REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE September 1994

3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE
ASSESSING THE IMPACTS OF LEAN LOGISTICS INFRASTRUCTURES ON STRATEGIC AIRLIFT CAPABILITY

5. FUNDING NUMBERS

6. AUTHOR(S)
Russ C. Major, Captain, USAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology,
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GAL/LAL/95S-6

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
28 BS/MAU
Dyess AFB TX 79607

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The purpose of this research was to compare two lean logistics infrastructures to see which one would provide better support for the C-5 aircraft. The level of support was defined as the average number of mission capable parts (MICAPs) created by system operation. One infrastructure had the central storage facility (CSF) located at the depot, and the other had a geographically separate CSF. A computer simulation model developed by the Air Force Logistics Management Agency was run for a period of twelve years and the average number of MICAPs for each system was collected. The data was then analyzed using a paired T-test. The results showed that the infrastructure with the CSF located at the depot resulted in significantly fewer average MICAPs over a twelve year simulation period. The conclusion is that with regards to the average number of MICAPs produced by system operation, an infrastructure with the CSF located at the depot is desired.

14. SUBJECT TERMS
Lean Logistics, C-5 Aircraft, Strategic Airlift, Mission Capable Parts (MICAPs), Central Storage Facility (CSF), Depot, Computer Simulation, Paired T-test.

15. NUMBER OF PAGES 48

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified

20. LIMITATION OF ABSTRACT UL

ASSESSING THE IMPACTS OF LEAN LOGISTICS INFRASTRUCTURES ON STRATEGIC AIRLIFT CAPABILITY

THESIS

Russ C. Major, B.S.
Captain, USAF

AFIT/GAL/LAL/95S-6

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

Wright-Patterson Air Force Base, Ohio

AFIT/GAL/LAL/95S-6

ASSESSING THE IMPACTS OF LEAN LOGISTICS INFRASTRUCTURES ON STRATEGIC AIRLIFT CAPABILITY

THESIS

Russ C. Major, B.S.
Captain, USAF

AFIT/GAL/LAL/95S-6

Approved for public release; distribution unlimited

AFIT/GAL/LAL/95S-6

ASSESSING THE IMPACTS OF LEAN LOGISTICS INFRASTRUCTURES ON STRATEGIC AIRLIFT CAPABILITY

THESIS

Presented to the Faculty of the Graduate School of Logistics

and Acquisition Management of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

Russ C. Major, B.S.
Captain, USAF

September 1995

Approved for public release; distribution unlimited

Acknowledgments

Lean logistics is the way of the future for the Air Force Logistics System: An important aspect in the implementation of lean logistics is how the logistics infrastructure will look. The purpose of this thesis was to compare two possible lean logistics infrastructures.

I have many people to thank for making this thesis possible. First of all I would like to thank Major Mark Kraus. Without the numerous hours he spent helping me with SLAM, this research would have never been completed. He gave extra to ensure that learning was happening.

I would also like to thank Captain Steve Long and Captain David Gwinn from the Logistics Management Agency. They provided crucial support by helping me to gain the resources to use the model used by this research.

I would also like to thank my advisor, Major Michael Morabito for his help.

Finally, I would like to thank my wife Christine Major for being the perfect wife and supporting me along the way. A special thanks goes to my daughters Sydney and Shelby for always reminding me what is most important in life.

Russ Major

Table of Contents

List of Figures

List of Tables

AFIT/GAL/LAL/95S-6

Abstract

The purpose of this research was to compare two lean logistics infrastructures to see which one would provide better support for the C-5A aircraft. One infrastructure had the central storage facility (CSF) located at the depot and the other had a geographically separate CSF. The level of support was defined as the average number of mission capable parts (MICAPs) created by system operation. A computer simulation model developed by the Logistics Management Agency was run for a period of twelve years and the average number of MICAPs for each system was collected. The data was then analyzed using a paired T-test. The results showed that the infrastructure with the CSF located at the depot resulted in significantly fewer average MICAPs over the twelve year simulation period. The conclusion is that with regards to the average number of MICAPs produced by system operation, an infrastructure with the CSF located at the depot is desired

ASSESSING THE IMPACTS OF LEAN LOGISTICS INFRASTRUCTURES ON STRATEGIC AIRLIFT CAPABILITY

I. Introduction

Purpose

The purpose of this research is to assess the effects of different lean logistics infrastructures on the capability of the strategic airlift fleet. Past research has indicated that implementation of lean logistics principles will improve the USAF's logistics system (Ramey and Pyles, 1992:2). On 1 May 1994, Headquarters Air Mobility Command (AMC) began a demonstration to test the premise of the lean logistics architecture in a peacetime environment (Surrey, 1994b:1). This research effort will use a simulation model to explore the capability of the strategic airlift fleet concerning the implementation of different lean logistics infrastructures.

Background

The post-Cold War shift in US military strategy as well as the budgetary environment has resulted in a major focus on streamlining the military logistics structure. According to John Roos in his article "Force-Projection Logistics: Total Asset Visibility from Factory to Foxhole,"

> The post-Cold War shift in US military posture, from forward-deployed ground and air elements in Europe to US-based force projection units, is dramatically changing the logistics planning process. Instead of prepositioning large stockpiles of materiel to await reinforcing US units in Europe, the military will have to deploy

> US forces to far-flung operations simultaneously with organizational equipment and comprehensive force-sustainment packages. (Roos, 194:29)

The future logistics structure is further complicated by budget reductions and force drawdowns. The Department of Defense (DoD) can no longer afford large inventories, nor can it tolerate a support system that does not respond quickly and effectively (RAND, 1994:1)

Given the changes in the world political situation and reduced defense budgets, many have examined the current logistics system and found it unacceptable. In a time when many laud the logistics system's efforts in Operation Desert Storm/Shield (ODS), further analysis shows that there is a need for change. The current logistics system is neither viable given today's budget cuts, nor impressive in performance given today's new technology (Cohen, Pyles and Eden, 1994:1-2). Although many say the logistics system got the job done in ODS, this perspective does not address problems with the process that only promise to grow larger with budget cuts and the shift to contingency operations (Moore and others, 1993: 1). The current state of the logistics system is summed up by Timothy Ramey and Raymond Pyles in their article, "Would Just In Time Improve Logistics Responsiveness and Cost?"

> The difficulty in predicting demand for logistics support in peacetime, let alone wartime has just been multiplied by the discontinuance of the Cold War, the dissolution of the Soviet Union, the consequent emergence of numerous regional threat to US interests, the need to diminish the US budget deficit and the downsizing of the US military forces. Whatever modest confidence one had in the logistics system's ability to meet the dominant threat by prediction based long-term planning and prepositioning evaporates when one considers the new, less stable, geopolitical environment. (Ramey and Pyles, 1992:1)

Air Force logistics doctrine states that, "the purpose of Air Force logistics is to create and sustain force generation capabilities whenever and wherever needed to conduct military operations" (Department of the Air Force, 1994a:3). To accomplish this, the logistics system needs to be responsive and flexible. Air Force doctrine states that responsiveness is the keystone logistics principle and stresses that it may be difficult to achieve given insufficient resources (Department of the Air Force, 1994a:7). Air Force strategic logistic plans dictate, "the logistics community must be able to provide flexible, responsive support across the broad spectrum of warfare ranging from low intensity conflict to global warfare" (Department of the Air Force, 1994b:2).

The changes in the global environment and the need for a responsive, flexible logistics system have increased the importance of strategic airlift. General Ronald Fogleman, former Commander, U.S. Transportation Command , Air Mobility Command, and current Air Force Chief of Staff stated:

> We see that, as the nation and the Air Force continue to reduce overseas presence and we come to increasingly rely on a CONUS-based contingency force, the air mobility system becomes absolutely crucial to every military and humanitarian operation that we wage around the world. (Fogleman, 1993: 1)

The overwhelming bulk of equipment to sustain military operations overseas would be supported by sealift (Stone and Wright, 1986: 3). However, during the early days of an operation, airlift and prepositioned stock are the only means of supporting combat forces (Stone and Wright, 1986: 3). An example of the importance of timely strategic airlift can be found in ODS when almost 90% of the total 13 billion pounds of cargo destined for use by the coalition traveled by sea, much of it never reaching the theater before the cease-fire (Suit, 1991: 13). Given the increasing importance of airlift and the fact that we can no longer count on logistics lead time in future conflicts, it is important to find the best lean logistics infrastructure to support strategic airlift.

Problem Statement

There is a need to know the effects on strategic airlift capability of different lean logistics infrastructures.

Research Objectives

The objectives of this research are two-fold. First, a model that accurately represents proposed lean logistics infrastructures will be built. Second, the effects of different lean logistics infrastructures on strategic airlift capability will be assessed. For this research effort, capability will be measured as the average number of mission capable parts (MICAPs) in the logistics system. A MICAP condition exists when a part that is required for an aircraft to carry out its mission is unserviceable, and a replacement part is not immediately available for issue. MICAP parts receive the highest priority in a logistics system as they are essential for the mission to be conducted. A logistics system that produces fewer MICAPs is more capable of supporting the strategic airlift mission.

Research Questions

To satisfy objective one, the following questions must be answered:

1. What are the options for lean logistics infrastructures?
2. What are the transportation times involved in the different infrastructures?
3. What are the appropriate standard base supply system (SBSS) data?

To satisfy objective two, the following question must be answered:

1. What is the effect of the different infrastructures on the average number of MICAPs in logistic system?

II. Literature Review

Introduction

In March of 1991, the Air Force sponsored RAND Corporation in a research effort to study the air campaign of Operation Desert Storm (Lund, 1993: iii). Many lessons have been gleaned from this analysis. Most important for logistics is the realization that unpredictable taskings combined with demand unpredictability require a logistics system that can rapidly re-adjust operations to deliver the support needed by the forces in increasingly unpredictable venues and missions (Pyles and Cohen, 1993: 1). To accomplish this flexible, responsive logistics system, RAND suggested the Air Force adopt a lean logistics system for reparable aircraft components.

This chapter will begin by discussing lean logistics as described by RAND. Then some of the technology that can make a lean logistics system a success will be discussed. Next, the focus will be directed to two of the principles of lean logistics as identified by RAND. The first will be the principle of empowering the command. The second will be the use of just in time (JIT) logistics. Finally, research efforts by RAND, HQ AMC and the Air Force Logistics Management Agency (AFLMA) evaluating lean logistics will be addressed and will show the need for this research effort.

Lean Logistics

Lean logistics is defined by RAND as the, "application to the Air Force logistics system of technological and management innovations that have been proven in the commercial world, are relevant to the central support problems of the Air Force and are achievable at very affordable cost" (Cohen, Pyles and Eden, 1994: 1). A logistics system based on lean logistics meets the current demands of flexibility and responsiveness because it reduces dependence on long-term predictions of buy and repair actions based on historical data and seeks ways to learn users' current needs more quickly, to adjust product mix more quickly, and to shorten production and delivery times dramatically (Ramey and Pyles, 1994: 2). RAND has identified the six principles of lean logistics as:

> 1. **Empower the operational commands** so that they have more control over the logistics resources that directly affect weapon system readiness and sustainability.
> 2. **Develop "just in time" logistics** so that materiel management and distribution processes are much more responsive while buffer stock and real-time management decision making are greatly reduced.
> 3. **Tighten repair and manufacturing** so that management is simplified, non-value added actions and indirect labor are reduced, and "repair on demand" can be implemented with small amounts of system wide stocks.
> 4. **Use managed competition** to improve organic and contractor performance, not just on cost, but on a wide range of measures pertinent to lean logistics.
> 5. **Expand Integrated Weapon System Management** to ensure that weapon system designs are well suited to lean production and lean support systems.
> 6. **Embed continuous improvement** so that the logistics leadership expects and seeks to improve system performance constantly rather that simply meet standards. (Cohen, Pyles and Eden, 1994: 2-3)

This research effort will focus on the lean logistics aspects of empowering the command and developing JIT logistics. In order to effectively implement these two principles, a total asset visibility (TAV) program is beneficial. Total asset visibility enables the commands to track their assets allowing them to effectively control the logistics resources at their disposal and make a JIT system run smoother.

Total Asset Visibility

Total asset visibility (TAV) utilizes recent technological advances that make lean logistics possible. TAV is described as using command and control processes to ensure the quantity, condition, and location of critical assets are visible (Department of the Air

Force, 1994a: 11). The importance of TAV is illustrated by the fact that it has been included as one of seven logistics concepts in Air Force Logistics Doctrine. The doctrine states that, “knowing with confidence where parts or supplies are located, or when and how the will arrive, is the key to the logistician’s ability to support operational requirements” (Department of the Air Force, 1994a: 11).

The importance of TAV is increasing in today’s logistics environment. Given the current budget cuts and the shift to US based contingency forces, the Air Force is looking to decrease its reliance on stockpiling assets. However, “until the logistics community can tell supported commanders what is where in the pipeline, we’re going to have to continue stockpiling more equipment than we need in a theater” (Roos, 1994: 31).

The DoD currently does not have a TAV system although,

> ODS spawned or reinforced six important asset visibility initiatives. The six were the USTRANSCOM Global Transportation Network (GTN), the Army’s Total Asset Visibility program (TAV), the OSD Total Asset Visibility Program, the Army’s Total Distribution System Initiative (TDS), the Joint Logistics Commander’s study of Item In-Transit Visibility, and the Air Force’s Logistics Intelligence File (AFLIF) initiative. (Wykle and Wolfe, 1993: 8)

Despite Air Force efforts, the Air Force currently does not have a TAV system fielded that meets the logistics communities needs. This lack of TAV was demonstrated in ODS when 25,000 of the 40,000 containers shipped to theater had to be opened simply to determine contents and destination (Halliday and Moore, 1994: 1). The same problem was evident in the Somalia operation causing retired US Army General William Tuttle, now president of the Logistics Management Institute to state that the inability to know where things were once they had been shipped was one of the greatest frustrations for the commanders and logisticians (Tuttle, 1993: 14).

Although the Air Force does not have TAV capability, technology is available that will allow the Air Force to achieve TAV. Two technologies that can help are electronic data interchange (EDI) and bar coding.

EDI is defined as a direct computer-to-computer communication between two organizations via a telecommunications system (Udo, 1993: 33-34). The biggest advantage of EDI for TAV is as a result of the single-data input feature, time is saved and entry errors are minimized. EDI also enables quick response to customer demands, faster and more accurate order processing and increased customer satisfaction (Udo, 1993: 34).

Bar coding involves the process of affixing a bar coded label to assets and using scanners to read the labels directly to computer systems (Kulwiec, 1993: 69). Bar coding not only allows logisticians to locate assets, but it also helps to reduce picking and shipping errors (Forger, 1993: 50).

Total asset visibility however, is not the answer to the Air Force's logistics challenges. In June 1992, industry and government leaders participated in an interactive workshop on integrating commercial/defense transportation. Major Generals Kenneth Wykle and Michael Wolfe were two participants who provided a summary of the workshop in their article, "Looking Beyond In-Transit Visibility." They stated,

> The top issue, in the view of the participants, is that DoD has not articulated a long-term requirement or clear strategy for the use of in-transit visibility. In effect, many participants were suggesting that more thought is needed on how improved visibility data would be used to improve operations and planning. (Wykle and Wolfe, 1993: 9)

To improve operations using TAV, a reorganization must take place that includes a centralized logistics control agency which has to be able not only to keep track of critical assets, but also has the responsiveness to redirect them if necessary (Roos, 1994: 32). Reorganization has to occur to take the fullest advantage of technological innovations.

Reorganization coupled with technological innovations allowed Portland General Electric to reduce the time required for a given process from 15 days to one-half day, and the cost from $90 to $10 (Moore and others, 1993: xii). TAV is a step in the right direction, but TAV alone falls short. Wykle and Wolfe suggest the concept of dynamic flow control as an organizing vision for DoD distribution. They define dynamic flow control as, "the active, intelligent allocation of logistics and transportation demand and supply to minimize congestion and maximize capacity and flexibility" (Wykle and Wolfe, 1993: 11). Dynamic flow control is what is used as the concept of operations under the lean logistics principle of empowering the command.

Empowering the Command

The lean logistics concept of empowering the command, embraces the idea that "users should control those logistics processes that most affect their performance, especially those associated with readiness and sustainability" (Cohen and Pyles, 1992: 2). One aspect required in empowering the operational commands would be the creation of a command logistics control center (CLCC) to allocate available assets to individual bases within each operational command as determined by the command based on operational commitments and aircraft availability targets (Cohen, Pyles and Eden, 1994: 7). This CLCC would also prioritize depot repair, assuring that inevitable asset shortfalls are as short-lived as possible (Cohen and Pyles, 1992: 7).

The problem is that in the current system, Air Force Materiel Command plays a significant role in establishing repair priorities and in distribution decisions (Cohen and Pyles, 1992: 3). Lean logistics is based on the belief that combat commands should take over these roles in peacetime, similar to the way they do in wartime (Cohen and Pyles, 1992: 6). This philosophy matches the logistics concept of transition to and from war described in Air Force Logistics Doctrine. The doctrine states that, "to perform effectively in war, peacetime operations should duplicate wartime activity," and that "combat effectiveness is the key to deciding policies for peacetime operations" (Department of the Air Force, 1994a: 11). However, the implementation of command control of distribution decisions and repair priority is one that has not been achieved. Not only does AFMC still have decision authority, but the commands do not have the asset visibility tools to allow them to effectively control distribution decisions and repair priorities. The principle of empowering the command is one of the most important principles of lean logistics; however, it may be the hardest one for the Air Force to implement.

Just In Time Logistics

The other lean logistics principle discussed in this research is the use of just in time logistics. According to Timothy Ramey and Raymond Pyles:

> The basic idea is that small amounts of stock would be held at each operating location to cover their needs during the one or two day transportation delay to a pooled stockage. The bulk of stocks would be stored at a buffer warehouse (the pooled stockpile) under the direct control of the CLCC. The CLCC would be responsible for periodically setting stock levels and aircraft availability goals for its operating units, and for allocating shortages of parts on the occasions when they arose. The CLCC would task and prioritize depot repair and resupply. (Ramey and Pyles, 1992: 3)

An important aspect of a JIT style logistics system is the reduction of order and ship time (OST) to two days using express air and immediate processing of all parts. The current reparable component logistics system is shown in Figure 2-1.

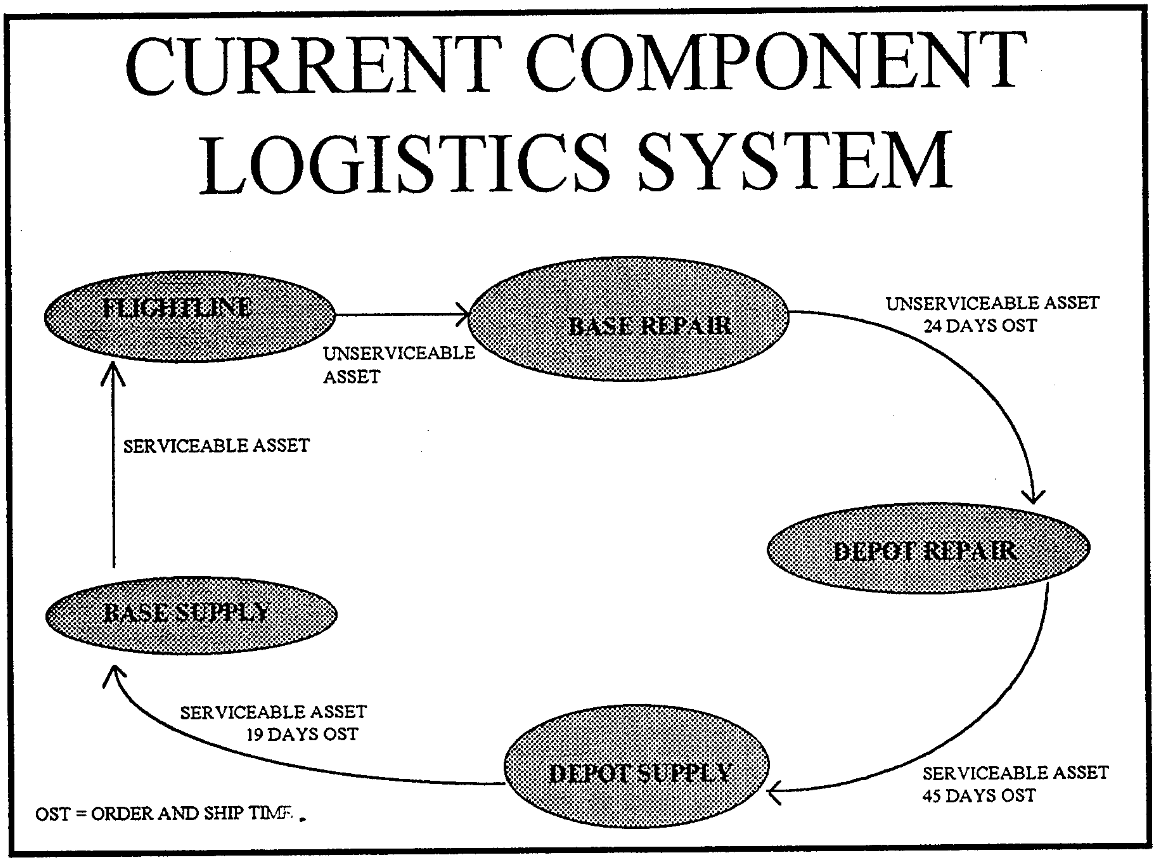

Figure 2-1. Current Component Logistics System

The JIT style component logistic system used in lean logistics is shown in Figure 2-2.

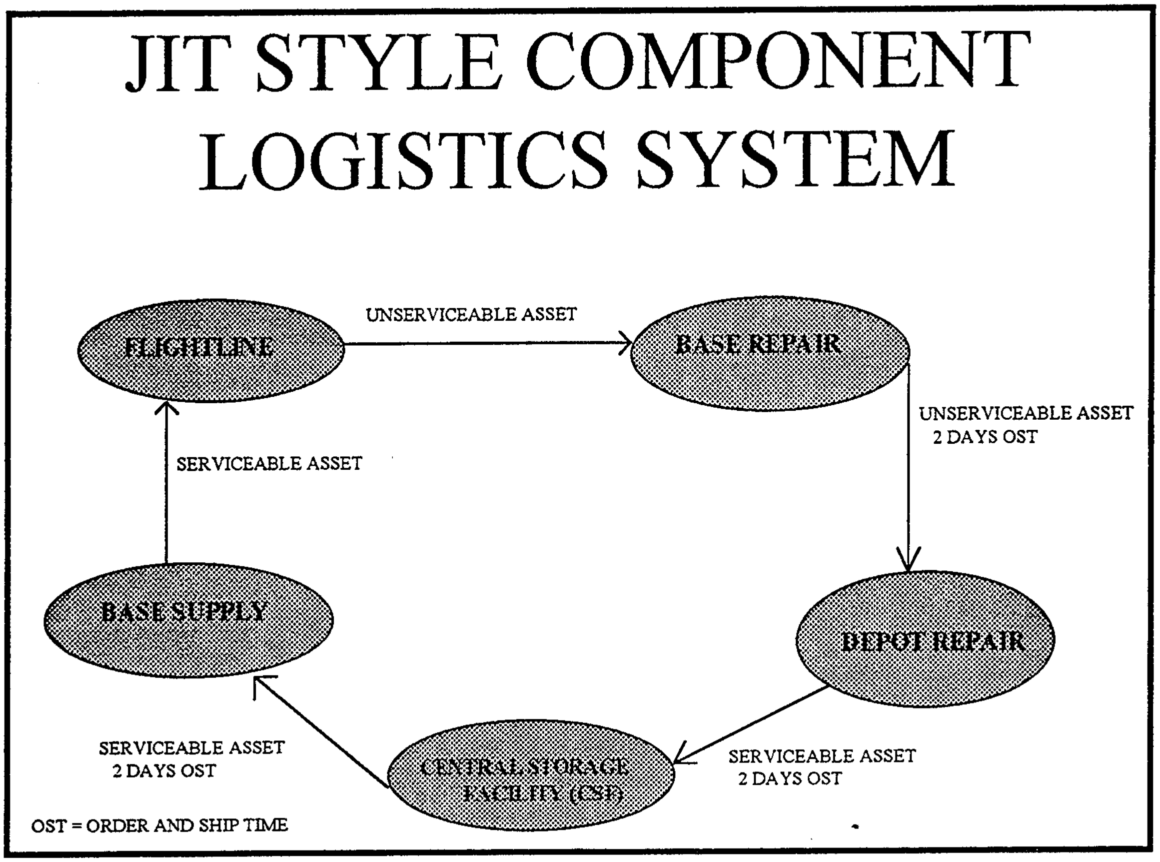

Figure 2-2. JIT Style Component Logistics System

The JIT logistics system uses lean levels of stock located at the bases. These levels are set by the CLCC. The CLCC also manages a central storage facility (CSF) which contains buffer stock to fill base level requirements. When a part is removed from an aircraft, and it cannot be repaired at base level within a couple of days, it is sent directly to the depot and a serviceable asset is shipped to the base from the CSF. If no asset is available at the CSF, then the CLCC coordinates a direct shipment of the next available serviceable asset from the depot to the base (Surrey, 1994: 5-6).

RAND Research

RAND completed research using Dyna-METRIC Version 6 to test if lean logistics would provide better support than the current system for the F-16C aircraft. They evaluated three measures: robustness, simplicity and efficiency. Robustness was measured by the number of fully mission capable (FMC) aircraft after a period of time, under a variety of conditions. Simplicity was measured by the number of items at each site, warehousing requirements and procedural activities. Efficiency was measured as inventory investment, recurring inventory costs, manpower needs and information needs (Ramey and Pyles, 1992: 4).

The results showed that lean logistics is more robust. The lean logistics system consistently outperformed the current system, with the largest performance gap demonstrated during surge operations. Results also showed lean logistics is simpler with roughly 1500 assets at a typical 72 primary available aircraft (PAA) base as compared to the current system's 5400 assets. Finally, results showed that lean logistics is less expensive with a decrease of approximately $600 million worth of stocks annually (Ramey and Pyles, 1992: 4-6).

This research can be considered the starting point for lean logistics in the Air Force. The results from this research showed that lean logistics may be a better alternative to the current logistics system. However, it is important to note that this research was just the beginning of the research effort on lean logistics and not all conclusions reached in this research are final. For example, this research assumed that robustness could be measured as a snapshot of FMC aircraft when a more accurate measure of robustness would consider a time integrated average number of FMS aircraft. Despite any shortcomings, the RAND research helped the Air Force identify an alternative to the current logistics system and pointed to the need for future research.

The research stated a need for future research assessing the effectiveness of lean logistics design for combat commands that differ significantly from tactical fighter or bomber wings (e.g., airlift wings). This research was followed by a demonstration of lean logistics principles by HQ AMC, to assess the effectiveness of lean logistics principles for airlift aircraft.

AMC Lean Logistics Demonstration

On 1 May 1994, HQ AMC began a demonstration using the principles identified in lean logistics. The primary objective of the demonstration is to test the premise of the lean logistics architecture in a peacetime environment (Surrey, 1994a: 1). According to the test plan, the expected outcomes include maintaining support to the C-5 fleet with reduced support infrastructure by:

1. Empowering the lead major command (HQ AMC) to maintain a central stock control function, which will set appropriate stock levels, determine repair priorities, and distribute available assets,
2. Decreasing transit times for repair cycle assets moving to and from depot repair,
3. Streamlining base repair processes, and
4. Accelerating depot repair processes.

The test is not designed to summarily reduce stock levels or increase aircraft availability, although both are expected outcomes. The test is also not designed to streamline the depot repair process; only the handling processes will be streamlined (Surrey, 1994a:1).

The test concluded on 31 October 1994 and results showed reduced transportation, handling and repair time, as well as significant reductions in inventories.

AFLMA Research

In March of 1994, the Air Force Logistics Management Agency conducted a study of lean logistics. The study involved a computer simulation program that contained 31 critical recoverable assets and six C-5 bases. The research developed four different logistics infrastructures using three different stockage schemes in order to compare the expected performance and inventory cost of each alternative. One of the main goals of this research effort was to determine the lean stock levels for each of the 31 recoverable assets at each of the bases. The study produced suggested lean stock levels for each alternative with each stockage policy. This thesis research uses the same computer simulation program with the lean stock levels suggested by the LMA study as a starting point for evaluating two of the four infrastructures using the current standard base supply system (SBSS) stockage policy.

Conclusion

This chapter has reviewed the current literature on lean logistics and its importance to the Air Force. It has also showed that although there has been some research on the effects of lean logistics on weapon system support, more research is needed. The RAND study only focused on fighter aircraft, and the AMC demonstration examined the peacetime effects of lean logistics on strategic airlift. The LMA study resulted in the appropriate lean levels to be used for the AMC demonstration. The need exists for research to examine the question of whether or not different lean logistic infrastructures will be more effective in supporting the strategic airlift fleet using the lean levels developed by the LMA study.

III. Methodology

Chapter Overview

The Air Force is rapidly moving towards implementing Lean Logistics for all reparable item logistics systems. In order to implement the most effective system, research needs to be conducted to determine what type of logistics infrastructure will best support lean logistics. The goal of this study is to compare two infrastructures to see which one will best support the strategic airlift fleet. This chapter will begin by discussing the experimental design chosen to meet the research objectives. Next, the computer simulation model that will be used by this study will be discussed. Finally, the data collection and analysis techniques necessary to support or refute the hypotheses will be discussed.

Experimental Design

In order to conduct this study, it was decided that a computer simulation model would be the best tool to use to meet the objectives of this study. "In its broadest sense, computer simulation is the process of designing a mathematical-logical model of a real system and experimenting with this model on a computer" (Pritsker, 1986: 6). Pritsker in his book Introduction to Simulation and SLAM II states that computer simulations permit inferences to be made about systems without

1. building the systems, if they are only proposed systems;
2. disturbing the systems, if they are operating systems that are costly or unsafe to experiment with;
3. destroying the systems, if the object of an experiment is to determine their limits of stress (Pritsker, 1986: 6).

Since the infrastructures described in this study are proposed systems, simulation is an appropriate tool to experiment with the proposed systems.

Variables

This experiment examined a single dependent variable. The dependent variable of interest in this study is the average number of mission capable parts (MICAPs) that are generated by the operation of each logistics infrastructure during a twelve year simulation. The average number of MICAPs in the system will be used to operationalize airlift capability. A MICAP condition exists when a part that is required for an aircraft to carry out its mission is unserviceable, and a replacement part is not immediately available for issue. MICAP parts receive the highest priority in a logistics system as they are essential for the mission to be conducted. As such, the average number of MICAPs that are generated by the operation of each proposed system was chosen to determine which system would better support strategic airlift capability.

This study used a single independent variable at two levels. The independent variable was the location of the CSF. Under one system the CSF is located at the repair depot and under the other system the CSF is geographically separated from the repair depot as well as the operating bases. These two systems resulted in the independent variable being expressed in two levels of transit time from the depot repair facility to the CSF. In the system that has a collocated CSF, there is no transit time, and in the system that has a geographically separated CSF, the transit time is two days.

Experimental Hypotheses

The following hypotheses served as the framework for comparing the two logistics infrastructures.

Null Hypothesis: The number of average MICAPs are the same for both systems.

Alternative Hypothesis: The number of average MICAPs are different.

Pritsker states in his book that simulation encompasses a model building process as well as the design and implementation of an appropriate experiment involving the model (Pritsker, 1986: 6). Now that the design of the experiment has been discussed, the focus will be turned to the model building process.

Model

The model building process was made significantly easier when it was discovered that AFLMA Final Report LS940390 reported the results of a study that used a simulation language for alternative modeling (SLAM) computer simulation to accurately model four different lean logistics infrastructures (Reynolds and others, 1994). Two of the infrastructures modeled by the LMA simulation were used in this study and are depicted on the following page.

Infrastructure one is shown in Figure 3-1.

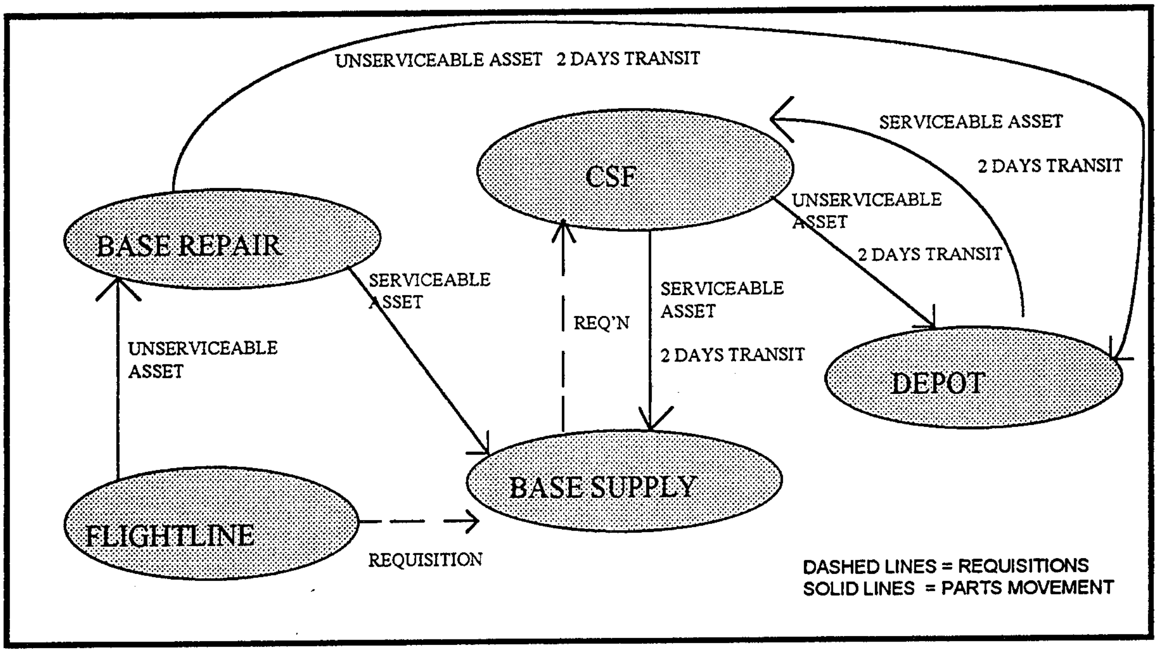

Figure 3-1. Geographically Separate CSF

Infrastructure two is shown in Figure 3-2.

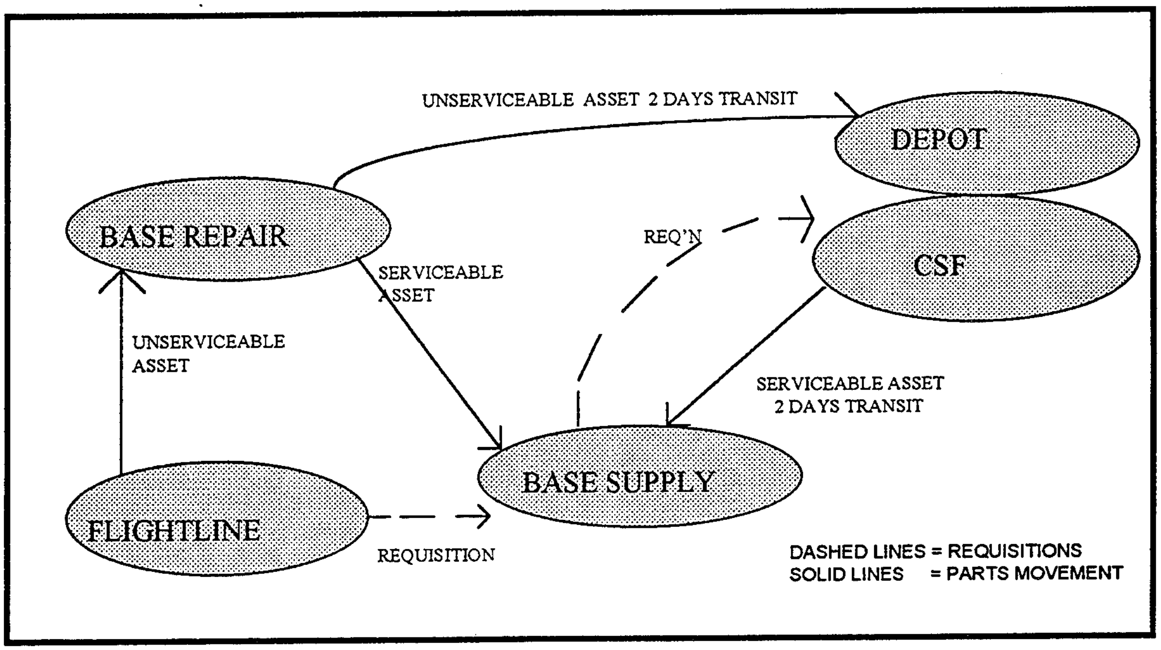

Figure 3-2. CSF Located at Depot

Since a model is a description of a system, it is also an abstraction of a system. As a result, a model builder must decide the elements to include in the model as well as the elements that will be left out of the model (Pritsker, 1986: 4). To define what elements are included in the model, assumptions have to be made. The assumptions used in this study follow.

Assumptions

The following assumptions were stated in the LMA study that explained the computer simulation model that will be used by this study and are applicable for this study also.

1. Customer arrivals were approximately Poisson distributed; thus, exponential interarrival times were appropriate. Customer arrivals are defined as a demand on the supply system caused by a component failure.
2. Average base demands were constant over time; thus past demand rates were reasonable approximation of future demand rates. The average base demands were used to determine the rates of failures for each part at each base.
3. Depot repair flow times were constant over time and correctly approximated by the high velocity repair times (HVRT). RAND estimates and AFMC negotiated times were used providing a range of one day to 270 days. HVRT used in this study are in Appendix A.
4. The system stock available to fill demands was limited to the sum of base and CSF lean stock levels over the entire period of the simulation.
5. The C-5 lean stock levels were filled at the beginning of each simulation run. Lean stock levels ranged from zero to eight parts at the base level and two to 58 parts at the CSF. Lean stock levels used in this study are in Appendix B.
6. Neither base nor depot repair shops were constrained by awaiting parts (AWP) problems or funding shortfalls.

7. There was no lateral resupply among bases; thus available stock from one base could not be used to fulfill a shortage at another base.

8. Item interchangeable and substitute grouping took precedence when base data indicated different relationship codes for grouped test items (Reynolds and others, 1994: 5).

The following assumptions were not part of the LMA study but were made in this study.

1. The steady state analysis performed for the LMA study is also appropriate for this study.

2. Unserviceable retrograde and serviceable shipment transportation times were a constant two days for all six test bases using express air.

Input Data

The input data used in this study were gathered by a combination of sources. All supply data used were the same SBSS data that were used by the LMA study. The SBSS data included the following: national stock number (NSN), high velocity repair time (HVRT), percentage of base repair (PBR), not repairable this station (NRTS) condemned time (NCT), and daily demand rate (DDR). The SBSS data are included in Appendix A. The model input data that were used to set the initial lean stock levels for all parts were gathered from the results of the LMA study and are included in Appendix B.

Validation and Verification

Model verification is defined by Pritsker as "the process of establishing that the computer program executes as intended" (Pritsker, 1986: 11). He defines validation as "the process of establishing that a desired accuracy of correspondence exists between the simulation model and the real system" (Pritsker, 1986: 11). One of the advantages of using the model that was developed by the LMA was that it had already been verified and validated by the LMA. However, since some minor changes were made to the computer simulation model, model verification and validation were re-accomplished.

The simulation model used in this research was verified using an informal analysis technique called desk checking. This type of verification is one of the most common verification approaches since it is not difficult to perform and requires very little computer resources. Desk checking is usually accomplished as the model is developed and involves verifying that each section does what it is intended to do before moving on to the next section. Since the model was already built, desk checking was done by breaking the computer code into sections and verifying each section individually by manipulating the input and examining the resultant output. For example, to test the module that initially loaded the lean stock levels the simulation time was changed to 0.1 day. The output was analyzed to ensure that the appropriate number of parts was loaded at each level at the start of the simulation. The result of the verification process is that the model executed as correctly.

The technique used to validate the model is called face validation. Under this technique, "people knowledgeable about the system under study, based upon their estimates and intuition, subjectively compare model and system behaviors to judge whether the model and its results are reasonable" (Balci, 1989: 68). Although the systems under study in this research are proposed systems, anyone with a good understanding of how the Air Force logistics system works is capable of comparing the model and system behaviors to judge reasonableness. As stated earlier this was accomplished by the researchers at the Logistics Management Agency as well as the author of this study. The result of the validation process is that the model accurately depicts the systems under study.

Data Collection and Analysis Techniques

When comparing two systems by using computer simulation, it is it often desirable to use common random numbers to induce a positive covariance thus resulting in a reduction in the variance of the differences between the sample means. Common random numbers were used in this research effort by specifying the random number seeds that were used. The result was a reduction in the variance that allowed the study to be conducted with a limited number of simulation runs.

Sample Size

In order to determine the sample size, five pilot runs were made. From these pilot runs the variance of the five runs for each system was computed and then added together to estimate S^2. The following equation was used to solve for n:

$$n = \frac{t^2_{n-1,1-\alpha/2} S^2}{w^2} \quad \text{(Pritsker, 1986: 46)}$$

Where: $\alpha = .05$

$t^2_{n-1,1-\alpha/2} = 7.706176$

$S^2 = .09040144$

$W = 1$

The half width chosen was one MICAP so the number of runs would be sufficient to determine a difference of plus or minus one MICAP. The resulting number of runs was calculated to be .696649407. A low number of runs is not uncommon when using common random numbers. However, ten total runs were conducted to ensure normality of the data.

Statistical Tests

The data analysis required to evaluate the experimental hypotheses was a paired t-test. This test allowed the comparison of the average number of MICAPs for the two different systems. The only assumption necessary in using the paired t-test is that the data be normally distributed. To verify the assumption of normality, the average number of MICAPs were analyzed using a Wilk-Shapiro test for normality. The test statistic returned was then compared to the minimum value for a 0.01 level of significance with a sample size of ten. The minimum value is 0.781 (Conover, 1980). Any data that returns a test statistic greater than the minimum value meets the assumption of normality. Once the assumption of normality was verified, a paired t-test was performed to evaluate the experimental hypotheses using Statistix, a statistical software package (Statistix, 1992).

Summary

The goal of this study was to determine the effect of lean logistics infrastructures on the average number of MICAPs in the logistics system. This chapter explained the experimental design used to conduct this experiment. Next, the model that was used to conduct the experiment was discussed. Finally, the data collection and analysis techniques were discussed. Results and analyses of data follow in Chapter IV.

IV. Results and Analysis

Chapter Overview

The goal of this study was to compare the effects of two different lean logistics infrastructures on strategic airlift capability measured by the average number of MICAPs generated by each system over a period of twelve years. A computer simulation model developed by the AFLMA was used to experiment with each system resulting in data being generated on the average number of MICAPs in the system. This chapter displays this data and shows the results of the statistical tests accomplished to analyze the data. Next, the chapter analyzes the results to answer the experimental hypotheses.

Results

Following the parameters used by the AFLMA in their study, the computer model used in this simulation was run for a period of twelve years, with statistical arrays cleared at the end of the second year. The AFLMA study, as well as this research, was a steady state analysis study. In discussing the model with the AFLMA researchers it was determined that the system reached steady stated after two years of simulation time and thus was the point at which the statistical arrays should be cleared. The result is the average number of MICAPs in the system over a ten year period for each infrastructure. The model was run ten times for each infrastructure. The resulting data is displayed in Table 4-1. Structure one has the CSF separate from the repair depot and structure two has the CSF located at the repair depot.

Table 4-1. Average Number of MICAPs

Run Number	Geographically Separate CSF	CSF Located at Depot	Difference
1	10.458	10.068	.39
2	10.319	9.958	.361
3	10.466	10.086	.38
4	9.942	9.566	.376
5	10.348	9.971	.377
6	10.169	9.81	.359
7	10.285	9.932	.353
8	10.183	9.81	.373
9	10.640	10.211	.429
10	10.711	10.342	.369

A Wilk-Shapiro test for normality was performed on the data shown in table 4-1. The data for the system with a separate CSF returned a Wilk-Shapiro value of .9762. The Rankit Plot is shown in Figure 4-1. Using the minimum value of 0.781, the hypothesis that the data is distributed normally is accepted.

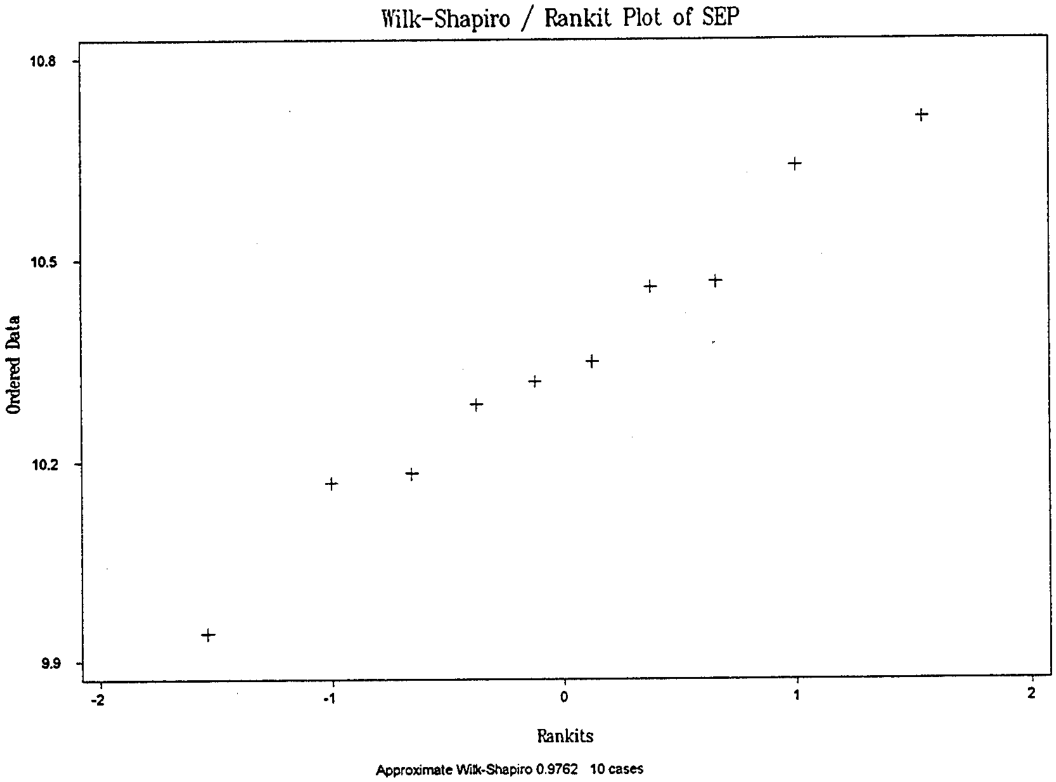

Figure 4-1. Rankit Plot for Geographically Separate CSF

The data for the system with the CSF located at depot returned a Wilk-Shapiro value of 0.9716. The Rankit Plot is shown in Figure 4-2. Using the minimum value of 0.781, the assumption of normality is accepted.

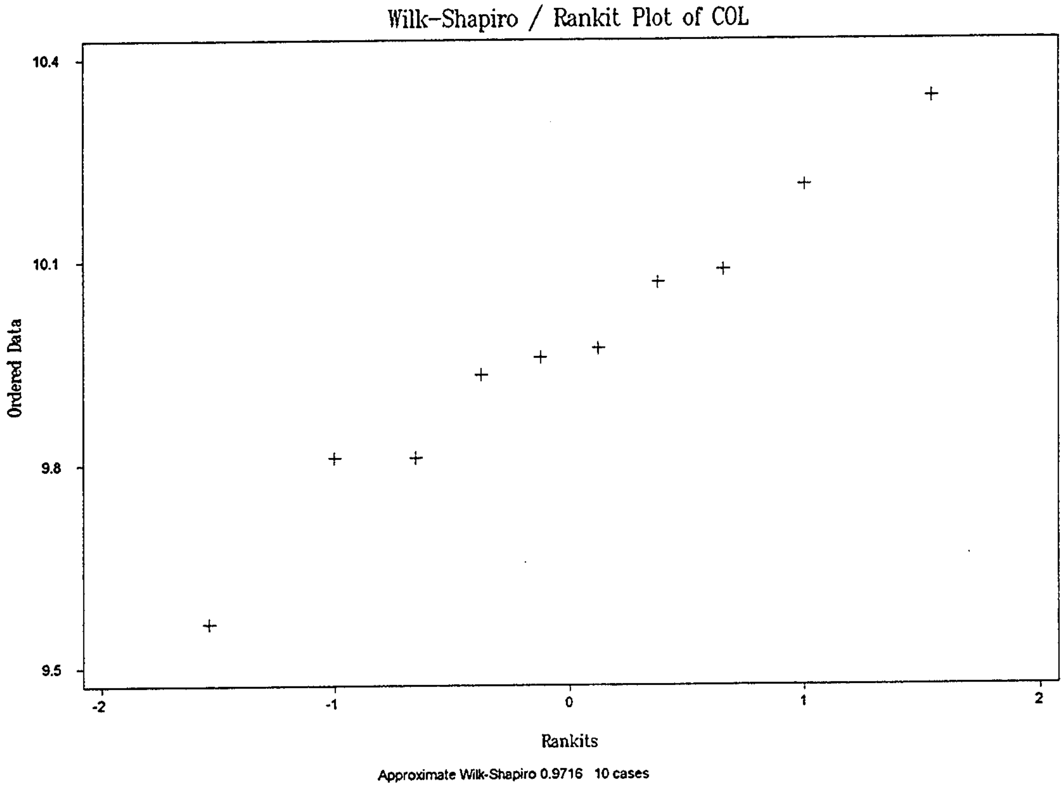

Figure 4-2. Rankit Plot for CSF Located at Depot

Paired t-test Results

Having verified the validity and the normality of the data, a paired two sample t-test for means was performed for the following hypotheses.

Null Hypothesis: The number of average MICAPs are the same for both systems

Alternative Hypothesis: The number of average MICAPs are different.

At a 95% significance level, with nine degrees of freedom, the critical value for the test statistic t is 1.833. The calculated t-statistic was 55.69. Comparing these two values, the null hypothesis is rejected since the calculated t-statistic is higher than the test statistic. Thus, the alternative hypothesis that there is a difference in the average number of MICAPs between the two systems is accepted. The Paired-t 95% confidence interval is [0.3614, 0.3920]. This shows that 95% of the sample means of the difference between the two structures will fall between 0.3614 and 0.3920. These results show that the infrastructure chosen for lean logistics will impact the average MICAPs generated by the operation of the logistics system. The results of the paired two sample t-test are shown in Table 4-2.

Table 4-2. Paired t-test Results

Mean	0.3767
Standard Error	0.00676
T-Statistic	55.69
Degrees of Freedom	9
P Value	0.0000

Summary

This chapter displayed the data that was collected as a result of running the computer simulation model. The resulting data was then tested using a paired two sample t-test at a 95% confidence level. The results showed that the null hypothesis was rejected, thus the alternative hypothesis that the mean number of average MICAPs produced by each system are not equal is accepted. The infrastructure with the CSF located at the depot produced 0.3767 fewer average MICAPs than the system with a geographically separate CSF. These results indicate that concerning the number of average MICAPs generated by system operation, an infrastructure with the CSF located at depot is preferred to an infrastructure with a geographically separate CSF. A discussion of the meaning of these results is presented in Chapter V.

V. Discussion, Recommendations, and Conclusions

Chapter Overview

This chapter discusses the importance of the rejection of the hypothesis that the mean number of average MICAPs generated by each system are equal. The chapter will begin by revisiting the research objectives and research questions found in Chapter I. Next, the importance of the findings will be discussed. Finally, recommendations for future research will be presented.

Research Objectives

Research objective one was to build a model that accurately represents proposed lean logistics infrastructures. This objective was made significantly easier by the discovery of the AFLMA computer model that represented different lean logistics infrastructures. Minor changes were made to the model for this specific research effort and the model was revalidated as an accurate model. In order to satisfy objective one the following questions were answered.

What are the options for lean logistics infrastructures? Although the AFLMA study examined four different infrastructures, only two infrastructures were chosen for this research. The two options for lean logistics infrastructures adopted by this thesis were one with a geographically separated CSF and one with a CSF located at the repair depot.

What are the transportation times involved in the different infrastructures? For the infrastructure with a geographically separated CSF, transportation times were determined by the researcher to be two days using express air. For the infrastructure with a CSF located at the repair depot, it was determined that there was no significant shipping time.

For all other shipments involved in the logistics system it was determined that both structures would use two days by express air.

What are the appropriate SBSS data? The appropriate SBSS data included national stock numbers, base repair cycle times, NRTS condemned times, percentage of base repair, high velocity repair times and daily demand rate. These data can be found in Appendix A. The lean levels for each part was also required and was collected as a result of the AFLMA research effort. The lean levels for each part can be found in Appendix B.

Research objective two was to assess the effects of different lean logistics infrastructures on strategic airlift capability. This objective was satisfied by answering the following research question.

What is the effect of the different infrastructures on the average number of MICAPs in the logistic system? This question was answered by testing the hypothesis that the mean number of average MICAPs for each system would be the same. The statistical results showed that the means were not the same. The system with a CSF located at the depot will have on average 0.3767 fewer MICAPs, over a period of twelve years, than the system with a separated CSF. The importance of this finding is discussed below.

Discussion of Findings

The statistical results displayed in Chapter IV proved that the average number of MICAPs for each system were not the same. The results show that the system with a CSF located at the depot will have on average .3767 fewer MICAPs, over a period of twelve years than the system with a separated CSF. Therefore, concerning the average number of MICAPs in the system, the infrastructure with a CSF located at depot is the best choice for implementation. However, it is important to note that average number of MICAPs is only one of many performance measures that can be used to evaluate a logistics system. These results do not show that one system is better than the other system in all areas. This research does show that the infrastructure chosen to implement lean logistics is an important consideration as different infrastructures can be expected to lead to different numbers of MICAPs in the system.

The results indicate that by having the CSF located at the repair facility the expected number of MICAPs in the system should be less than the expected number of MICAPs in the system if the CSF is geographically separated. These results are more than likely a function of the reduction of the total number of days in the logistic pipeline. It was anticipated that having the CSF located at the repair depot would result in fewer MICAPs; however, without statistical evidence to demonstrate otherwise it was possible that the location of the CSF was not a significant factor when considering the overall logistics infrastructure.

These results do not prove that one logistics system is better than the other. Again, it is important to note that this research compared the two systems based only on the average number of MICAPs. The average number of MICAPs does not provide any information as to the operating cost of each system. It also does not provide any direct information as to aircraft availability or number of flying hours produced. The inability to translate the average number of MICAPs into a more meaningful performance measure is the largest shortcoming of this research effort. Average number of MICAPs is just one of many performance measures that can be used to evaluate a logistics system. Other measures that would be more useful in determining which infrastructure are best are discussed below.

Suggestions for Future Research

In conducting this research it became obvious that more research could provide better insight into which lean logistics infrastructure would best support strategic airlift capability. This research effort used the average number of MICAPs in the system to compare the two infrastructures. The number of MICAPs in the system is by no means the definitive performance measure. Future research could use different performance measures to examine whether or not the same conclusions are found. Aircraft availability is a difficult performance measure to examine, but would certainly provide more valuable insights into which infrastructure is best for strategic airlift capability.

For research using aircraft availability as a performance measure, the same computer model that this study used could be used again. Changes would need to be made to receive the proper output from the model.

This research effort treated the depot repair activity as a black box, with no awaiting parts or funding shortfalls, and no repair constraints. Every part that entered the depot, exited immediately following the appropriate high velocity repair time. This situation does not exist at depots. As with any repair center, depots face constrained repair capacity and AWP problems. This model excluded these aspects for simplicity, and for a focus on transportation times. A research effort that used a model that considers a depot with a constrained repair capacity would give a more realistic picture of logistics pipeline capabilities. This could be accomplished by modifying the depot section of the same model that was used by this research. The model would have to depict the fact that each part would have only a certain number of repair stations and that each part has its own distribution of repair time that could be gathered from historical data.

Conclusion

The question of whether or not to implement lean logistics for the Air Force is one that has already been answered. The Air Force is rapidly moving towards implementing lean logistics in support of weapon systems. The pertinent questions now are how can the Air Force best implement lean logistics and what factors are important to consider when implementing lean logistics? By concluding that there is a significant difference between performance of the two infrastructures with respect to the average number of MICAPs in the system, this research showed that logistics infrastructure is an important factor to be considered when implementing lean logistics.

Appendix A. Model Input Data

Travis AFB

Stock number	HVRT	PBR	BRCT	NCT	DDR
1630011897830	4	0.8143	10.42	8.222	0.1802
1650001575945	7	0.2308	1.00	1.438	0.2878
1650004866297	11	0.2500	25.40	3.083	0.0526
1650011780487	17	0.1310	2.64	2.500	0.1976
1650012481754	6	0.3235	8.00	5.474	0.0756
1650013044171	6	0.4667	8.57	6.053	0.1109
1660004907426	4	0.1964	8.09	3.139	0.1244
2835001522382	2	0.1803	7.18	2.122	0.1520
2835004767768	2	0.0000	0.00	4.278	0.0556
2840002336043	28	0.1167	1.00	1.894	0.1333
2840010491177	15	0.0144	1.00	0.866	0.6156
2840011584264	12	0.0000	0.00	2.698	0.1067
2910009081429	2	0.1020	15.00	9.839	0.1308
2910011426707	3	0.1059	18.56	3.578	0.1943
2915001117770	3	0.0833	4.00	2.000	0.0322
4320004282147	3	0.0000	0.00	2.535	0.1111
4810002399239	4	0.1111	1.00	4.286	0.0709
4810007604136	3	0.0667	8.20	3.455	0.1667
4920002510569	3	0.2727	8.50	2.077	0.0489
5998000140041	1	0.0000	0.00	1.813	0.0400
6110002564309	1	0.1136	6.40	2.278	0.1033
6610000180683	8	0.4324	9.25	8.111	0.1124
6610001691601	10	0.2778	13.25	5.773	0.1984
6610005061745	10	0.6104	14.66	15.269	0.1711
6610012776337	3	0.2447	2.04	1.660	0.2226
6615012477291	270	0.7120	6.60	7.893	0.2998
6615012620503	270	0.8704	10.76	7.278	0.4121
6620012816386	8	0.2804	6.97	7.409	0.2488
6680011016437	2	0.2727	1.50	2.154	0.0544
6680011016438	3	0.3333	1.00	2.500	0.0294
6685008091394	3	0.0000	0.00	2.500	0.0390

Dover AFB

Stock number	HVRT	PBR	BRCT	NCT	DDR
1630011897830	4	0.1235	3.80	2.750	0.3983
1650001575945	7	0.0096	1.00	2.526	0.2448
1650004866297	11	0.1250	5.00	3.077	0.0685
1650011780487	17	0.0840	4.00	2.167	0.2863
1650012481754	6	0.1224	3.00	3.500	0.1116
1650013044171	6	0.9136	6.38	2.000	0.2129
1660004907426	4	0.1091	8.00	2.825	0.1222
2835001522382	2	0.2762	8.62	4.327	0.2525
2835004767768	2	0.0000	0.00	3.000	0.1333
2840002336043	28	0.0000	0.00	2.783	0.2222
2840010491177	15	0.0135	1.00	1.822	0.1644
2840011584264	1	0.0571	10.50	3.346	0.1556
2910009081429	2	0.0000	0.00	0.000	0.0492

2910011426707	3	0.2025	7.56	4.750	0.3621
2915001117770	3	0.0833	1.00	6.444	0.0540
4320004282147	3	0.0313	1.00	2.074	0.1422
4810002399239	4	0.1818	1.33	4.304	0.0897
4810007604136	3	0.1163	5.00	3.324	0.1911
4920002510569	3	0.0571	1.00	2.692	0.0778
5998000140041	1	0.0769	1.00	1.478	0.0578
6110002564309	1	0.1765	11.67	3.512	0.1593
6610000180683	8	0.3889	3.00	2.154	0.2120
6610001691601	10	0.3607	2.30	1.491	0.2985
6610005061745	10	0.6194	3.02	2.083	0.2978
6610012776337	3	0.0339	2.75	1.694	0.2923
6615012477291	270	0.8707	2.77	3.250	0.3952
6615012620503	270	0.8826	2.07	4.043	0.5822
6620012816386	8	0.4804	1.98	1.477	0.2705
6680011016437	2	0.0800	7.00	1.294	0.0610
6680011016438	3	0.0000	0.00	1.600	0.0509
6685008091394	3	0.0000	0.00	1.000	0.0208

Altus AFB

Stock number	HVRT	PBR	BRCT	NCT	DDR
1630011897830	4	0.0000	0.00	3.778	0.0489
1650001575945	7	0.0000	0.00	5.400	0.0378
1650004866297	11	0.1667	1.00	3.000	0.0133
1650011780487	17	0.1429	1.00	5.333	0.0156
1650012481754	6	0.0000	0.00	39.000	0.0022
1650013044171	6	0.9000	1.56	0.000	0.0222
1660004907426	4	0.1111	1.00	2.600	0.0200
2835001522382	2	0.0000	0.00	2.250	0.0200
2835004767768	2	0.0000	0.00	4.000	0.0156
2840002336043	28	0.0	0.0	0.0	0.0
2840010491177	15	0.0	0.0	0.0	0.0
2840011584264	12	0.0	0.0	0.0	0.0
2910009081429	2	0.0000	0.00	2.444	0.0222
2910011426707	3	0.0000	0.00	3.500	0.0178
2915001117770	3	0.2000	1.00	1.750	0.0111
4320004282147	3	0.0000	0.00	0.000	0.0000
4810002399239	4	0.0000	0.00	3.250	0.0156
4810007604136	3	0.0000	0.00	2.600	0.0178
4920002510569	3	0.0000	0.00	2.800	0.0111
5998000140041	1	0.0000	0.00	1.000	0.0289
6110002564309	1	0.0000	0.00	2.333	0.0267
6610000180683	8	0.0000	0.00	3.500	0.0178
6610001691601	10	0.0714	1.00	3.500	0.0311
6610005061745	10	0.7000	8.29	4.000	0.0222
6610012776337	3	0.0000	0.00	4.474	0.0422
6615012477291	270	0.8333	4.80	0.000	0.0133
6615012620503	270	0.7778	5.57	4.000	0.0200
6620012816386	8	0.3889	5.57	4.778	0.0400
6680011016437	2	0.2353	1.00	3.182	0.0378
6680011016438	3	0.1000	1.00	3.500	0.0222
6685008091394	3	0.0000	0.00	0.000	0.0022

Kelly AFB

Stock number	HVRT	PBR	BRCT	NCT	DDR
1630011897830	4	0.6667	4.33	7.000	0.0200
1650001575945	7	0.0541	80.00	14.400	0.0822
1650004866297	11	0.1250	1.00	3.571	0.0178
1650011780487	17	0.2143	5.67	4.857	0.0311
1650012481754	6	0.0000	0.00	4.000	0.0067
1650013044171	6	0.4286	2.00	4.500	0.0156
1660004907426	4	0.2857	2.50	1.500	0.0156
2835001522382	2	0.0000	0.00	0.000	0.0044
2835004767768	2	0.0000	0.00	4.000	0.0156
2840002336043	28	0.0000	0.00	6.136	0.0578
2840010491177	15	0.0000	0.00	6.295	0.1400
2840011584264	12	0.0000	0.00	7.421	0.0489
2910009081429	2	0.0	0.0	0.0	0.0
2910011426707	3	0.1111	14.00	5.200	0.0200
2915001117770	3	0.0000	0.00	8.333	0.0067
4320004282147	3	0.0000	0.00	7.000	0.0089
4810002399239	4	0.0000	0.00	5.000	0.0244
4810007604136	3	0.2857	22.00	25.600	0.0156
4920002510569	3	0.8333	7.20	4.000	0.0133
5998000140041	1	1.0000	14.00	0.000	0.0022
6110002564309	1	0.0000	0.00	4.250	0.0178
6610000180683	8	0.7500	4.89	4.500	0.0267
6610001691601	10	0.6364	6.43	6.750	0.0244
6610005061745	10	0.8333	5.80	4.000	0.0400
6610012776337	3	0.6667	1.00	1.000	0.0067
6615012477291	270	1.0000	2.67	0.000	0.0133
6615012620503	270	1.0000	6.59	0.000	0.0489
6620012816386	8	0.8000	9.42	38.000	0.0333
6680011016437	2	0.0000	0.00	2.500	0.0044
6680011016438	3	0.0000	0.00	3.500	0.0067
6685008091394	3	0.0000	0.00	0.000	0.0000

Westover AFB

Stock number	HVRT	PBR	BRCT	NCT	DDR
1630011897830	4	0.3000	8.67	2.571	0.0222
1650001575945	7	0.2500	2.00	3.000	0.0178
1650004866297	11	0.2000	12.00	8.750	0.0111
1650011780487	17	0.2857	2.33	3.500	0.0467
1650012481754	6	0.8378	22.10	3.500	0.0822
1650013044171	6	0.6429	11.56	2.800	0.0311
1660004907426	4	0.6364	16.14	4.500	0.0244
2835001522382	2	0.0714	36.00	80.308	0.0311
2835004767768	2	0.1667	1.00	2.667	0.0133
2840002336043	28	0.0	0.0	0.0	0.0
2840010491177	15	0.0	0.0	0.0	0.0
2840011584264	12	0.0000	0.00	0.000	0.0000
2910009081429	2	0.0	0.0	0.0	0.0
2910011426707	3	0.000	0.00	3.000	0.0156
2915001117770	3	0.0000	0.00	0.000	0.0067
4320004282147	3	0.0000	0.00	2.400	0.0133
4810002399239	4	0.5000	10.00	2.333	0.0133
4810007604136	3	0.9697	25.13	34.000	0.0733

4920002510569	3	0.0000	0.00	4.900	0.0222
5998000140041	1	0.0000	0.00	3.167	0.0133
6110002564309	1	0.0667	1.00	78.786	0.0333
6610000180683	8	0.0000	0.00	3.000	0.0044
6610001691601	10	0.4000	8.25	3.750	0.0444
6610005061745	10	0.7273	8.25	4.000	0.0244
6610012776337	3	0.2222	4.00	3.167	0.0200
6615012477291	270	0.9167	6.82	4.000	0.0267
6615012620503	270	0.9231	7.75	4.000	0.0578
6620012816386	8	0.5217	12.42	3.125	0.0511
6680011016437	2	0.0000	0.00	4.000	0.0044
6680011016438	3	0.0000	0.00	2.000	0.0067
6685008091394	3	0.0000	0.00	0.000	0.0000

Stewart AFB

Stock number	HVRT	PBR	BRCT	NCT	DDR
1630011897830	4	0.3333	7.40	2.714	0.0333
1650001575945	7	0.1111	2.00	3.143	0.0200
1650004866297	11	0.0000	0.00	3.000	0.0089
1650011780487	17	0.1515	4.80	3.000	0.0733
1650012481754	6	0.6000	3.78	4.000	0.0333
1650013044171	6	0.9000	5.89	4.000	0.0222
1660004907426	4	0.2222	1.00	2.000	0.0200
2835001522382	2	0.1200	2.67	2.588	0.0556
2835004767768	2	0.0000	0.00	0.000	0.0000
2840002336043	28	0.0000	0.00	0.000	0.0000
2840010491177	15	0.0000	0.00	0.000	0.0000
2840011584264	12	0.0000	0.00	0.000	0.0000
2910009081429	2	0.0	0.0	0.0	0.0
2910011426707	3	0.0625	1.00	3.308	0.0356
2915001117770	3	0.0000	0.00	4.000	0.0022
4320004282147	3	0.2857	1.00	2.667	0.0156
4810002399239	4	0.1429	1.00	3.250	0.0156
4810007604136	3	0.5000	4.67	2.571	0.0400
4920002510569	3	0.1000	1.00	2.571	0.0222
5998000140041	1	0.0000	0.00	0.000	0.0000
6110002564309	1	0.2963	3.25	3.133	0.0600
6610000180683	8	0.0000	0.00	4.300	0.0244
6610001691601	10	0.2727	5.33	6.154	0.0489
6610005061745	10	0.0000	0.00	3.125	0.0533
6610012776337	3	0.0000	0.00	11.000	0.0244
6615012477291	270	0.8710	4.70	3.500	0.0689
6615012620503	270	0.7031	4.24	3.583	0.1422
6620012816386	8	0.2500	4.67	2.333	0.0267
6680011016437	2	0.0000	0.00	3.000	0.0111
6680011016438	3	0.0000	0.00	3.333	0.0111
6685008091394	3	0.0000	0.00	0.000	0.0022

Appendix B. Lean Stock Levels

Stock Number		Travis	Dover	Altus	Kelly	Westover	Stewart	CSF
1630011897830		4	4	1	1	1	1	8
1650001575945		2	3	1	4	1	1	12
1650004866297		2	1	0	1	1	0	5
1650011780487		2	3	1	1	1	1	19
1650012481754		2	2	1	0	4	1	5
1650013044171		3	3	0	1	1	1	3
1660004907426		2	2	1	0	1	1	5
2835001522382		2	4	1	0	5	1	6
2835004767768		1	2	1	1	0	0	4
2840002336043		2	3	0	2	0	0	20
2840010491177		4	2	0	3	0	0	27
2840011584264		2	3	0	2	0	0	9
2910009081429		4	1	1	0	0	0	4
2910011426707		3	5	1	1	1	1	8
2915001117770		1	2	0	1	0	0	3
4320004282147		2	2	0	1	0	0	5
4810002399239		2	2	1	1	1	1	4
4810007604136		3	3	1	2	4	1	7
4920002510569		1	1	0	1	1	1	3
5998000140041		1	1	1	0	1	0	3
6110002564309		2	3	1	1	5	1	5
6610000180683		3	2	1	1	0	1	7
6610001691601		4	3	1	1	1	1	11
6610005061745		6	3	1	1	1	1	7
6610012776337		2	3	1	0	1	1	8
6615012477291		5	3	0	0	1	1	51
6615012620503		8	4	1	1	2	2	58
6620012816386		5	2	1	2	2	1	9
6680011016437		1	1	1	0	0	0	3
6680011016438		1	1	1	0	0	0	3
6685008091394		1	0	0	0	0	0	2

References

Balci, Osman. "How to Assess the Acceptability and Credibility of Simulation Results," Proceedings of the 1989 Winter Simulation Conference (Not Published).

Cohen, I.K., R.A. Pyles and R.A. Eden. "Lean Logistics: A More Responsive, Robust and Affordable System." RAND Draft Report DRR-630-AF. Prepared for the USAF. January 1994.

Cohen, I.K. and R.A. Pyles. "Empowering the Commands to Provide Logistics Support." RAND Issue Paper Vol X, Number X. Prepared for the USAF. 1992.

Conover, W.J. Practical Nonparametric Statistics (Second Edition). New York: John Wiley and Sons, 1980.

Department of the Air Force (a). Draft Air Force Doctrine. Document 40: Logistics. Class handout, LOGM 568, Logistics Management. School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson AFB OH, Fall Quarter 1994.

Department of the Air Force (b). Draft U.S. Air Force Logistics Strategic Plan. Class handout, LOGM 568, Logistics Management. School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson AFB OH, Fall Quarter 1994.

Fogleman, Ronald R. "Air Mobility: A Key to Success in Joint Warfare." Vital Speeches of the Day. Vol LIX No. 14. 1 May 1993.

Forger, Gary. "What to do When Your Customer Insists on Bar Coded Labels." Modern Materials Handling: 49-54 (May 1993).

Halliday, John M and Nancy Y. Moore. "Materiel Distribution: Improving Support to Army Operations in Peace and War." Arroyo Center RAND Issue Paper, March 1994.

Kulwiec, Ray. "Bar Code System Cuts Packaging, Inventory Costs." Modern Materials Handling: 69 (May 1993).

Lund, John, Ruth Berg and Corinne Replogle. "An Assessment of Strategic Airlift Operational Efficiency." RAND Report R-4269/4-AF, Santa Monica CA, July 1993.

Moore, N.Y. and others. "Material Distribution: Improving Support to Army Operations in Peace and War." RAND Draft Report DRR-440-A. Prepared for the U.S. Army, Novermber 1993.

Pritsker, A. Alan B. Introduction to Simulation and SLAM II Third Edition. New York: Halsted Press, 1986.

Pyles, Raymond A. and I.K. Cohen. "Using Emerging Business Practices to Meet New Logistics Challenges. RAND Issue Paper IP-108. Prepared for the USAF, February 1993.

Ramey, Timothy L. and Raymond A. Pyles. "Would Just-In-Time Improve Logistics Responsiveness and Cost." Rand Issue Paper IP-110. Prepared for the USAF, 1992.

RAND Corp. "Businesses' Lean Production Adapted to Lean Logistics." Executive Summary. Class handout, LOGM 568, Logistics Management. School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson AFB OH, Fall Quarter 1994.

Reynolds, Steve and others. AMC Lean Stock Levels. AFLMA Final Report LS940390, Air Force Logistics Management Agency, March 1994.

Roos, John G. "Force-Projection Logistics: Total Asset Visibility from Factory to Foxhole." Armed Forces Journal International: 29-32 (February 1994).

Statistix User's Manual. Version 4.0. Analytical Software, 1992.

Stone, Donald G. and Michael A. Wright. Applying the Dyna-METRIC Inventory Model for Strategic Airlift. MS Thesis, AFIT/GLM/LSM/84S-62. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1986 (AD-A-147268).

Suit, William, Dr. "The Logistics of Air Power Projection." Air Power History: 9-18 (Fall 1991).

Surrey, William Capt USAF. (a) "C-5 Lean Logistics Test Plan." Report prepared for the USAF, October 1994 (Not Published).

Surrey, William Capt USAF. (b) "Lean Logistics Demonstration." Report prepared for the USAF, March 1994 (Not Published).

Tuttle, William G.T. Jr."Control and Accountability: Key to In-Transit Asset Visibility." Defense Transportation Journal: 14-16 (August 1993).

Udo, Godwin J. "The Impact of Telecommunications on Inventory Management." Production and Inventory Management Journal: 32-37 (Second Quarter 1993).

Woodworth, Donald A Jr. "Air Transportation In-Transit Visibility." Defense Transportation Journal: 17-20 (September/October 1993).

Wykle, Kenneth and Michael Wolfe. "Looking Beyond In-Transit Visibility." Defense Transportation Journal: 8-11 (August 1993).

Vita

Captain Russ C. Major was born on 29 April 1969 in Vineland, New Jersey. He graduated from Gresham High School in Gresham, Oregon in 1987. He earned his Bachelor of Science degree in General Studies from the United States Air Force Academy in 1991. After receiving his commission into the United States Air Force and completing the Aircraft Maintenance and Munitions Officers Course, he was assigned to the 96th Organizational Maintenance Squadron at Dyess AFB, Texas.

During his tour at Dyess AFB, Captain Major spent all his time on the flightline, filling different positions in support of the B-1B aircraft. These positions included Assistant Maintenance Supervisor in the 96th OMS, Officer in Charge of the Specialist Flight in the 338th Combat Crew Training Squadron, and Maintenance Supervisor of the Sortie Generation Flight in the 337th Bomb Squadron. Captain Major entered the Air Force Institute of Technology at Wright-Patterson AFB, Ohio, and graduated in 1995 with a Masters degree in Logistics Management. He was subsequently assigned to Headquarters Air Mobility Command.

Permanent Address: 1313 Park Ave.
Sanford, FL 32771

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
September 1994

3. REPORT TYPE AND DATES COVERED
Master's Thesis

4. TITLE AND SUBTITLE
ASSESSING THE IMPACTS OF LEAN LOGISTICS INFRASTRUCTURES ON STRATEGIC AIRLIFT CAPABILITY

5. FUNDING NUMBERS

6. AUTHOR(S)
Russ C. Major, Captain, USAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Institute of Technology,
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GAL/LAL/95S-6

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
28 BS/MAU
Dyess AFB TX 79607

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The purpose of this research was to compare two lean logistics infrastructures to see which one would provide better support for the C-5 aircraft. The level of support was defined as the average number of mission capable parts (MICAPs) created by system operation. One infrastructure had the central storage facility (CSF) located at the depot, and the other had a geographically separate CSF. A computer simulation model developed by the Air Force Logistics Management Agency was run for a period of twelve years and the average number of MICAPs for each system was collected. The data was then analyzed using a paired T-test. The results showed that the infrastructure with the CSF located at the depot resulted in significantly fewer average MICAPs over a twelve year simulation period. The conclusion is that with regards to the average number of MICAPs produced by system operation, an infrastructure with the CSF located at the depot is desired.

14. SUBJECT TERMS
Lean Logistics, C-5 Aircraft, Strategic Airlift, Mission Capable Parts (MICAPs), Central Storage Facility (CSF), Depot, Computer Simulation, Paired T-test.

15. NUMBER OF PAGES
48

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified

20. LIMITATION OF ABSTRACT
UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std Z39-18