3-2004

An Analysis of Depot Repair Capacity as a Criterion in Transportation Mode Selection in the Retrograde Movement of Reparable Assets

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THESIS

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AFIT/GLM/ENS/04-08

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THESIS

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

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March 2004

AFIT/GLM/ENS/04-08

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Abstract

To support smaller reparable asset inventories, current Air Force logistics policies direct the "expedited evacuation of reparables … to the source of repair." Mode selection is based on the asset. Focusing on the asset is an efficient and effective method of getting assets to where they are needed in a timely manner in the forward portion of the supply pipeline. However, in the reverse portion of the pipeline, the demand for an asset may no longer be critical to how it is transported. The quantity of the asset at the depot may already exceed repair capacity. In this instance, rapid movement, results in the asset being added to the backlog already awaiting repair. Retrograde modal selection focus should shift to repair capacity. Since the depots face budget and manning constraints and do not operate on a continuous basis, their repair capacity is limited. With finite repair resources, the question of when an asset can be repaired should be involved in mode determination.

This thesis will evaluate current Air Force retrograde transportation mode selection policy. Using Warner Robins Air Logistics Center reparable asset production data, this thesis will compare depot pipeline inventory for a random sample of reparable assets against the depot's repair capacity. If depot pipeline quantity is greater than the depot repair rate, then use of premium transportation is inappropriate, unless it is the lowest cost mode. The difference in cost between the mode used and the alternate mode will demonstrate the potential savings of using depot repair capacity as a determinant of mode selection.

For Mom & Dad

Acknowledgements

First and foremost, I give praise and thanks to the Lord Jesus Christ for the abundant grace, wisdom and love which He has given to the Kahler family during our time at AFIT and especially in the completion of this thesis.

I also owe a debt of gratitude to my wife and children who endured what almost amounted to a hardship tour, full of many nights and weekends with me absent at the school working on my studies. Thank you for your love and support. The cheers of "Yeah, Daddy's done with his thesis!" will not soon be forgotten.

I would also like to express my sincere appreciation to my thesis advisor, Dr. William Cunningham, for his guidance and support throughout the entire thesis process. Without him, this research would not have been accomplished. Thanks is also due to Lieutenant Colonel Swartz, my reader, whose knowledge of depot level repair and insight into the work our air logistics centers do, helped overcome a potential work stoppage.

In addition, I would be mistaken not to mention my friend and fellow AFIT student, Captain Steve Gray, for his insight into the Air Force supply system and for providing the depot supply data so vital to this research. I'm not sure if there is anyone else who has such a cogent grasp of how the Air Force supply system functions.

Finally, I'd like to thank my fellow loggies in AFIT GLM-04. They have made this experience enjoyable at times and bearable in others and I have learned a great deal from them.

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AN ANALYSIS OF DEPOT REPAIR CAPACITY AS A CRITERION IN TRANSPORTATION MODE SELECTION IN THE RETROGRADE MOVEMENT OF REPARABLE ASSETS

I. Introduction

Background

Current Air Force retrograde transportation mode selection policy is focused on the reparable asset. It is the category (type) or priority (based on asset type or demand) of the asset which dictates the transportation mode used in the shipment of a not-reparable this station (NRTS) reparable asset is returned to the depot for repair. Both supply and transportation have policies or processes which influence (or direct) how a NRTS asset gets from its base to the repair depot. This most often equates to a broken asset being shipped back to the repair depot via premium air transportation. Subsequently, the Air Force spends a significant amount of money on this retrograde movement of NRTS reparable assets. The Air Force stands to realize substantial savings in transportation costs if it uses a least cost selection method in determining mode for the shipment of these assets.

The Air Force supply system has switched from the traditional reliance on inventories to a reliance on the use of transportation. While Chapter II of this research will discuss this in further detail, the Air Force supply system is transportation based. As one Air Force Logistics Management Agency study stated, "Air Force supply policies are closely linked to the use of premium transportation. The logic for these policies is based on the classic tradeoff between inventory investment and transportation costs…" (Masciulli, Boone, & Lyle, 2002:2). In order to take full operational advantage of its capabilities, in light of smaller inventories, the Air Force has made reliance on the quick movement of assets throughout the supply chain an imperative. To support the smaller reparable asset inventories, Air Force supply policy directs the "expedited evacuation of reparables by bases and deployed units to the source of repair." (USAF, June 1998: 1).

It is the Reparable Information Management Control System (RIMCS) that puts this process in motion. RIMCS is the Air Force system directly concerned with the "the movement of reparable carcasses from the base … when the local maintenance does not have the capability or authority to repair the item." Based on the RIMCS control code assigned by the materiel manager of a specific item (which are based on the inventory position of the asset), the base supply function puts a supply priority designator of 03 (high) or 13 (low) on the asset (USAF, July 2003: 17). The asset is then transferred to base transportation for movement to the depot.

Two important points can be made about Air Force supply policies and process. First, the overall emphasis here is on the asset. Which is to say the focus is on the type of asset or on the demand for the asset and its inventory position in light of that demand. Second, reparable asset management directs the asset's "expedited" movement off the base and to the depot. This rationale for this is the use of fast transportation to offset smaller inventory levels.

It is at this point that Air Force transportation policy impacts how a NRTS asset moves to the depot. The Transportation priority assignment, according to AFI 24-201, *Cargo Movement*, corresponds to the supply priority, although certain other policies (such as GSA small package express and Agile Logistics) may dictate faster movement for certain reparable items that fall within the scope of those policies. Very succinctly, Air Force transportation guidance states the "norm" for reparable assets is commercial express carriers (USAF, 1999: 9). Bottom line, Air Force transportation guidance directs that if it is a reparable asset it is going via fast transportation. As with the supply policies above, the same two points can be made here. Once again the focus is on the asset (does it fall within the guidelines of a specific policy) and its quick movement off the base and to the depot.

Focusing on the priority of the asset and moving it quickly is an efficient and effective method of getting assets to where they are needed in a timely manner in the forward portion of the supply pipeline. This is true because in the forward portion of the pipeline, it is the demand for the item which should drive speed of shipment. However, in the reverse portion of the pipeline, the demand for a particular type of asset should no longer be the sole determinant of how fast an asset is shipped. The focus should shift to the capacity of the Air Logistics Centers (ALC) to repair the asset. Since the ALCs do not operate on 24-hour shifts, 365 days a year and also have budget constraints, their capacity to fix reparable assets is limited. With finite repair resources, the question of when an asset can be repaired should be involved in mode determination. Obviously, if there are no assets at a deport repair facility and it is idle, then assets should be expedited, so asset priority should be factored into mode selection, but in only to a limited extent.

Depot repair capacity and depot pipeline inventory (that is what assets are already at the depot awaiting repair or currently being repaired) determine how quickly an asset can be inducted and repaired. Both limited repair capacity and the quantity of items in the depot pipeline mean that a NRTS asset that is shipped fast may arrive at the depot only to sit and wait for repair. The quantities of the asset within the depot pipeline may exceed the capacity for the depot to induct and repair. Thus the quantity of assets already at the depot, as well as the available capacity to fix these assets should be taken into account in determining transportation mode. Otherwise valuable assets merely stack up at the depot awaiting repair and the limited repair capacity shows itself as the constraint in the entire system.

The focus of mode selection should be shifted from the asset to what is happening at the depot. The depot's repair capacity at the depot should be taken into account in determining transportation mode. Linking what is happening at the depot repair facilities and how a NRTS asset is shipped entails synchronization. This synchronization of transportation mode selection with depot repair capacity is essential to achieve gains in this area. The Strategic Distribution program that is co-operatively run between U.S. Transportation Command (USTRANSCOM) and the Defense Logistics Agency (DLA) cites reverse logistics as an area where important gains can be made in "readiness, reduced inventories, and long-term cost savings." (USTRANSCOM and DLA, 2003: 15).

Problem Statement

Overall Air Force mode selection policy is by fast, time-definite and traceable means. While mode is not dictated, certain transportation policies, such as Agile Logistics, Two-Level Maintenance and Rapid Parts Movement, dictate the use of fast transportation in the retrograde movement of reparable assets that are not-reparable this station (NRTS). This most often equates to a broken asset being shipped via premium air transportation (Masciulli, Boone and Lyle, 2002 and Kossow, 2003). Subsequently, Air Force spends a significant amount of money on the retrograde movement of NRTS reparable assets, when it may be unnecessary.

Thus the transportation mode criteria being used in the retrograde movement of NRTS assets may be inappropriate. The focus is on the asset, and its type and the current demand for the asset. While these are important, in the reverse portion of the logistics pipeline, using these to determine the shipment mode is does not consider an important factor affecting this decision. This factor is the limited or finite repair capacity within Air Force depots. The fact that there is a finite repair capacity should be the major determinant in how an asset is shipped. Even in the example of the idle repair shop, it is the available capacity of repair which correctly drives how a NRTS asset should be shipped. In short the mode selection decision must be linked to what is happening at the depot.

Once again, the focus should be on what is happening at the depot. Depot pipeline inventory has a major influence on how quickly an asset can be inducted and repaired. Mode selection for NRTS assets should take this into account. As discussed significant gains can be made if mode selection and repair capacity are linked. Quantity of assets already at the depot should be taken into account in determining transportation mode. If the number of assets already in the depot pipeline exceeds the depots repair capacity, then getting it there quickly will mean the asset just sits and awaits repair. In such cases a least cost mode selection method is warranted.

Research Question

The question this thesis will seek to answer concerns how the Air Force selects which transportation mode to use in the reverse segment of its reparable pipeline, that is the segment from base to repair facility. The research question which will guide this study is, should depot repair capacity be a factor in retrograde transportation mode selection? Thus, this study will evaluate whether or not the capacity of the depot to repair a NRTS asset should be taken into account in modal determination.

Investigative Questions

In order to answer this question, four investigative questions will be used to answer portions of the overall issue. The first question is, what factors determine modal selection? The answer to this question will entail a review of the academic/practitioner literature on transportation mode selection, as well as a review of Air Force policy and studies on that policy. The second question is when is a slower mode appropriate and when would it be inappropriate? This question will look at whether or not a slower mode is always better or if there are times that premium transportation should be used. The third question, how many assets have a depot stock quantity greater than the depot repair rate, will be answered through analysis of the supply data. The fourth question, what are the potential savings available by using depot constraints to determine transportation mode, will take the results of the third question and use the lowest cost mode to calculate savings.

Research Objectives

This thesis will build upon previous graduate research which found that significant savings are readily available if policies affecting mode selection are relaxed (Kossow, 2003). This will be accomplished by evaluating whether depot repair capacity should be a factor in retrograde transportation mode selection. In doing so it will review applicable supply and transportation policy and previous research on reparable asset management and mode selection to determine when it is advantageous to use a slower mode of transportation.

While the methodology will be discussed at greater length in chapter III of this thesis, the approach used will be to compare depot pipeline inventory for a random sample of reparable assets against the against depot repair capacity. If depot pipeline quantity is greater than the depot repair rate, then use of premium transportation is inappropriate, unless it is the lowest cost mode. The difference in cost between the mode used and the alternate mode multiplied by the number that could be shipped using a least cost approach will yield the total potential savings had depot repair capacity been used to determine mode. In essence, the depot repair capacity is being used to establish the service level required for retrograde shipments.

Research Significance

As the Strategic Distribution program's guidance states the synchronization of repair and transportation of reparable assets back to depots can achieve significant gains in readiness, reduction of inventories and in long-term savings. The fact of the matter is that the Department of Defense, in general, and the Air Force, in specific, expend a significant amount of resources in the retrograde movement of reparable assets. The research that this thesis is building upon, in its comparison of mode rates showed the Air Force could save close to $1 million annually by relaxing mode selection policies--with no loss of effectiveness. The Air Force, in the period between January and July 2002 (the period covered by the transportation data obtained for this study), alone spent approximately $21 million on the retrograde movement of NRTS assets world-wide[*]. Clearly the Air Force and thus the Department of Defense (DoD) are leaving a significant sum of money on the table and stand to gain through more effective management in the retrograde portion of the supply pipeline.

Scope and Limitations

On a daily basis, the Air Force ships a tremendous amount of cargo both to and from its depots. In order to effectively examine retrograde shipment policies it is essential to limit what will be examined. This research is intended to evaluate the use of depot repair capacity in retrograde mode selection for NRTS reparable assets. In doing so it will consider only shipments from within the continental United States (CONUS) to

[*] Note: This figure is derived from the transportation data from the D087T, "Tracker" database. The data covered some 250,777 retrograde shipments. The data was missing entries in several fields and only 103,717 records (or 41.3%) contained cost data. The total of all the available cost data was $20,931,067.70.

Air Force repair depots. Shipments from overseas and shipments to contractor repair facilities will not be used.

Furthermore, this thesis is the first step in looking at the efficacy of using depot repair capacity as a mode selection criteria. The objective is to determine the extent of savings available, if any, of using it depot repair capacity in this manner. If savings are found, further work will be required to determine and evaluate how to best use this information at operational bases for mode selection.

II. Literature Review

Introduction

This thesis seeks to examine current Air Force transportation mode selection for the retrograde movement of Not-Reparable-This-Station (NRTS) reparable assets. Preceding graduate research has determined that transportation mode criteria may be inappropriately determined by the priority of the asset. The focus here is on the asset, rather than on what is happening upstream in the depot repair pipeline. There may already be sufficient quantities of the asset within the pipeline for the repair shop to induct and repair. The focus should be on what is happening at the depot. Depot pipeline inventory has a major influence on how quickly an asset can be inducted and repaired. Quantity of assets already at the depot, as well as depot repair capacity should be taken into account in determining transportation mode. If there are a large number of assets in the depot pipeline, then the use of premium transportation in this instance would be an inefficient use of limited transportation resources. Getting it there quickly only means the asset sits at the depot. In such an instance a least cost method may be warranted.

Transportation mode selection for the retrograde movement of reparable assets falls into three distinct categories of logistics. The first is reverse logistics. This area provides the overall context for the thesis; of interest is a definition of reverse logistics and current thought on the area from military and business sources. The second area, also provides a context for the thesis, it is the management of reparable assets. The focus will be on how the Air Force manages reparable assets. The last area is transportation mode selection. Current thought on mode selection will be looked at and also how air force transportation managers conduct mode selection.

Reverse Logistics

If, as Peter Drucker once wrote, logistics was "the economy's dark continent" (Drucker,1962: 8), then reverse logistics is its deepest heart. Reverse logistics is a relatively new area in logistics and firms are just beginning to come to terms with its importance. It has been described by one author as "a fairly new concept in logistics…" (Dowlatshahi, 2000: 30). According to Rogers and Tibben-Lembke (2001:129), "little is known about the size and scope of reverse logistics activities." Stock (2001: 2) stated that many firms know little about reverse logistics and its importance. Stock and Lambert's 1981 book *Strategic Physical Distribution Management* (now in its fourth edition and re-titled *Strategic Logistics Management*), describes reverse logistics as, "…going the wrong way on a one-way street because the great majority of product shipments flow in one direction" (Stock & Lambert, 2001: 24).

Reverse logistics provides the general context for this research, in that, it is the reverse or return flow of NRTS reparable assets back to the depot upon which this research will focus. In this light, it is important to review how the literature defines reverse logistics, take a look at its importance and the characteristics of an effective reverse logistics system.

Reverse Logistics Defined

While the body of knowledge on reverse logistics may be limited, several logistics professionals have developed definitions of this area of logistics. Rogers and Tibben-Lembke adjusted the Council of Logistics Management definition of logistics and defined reverse logistics as:

> The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or proper disposal (Rogers & Tibben-Lembke, 2001: 130).

Two of the largest areas of reverse logistics are recycling and product returns. With this in mind, Stock (2001: 24) defined reverse logistics broadly and provides insight into its activities with this definition, "the role of logistics in product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal and refurbishing, repair and remanufacturing." In looking at Stock's definition it is easy to see the connection between reverse logistics and green logistics (that part of logistics seeking to reduce the environmental impact of logistics activities) and quite a few authors (for example, Jayaraman, Guide, & Srivastava, 1997: 1160; Carter and Ellram (1998), Dowlatshahi (2000)) have defined reverse logistics in that manner. Many use the terms interchangeably (Rogers & Tibben-Lembke, 2001: 130). Figure 1 shows the overlap between reverse and green logistics, as well as the activities involved:

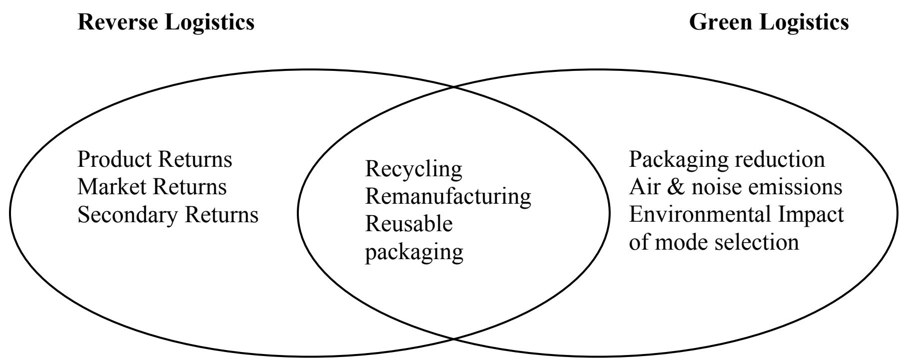

Figure 1. Overlap of Reverse and Green Logistics

(Rogers & Tibben-Lembke, 2001: 131)

For the purposes of this research, the focus will be narrowed to the movement of materials from "point of consumption to the point of origin" (Rogers and Tibben-Lembke, 2001). Robert Banks (2002: 3), in an article in, *Army Logistician*, further clarifies this perspective with this definition of reverse logistics. He defines it as, "the timely and accurate movement of serviceable and unserviceable materiel from a user back through the supply pipeline to the appropriate activity." The purpose of that upstream movement will be for either repair or disposal. This definition is more closely aligned with the thesis topic for the concern is the movement of NRTS assets from the user to the repair activity (depot).

Importance of Reverse Logistics

Both the Banks (2002) and Rogers & Tibben-Lembke (2001) articles agree there has been an increase in the importance of reverse logistics. Why is this so? The answer lies in the growing recognition of the need to curtail costs and increase efficiency. Reverse logistics costs are estimated at approximately $35 billion (Stock, Mar 2001). One author states the importance of reverse logistics lies in "…the avoidance of lost buying power; RL [reverse logistics] makes the greatest and most efficient use of existing resources (Banks, 2002: 3). Another article states, "…by ignoring the efficient return and refurbishment or disposal of a product many companies miss out on a significant return--on investment" (Andel, 1997: 61). Effective management of reverse logistics is not just a cost avoidance measure; it can also generate revenue (Andel, 1997; Stock, Mar 2001; Rogers & Tibben-Lembke, 2001 and Mason, 2002). One author stated, "…any manufacturer not paying attention to its reverse logistics process…is simply siphoning profits from the bottom-line" (Richardson, 2001: 37).

Characteristics of an Effective Reverse Logistics System

Different authors provide unique perspectives on reverse logistics and thus emphasize certain aspects as important, but even so two characteristics are frequently referred to as key to an effective reverse logistics system: efficiency and synchronization.

Effective management of reverse logistics can give a competitive advantage (Dowlatshahi, 2000 and Stock 2001). Playing on the "seven deadly sins" of Dante's *Divine Comedy*, Stock, states the failure to recognize this advantage is the first deadly sin of reverse logistics (Stock, Mar, 2001: 2). The savings and service improvements that can be garnered in reverse logistics can be the edge a firm needs in a competitive industry. While reverse logistics is not large enough for a firm to compete solely on the cost savings or revenue generated by it (Rogers & Tibben-Lembke, 2001; Stock, 2001), it can be a point of differentiation (Stock, interviewed in Mason, 2002: 46).

While it will never be as important as the forward side, there is a significant amount of resources involved in reverse logistics and firms neglect it at the risk of passing over at least a source of cost avoidance, if not revenue (Andel, 1997, Stock, Mar 2001; and Mason, 2002). In order to realize these gains, an effective reverse logistics system needs to be efficient and cost effective. Other aspects of logistics, such as quality or time-definite delivery, that are considered more important are quickly becoming order qualifiers; expected by customers (Stock, Mar 2001). As stated above, an efficient, well-thought out reverse logistics system can differentiate them from their competitors as they reduce customer risk through efficient return/repair processes (Stock, Mar 2001; Rogers & Tibben-Lembke, 2001: 145). The key is providing the service in such a manner as to maximize the use of resources. Maximizing resources is the "logistician's ace in the hole" (Banks, 2001:3).

Efficient use of resources relies to a great extent on the second characteristic of an effective reverse logistics system, the visibility of what is happening upstream with the reverse or retrograde movement of NRTS assets. In forward logistics the urgency of an item can be the sole determinant in the expenditure of resources (the selection of transportation mode). However, in the reverse pipeline, what is happening upstream at the depot needs to be taken into consideration (Kossow, 2003: 4). Visibility of what is occurring upstream will allow for a more efficient utilization of resources, in the form of a more efficient means of transportation and in a smoother scheduling of repair activities (Kossow, 2003:48 & Banks, 2001). This potential for synchronization within the reverse logistics pipeline, to a great extent, has to do with how reparable items are managed. This is the second topic of this literature review.

Reparable Item Management

Similar to reverse logistics, this area also provides context for this study for the concern is with NRTS reparable assets. Reparable item management is very much related to reverse logistics, because a portion of it deals with the planning for the movement of unserviceable assets from the user to the repair activity. For this study, we are not directly concerned with the theory behind reparable item management. Instead it focuses on the Air Force manages its reparable pipeline. However, before reviewing how the Air Force reparable pipeline is managed, a basic definitional look at repairable (or reparable) items is beneficial.

Reparable Inventory Management

A reparable item is an item which "is not consumed in use" (USAF, 1994: 3). These assets can be readily repaired for reuse when they become unserviceable (Anderson, 2003). Reparables are typically high cost, long-life assets which are more economical to repair than to replace with new assets (Guide & Srivastava, 1997). One author describes reparable items in this manner:

> ...our weapons systems are more sophisticated, logistically complex, costly, and automated than at any time in our history. No one will argue that components eventually will fail and have to be replaced. And no one will argue that it generally is more cost effective to repair or rebuild these components that to purchase new ones… (Banks, 2001:5)

Reparable pipelines are concerned with the optimal stocking of parts at bases and at a central repair activity. The goal is to maximize weapon system availability, subject to a budgetary constraint (Guide & Srivastava, 1997: 1).

The Air Force reparable pipeline is essentially a self-contained system or what is known as a closed loop system. One study described such a system like this: "The flow of materials in this environment occurs in both directions from customer and the remanufacturers. Since most of the products and materials are conserved this essentially forms a closed-loop logistics system…" (Jayaraman, et. al., 1997: 1159). Unserviceable or not-repairable-this-station (NRTS) assets are recovered from users, repaired and returned. There are two parts to this pipeline, a forward (flow from depot to base) and retrograde (or reverse). Kossow (2003:11) provides a detailed review of the pipeline.

One important aspect of such a system is that the retrograde portion of the pipeline (concerned only with the return of NRTS assets to the repair activity) is supply-driven vice demand-driven. In other words, the repair facility is not in control of when (or for that matter what condition) NRTS assets are returned. This creates more uncertainty in regards to quantity, timing and condition of items (Jayaraman, et. al., 1997: 1160). Figure 2, on the next page, provides a simple model of a reparable pipeline (forward portion in gray).

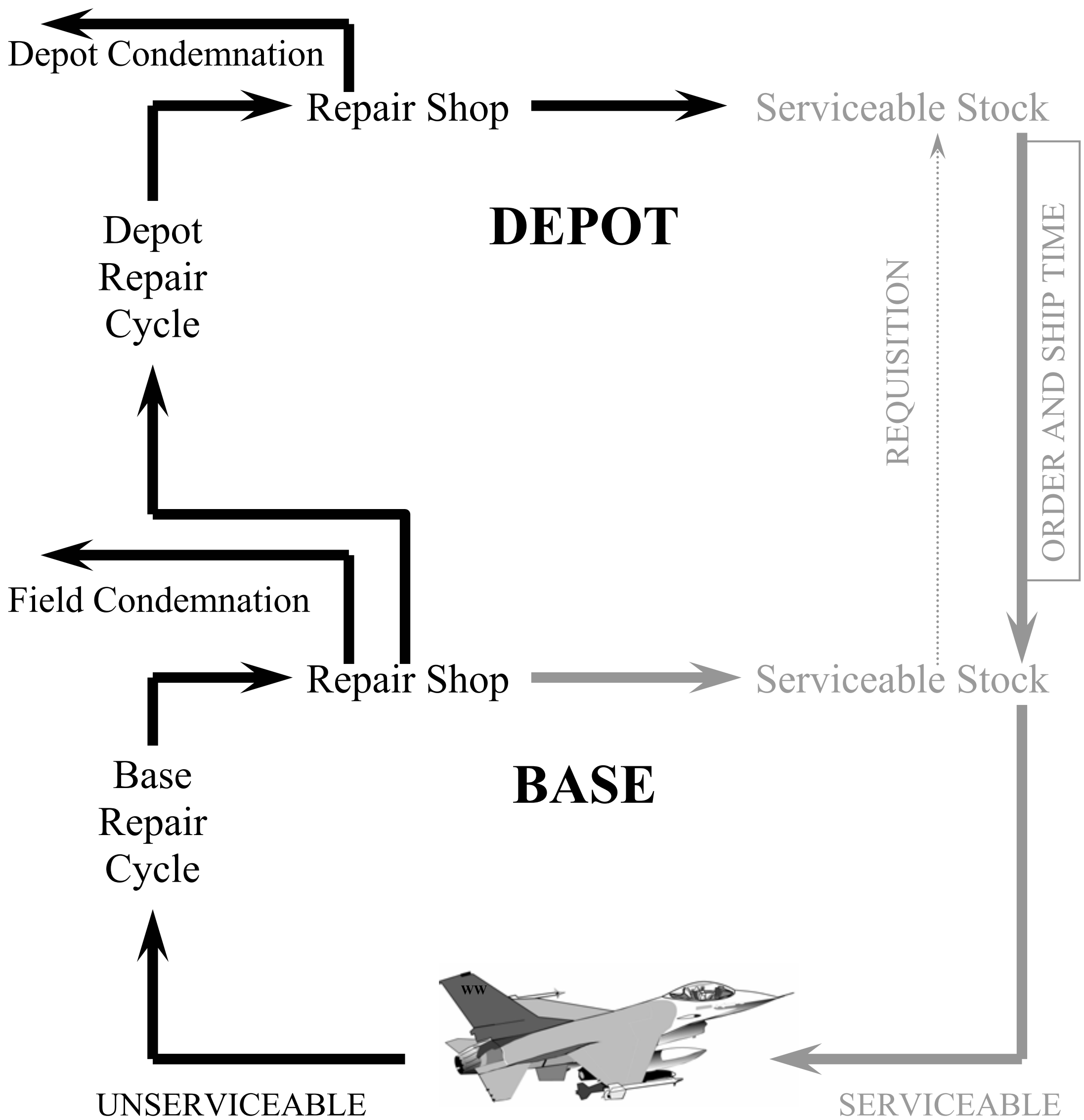

Figure 2. Conceptual Closed-loop reparable pipeline

(Isaakson, et. al., 1988: 6)

The Air Force Reparable Pipeline

Air Force guidance on management and direction of the reparable item pipeline is primarily found in AFPD 20-3, *Air Force Weapon System Reparable Asset Management* (USAF, Jun 1998) and the Air Force instruction which implements this policy directive, AFI 21-129, *Two Level Maintenance and Regional Repair of Air Force Weapon Systems and Equipment* (USAF, May 1998). This guidance provides the scope of the reverse pipeline which, "begins when a weapons system reparable asset is removed from an end item, repaired or declared as NRTS and concludes when the item has returned to the serviceable inventory" (USAF, Jun 1998:3). This is a slightly expanded view of reverse logistics previously discussed which ended when the item returned to point of origin. In AFPD 20-3 the Air Force expands the scope of retrograde logistics to include the re-positioning a newly-repaired asset. This guidance provides the basis for the reparable pipeline:

> The objective of Air Force logistics is to maximize operational capability by using high velocity, time definite processes to manage mission and logistics uncertainty in-lieu of large inventory levels--resulting in shorter cycle times, reduced inventories and cost, and a smaller mobility footprint (USAF, Jun 1998: 1).

The policy directive goes on to direct the "expedited evacuation of reparables by bases…to the source of repair" (USAF, Jun 1998: 1).

The most significant aspect of this guidance is that the Air Force pipeline is transportation-based. Air Force logistics relies on a time definite and expedited means of transportation instead of inventory to counter variability. An Air Force Logistics

Management Agency (AFLMA) study described the rationale for this reliance in this manner:

> Air Force supply policies are closely linked to the use of premium transportation. The logic for these policies is based on the classic tradeoff between inventory investment and transportation costs…Air Force inventory policies are sensitive to transportation or pipeline times because inventory costs tend to be relatively high and transportation costs low. (Masciulli, Boone, & Lyle, 2002:2).

The Air Force's transportation guidance, AFI 24-201, *Cargo Movement*, also reinforces this notion: "Increased transportation costs are offset by reduced inventory levels resulting in overall logistics savings and mission sustainment" (USAF, Jan 1999:9)

Transportation Mode Selection

Reliance on transportation to support lower inventory levels and faster cycle times, places a premium on transportation mode selection. This is especially true, in light of the implications it has on other areas of logistics. In this section of the literature review, the importance of modal choice will be reviewed and determinants of modal choice will be looked. After reviewing this, how the Air Force sets transportation priorities and accomplishes mode selection will be discussed.

Importance of Modal Selection

As discussed earlier with reverse logistics, firms are looking for ways to be more efficient and gain a competitive advantage. In doing so, they are looking at system wide inventories and many are looking at the impact of mode selection and its impact on the whole logistics system. Various authors have stated that the importance of transportation mode selection lays in its impact on a firm's total logistics system (Stock and Lambert, 2001; Coyle, Bardi, & Novak, 2000; Liberatore & Miller, 1995; Sheffi, Eskandari, & Koutsopoulos, 1988). But more than that, it is the interaction and synergy between logistics activities that drive costs. Stock and Lambert (2001: 28) state, "Effective management and real cost savings can be accomplished only by viewing logistics as an integrated system and minimizing its total cost given the firm's customer service level." Figure 3 illustrates the interaction between logistics activities.

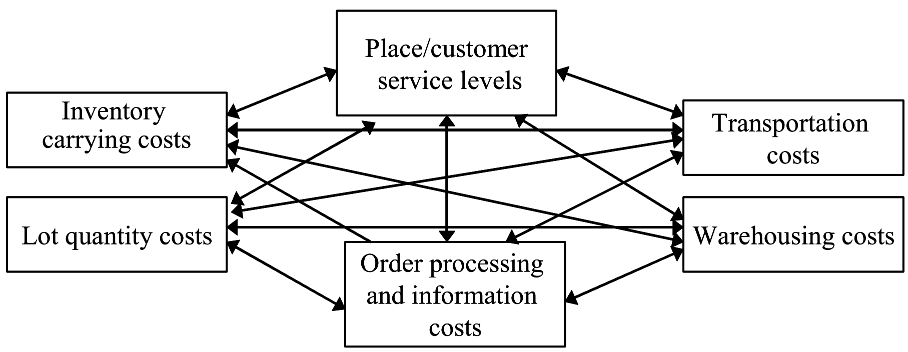

Figure 3. Logistics activity trade offs

(Stock and Lambert, 2001: 29)

It is this interrelationship that makes the modal selection decision important. Firms have to be cognizant of how inventory, warehousing, transportation, and customer service are interrelated and that a change in one will have an impact on the other areas too. Because of the interrelationship between logistics activities, the decision of modal choice involves tradeoffs between the activities. Modal choice is important because of the impact it has on customer service and total logistics costs.

Determinants of Modal Choice

These two factors, customer service and total logistics costs, are also the major determinants, or major points of commonality in the literature on modal choice of modal choice. Added to them is the need for flexibility in determining mode. This portion of the literature review will review what the literature says about each.

The customer service level provided by a mode of transportation is the preeminent factor involved in mode choice. It should be noted that by customer service we are not talking about a warm greeting and a friendly smile. We are talking about the ability of the mode to deliver shipments reliably, in minimal time with minimal damage. Stock and Lalonde, in a pre-deregulation study found that service related variables, such as reliability, loss/damage, and total transit time, were most important (Stock & Lalonde, 1977: 57). For pre-deregulation this would have to be true, since price was set by law and the only way for a mode/carrier to differentiate itself from its competition was through service (Maciulli, 2001: 9).

However, other studies (McGinnis, 1990, Murphy & Hall, 1995) have shown this to be true even after deregulation. Confirming this and broadening the scope to post-deregulation, McGinnis found that, "While post-deregulation literature suggests that shippers have placed greater emphasis on costs since 1980, shipper priorities have not changed fundamentally…" (McGinnis, 1990: 17). Murphy and Hill (1995), in their analysis using studies published in the early 1990s showed that customer service still was the preeminent factor, however costs has grown in importance during post-deregulation, "Shippers in the U.S. value reliability more highly than cost and other service variables in the freight transportation choice process…" (Murphy & Hill, 1995: 37)

It should also be noted that when costs are considered, transportation literature cite the trade-offs between costs and customer service. The goal in this trade-off is to use the lowest cost transportation *consistent with a given service level*. The overwhelming driver of mode choice cited was customer service first, followed by an optimization of costs (Giese, 1995; Rautenberg, 1995; Coyle, et. al, 2001; Stock & Lambert, 2001) or rather as Stock and Lambert (2001) put it minimizing costs given a given level of customer service.

However, costs must be considered. Quite a few authors make this point. "Freight rates are an important variable that should not be ignored…" (McGinnis, 1990:17). "Economic and resource constraints mandate that organizations make the most efficient and productive mode and carrier choice decisions possible (Stock and Lambert, 2001: 355). But when costs are considered, freight cost should not be considered in isolation. Coyle, Bardi and Novak (2001) state that not considering the total picture is hazardous, in that simply selecting a low cost mode, while lowering transportation costs, may raise inventory or warehousing costs, as well as lower customer service.

Sheffi, et. al. (1988), in a study for the Burlington Northern Railroad (BNR), developed a model based on total logistics costs. The total logistics costs (TLC) considered in this model were "the sum of transportation, inventory carrying costs and any other cost of doing business with a particular mode…" (Sheffi, et. al, 1988: 138). While the last of the costs is the somewhat vague, "any other costs," the key point is that the mode selection decision has to consider the costs beyond that of the rate being charged.

In addition to service and total costs, flexibility is also a key determinant of modal choice. If modal selection is dependent upon the trade-offs made between service-level and total costs, then there needs to be some flexibility in the selection mechanism or methodology to allow for opportunities where cost is more important than service.

The aforementioned studies by McGinnis (1990) and Murphy & Hall (1995) take this up. McGinnis (1990: 14) proposed six factors which influenced mode selection:

1. Freight rates (costs, charges, rates)
2. Reliability (reliability, delivery time)
3. Transit time (time-in-transit, speed, delivery time)
4. Over, short and damaged (loss, damage, claims processing, and tracing)
5. Shipper market considerations (customer service, user satisfaction, market competitiveness, market influences)
6. Carrier considerations (availability, capability, reputation, special equipment)

These factors include both service and cost variables. Both studies showed the variability in the relative importance of these factors and mentioned there would be occasions where cost may be more important. "…price becomes a major factor after service objectives have been met and in some instances may be the most important variable…" (McGinnis, 1990:18). Thus the influence of the six factors can/will vary, not only by shipper, but also by transaction, depending upon the specific situation (McGinnis, 1989: 44). This implies a need for flexibility.

Air Force Transportation Mode Selection

As previously mentioned, the Air Force logistics system is transportation-based and relies on a time definite and expedited means of transportation instead of inventory to counter variability. This places a premium on effective mode selection. The applicable transportation guidance in this area consists of: the *Defense Transportation Regulation* (DTR), Part 2 (DoD, 2000) which sets time standards and allows for expedited movement of cargo when needed; AFI 24-201, *Cargo Movement* (USAF, Jan 1999), which is the overarching Air Force transportation regulation and *Air Mobility Command Freight Traffic Rules,* Publication Number 5 (AMC, 1999), which applies DoD transportation rules to all carriers hauling freight for the DoD. These three regulations cover the span of the movement of freight within the DoD and the Air Force. In addition to the transportation guidance, AFI 21-129, *Two-level Maintenance and Regional Repair of Air Force Weapons Systems and Equipment* (USAF, May 1998) states the following:

> Traffic managers must ensure that reparable 2LM [two-level maintenance] items are evacuated as quickly as possible for shipment to repair activities. Shipment planners must make every effort to ship those assets the same day they are received from Supply or Maintenance organizations (USAF, May 1998: 11).

So from the guidance on reparable maintenance come instructions to get the NRTS asset off the base as quickly as possible. It also states that the reparable assets should be "moved using fast, time-definite best value transportation…" (USAF, May 1998: 11).

However, as one study of Air Force shipping policies states, "the definitive word comes from AFI 24-201" (Masciulli & Cunningham, 2001: 4). This transportation instruction provides Air Force transportation managers with the direct guidance that tell them how to go about selecting the mode of transportation for a NRTS asset. Chapter 2 of AFI 24-201, provides the concept of operations for transportation managers.

It specifies that all reparable items will be shipped using commercial express: "Commercial air express small-package delivery service… is the norm for Agile

Logistics/2LM/Rapid Parts Movement shipments to met Air Force sustainment goals."(USAF, Jan 1999: 9-10; Masciulli & Cunningham, 2001:4 and Kossow, 2003: 16-17). It also sets a rigorous and compressed time standard of 24 hours from the time an item is declared NRTS by maintenance till it is processed through supply to transportation and picked up by the carrier. (USAF, Jan 1999:10). AFI 24-201 also states that the DoD, is a mandatory user of the GSA small package express program. In other words, any item shipped by the DoD (and thus the Air Force), must be sent by express air. The exceptions to this are provided in paragraphs 6.1.1 through 6.1.5 of the instruction (USAF, Jan 1999: 22). Three of the major exceptions are, under 500 miles, contingency operations and shipments over 151 pounds.

The overall Air Force policy on transportation mode selection (be it for forward or retrograde movement of assets) is a fast, time-definite, traceable means. Mode is not dictated (see also Kossow, 2003; Masciulli, et. al, 2002; and Masciulli & Cunningham, 2001). However, as is seen in AFI 24-201, it may be specified in certain instances. For example, an individual shipment under 151 pounds and over 500 miles distant from origin will be sent via express air under the terms of the GSA small package express contract. Three studies were found that evaluate the Air Force's mode selection policies. Two of which looked at the forward portion of the pipeline (Masciulli, et. al, 2002 and Masciulli & Cunningham, 2001) and one which recently looked at the retrograde movement of assets (Kossow, 2003).

Masciulli and Cunningham (2001), in the first of the forward logistics studies looked at Air Force Mission Capable (MICAP) part shipping policies and examined

MICAP shipment data. They found that, "current Air Force shipping policies are less than optimal from a cost standpoint"(Masciulli & Cunningham, 2001:4). Of interest is the finding of an over-reliance on the use of premium, over-night air to ship items. The data they used in this study had several examples of misuse of premium, over-night air, including a shipment that traveled a total of 11.4 miles. They raised the following question regarding this issue:

> …is the use of FedEx so ingrained in the Air Force and DoD corporate culture it is automatically assumed and used as the carrier for MICAP items and other time-critical shipments without regard to cost, distance or other factors? (Masciulli and Cunningham, 2001: 7)

The study compared the use of a lower cost mode of transportation to premium transportation. In conjunction with this they also asked whether or not all time-critical parts needed to be sent over-night or if a slower means would suffice. The mode they evaluated was less-than-truckload (LTL). Holding service level constant they found substantial savings were available in the shipment of MICAP parts within CONUS (Masciulli and Cunningham, 2001: 42).

The second forward logistics study was an AFLMA study of the Air Force use of premium transportation prompted by the Strategic Distribution Board of Directors, who were concerned that the Air Force was too reliant on this means of transportation. One area of interest in this study is the "disconnect" it found between the Air Force supply and transportation communities use of the terms fast and premium, "The Air Force supply community uses the term premium to indicate a desired velocity of movement (fast); however, the Air Force transportation community often interprets premium as a modal requirement (overnight air)" (Masciulli, et. al., 2002:2). These two thoughts together seem to confirm the previous study's notion of that the use of premium overnight air is ingrained in the Air Force corporate culture. While the study found that the use of premium transportation was "still a wise, economical decision" (Masciulli, et. al., 2002:7), it also stated that the use of LTL trucking within the CONUS may be a viable (in terms of cost and equivalent service) alternative.

Kossow (2003), was the sole transportation mode selection in the retrograde pipeline study. The purpose of Kossow's study was to show that with more flexibility in modal selection the logistics pipeline could be more efficient while maintaining the same level of service effectiveness. He first compared the services provided by the two modes and found that in terms of what the DoD requires, fast, time-definite, traceable (in transit visibility) and door-to-door service, both modes provide comparable levels. However, LTL's ability to get a package delivered overnight is limited to a regional service. LTL was also not always the low cost provider, with its cost increasing as distance increase and weight decreased (i.e. you would not want to send a simple letter via Roadway across country, it would be disproportionately expensive), likewise air becomes more expensive as weight increases and distant decreases (Kossow, 2003: 24, also Masciulli, 2001). Kossow's study compared the rates of express air and LTL trucks against historical retrograde shipment data. Table 1 shows the results of this analysis:

Table 1. Summary of Kossow Mode Comparison

	LTL only	Express Air Only	Lowest Cost	# LTL	% LTL	# Exp Air	% Exp Air
Less than 151 lbs (no consolidation)	$151,720	$73,810	$58,676	534	18.4	2,361	81.6
More than 150 lbs (no consolidation)	$64,072	n/a	$64,072	839	100.0	n/a	n/a
All weights (no consolidation)*	$215,756	$137,811	$122,713	1,371	36.7	2,361	63.3
All weights (consolidated)**	$62,748	$119,147	$60,401	420	48.5	446	51.5
* Express Air Only includes LTL portion for shipments greater than 150 lbs ** Includes consolidated LTL portion for shipments greater than 150lbs							

His analysis shows that the Air Force stands to reap significant cost savings by going to a low cost mode selection policy (while retaining the same service effectiveness). This figure gets even larger when you consider consolidating shipments. It should also be noted that this study used a small sample of Air Force only shipments, the cost savings could be even more substantial if applied DoD-wide (Kossow, 2003: 48). However, as policy currently exists, transportation managers do not have the flexibility in all cases to select the lowest cost mode nor can they hold onto an asset to gain efficiencies through consolidation.

Conclusion

The purpose of this thesis is to conduct an analysis of transportation mode selection for the retrograde movement of reparable assets in light of depot repair pipeline constraints. This study falls into three distinct categories of logistics: reverse logistics, reparable item management and transportation mode selection.

In reverse logistics, the literature reviewed showed a movement towards determining costs and gaining efficiencies, to maximize the use of existing resources. In addition, the need for visibility throughout the entire reverse logistics pipeline has the potential for synchronization of the return shipment of assets, which could result in even greater efficiency gains. This area provides the overall context for the thesis.

The second area, which also provides a context for the thesis, is the management of reparable assets. The Air Force manages reparables through the use of a transportation-based system, which leverages the cost savings gained by reduced inventories against the higher priced premium transportation to achieve high levels of logistics service effectiveness. One consequence of this system is that it is sensitive to changes in transit time, assets have to move through the system quickly in order for the service effectiveness to remain high.

The last area is transportation mode selection. Current thought on mode selection will be looked at and it was shown that service level, cost minimization and flexibility were overarching determinants of mode selection in current literature. The Air Force policy on mode selection were reviewed along with three studies which evaluated the efficacy of those policies. All three of these studies showed that from a cost perspective the Air Force was spending too much money on express transportation and could use less than truck load (LTL) trucking as a method of saving (Kossow, 2003; Masciulli, et. al, 2002; and Masciulli & Cunningham, 2001). Kossow (2003) also demonstrated the lack of flexibility in the current mode selection policies that direct transportation managers to get a NRTS asset off the base as quickly as possible, by the quickest means possible and that savings are available if a low cost mode selection policy was adopted. It is the purpose of this study to determine the extent and significance of this potential savings.

III. Methodology

Problem Statement

Current Air Force reparable asset management policy calls for the expedited movement of reparables, "…using high velocity, time definite processes to manage mission and logistics uncertainty in-lieu of large inventory levels…" (USAF, Jun 1998:1). In addition, Air Force transportation policy, while not dictating mode, further calls for the fast movement of reparable items (USAF, Jan 1999). This policy may focus inappropriately on the asset, rather than being contingent upon what is happening at the repair depot. The quantity of the asset at the depot may already exceed the depot's repair capacity. In this instance, the rapid movement of an asset to the depot would result in the asset arriving at the depot and being added to the backlog of items awaiting repair. This would be an inefficient use of transportation resources.

This thesis will gauge the efficacy of using depot capacity as a determinant of retrograde mode selection. As with the previous graduate research this thesis builds upon, no specific methodology was found, either in the DoD or commercial sector that deals with a comparative analysis of mode costs in the selection of transportation mode. In addition, no methodology was found that drew on the use of receiver capacity to process (by repairing or otherwise modifying) the item shipped as a determinant in mode selection. This thesis will follow a modified version of the methodology used by Masciulli (2001) and Kossow (2003) of comparing the efficiency of modal choice in terms of cost while holding service level constant. In this methodology, as the review of the literature showed, "…price becomes a major factor after service objectives have been met …" (McGinnis, 1990:18). The goal is to identify this "lowest cost mode" (Kossow, 2003). However, in this study, the required transportation service level will be determined by what is occurring at the depot. The quantity of assets at the depot and the depot's repair capacity will be used to determine what service level is required and then Masciulli and Kossow's methodology will be used to judge the efficacy of mode selection and determine cost savings.

Required Data

The data required would still consist of supply and transportation data and subsequently has numerous sources. The data sources for both types of data are as Department of Defense or Air Force supply and transportation databases. The supply data will consist of depot pipeline data and depot repair production data. While the transportation data will consist of transportation record data and rate information.

Supply Data

The supply data was provided by Headquarters Air Combat Command Supply Wartime Policy Office, from the DO35K wholesale and retail receiving and shipping database. According to a recent DoD inspector general report, "The D035K is the primary data system used by the Air Force to provide materiel support for depot-level operations…" (DoD, 2003: 2). The data consists of two measurements per month from January to July 2002. These measurements are "snapshots" of NSN supply status for that day. The depot pipeline data need from these measurements are the quantities of each NSN that are in the depot pipeline (or in other words that are physically at the depot) prior to induction for repair. This information comes in two forms (or types of inventory) and goes from asset arrival at the depot to its transfer from depot supply to depot maintenance. First, there are the carcasses awaiting induction for repair (condition code F). Together these two types of inventory are the stock the depot has on hand to maintain production.

The final piece of supply data required is depot capacity. While on the surface this may seem to be fairly simple and data that should be readily accessible, for if you do not know how much you are capable of producing, how can you plan production or budget for expenses? Or even more poignantly, what is capability of the depot to surge to meet an increase in demand due to a major regional conflict? However, depot capacity data could not be obtained from the air logistics centers (ALC). The Oklahoma City ALC's responded to a request for capacity data with the following:

> As we operate today Capacity is a very, very rough cut determination … capacity requirements planning at the rough cut level may indicate sufficient capacity exists to execute a master production schedule only to find at the micro level (close to or at the time of production) that capacity is insufficient … there are too many variables surrounding the determination of shop capacity to make any kind of reliable statement concerning the mode of shipment based on capacity data" (OC-ALC, 2004)

The other depots confirmed this, describing shop capacity as a "floating" or "running" figure based not only on budget, manning and equipment. With what a specific shop could produce in a given period varying on things such as training, vacation/sick leave, equipment maintenance and shop floor space. So a surrogate measure for depot capacity was developed.

The surrogate for repair capacity used in this study is monthly production rate. Historical depot production data was acquired from Warner Robins ALC (WR ALC). This data consisted of monthly quantities of NSNs produced by repair shops at WR ALC from October 2000 to December 2003 (although April 2002 data was unavailable). Rather than focus on the maximum amount a depot repair shop could produce in a given period, this study would obtain a measurement for production capacity by looking at how much of a given NSN was produced. The advantage to this is that while it does not give shop capacity it does provide an illustration of what a shop was able to produce (and accounts for the variability affecting shop capacity (cited by the depots as making a measurement of capacity problematic--since it accounts for the fact the shop also performed other tasks during the period too). An added advantage is that the period of the supply cover a period of high operations tempo (steady state operations in Bosnia, Kosvo, Turkey and Southwest Asia as well as the wars in Afghanistan and Iraq). So weapons systems were busy, which should require an increase in the number of assets requiring repair.

The data obtained provided production data for approximately 5,500 NSN per month between October 2000 and December 2003. The specific NSNs and their quantity varied each month, so that not every NSN was in each monthly record. Using Microsoft Access, these files were joined together to yield a sample of NSNs which were in each month. Thus yielding NSN with 38 observations of production data. These observations were summed and descriptive statistics (mean and standard deviation) were calculated to compare against depot stock. Since the number of observations is sufficiently large, normality is assumed under the central limit theorem.

Transportation Data

Transportation data came from Headquarters, Air Force Materiel Command's Logistic Support Office (LSO), and the D087T, "Tracker" database. Essentially it is basic asset transit data or in other words, information about an asset's trip from origin to destination. It consists of information about the asset: national stock number (NSN), asset condition code, number of pieces, weight. The rest of the transportation data are information about an asset's "trip," such as the transportation control number (TCN) (essentially the same as a FEDEX or UPS tracking number), origin and destination, ship and arrival dates, mode, cost, and weight. The transportation data required consisted of the trip information and cost data. Actual cost data was available in these records and will be used in the calculation of any cost savings.

In addition to actual transportation data, information on an alternate transportation mode is needed to evaluate the effectiveness of mode selection. For this study, that alternate mode will be less than-truck-load (LTL) trucking. It should be noted that, as demonstrated by Kossow (2003), LTL offers similar time-definite service, albeit limited by the distance to destination. The alternate data required are rate and transportation time data. As with the express air information, LTL tender rates from UPS were obtained and used to calculate LTL costs.

Methodology

The process begins with a paring down of the data available. Since only WR ALC provided production data, the pool of NSNs is limited to those which WR ALC is either the source of repair (SOR) or source of supply (SOS). The difference between SOR and SOS is repair (SOR) and management of the asset (SOS). An ALC that is SOR for an asset may not be its SOS (and vice versa). To ensure 30 or more observations, only those NSNs that were in all three years of the monthly production data will be used. These NSNs will then serve as a filter for the transportation data, NSNs having one or less shipments (air or ground) will also be culled out. Of the NSNs remaining, only those with eleven or more shipments will be used in this study.

Once the sample is obtained, the methodology for this study is fairly simple in nature. The intent is to evaluate the efficacy of the modal choice made. Throughout it will involve comparing the depot stock (consisting of condition code F carcasses in depot supply (CARC) and those carcasses in transit to the depot repair shop from depot supply (INT TO) with the depot production averages calculated from the WR ALC production data. If the depot stock is greater than the average monthly production plus three standard deviations, for a given reparable asset the asset can be sent by the least cost method. This test will be performed on all 3189 NSNs. Because there are 14 different DO35K data files available each NSN will be evaluated for efficiency of modal selection 14 times.

The use of $\mu + 3\sigma$ was decided upon because according to the empirical rule, 99.7% of all measurements fall within three standard deviations of the mean. Since for the purposes of this study only the right tail of the distribution is relevant (a measurement being $> +3\sigma$), that means 99.85 % (virtually all occurrences) of the time the depot repair shop's production rate will be less than $\mu + 3\sigma$. Figure four shows the calculations used in the for modal efficiency evaluation.

DEPOT STOCK = CARC + INT TO
IF DEPOT STOCK ≥ $\mu + 3\sigma$: fast transportation inappropriate
IF DEPOT STOCK ≤ $\mu + 3\sigma$: fast transportation is appropriate

Figure 4. Modal Efficiency Evaluation

The final step is to calculate a potential savings figure using an alternate mode (in this study FEDEX ground shipments) rate for shipments from the transportation data. Of the NSNs remaining after the paring is accomplished, a random sample of 35 NSNs will be selected to calculate this cost savings. In Microsoft Access, the results of the modal tests and the transportation data will be linked in a query which will filter for shipments of the 35 randomly selected NSNs, then for the given date of the DO35K file, and also will screen out those which had failed the test. So the calculation of savings will be limited to only those shipments on the date of the supply file which passed the depot stock v mean production test were used in savings calculation.

A significant number of transportation records were missing the actual cost data. Due to this fact, the 2004 FEDEX government domestic express rate for standard overnight shipments was used for the cost of the shipments. The 2004 FEDEX government rates for two and three day rates and the FEDEX standard commercial ground shipment rates were used to calculate the savings gained by going with a slower mode and the percentage off of the standard overnight rates were also calculated. The difference in cost between the mode used and the alternate mode multiplied by the number that could be shipped using a least cost approach gives the total potential savings. In order to ascertain what these savings might constitute when projected over the entire organically repaired NSNs, we extrapolate the savings from the random sample to the population. This will be accomplished by dividing it by the ratio formed by the dividing the sample from the next level up. These results will be discussed in the next chapter.

IV. Analysis

Preparation of Data Files

Before work on determining depot supply status and the ability to send NRTS assets by a slower method without jeopardizing service could begin the data had to be pared down. This involved filtering of both the transportation and supply data files to get to those records which are useable for this study.

Treatment of Transportation Data

The transportation data was received in text file format. There were considerable gaps in the data where information required for this study was missing. The data was imported into Microsoft Excel and required significant filtering to get to the useable records. That is, those records which were shipments via air within the continental United States (CONUS). This included filtering out records that did not fall within the scope of this study as well as those records missing information in the fields necessary for this study.

The process of getting to the useable records started out with filtering out the shipments originating from overseas (or OCONUS). This included those shipments from Hawaii, Alaska, Puerto Rico and Guam. The second step was to eliminate all shipments with blank origin fields. Eliminating both the overseas shipments and shipments with blank origins was done by scanning three fields from the transportation data (these fields were the origin, shipper loc and shipper loc inv fields).

Next, those records listing AMC or Military non-AMC in the carrier field were filtered out. In addition, AMC channel missions and special air assignment missions (transportation mode code F) were eliminated because these shipments are similar in nature to military shipments. The final step was to get eliminate all non-air modes of shipment. The transportation mode field was used to do this. Any non-air modes as well as those records with no data in that field were filtered out.

Filtering of the Supply Data

The DO35K database contains status for all NSNs in the Air Force inventory. However, since only WR ALC provided production data, the pool of NSNs was limited to those contained in the data provided by WR ALC. The DO35K data was received in Microsoft Access database format. The WR ALC production data was received in Microsoft Excel spreadsheets. The production data was imported into the database to filter for only those NSNs that were contained in the WR ALC production data.

The first step in the paring process was to ensure 30 or more observations of production data for any NSN looked at for potential retrograde shipment cost savings. Thus only those NSNs that were in all three years of the monthly production data were used. Each month of production data contained approximately 6,400 NSN records. Using Microsoft Access, a query was developed which linked the monthly files together by year and then another query was designed which linked the yearly queries together. This yielded 3189 NSNs which had production data in all three years.

The next step in the paring process was filtering out those records which had few transportation records. The 3189 NSNs obtained above were used as a filter for the transportation data, to determine how many shipments each of these NSNs had. NSNs having one or fewer shipments (air or ground) were filtered out. This resulted in the removal of the bulk of the NSNs, with only 593 NSNs having more than one shipment.

Of the 593, 380 NSNs had 10 or fewer shipments and were subsequently pared out; while 213 were more actively shipped and had 11 or greater shipments during the period under study. The 213 actively shipped NSNs were used for further analysis. The depot stock > $\mu + 3\sigma$ evaluation was performed on all of the 3189 NSNs for which production data was available for. Savings calculation was conducted only on the random sample of 35 NSNs drawn out of the 213.

Transportation Mode Evaluation

Once the sample was obtained, the ability to ship via a slower or lower cost mode was evaluated. The depot stock figure, consisting of the sum of condition code F carcasses in depot supply and those intransit from depot supply to the repair shop, was calculated. This figure was calculated for all 3189 NSNs for all 14 of the DO35K files. and was compared with the average monthly production plus three standard deviations. The following table displays the results of this comparison by sample size:

Table 2. Results of Modal Evaluation

Sample	Trials	Success	%
35	490	410	83.7
213	2982	2585	86.7
593	8302	6283	75.7
3189	44646	24189	54.2

The following chart shows the percentage of frequency with which NSNs' depot stock exceeded it production rate.

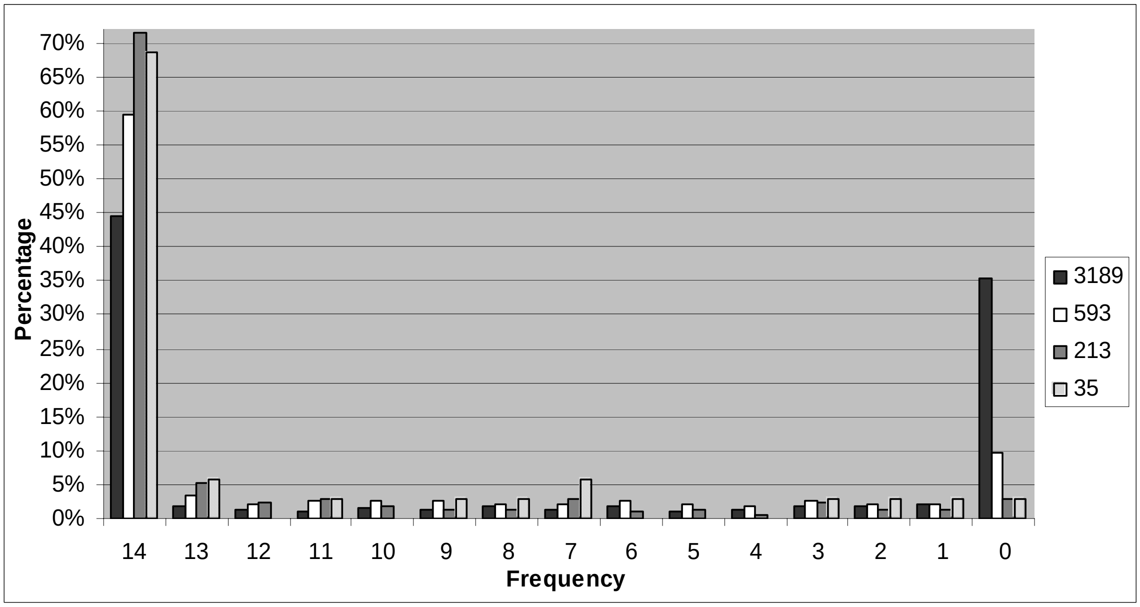

Figure 5. Modal Evaluation Results by Frequency Percentages

Potential Savings

After obtaining the results of the modal evaluation analysis, the data was filtered for those shipments on the dates of the DO35K files from the 35 NSNs whose depot stock allowed for slower transportation. From those shipments from NSNs whose depot stock exceed production rate the cost savings were calculated. 34 of the 35 sample NSNs had at least one occasion of depot stock exceed production rate. These NSNs had 114 shipments on the dates of the 14 DO35K files. The calculation of savings is The following table shows the results.

Table 3. Savings from Random Sample

	Cost	Savings	% of SO
Standard Overnight (SO)	2577.96		
2 day	2202.36	375.6	14.57%
3 day	2071.88	506.08	19.63%
Ground	**1080.05**	**1497.91**	**58.10%**

Looking at what that savings might constitute when projected over the entire organically repaired NSNs, we "inflate" the savings by dividing it by the ratio formed by the dividing the sample from the next level up. The following table shows the results of this extrapolation.

Table 4. Extrapolation of Savings

	Sample Size	Ratio	Savings
Total Organic Repair NSNs	133538		$ 5,715,083.02
WR ALC NSNs	50732	0.380	$ 2,171,199.15
NSNs with Production Data	3189	0.063	$ 136,481.00
NSNs with Activity	593	0.186	$ 25,378.88
213 > 11 ships	213	0.359	$ 9,115.85
Random Sample	35	0.164	$ 1,497.91
***This assumes the ratios hold throughout**			

Once again this figure is only for 14 days, assuming the ratios hold throughout. To get annual savings you would have to divided the savings figure by the ratio of 14/250 (assuming no shipments on weekends or federal holidays). Annualized extrapolation would yield savings of $ 102,055,053.87 for all NSNs and $ 38,771,413.33 for those managed by WR ALC

V. Conclusions

Research Objective

This research addressed the basis for Air Force transportation mode selection in the retrograde movement of reparable assets. Air Force inventory policy is transportation-based, offsetting the increased transportation costs with lower inventory expenses. Overall policy directs shipment by a fast, time-definite and traceable means. While in general mode is not directed, in the review of Air Force policy, it was shown that certain supply and transportation policies, such as Agile Logistics, Two-Level Maintenance and Rapid Parts Movement required fast movement of reparable items in those categories. According to one AFLMA study, this most often meant that a NRTS asset shipped via premium air transportation (Masciulli, Boone and Lyle, 2002).

The literature review has shown the focus of Air Force modal selection to be on the asset, its type and the current demand for it. While these are important in mode selection, in the reverse portion of the logistics pipeline, using these to determine the shipment mode omits a critical factor affecting this decision. This factor is the limited or finite repair capacity at repair depots. The fact that there is a finite repair capacity should be the major determinant in how an asset is shipped. Otherwise, if the depot has a sufficient quantity to work on (for this study a one month supply was considered sufficient), after express shipping the asset to the depot, it will just sit and await repair--a situation analogous to our military's notorious penchant for "hurry up and wait." A situation which also results in the over-expenditure of resources for premium air when a slower, cheaper mode would have sufficed.

Review of the Investigative Questions

In the review of the literature on transportation mode selection, variability was seen to occur not only by shipper and item but also by transactions of similar items, in what the factors influencing mode choice. So modal selection is not a "one size fits all" decision. Flexibility is required in how mode is determined. More importantly we saw that: "…price becomes a major factor after service objectives have been met and in some instances may be the most important variable…" So we that the answer to the first investigative question, what factors determine modal selection, is service, but cost if services are equivalent, with a need for flexibility in choice and a system wide view.

For the second question, when is a slower mode appropriate and when would it be inappropriate, in reviewing the three studies on Air Force transportation policy, we saw that the slower mode is appropriate when it can meet the required service level. For instance we saw premium air is still cost effective for the air force, but in the CONUS, savings could be had without service level unduly suffering. Kossow (2003) and FEDEX (2004), confirmed that ground shipment can offer the same service as premium air. As for the other side of this question, the slower mode becomes inappropriate as it fails to meet established service levels (once again, Masciulli's study confirmed the cost effectiveness of premium air in helping the Air Force meet service requirements with reduced inventories). So we cannot merely look at what's cheapest, but rather what gets the mission accomplished.

The third question was a natural outcome of the calculations used in the methodology. How many assets have a depot stock quantity greater than the depot repair rate? From the random sample of 35 reparable assets 83.7% (410 out of 490 trials) of the time when depot stock was compared to mean production rate plus three standard deviations, depot stock was greater. In addition, within the random sample, only one asset had no instances of depot stock being greater than the production rate. This meant that 83.7% of the time, for those 35 assets, the Air Force had more than what it had produce in a month.

The fourth and final investigative question sought to determine the potential savings that the use of depot constraints would garner for the Air Force. The methodology used to determine this was very conservative (using three standard deviations of a month's average production and not looking at shipments on any other dates but those from which depot pipeline data was taken). From the sample of 35 assets there were 114 total shipments over the 14 dates of the supply data files. From those shipments, the Air Force would have saved $1497 in using FEDEX's "off the shelf" ground shipment rate over the General Service Administration's small package express FEDEX standard overnight shipment rate. On average, this standard FEDEX ground rate was 58% cheaper than standard overnight. Assuming the sample ratios hold, this amount, projected over the entire organically repaired asset population presents savings of approximately $5.7 million.

Conclusions

USTRANSCOM's Strategic Distribution program guidance states, "Improved retrograde of valuable, repairable stock to Service maintenance depots, synchronized with depot repair schedules, has enormous potential in areas of readiness, reduced inventories, and long-term cost savings" (USTRANSCOM, 2003: 15). While reverse logistics and synchronization may not seem directly germane to transportation mode selection, it is essential to see that mode selection cannot be made in a vacuum but you must also consider the entire system. As Stock and Lambert put it, "effective management and real cost savings can be accomplished only by viewing logistics as an integrated system and minimizing its total cost given the firm's customer service level" (Stock and Lambert, 2001: 29).

Part of this systemic view entails taking into account what is happening at upstream at the source of supply and repair. This research asked the question, should depot repair capacity be a factor in retrograde transportation mode selection? The results make the answer to this question an emphatic yes. The high percentage of "passes" (incidences of depot stock being greater than depot production) indicates depot has more than enough to work on. For these items, shipment by premium air (standard overnight service) will not result in efficient induction, repair and return to using bases. Rather it will mean their addition to the assets already awaiting induction for repair.

Implicit in Air Force reliance on fast transportation to offset smaller inventories is that this tradeoff has to be made. So it should follow that the depot should be dependent upon fast shipment to maintain production. But, while this methodology presented depot stock as being greater than production rate as a "pass" or "success," it actually represents a failure of the logistics system to successfully make the tradeoff between inventory and transportation. In those instances a part was either sent too fast or a point where the Air Force possesses too much inventory was identified. This research illustrated that it is possible to switch modes without relaxing service level (in many instances, ground can match air in next day service) and also, with the 83.7% pass rate of depot stock greater than depot production, the service level can be reduced without impacting production.

Furthermore, this research was conservative in its determination of situations where assets could be shipped slower without impacting production. Under the methodology used in this analysis, even shipping the items back via ground (with the worst case transit time being a five day trip from the Pacific Northwest) would still result in those items awaiting repair, albeit at reduced transportation cost. This analysis has not approached the point of synchronization of transportation with repair production scheduling. It assumed, regardless of mode selected, that the items would still ship. However, because the production rate used was a monthly figure, the "passing" of the depot stock test, could also be a hold signal to the transportation coordinator. This could allow for further efficiencies and savings to be attained through shipment consolidation (perhaps even at the truck load level). Finer production rate data (at the weekly level) would further enhance the ability of this test to determine mode and get closer to synchronization. The closer the Air Force can get to synchronization of transportation with repair schedules the greater the transportation savings yield.

Recommended Research

As was mentioned, this study was very conservative in its estimation of cost savings. There are considerably more savings available in this venue, savings which require further research to verify. This research can be broadened in three manners. The first is to examine Oklahoma City and Ogden ALCs to see if their depot pipeline situation is, as is suspected, similar to that of Warner Robins ALC. Second, the transportation records used could be expanded to include assets coming from overseas shipments or to those shipments going to contracted repair facilities. In these first two, the focus is attempting to get an understanding of the size of potential savings. The third manner of broadening this study is to look at the forward portion of the logistics pipeline to see if some assets are being shipped too fast to operational bases (or stockage points), for the overall question is why ship if the quantity on hand exceeds demand.

The next logical and necessary step out of the research to determine the efficacy of using depot capacity in transportation mode selection is to develop a method to effectively communicate depot pipeline status to transportation managers at operational bases for mode selection. The information is already accessible in a variety of Air Force supply and depot maintenance data systems, a link of this to the base level managers of the supply and transportation processes is needed to effectively use depot pipeline quantity to make the decision.

Finally, both Mascuilli and Kossow cited an apparent pre-disposition among transportation coordinators to use express air. While it the proportion of transportation records going via express air was not directly looked at in this study it was noticed that there were several instances of the use of overnight air rather than ground shipment, when express air was not required by Air Force policy (under 500 miles) or when ground service could match the overnight air service level. Survey research among Air Force transportation coordinators could be done to examine this apparent pre-disposition.

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 074-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From – To)*
03-10-2004	**Master's Thesis**	Sep 2002 - Mar 2004

4. TITLE AND SUBTITLE

An Analysis Of Depot Repair Capacity As A Criterion In Transportation Mode Selection In The Retrograde Movement Of Reparable Assets

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Kahler, Harold M., Captain, USAF

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)

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8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/GLM/ENS/04M-08

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

HQ Air Force Materiel Command (AFMC)
Logistics Readiness Division (LGR)
Analysis Group (LGRM)
4375 Chidlaw Road, Room B113
Wright-Patterson AFB OH 45433-5006

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

To support smaller reparable asset inventories, current Air Force supply and transportation policies direct the "expedited evacuation of reparables by bases and deployed units to the source of repair." Mode selection is based on the asset. Focusing on the asset and moving it quickly is an efficient and effective method of getting assets to where they are needed in a timely manner in the forward portion of the supply pipeline. However, in the reverse portion of the pipeline, the demand for a particular type of asset may no longer be the most important factor in how it is transported. The quantity of the asset at the depot pipeline may already exceed the repair shops' capacity. In such an instance, the rapid movement of an asset to the depot, results in the asset being added to the backlog of items already awaiting repair. The focus should shift to the capacity to repair the asset. Since the depots have budget and manning constraints and do not operate on 24-hour shifts, 365 days a year, their capacity to fix reparable assets is limited. With finite repair resources, the question of when an asset can be repaired should be involved in mode determination.

This thesis will evaluate current Air Force retrograde transportation mode selection policy. Using Warner Robins Air Logistics Center reparable asset production data, this thesis will compare depot pipeline inventory for a random sample of reparable assets against the depot's repair capacity. If depot pipeline quantity is greater than the depot repair rate, then use of premium transportation is inappropriate, unless it is the lowest cost mode. The difference in cost between the mode used and the alternate mode will demonstrate the potential savings of using depot repair capacity as a determinant of mode selection.

15. SUBJECT TERMS

Reverse Logistics, Transportation Priority, Reparable item, Depot Level Repair, Fast Transportation

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					William A. Cunningham
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	65	(937) 255-6565, ext 4283 william.cunningham@afit.edu

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18