effective relative to the other sub parts of CWT (ITT and CPT). USAMMCE's role in the supply chain is measured in DPT. DPT averages 12 ± 3 days. 30% of the average CWT is found in DPT. 70% resides outside the realm of USAMMCE's direct influence. My initial assumption that improvements made in USAMMCE will be directly reflected in overall supply chain performance is not accurate. At best 30% of any improvements made at USAMMCE will be reflected in the overall supply chain's performance. It is more likely that any improvements made by USAMMCE will be overcome by inefficiencies elsewhere in the supply chain, most likely in the transportation functions. This statement is reflected in the correlations between CWT and the two variables DPT and ITT and the instability surrounding ITT.

## Conclusion

Stable DPT characteristics coupled with variable ITT characteristics directs future research on medical supply chain performance for OIF and OEF away from depot operations and toward transportation operations. Reducing variation in the transportation functions of the supply chain should be the primary focus of future research, followed by reducing mean ITT.

Immediate improvements in ITT stability will allow units to plan supply operations better. Reducing the window of expected receipt time from 40 to 20 days will give units more confidence in the distribution system even if the overall wait time remains long. This study shows a moderate inverse relationship between USAMMCE's DemAcc and ITT. Research focused on the costs (e.g. time, effort, and money) for USAMMCE to improve DemAcc might benefit the supply chain. Determining other transportation functions that have a greater impact on ITT would likely be more beneficial to the supply chain. Reducing variability in ITT leads to reduced variability in CWT.

Research focused on establishing performance objectives for CWT into the OIF and OEF theaters is a key first step to improving this metric. At this point no enterprise level standard has been established for CWT. Therefore no cost tradeoff analysis can be made in determining strategies for reducing CWT. Understanding end user expectations of wait times and capabilities within the supply chain will help to establish a base for developing CWT objectives. Until an objective is set for CWT, no course of action can be established to truly improve CWT or any subcomponent of CWT (CPT, DPT, ITT, and RWT).

The purpose of this study is to examine the degree of influence supply chain factors exert on customer wait times for medical supplies and equipment to the OEF and OIF theaters. The results of this study show a range of relevancy to the purpose of this research. The results of the regression analysis failed to achieve the desired information. The failure is due in great part to the operationalization of the constructs in the model to measurable variables for the hypotheses tested. The colinearity among the independent variables is a direct result of operationalizing the constructs for testing. Despite this failure, the proper execution of the research revealed unexpected findings in the descriptive statistics that summarize the dependant variables. These characteristics reveal that most of the variation found in CWT and RWT is most likely found in ITT and not in DPT or CPT. This unexpected finding directs future research in identifying the influence supply chain factors exert on CWT for medical supplies and equipment to the OEF and OIF theaters toward transportation functions that affect ITT. Although the purpose of this study was not achieved through this research, it has provided direction for future research which may eventually achieve the stated purpose.

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