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Model Selection Analysis of Depot Level Reparable Asset Retrograde Shipments within the Continental United States

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MODAL SELECTION ANALYSIS OF DEPOT LEVEL REPARABLE ASSET RETROGRADE SHIPMENTS WITHIN THE CONTINENTAL UNITED STATES

THESIS

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Abstract

Transportation modal choice for the Air Force retrograde movement of reparable assets within the CONUS is inflexible and is not synchronized with the depot repair process. Additionally, transportation coordinators are compelled by unsynchronized priorities and shipping policies to use express air modes in all cases when the use of LTL modes may be available to meet actual service level requirements at a lower cost. There may be cases where the retrograde shipments of reparable assets via an alternative transportation mode, such as LTL, can still meet fast transportation requirements at an even lower cost than can premium transportation.

Historical retrograde shipment data of reparable assets was analyzed in terms of dollars to determine efficiencies resulting from various modal choices between express air and LTL modes. Additionally, the feature of consolidation was explored in portions of the analysis when LTL modes were selected.

The *Lowest Cost Mode* method of modal selection in conjunction with a consolidation strategy whenever LTL was used resulted in a 62,312 dollar or 50.8 percent cost benefit of aggregate transportation costs over a *Lowest Cost Mode* method without a consolidation strategy. Just the consideration of either LTL or express air modes in each shipment significantly reduced aggregate transportation costs.

Exclusive use of just one mode does not result in the most effective and efficient logistics pipeline. However, modal selections of both express air and LTL modes and exploitation of each mode's strengths of speed and consolidation, respectively is an effective tool to manage velocity of fast transportation in the Air Force logistics pipeline.

MODAL SELECTION ANALYSIS OF DEPOT LEVEL REPARABLE ASSET

RETROGRADE SHIPMENTS WITHIN THE CONTINENTAL UNITED STATES

I. Introduction

Background

"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 [keeping] large inventory levels—resulting in shorter cycle times, reduced inventories and cost, and a smaller mobility footprint" (AFPD 20-3, 1998:1). Fast transportation is one of the Air Force's high velocity, time-definite processes used as a tool to manage Air Force logistics uncertainty. "The higher cost of fast transportation modes is traded for the lower cost of reduced inventories; the Air Force is moving from a supply-based logistics system to a transportation-based system to reduce the logistics pipeline" (AFI 24-201, 1999:9).

"The Air Force transportation community interprets premium [transportation] as a modal requirement (overnight air)" (Masculli, 2002:4). Thus, premium transportation modes typically involve the use of express air carriers to achieve this next-day service level. Federal Express (FedEx), United Parcel Service (UPS), and Emery Express are three of a group of such government contracted carriers that provide next-day express air modes of transportation generally for shipments weighing 150 pounds or less (HQ AMC,

2002). These carriers are used by the Department of Defense (DoD) as premium transportation mode carriers for shipments within the Continental United States (CONUS), Alaska, Hawaii, and Puerto Rico (Masculli, 2001:3).

Although express air overnight service is considered the fastest mode of transportation, expedited surface modes exist that can provide comparable service levels and comparable or near comparable service levels for shipments moving in certain ranges of distance and weights within the CONUS. Additionally, the next-day air express mode is the most costly of transportation modes providing fast transportation (Masculli, 2001: 5). Less-than-truckload (LTL) shipping is a form of an expedited surface mode of transportation. "LTL carriers provide service to shippers who tender shipments lower than truckload quantities up to 20,000 pounds and consolidate these smaller shipments into truckload quantities for line haul to a facility where the shipments are disaggregated and into loads to same destinations (Coyle, 1994:134). Major LTL carriers include traditional carriers such as Roadway Express, Yellow Freight, and ABF Freight. Recently, parent air express firms have also introduced LTL service, like FedEx and FedEx Freight. These LTL carriers offer time definite 1-day, 2-day, 3-day, 4-day, and 5-day ground service levels available for shipments moving within certain regional ranges and at sometimes at costs lower than overnight express air services. Furthermore, the LTL mode has the capability to consolidate shipments into a one load, which can result in reduced rate structures. Whereas, air express carriers charge a specific rate based on the weight of each parcel regardless of how many parcels are sent at the same time and regardless of the distance traveled by the shipment. However, unlike express air, LTL does not typically fall into the Air Force's category of premium transportation.

The Air Force ships various kinds of assets through the logistics pipeline. One type, the reparable asset, is of much importance to the Air Force mission. A depot level reparable asset is a component part, subassembly, or accessory of a higher assembly of a weapon system that is not consumed in use but is designed to be repaired at an organic or contract repair depot for reuse (AFI 23-102, 3:1994). Air Force weapon systems can include various types of aircraft, vehicles, and equipment used to meet routine and mission critical requirements. The Air Force relies on the availability of reparable assets to maintain readiness of weapon systems. A major part of the Air Force logistics system is the logistics pipeline of reparable assets. From this point forward, a depot level reparable asset will be referred to as a reparable asset.

All reparable assets flow through a logistics system called the reparable logistics pipeline. Forward logistics and reverse logistics make up the bi-directional flow of reparable assets through this logistics pipeline. Forward logistics is the flow of serviceable assets from depots, consolidated inventory points, and other users of the asset to the weapon system maintainer in the field. Typically, the requesting unit needs the asset immediately to meet mission requirements and shipment is typically made using the fastest transportation mode available.

Reverse logistics is the management of the flow of unserviceable assets from the user of the asset to repair depots and the subsequent flow of repaired serviceable assets back to a consolidated inventory point where the asset is a state ready for issue. A repair depot is a centralized logistics facility where the using unit sends assets to be repaired or overhauled. The logistics system of unserviceable reparable assets moving from a user to a repair depot is the retrograde logistics pipeline of reparable assets.

All reparable parts are assigned supply priority codes to facilitate the desired velocity of movement through the retrograde pipeline depending on expected availability and demand of the asset in the overall logistics pipeline. A transportation priority is then assigned according to the urgency of the corresponding supply priority. Since repair depots do not have the capability to begin repair on each asset immediately, the repair of assets is prioritized and scheduled when repair resources will be available. Repair scheduling priorities are determined by a supply priority designators and urgency of competing assets to be placed back into active inventory. There is no direct synchronization of transportation priority and depot repair priority; therefore, retrograde transportation priority and transit times are based only on inventory and demand expectations.

The synchronization of supply and transportation priorities can be an effective tool in selecting transportation modes for forward logistics. In forward logistics, transportation coordinators should know the urgency of need of the asset by the user to select the appropriate transportation mode.

In reverse logistics, however, the urgency of need for the asset is also driven by the depot's repair schedule. Since repair depots do not have unlimited capacity to repair assets, depots cannot begin to repair every asset as soon as it is received that day. Therefore, bases should not need to ship every reparable asset to a repair depot via next-day premium transportation modes. Synchronization of the repair scheduling process with transportation mode selection could provide a means for transportation coordinators of retrograde shipments to make better transportation mode selections. The scope of this thesis will not attempt to design how this synchronization should occur, but points out the

advantage in synchronizing transportation modes more appropriately with repair schedules to allow use of lower cost transportation modes to meet velocity requirements.

A second driving factor in the selection of transportation modes of reparable assets is that the Air Force does not provide explicit defined guidance to transportation coordinators in the selection of transportation modes. However, current Air Force policies regulate modal selection, since reparable assets are required to be shipped using premium transportation (Masculli, 2002:4, 2001:2). Two programs that drive the policies in the selection of premium transportation modes are Small Package Express and Agile Logistics.

Small Package Express and Agile Logistics programs regulate the selection of transportation modes for retrograde shipments of reparable assets. Agile Logistics designates assets with an emphasis on the use of fast transportation modes to facilitate the high velocity, time definite requirements (AFI 24-201,1999:9). A vast majority of reparable assets is designated as those required to move via the fastest transportation modes (Masculli, 2002:4). The DoD mandates use of the Government Service Administration's (GSA) Small Package Express program for high priority shipments weighing 150 pounds or less and move 500 or more miles (AFI 24-201,1999:22). GSA negotiated rates with air express carriers for movements within the CONUS. A Worldwide Express program also exists for international shipments. This thesis will focus on the CONUS movement of reparable assets; therefore, the Domestic Express program is the relevant policy driving transportation mode selection.

Problem Statement

The Air Force is expending much effort to reduce all segments of the logistics pipeline: base evacuation cycles, depot repair cycles, and transportation transit times. In this reduction of the logistics pipeline, there is a tradeoff between increased transportation costs and a reduction in inventory costs.

There is no doubt that premium transportation is a necessary mode of transportation in this tradeoff of transit time and higher transportation costs. However, there may be cases where the retrograde shipments of reparable assets via an alternative transportation mode, such as LTL, can still meet fast transportation requirements at a lower cost than can premium transportation. With the reduction in surface transportation transit times becoming as fast or nearly as fast as air express transit times, more potential situations occur where LTL could be the more appropriate modal choice to meet repair depot schedules without an adverse affect on inventory levels. Transportation priorities are synchronized with expected inventory levels, but not directly with repair schedule priorities. Therefore, shippers may not be aware of when shipments could be made via LTL modes with time definite service levels of two, three, or even four day transit times.

Second, current transportation policies arising from Agile Logistics and Small Package Express programs discourage transportation managers from considering less expensive transportation modes, such as less-than-truckload (LTL) service, that potentially can meet required service levels at a lower cost than premium transportation. Furthermore, within certain ranges of distance and shipping weights, to include consolidated shipping weights, expedited surface transportation can meet the same service levels offered by premium transportation and at a lower cost. In some cases, LTL

will be fast enough to meet requirements and in some cases, express air is needed at all costs to meet velocity requirements.

Transportation modal choice for the Air Force retrograde movement of reparable assets within the CONUS is inflexible and is not synchronized with the depot repair process. Additionally, transportation coordinators are compelled by unsynchronized priorities and shipping policies to use express air modes in all cases when the use of LTL modes may be available to meet actual service level requirements at a lower cost.

Research Objectives

This thesis will review the retrograde logistics pipeline and the processes and policies that drive modal choice for shipments of reparable assets moving within the CONUS. Additionally, the thesis will review previous research on modal choice in the Air Force forward logistics pipeline and review modal choice theories in the civilian sector.

Historical retrograde shipment data and relevant modal choice conditions will be analyzed to compare the extent of efficiencies that result between utilizing premium transportation and LTL modes in different combinations at equal service levels. Additionally, consolidation of shipments will be considered in some of these combinations where LTL modes are selected as the transportation mode.

It should be noted here that previous research on modal choice in Air Force forward logistics was conducted by Jason Masculli (2001) and results showed the use of LTL transportation modes in certain cases realized the potential for significant cost

savings. This thesis serves as further research into the efficiencies and effectiveness of utilizing air and surface modal choices in the reverse or retrograde logistics pipeline.

Research Significance

"Improved retrograde of valuable repairable stock to America's maintenance depots (both commercial and organic), synchronized with depot repair schedules, has enormous potential in areas of readiness, reduced inventories, and long term cost savings" (USTRANSCOM; 2002:15).

This research is intended to make the Air Force aware of the potential to increase efficiencies in transportation cost savings through the increased flexibility of modal selection in the retrograde shipment of reparable assets. The author was unable to obtain total annual transportation costs for the retrograde shipment of reparable assets; however, in fiscal year 2002, the Air Force reported over 3.1 billion dollars of reparable assets in its inventory (GAO, 15:2002). The sheer value of these assets shows represents the magnitude of fiscal effort needed to position reparable assets throughout the Air Force logistics system.

Although logistics has become more transportation-based rather than supply-based and higher premium transportation costs are expected to be made up by savings in inventory costs reductions, the Air Force should not ignore opportunities to drive down transportation costs with cheaper modes of transportation if service levels are still appropriate. Although operations tempos are increasing, DoD and Air Force budget levels are not increasing at the same rate and in some cases, budgets are even decreasing. The Air Force must continue to find ways to operate efficiently and effectively within

these budgets. Cost savings could be realized if transportation coordinators are given more flexibility in modal selection that provides the right velocity for the given situation, and time definite delivery, reliable performance, at the right cost. The proper combination of express air modes and expedited surface modes should assist the flow of reparable assets through the retrograde logistics pipeline at the right velocity, while minimizing uncertainty, while minimizing transportation and inventory costs.

At most, this research could be used to spur changes in transportation policy that would encourage transportation coordinators to choose the most effective and efficient mode according to the necessary level of velocity and service. Furthermore, it is intended for this research to make the Air Force aware of further efficiencies that would result from better synchronizing transportation priorities with depot repair scheduling priorities through better modal selection that balances pipeline efficiency and effectiveness.

II. Literature Review

Review of the Reparable Asset Logistics System

Air Force reparable assets flow in a closed loop logistics system except for the induction of new assets or the condemnation of assets. A conceptual model of the Air Force's reparable assets system is depicted in Figure 1.
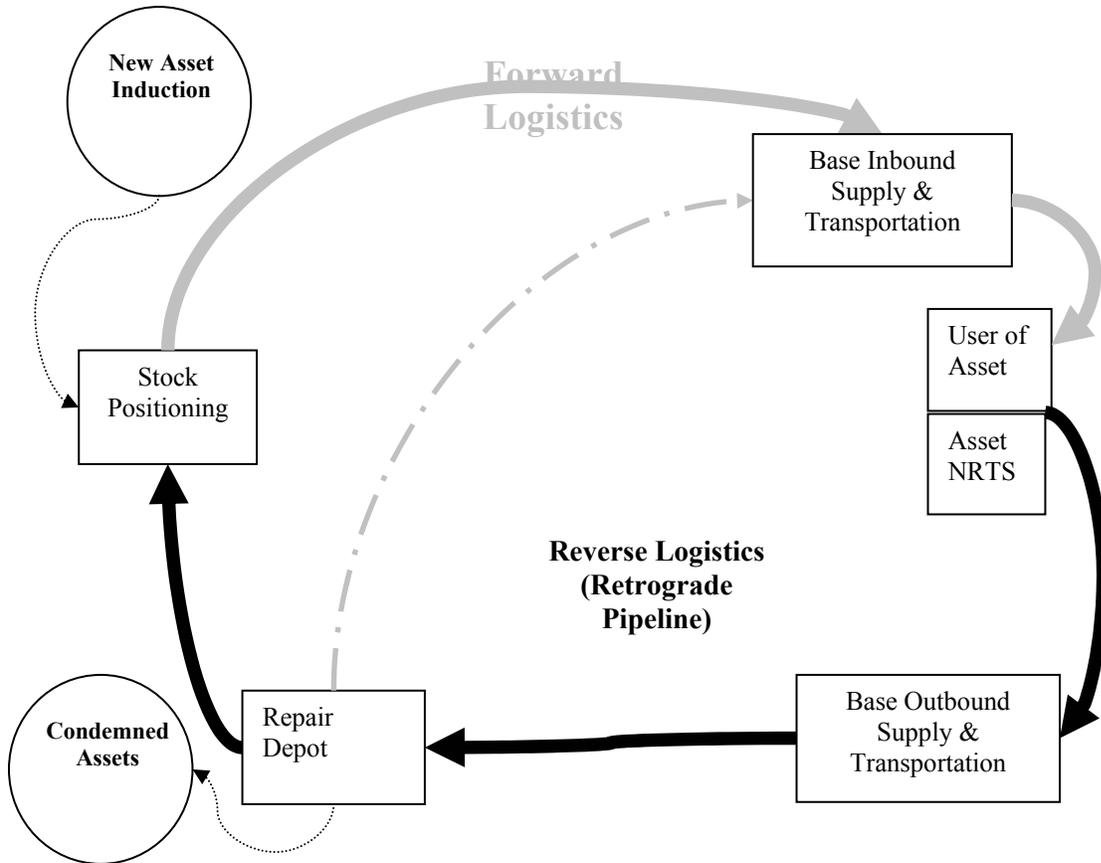
Figure 1. Conceptual Model of Reparable Asset Logistics System (AFPD 20-3, 1998:7)

"The flow of materials and products in this environment occurs both from the customer [base] to the remanufacturer [repair depot], and from the remanufacturer to the customer…since most of the products and materials are conserved, this essentially forms a closed-loop system" (Jayaraman, 1997:1). The Air Force's closed-loop logistics system is comprised of two logistics pipelines that flow in opposite directions: the forward logistics pipeline and the reverse logistics pipeline, also known as the retrograde pipeline.

The forward logistics pipeline consists of the chain of activities and processes that begin when a user submits a request for the issue of a reparable asset from a consolidated serviceable inventory point and ends when the user receives the assets at their location. The typical user of a reparable asset is an Air Force weapon system maintenance activity located at a military installation or deployed location. The reparable asset is moved forward from a consolidated inventory point, another user's location, or a depot repair facility to the requesting user's location. The request for a reparable asset typically occurs when a weapon system maintenance activity has declared a reparable asset unserviceable and no replacement part exists in local inventory stocks (Briggs, 1996:37).

The reverse logistics pipeline, or the retrograde pipeline, consists of the chain of processes and activities that, like the forward pipeline, begins when a reparable assets is deemed unserviceable by the weapon system maintenance activity. However, the retrograde pipeline ends after the asset is repaired and is inducted to serviceable inventory ready for issue to the user (AFPD 20-3, 1998:3).

Segments of the Retrograde Logistics Pipeline

The retrograde logistics pipeline is comprised of segments distinct by their functions within the system. Figure 2 illustrates a conceptual model of the retrograde logistics pipeline.

```
┌─────────────┐          ┌─────────────┐          ┌─────────────┐        ┌─────────────┐
│Consolidated │   2nd    │   Repair    │   1st    │    Base     │        │    Base     │
│ Serviceable │ ◄─────── │Depot/Facility│ ◄─────── │Transportation│ ◄───  │   Supply    │
│  Inventory  │          │             │          │             │        │             │
└─────────────┘          └─────────────┘          └─────────────┘        └─────────────┘
```

Stock Positioning Segment   **Repair Segment**   **Base Evacuation Segment**

Distribution Segments
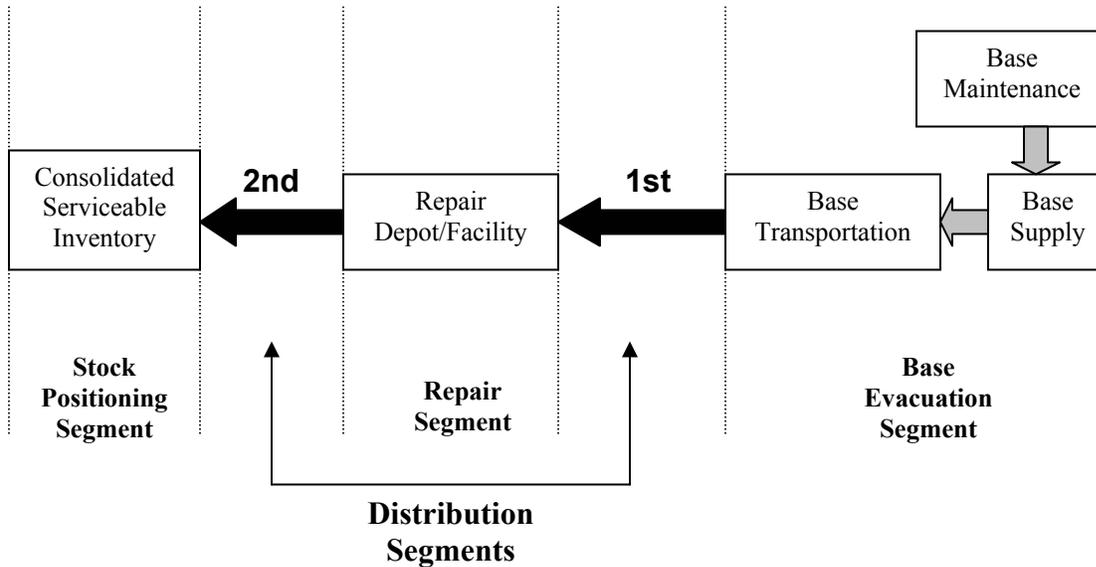
Figure 2. Conceptual Model of the Retrograde Assets Logistics Pipeline (AFPD 20-3, 1998:7)

Base Evacuation Segment.

The base evacuation segment includes the activities and processes when a reparable asset is identified as not-repairable-this–station (NRTS) by the local maintenance organization, the asset is transferred to the local supply agency for processing, and subsequently, the asset is transferred to the local transportation agency for mode and carrier selection (Briggs, 1996:39-40). The time standard for this segment is compressed. The total base supply and transportation processing time standard is 24

hours; the total time starts when maintenance declares the asset as NRTS and ends when the asset is released to the carrier (AFI 24-201, 2001:10).

First Distribution Segment.

In the first distribution segment, the local transportation agency releases the reparable asset to the carrier. The asset is then transported to the designated repair depot or facility (Briggs, 1996:40). This segment is intended to be compressed using premium transportation. This thesis focuses on transportation modal selection occurring during the base evacuation segment and the first distribution segment.

Repair Segment.

The repair segment includes receipt of the asset by the repair facility, prioritization of the asset for repair, actual repair of the asset, and processing the serviceable asset for distribution, which is similar to the processes in the base evacuation segment. Much has been done to compress this segment to the maximum extent. However, components that are repaired at the depot vary widely, as do the steps required in the repair of the individual items (Briggs, 1996:41). Thus, the repair segment is usually the constraining resource in the logistics pipeline relative to the other segments, which have significantly shorter cycles.

Second Distribution Segment.

The second distribution segment occurs when the depot transportation organization releases asset to the selected carrier and the asset is transported to a stock positioning facility. The activities and processes of this segment are similar to the first

distribution segment in that the transportation mode and carrier are selected under the same principles. Again, the urgency of need for the asset in the overall system should determine the required transportation priority, service levels, and mode.

Stock Positioning Segment.

The final segment, stock positioning, includes the receipt of the asset by the consolidated supply point and induction of the asset back into a ready for issue condition (Briggs, 1996:43). Occasionally, the asset is needed in the field once the part is repaired; the asset is then sent directly to the user in the field in lieu of stock positioning. However, this condition is a characteristic of forward logistics and this study will not focus on this exception. Occasionally, an unserviceable asset will be defective beyond repair and be eliminated from the logistics system altogether. Again, this study will not focus on this exception.

Supply and Transportation Prioritization Schemes

Before an unserviceable reparable part is shipped from the user to a repair facility, the local supply and transportation agencies assign two priority codes to the shipment respectively: a supply priority designator and a corresponding transportation priority code. These two priority codes influence transportation mode selection and subsequent carrier selection for the shipment of a reparable asset from a user to a repair facility.

Supply Priority Designator.

The first priority code, the supply priority designator, is obtained by the local supply agency through the Reparable Information Management Control System

(RIMCS). RIMCS is an information system in which materiel managers assign a supply

priority designator to an asset according to its importance in the overall distribution

system (AFMAN 23-110, 2002:24-33). A material manager is the agency which been

assigned wholesale responsibility for the Air Force inventory of a particular reparable

asset (AFI 23-102,1994:11). If an asset has a high demand and a low availability, priority

is higher. Conversely, if an asset is low in demand, but sufficient or high in availability,

the priority is set lower. Materiel managers provide weekly updates of priority

designators to local supply agencies (AFMAN 23-110, 2002:3-17). Local supply

agencies are then required to manually update the RIMCS information system with these

weekly updates. The local supply agency determines one of three supply priority

designators for shipment of an unserviceable reparable part to a repair facility: 3, 6, or 13.

Supply priority designator 3 is designed to induce expedited handling and shipping of

critical items and designators 6 and 13 are intended for items that require routine

handling and shipping. However, Air Force transportation policies, which are discussed

later, can modify the effect of supply priority designators on required transportation

service levels and modal choice.

Transportation Priority.

The local transportation agency assigns a subsequent priority code, transportation

priority, to movements of reparable assets according to supply priority designator. All

Air Force cargo shipments are transportation priority (TP) Expedite: TP-1 or TP-2, or

Routine TP-3" (AFI 24-201, 1999:14). Corresponding transit time standards are derived

from the Uniform Material Movement and Issue Priority System (UMMIPS) and are

further explained by applicable guidance and Air Force policies explained in publications DoD 4500.9R Defense Transportation Regulation (DTR) and Air Force Instruction 24-204 Cargo Movement, respectively. Two Air Force transportation policies that significantly affect transportation priority and transit times come from the Agile Logistics and Small Package Express programs. A review of these two policies will follow.

Agile Logistics Transit Time Standards

Within the scope of Agile Logistics, "Two-Level Maintenance (2LM) is an Air Force logistics program used to transfer the repair-level of select items from base to depot, eliminating high overhead and resource costs" (AFI 24-201,1999:9). 2LM compresses standard transit times for the movement of designated assets. All reparable assets are designated by the Standard Base Supply System (SBSS) to move via fast transportation (AFI 24-201, 1999,9; Masculli, 2002:4-5). Under the Agile Logistics concept, supply priority designators 1 and 6 will result in the assignment of TP-1 and TP-2, respectively. The corresponding transit time requirement for shipments moving within CONUS is 1-day for both transportation priorities (AFI-24-201,1999:9,62). Since most assets will be required to move through the pipeline via the fastest means, transportation coordinators will be compelled to use premium transportation as a means to meet these requirements.

Small Package Express Shipping Policies

According to the Defense Transportation Regulation, all DoD shipments less than 151 pounds with a transportation priority of TP-1/TP-2 must be shipped using either the Worldwide Express (WWX) or Domestic Express programs. The WWX program applies

to shipments that transverse overseas areas and the Domestic Express program applies to shipments that only move through the Continental United States (CONUS), Alaska, and Hawaii.

Since all reparable shipments are designated to be moved using fast transportation, the transportation mode should be selected under either of the two Small Package Express programs if the asset weighs less than 151 pounds. Thus, transportation coordinators are regulated to use premium transportation modes for retrograde pipeline asset moving within the CONUS from base level units to repair depots.

Table 1 summarizes how transportation priority codes correspond to supply priority designators and CONUS transit times for the shipment of reparable assets to repair depots within these programs.

Table 1. Reparable Shipment Supply Priority Designators, Transportation Priorities, and CONUS Transit Times (AFI 24-201, 1999:62)		
Supply Priority Designator	Transportation Priority	CONUS Transit Time (Days)
3	TP-1 (EXPEDITE)	1
3*	TP-1 (EXPEDITE)	1
6*	TP-2 (EXPEDITE)	1
6	TP-3 (ROUTINE)	9
13	TP-3 (ROUTINE)	9
*Agile Logistics Designated Items		

Depot Repair Prioritization Schemes

The depot repair priority system is operated by a method called repair-on-demand (ROD), which is "the ability to quickly and individually induct and repair a range of different reparable assets, rather than repairing batches of like assets to achieve

efficiencies in workload and bit/piece contracting" (AFPD 20-3, 1998:2). Instead of building batches of similar assets, holding them until a certain quantity is reached, and then inducting the batch into the system, the repair facility inducts assets into the repair system as they are received. Depot repair resources are not unlimited, thus, not every asset can and will be repaired the same day, or possibly even the next day after the depot receives the asset. Therefore, some sort of repair priority system must be established so that assets are repaired in an order that minimizes inventory requirements of those assets.

The Execution and Prioritization of Repair Support System (EXPRESS) is:

> a daily execution system designed to make critical choices in a constrained depot environment. The system takes a fresh view of customer needs and the repair environment daily using current asset and resource information. System decisions are driven by today's overall asset and resource picture. An applied rule is that once an asset is moved into the repair shop, that repair is accomplished regardless of changing conditions and therefore will continue to completion…or is stopped by exception (AFMCI 21-129, 2001:77).

Using EXPRESS and other related information systems, material managers are aware of assets declared NRTS and *intransit*, assets in the queue awaiting repair, and the repair schedule and capacity at the repair depot (AFMCI 21-129,2001:24). Based upon this known information, a synchronization of supply and transportation priorities with repair schedule priorities should be possible. Although, it is beyond the scope of this thesis to explicitly state the particular design of this synchronization, the author intends to at least establish an awareness of the possibility and significance of synchronizing priorities and the selection of transportation modes for the retrograde movement of reparable asset to repair depots.

Review of Available Premium Transportation and LTL Service Levels

A comparison of services levels between air express and LTL modes of transportation is illustrated in Table 2.

Table 2. Comparison of Express Air and LTL Service Levels (FedEx, 2003; Roadway, 2003)		
	Express Air	LTL
Time Definite Transit Times	1-Day, 2-Day	(1-Day, 2-Day, 3-Day, 4-Day)*
Rate Structure	$/Pound per Piece Determined by Region	$/Pound/Miles Traveled**
Consolidation Rates	No	Yes
Time Definite Delivery	Yes	Yes
Door to Door Service	Yes	Yes
Dimensional Limitations	Less than 150 pounds	Up to 20,000 pounds
Scheduled Service	Yes	Yes***
Traceable/ITV	Yes	Yes
Government Contract Carriers Available	Yes	Yes
*Availability of services depends on regions through which shipments must travel ** Minimum weight may apply ***Negotiated in service contract		

The range of transit times refers to time definite delivery service levels of both modes. Both modes offer similar levels of time definite delivery; however, express air does not limit these delivery levels within certain geographic regions.

The rate structure refers to how transportation costs are computed for each mode. Some carriers charge extra fees for certain additional service levels in addition to transportation rates. Express air rates are typically charged for the weight of each parcel, but multiple parcels may not be consolidated into one shipment for a reduced rate.

LTL transportation costs are determined by the weight of the shipment and the distance it will travel. Multiple pieces of cargo moving on the same load may be consolidated into one shipment weight to determine a single rate—usually a rate lower than if the shipment cost was determined singularly. As shipment weight increases, certain weight breakpoints may allow for a reduced rate. For instance, a consolidated shipment between 1,000 and 1,500 pounds may be charged at single rate for the range of total weight, rather than being charged at a per pound, per mile rate. Typically, LTL loads are charged a minimum rate. For instance, if an LTL carrier may charge the cost to move a minimum of 100 pounds even if the shipment weighs only 50 pounds.

Door-to-door service is generally defined as when carriers are able to pickup and deliver shipments to and from the shippers preferred origin and destination locations respectively. Both modes offer *door-to-door* service for shippers.

Dimensional limitations for express air are parcels that are less than 151 pounds and smaller than 119 inches in length and 165 in length and girth combined (FedEx, 2003). LTL shipments historically include shipments totaling less than 20,000 pounds and the total density of the entire shipment is limited by the interior of each truck trailer.

Both modes offer scheduled service. Express air scheduled service is typically determined well in advance and is less flexible than LTL. Although more flexible in routing and scheduling, LTL standard transit times may be limited by how much one or two truck operators can drive per day. Next-day service is possible in many regions of the CONUS with one truck operator, and is even more possible in the majority of regions with two operators.

Express air and LTL both have comparable *intransit* visibility (ITV) capabilities so that shipments can be traced once the assets are released to the carrier, during transit, and upon delivery—all in real time. Both transportation modes have carriers who have filed government rates and have the capability to make contracts with the government.

Review of Research in Transportation Modal Choice in the Forward Logistics Pipeline

No previous research regarding modal choice between premium transportation and expedited surface modes in Air Force reverse logistics systems was found by the author. However, previous research exists regarding management of the flow of reparable assets in the Air Force logistics pipeline, relative prioritization schemes, and modal choice between premium transportation and expedited surface modes in Air Force forward logistics systems.

The graduate research of Tracey L. Hill and William N. Walker in 1994 investigated the effects of Lean Logistics on the Air Force reparable pipeline (Hill and Walker, 1994). This research was being conducted at a time where the Air Force was just began adopting the Lean Logistics concept. Hill and Walker defined Lean Logistics as "a philosophy of operation that seeks to improve the responsiveness of the Air Force logistics pipeline by consolidating reparable asset pipeline and streamlining the flow of assets through the repair process" (Hill and Walker, 1994:5). This definition closely, if not exactly, matches that of the concept of Agile Logistics mentioned earlier in this chapter.

One of the major propositions of Lean Logistics is to "reduce transportation time standards for reparable shipment to base from the depot and retrograde shipment from the base to the depot…the reduced transportation time compresses the [logistics] pipeline, and thus minimizes asset needs during supply" (Hill and Walker, 1994:5). Hill and Walker's research, though, focused primarily on the forward movement of assets from depot to bases. When discussing transportation segments in their research of the logistics pipeline, it is stated, "the longer it takes to transport an item to its final destination, the more safety stock is necessary to be kept on hand to prevent stock outs and the subsequent reduction in mission capability" (Hill and Walker, 1994:20). There is an assumption in this statement that all assets are needed immediately for mission use or, in the case of retrograde movement, for immediate repair.

One of Hill and Walker's conclusions in their study was that fast transportation costs were higher in the Lean Logistics managed pipeline than were in a conventionally managed logistics pipeline; however, the savings in inventory costs outweighed transportation cost increases (Hill and Walker, 1994:100). The study did not explicitly make any conclusions as to the appropriate mode of fast transportation required to meet these conditions.

Another comparative study of the effects of Lean Logistics on the Air Force reparable pipeline on order and ship times (OS&T) was conducted by Clifford G. Altizer in 1995. Although some aspects on the use of fast transportation in the retrograde pipeline are discussed, the study did not address synchronization of transportation priorities with repair schedules and the selection of transportation modes in fast transportation. The study showed inventory costs were reduced when premium

transportation like modes was used to ship reparables in the logistics pipeline, but the assumption again is that every asset was needed immediately and prioritized accordingly (Altizer, 1995:41). Although cycle times and inventory costs were reduced significantly under Lean Logistics, modal selection was limited to premium transportation like modes and no test was performed to determine if transportation costs could be further reduced through alternative modes while maintaining inventory cost reductions.

The objective of the thesis research of Brigham K. Briggs was to "determine the prioritization schemes employed in each segment of the reparable pipeline" (Briggs, 1996:70). Briggs identified the two priorities of the retrograde segment, supply priority designator and the transportation priority, but did not mention mode selection except when discussing forward logistics distribution processes (Briggs, 1996:38,42). There was mention of modal choice and what happens if two modes have identical transit time service levels. Briggs states "transportation segments also employ the low-cost carrier rule as a tie-breaker if two modes deliver the item within acceptable time standards"; however, the policy of Small Express Package Shipments was not in effect during that time period (Briggs, 1996:56). Synchronization of transportation priorities, transportation mode selection, and depot repair scheduling is not explicitly addressed in this research. However, Briggs does mention that transportation priorities are selected using local prioritization rules—the supply priority designator accompanying the asset— so transportation priority is assigned without knowledge of depot repair schedules (Briggs, 1996:53-54).

Jason L. Masculli has performed notable research in transportation mode selection in the Air Force forward logistics pipeline (Masculli, 2001a). It is this research upon

which most of the author's thesis is based. Masculli compared costs of shipping mission

capable parts (MICAP) from depots and bases to other bases within the CONUS via

premium transportation modes and LTL transportation modes. MICAP is defined as

"parts needed in order to keep mission critical aircraft, vehicles, and equipment fully

operational…parts that are not in the inventories of supply warehouses at the bases they

are needed" (Masculli, 2001:4). Portions of the Air Force's reparable and consumable

assets are designated as MICAP assets. These MICAP assets are typically provided the

highest priority in the segments of logistics pipeline.

Masculli's comparison of premium transportation and LTL costs illustrated the

following trends:

- Ground mode costs become greater than air mode costs as the distance increases and the weight decreases
- Air mode costs become greater than ground mode costs as the weight increases with a smaller distance range (Masculli, 2001a:29).

Masculli, Boone, and Lyle also conducted further research in the use of premium

transportation in the Air Force forward logistics pipeline (Masculli, 2002). This research

was expanded to include Air Force reparable and consumable asset movement from

depots to bases within the CONUS and to bases in overseas areas, too. Using the Air

Force's Aircraft Availability model and an estimate of 2001 reparable movement

requirements, expending 17 million dollars in fast transportation versus using slow

transportation would eliminate the need for 96 million dollars in Air Force reparable

inventory (Masculli, 2002:5). Information on the model's assumptions is not provided in

the article. However, "the conclusion makes no statement as to what mode of

transportation is fast and what mode is slow" (Masculli, 2002:5). However, the study did

reveal some insights as to the use of LTL modes in the forward logistics of reparable assets. "Opportunities, such as scheduled truck routes, may exist for using alternatives to premium transportation in the CONUS should be assessed" (Masculli, 2002:7).

Masculli also refers to the limitations that are put on the modal choice process by policies from Small Package Express and Agile Logistics programs. "This restricts the modal/carrier choice decision for the Air Force and does not give the local traffic manager the discretion to choose a modes or carrier to meet mission requirements" (Masculli, 2001:2).

The results of Masculli's research found that use of LTL shipments, when cheaper that express air, resulted in a cost savings of 11 percent, or 3,828.27 dollars over a one-month period for a portion of forward logistics reparable movements (Masculli, 2001:37). LTL was not the least expensive mode in every case, but was a viable alternative assuming service levels were equal with those of premium transportation. Typically, LTL was less expensive for shipping distances less than 500 miles as shipping weight increased (Masculli, 2001:29).

None of Masculli's research discusses synchronization of supply, transportation, and repair priorities. However, it is suspected by the author that some of his conclusions, trends, and insights resulting from Masculli's research in modal choice in forward logistics pipelines may be applicable to modal choice in the Air Force retrograde logistics pipeline, the focus of this particular thesis.

Review of Modal Choice Theory Relative to the Civilian Sector

As was the result in the literature search of previous Air Force forward logistics research, the author has found that little literature exists regarding civilian sector modal choice, and none exists discussing cases where service levels of modes are equal (Masculli, 2001:8). However, the author feels it is at least noteworthy to introduce some of the nuances of modal choice theory as it relates to the civilian sector.

A simple modal choice model was developed in an article authored by Yosef Sheffi, Babak Eskandari, and Haris N. Koutsopoulos (Sheffi, 1988). The model selects the appropriate mode by calculating total logistics costs (TLC). The elements of TLC are inventory carrying cost, and any other costs of doing business with a particular mode or carrier (Sheffi, 1989:138). Some of the service elements of transportation costs, inventory carrying costs, and cost of doing business include rates, availability of electronic data interchange, safety stock levels, billing accuracy, transit time, reliability, equipment capacity, and responsiveness (Sheffi, 1988:137). This model requires subjective guesses in many of the inclusive costs and may provide obvious differences in modal alternatives, but the model's practical use is geared towards comparing surface transportation modes such as trucking and rail.

 In the research performed by Michael A. McGinnis, four freight transportation choice models are reviewed and an overall theory is derived and proposed (McGinnis, 1989:36). The four models discussed are the classic economic model, the inventory-theoretic model, the trade-off model, and the constrained optimization model.

The classic economic model "evaluated the fixed and variable costs of competing modes (for example, rail and truck) and argued that below a theoretical distance, freight

movement should be dominated by one mode and beyond that distance by the other mode" (McGinnis, 1989:37). This model determines competing modes by percentage of market share.

The Inventory-Theoretic model computes the tradeoff among freight rates, transit times, dependability, and enroute lossage (McGinnis, 1989:38). The model searches for sensitivities to inventory requirements affected by the tradeoffs. "Two major shortcomings of this model are that (1) no attempt is made to evaluate the cost of *stockouts* on the modal choice process, and (2) any affect that a high level of customer service would have on the demand for the product shipped is neglected" (McGinnis, 1989:38).

The Trade-Off model separates costs into two categories: transportation costs and non-transportation costs and modal choice is made by minimizing the sum of these two cost categories in two alternative modal choices (McGinnis, 1989:38). Quantifying the non-transportation costs is highly subjective and assumptions could obscure decisions; however, the model has the potential to consider how modal choices can affect the overall system.

The Constrained Optimization Model optimizes basic transportation costs (TC) subject to the constraints of non-transportation costs (NTC). The assumptions of this model are that many NTC costs are qualitative, some NTC variables are quantified on a different basis of measurement than TC, there are many methodological problems to quantifying the costs of some variables, and NTC costs are situational (McGinnis, 1989:39). Although quantifying and deciding on NTC costs seems confounding, this model seems to capture more in the modal choice decision process than the other three.

The study also compiled the results of 11 empirical studies in the choice of transportation modes. Seven variables were found to affect freight transportation choice:

> (1) freight rates,
> (2) reliability,
> (3) transit time,
> (4) over, short, and damaged (OS&D),
> (5) shipper market considerations
> (6) carrier considerations,
> (7) and product characteristics

> Other points of interest in the compiled data was that reliability was ranked more important than freight rates in 10 of the 11 studies. Transit time was ranked as more important than freight rates in 7 of 10 studies. OS&D was ranked more important than freight rates in 3 of 8 studies. Shipper market considerations were ranked higher than freight rates in 4 of 6 studies. Finally, product characteristics ranked higher than freight rates in none of the studies (McGinnis; 1989:41-42).

McGinnis concluded that "freight transportation choice is the result of interactions among an array of variables…these variables vary as much among shippers as among carriers (McGinnis, 1989:44). Therefore, flexibility to choose transportation modes according to the degree of desired service elements could be related to modal choice in Air Force logistics.

Conclusion of Literature Review

The Air Force reparable assets logistics system is a closed model system made up of two pipelines: the forward logistics pipeline and the reverse logistics pipeline. Reverse logistics, or the retrograde reparable asset pipeline is made up of several segments: the base evacuation segment, the first distribution segment where the asset is transported from the base to the repair depot, and the second distribution segment where the asset is

transferred, in most instances, from the repair depot to a stock positioning point, and the final segment where the asset is received and ready for issue. The base evacuation segment and first distribution is where modal choice is selected and executed and is the focus of this thesis.

Supply and transportation priorities, regulations, and Air Force logistics policies drive the modal selection in this part of the retrograde pipeline. Supply priorities are driven by the demand for the asset by bases and the availability of serviceable assets in inventory. Transportation priorities are theoretically assigned according to the level of supply priorities. However, all reparable assets are do not need to arrive at depots overnight since induction into the repair cycle cannot occur for every asset received. There is a significant lack of synchronization with repair schedules and assets are shipped to depots faster than necessary. Additionally, transit time policies resulting from Agile Logistics and Small Package Express programs regulate the selection of modes limiting the choices to premium transportation.

A comparison of express air and LTL services levels shows that in many instances, LTL offers similar service levels. LTL can offer several advantages over express air modes under certain conditions. LTL offers consolidation of shipments and is more flexible in size and weight criteria. Although LTL may not have overall advantage in every situation, LTL can be an effective, alternative mode that can ensure fast transportation and aid in reducing inventory stock levels, at lower costs.

Some research was performed in the movement of reparable assets in the forward logistics pipeline of the Air Force. Lean Logistics, an Air Force logistics concept before Agile Logistics, promoted use of fast transportation for assets moving through the

logistics pipeline in order to reduce inventory levels. Although the research did not specify using premium transportation in every case, it assumed reparable assets were always needed immediately either by the user in the forward logistics pipeline, or the repair depot in the retrograde pipeline.

Another study investigated differences in cycle times and savings in inventory costs between a Lean Logistics and conventionally managed pipeline. While a Lean Logistics managed pipeline showed cycle time and inventory cost savings, it did not investigate modal alternatives. Other research of the Air Force logistics pipeline described how prioritization schemes result in transportation priorities being assigned without knowledge of repair schedules. Most recently, research was performed on the modal choice between premium transportation and LTL modes in forward logistics pipelines of reparable assets. This research concluded that using LTL in combination with premium transportation modes as the least cost mode showed certain cases of significant savings in transportation costs where LTL service levels are equal to those in premium transportation.

Some research was found concerning modal choice in the civilian sector. Most of this research compared alternatives in surface modes such as trucking and rail. Common in this research was ranking the importance of service levels and cost to the shipper in the selection of transportation modes. Although service level elements such as reliability, speed, and dependability ranked higher than cost in many situations, freight rates were consistently ranked high in every case.

Research Focus

It is intended for this thesis to show, with more flexibility in modal selection, the logistics pipeline can be more efficient while maintaining a high level of service level effectiveness in the movement of unserviceable reparable parts from the user to the repair facility when certain alternative expedited surface transportation modes are used instead of premium transportation modes. The analysis of these shipments can provide the extent of efficiency assuming no harm is done to the overall velocity of the retrograde logistics pipeline.

III. Methodology

Background

No methodologies were found that were appropriate in the analysis of modal choice between premium and LTL transportation modes for reverse logistics pipelines in the DoD, nor in the civilian sector for that matter. The methodology used in this thesis will be an analysis of modal selection of retrograde shipments of reparable assets within the Continental United States. While holding service levels (effectiveness) equal between modes, historical retrograde shipment data of reparable assets from a six-month period will be analyzed in terms of dollars to compare efficiencies resulting from various modal choices between express air and LTL modes. Additionally, the feature of consolidation will be explored in portions of the analysis when LTL modes are selected.

Data Collection

[This data has not been received yet] The historical shipment data was collected from HQ AFMC/LSOT. Data was limited to shipments destined for the repair depot at Warner Robins Air Force Base, Georgia and originating from the following locations: Dover Air Force Base, Delaware; Travis Air Force Base, California; Eglin Air Force Base, Florida; and Little Rock Air Force Base, Arkansas. Shipments from Dover Air Force Base and Travis Air Force Base are both major aerial ports so they will include shipments that originated from overseas locations.

These origin locations were chosen for several reasons. The origins locations represent a sufficient cross section of geographic distances for shipping. Additionally,

volumes should be sufficient since the repair depot at Warner Robins Air Force Base is responsible for repairing reparable assets from C-5 cargo aircraft, which are stationed at Dover and Travis Air Force Bases, from C-130 cargo aircraft from Little Rock Air Force Base, and from F-15 fighter aircraft stationed at Eglin Air Force Base. Although the Robins depot handles many reparable asset shipments from numerous other bases, this level of volume would become unmanageable for the scope of this thesis.

Shipment Data Characteristics

The historical data was limited to shipments occurring from 1 March 2002 to 31 August 2002. This six-month period was chosen to allow for better manageability of data in accordance with the time period allotted for this research. Microsoft Excel 2000 was used as the primary means of model building and data analysis.

The data was provided in Microsoft Excel 2000 and contained the following fields: transportation control number, requisition date, shipping date, delivery date, shipping time, supply priority designator, transportation priority, required delivery date, project code, national stock number, quantity of items, unit of issue, retrograde (yes or no), condition code of the asset, port of embarkation (if originating from overseas), port of debarkation (if originating from overseas), weight of the shipment, transportation cost, carrier, origin, destination, cube of shipment, and the number of pieces. These elements of the data were more information than required for the analysis; however, the author wanted to determine if there were opportunities to discover further exploratory research opportunities and any obvious trends.

Express Air Rates

Express air rates were obtained from the HQ Air Mobility Command's website for the Domestic Small Package Shipment program (HQ AMC, 2003). The rates do not consider distance traveled, just the shipment weight rounded to the nearest whole pound. The rate table is limited to 150 separate rates since the program only includes shipments up to 150 pounds. The rates used in the analysis were computed by taking the average of two rates from two government contracted express air carriers for each weight category. A portion of this rate table is provided in Table 3.

Table 3. Portion of Express Air Rate Table Used in Analysis (HQ AMC, 2002)								
Weights	10	11	12	13	14	15	16	17	18
Rates	$10.03	$10.79	$11.55	$12.31	$13.07	$13.83	$14.78	$15.73	$16.68

It is already apparent in the table that the rate is increasing while the shipment weight is increasing. Therefore, no rate reductions result with consolidation of shipments in express air modes of transportation.

LTL Rates

LTL rates were determined from the MTMC Class Rate Publication 100A (HQ MTMC, 1989) and an approximation of the industry average for DoD tenders. The purpose of the MTMC publication "is to provide the standardization necessary for achieving a fully authorized system for routing DoD less-than-truckload traffic…this is not in any way to be construed as the setting of rates or charges by MTMC" (HQ MTMC, 1989:7). LTL carriers, therefore, may set LTL rates above, below, or equal to

the baseline rates in this publication. An approximation of the industry average will be set at 60 percent of the baseline rate. Table 4 illustrates the rate table from the MTMC publication and an example calculation of shipment cost.

Table 4. Portion of LTL Rate Table Used for Analysis (HQ MTMC, 1989:15)

Mileage Base	Min Charge	0 to 499 pounds	500 to 999 pounds	1000 to 1999 pounds	2000 to 4999 pounds	5000 to 9999 pounds	10000 to 19999 pounds
Assumes an average LTL carrier will charge DoD 60% of the baseline rate							
0 to 50	$36.00	1179	943	802	696	607	519
51 to 75	$36.00	1284	1028	873	758	661	565
76 to 100	$36.00	1373	1373	1098	933	810	707
101 to 125	$36.00	1536	1536	1229	1044	906	791
Example of a shipment weighing 350 pounds traveling 120 miles via LTL carrier with a 60% rate tender: 1536 cents/cwt x 60% = 921.6 cents/cwt x 350 pounds/100 = 3226 cents /100 = $32.26. Since $32.26 is less than the minimum charge ($36.00), the total shipment cost is $36.00.							

Rates are calculated using the table in the following manner. The left column of the table signifies sets of distances ranges, for example, 0 to 50 miles and 51 to 75 miles and so forth. The top row of the table signifies sets of weight ranges, for example, 0 to 499 pounds and 500 to 999 pounds. Selecting the total distance and total shipment weights in the corresponding range sets are chosen and the row and column intersect at the raw shipping rate. The raw shipping rate is published in units of cents per one hundred pounds (cents/cwt). Each LTL carrier with a tender on file with the DoD will charge a percentage of this rate, for example, 50 percent. Additionally, for every set of

distance ranges, a minimum charge will apply. The greater of the actual calculated cost or the minimum charge will be assessed as the shipment cost.

Department of Defense Table of Official Distances

The Defense Table of Official Distances (DTOD) was used to determine distances from origin bases to the repair depot at Robins AFB, Georgia. The DTOD is contained in the website sponsored by HQ MTMC and provides typical routing for freight all kinds shipments. The distances used in the analysis are provided in Table 5.

Table 5. Official Distances from Origin Bases to the Repair Depot at
Robins AFB, GA (HQ MTMC, 2003)

Origin Base	Distance (Rounded to the nearest mile)
Travis AFB, California	2551.2 miles
Dover AFB, Delaware	775.5 miles
Little Rock AFB, Arkansas	600.3 miles
Eglin AFB, Florida	286 miles

Methodology

Five events are planned for the analysis of modal choice between express air and LTL using the given historical shipment data. The elements of service levels to include transit time, packaging, *door-to-door* service, reliability, dependability, and loss and damage will be held equal as the constraints in the analysis. The independent variables will be the rates of the two modes applied against the historical shipment data and the dependent variables are the rates structures that apply to each of the two modes.

First Analysis.

The first analysis of the historical data will consider the movement of shipments limited to those weighing less than 151 pounds. The cost per shipment via the two modes, express air and LTL, will be determined utilizing the respective aforementioned rate tables. The consolidation of shipments is not taken into consideration in this event. The following information will be determined from this modal selection event:

- Aggregate Cost: exclusive selection of LTL mode only
- Aggregate Cost: exclusive selection of express air mode only
- Aggregate Cost: Selection of the lowest cost mode per shipment
    - Quantity and percentage of express air mode selected
    - Quantity and percentage of LTL shipments

Second Analysis.

The second analysis of the historical data will consider the movement of shipments limited to those weighing more than 150 pounds. The cost per shipment the LTL mode will be determined utilizing the respective aforementioned rate table. The consolidation of shipments is not taken into consideration in this event. The following information will be determined from this modal selection event:

- Aggregate Cost: exclusive selection of LTL mode only
    - Quantity and percentage of LTL mode selected

In this case, the selection of express air mode is not applicable due to the 150 pound weight maximum for this mode.

Third Analysis.

The third analysis of the historical data will consider the movement of shipments of all weights. The cost per shipment via the two modes, express air and LTL, will be determined utilizing the respective aforementioned rate tables. The consolidation of

shipments is not taken into consideration in this event. The following information will be
determined from this modal selection event:

- Aggregate Cost: exclusive selection of LTL mode only
- Aggregate Cost: exclusive selection of express air mode only
- Aggregate Cost: Selection of the lowest cost mode per shipment
  - Quantity and percentage of express air shipments
  - Quantity and percentage of LTL shipments

In this case, the aggregate cost of the exclusive use of the express air mode will include
the aggregate cost of shipments weighing more than 150 pounds utilizing the LTL mode.

Fourth Analysis.

The fourth analysis of the historical data will consider the movement of shipments
of all weights; however, the consolidation of shipments will be taken into consideration
in this event. Wherever the LTL mode is selected, shipments will be consolidated at each
individual origin each shipping day. The cost per shipment via the two modes, express
air and LTL, will be determined utilizing the respective aforementioned rate tables. The
following information will be determined from this modal selection event:

- Aggregate Cost: exclusive selection of LTL mode only
- Aggregate Cost: exclusive selection of express air mode only
- Aggregate Cost: Selection of the lowest cost mode per shipment
  - Quantity and percentage of express air mode selected
  - Quantity and percentage of LTL mode selected

As in the previous case, the aggregate transportation cost of the exclusive use of the
express air mode will include the aggregate cost of shipments weighing more than 150
pounds utilizing the LTL mode with consolidation considered.

Fifth Analysis.

The fifth analysis is an overall comparison of the four previous analyses and will provide a view of how the various modal selections affect aggregate transportation costs and usage of the two modes.

IV. Analysis and Results

Background

The historical data collected from HQ AFMC/LSOT contained over 393,000 records of shipment moving between the dates 1 March 2002 and 31 August 2002. These records contained both retrograde and non-retrograde shipments with multiple origins and destinations. The data did contain 100 percent of the fields that discerned which records were retrograde shipments and the requisition dates for movement. Retrograde shipment records totaled 115,383; however, at least 5,100 of these records contained omitted weight, origin, and destination data germane to the research analysis, which rendered these records useless.

After reviewing each record for the minimum required data fields, 14,802 records were found that contained minimum shipment data of retrograde shipment destined for the repair depot at Warner Robins AFB, GA from 130 CONUS origin locations. From these 130 origins, the top four volume producing origins were selected: Barksdale AFB, Louisiana; Dover AFB, Delaware; Eglin AFB Florida; and Seymour Johnson AFB, North Carolina. Table 6 provides the quantity of shipments observed from the top four origins.

Table 6. Top Four Origins Selected For Analysis

Origin	Quantity of Shipments Observed
Barksdale AFB, LA	655
Dover AFB, DE	1,049
Eglin AFB, FL	1,137
Seymour Johnson AFB NC	891
Total Shipments Observed	3,732

Results of the First Analysis

The first event consisted of a modal analysis of all shipments weighing less than 151 pounds and consolidation was not considered. The results of this analysis are represented in Table 7.

Table 7. First Analysis – Aggregate Results of Shipments Less Than 151 lbs (no consolidation)

LTL mode only	$151,720
Express air mode only	$ 73,810
Selection of lowest cost mode	$ 58,676
Quantity of total mode selections	2,895
Quantity of LTL mode selected	534
Percentage of LTL mode selected	18.4 %
Quantity of express air mode selected	2,361
Percentage of express air selected	81.6 %

Exclusive selection of the LTL mode resulted in an aggregate transportation cost of 151,720 dollars, the highest of all three modal selection conditions. This high cost occurs since shipments were not consolidated and minimum LTL charges were additive. Exclusive use of the express air mode provided a lower aggregate cost: 73,810 dollars. The best aggregate cost performance resulted from the selection of the lowest cost mode for each individual shipment: 58,676 dollars—a 61.3 percent reduction from exclusively selecting the LTL mode and a 20.5 percent reduction from exclusively selecting the express air mode. Of the 2,895 shipments weighing less than 151 pounds, 534 shipments or 18.4 percent were moved by the LTL mode and 2,361 shipments or 81.6 percent were moved by the express air mode.

Results of the Second Analysis

The second event consisted of a modal analysis of all shipments weighing more 150 pounds and consolidation was not considered. Since the express air mode does not allow for shipping weights over 151 pounds, only the LTL mode was considered. The results of this analysis are represented in Table 8.

Table 8. Second Analysis – Aggregate Results of Shipments More Than 151 lbs (no consolidation)

LTL mode only	$ 64,720
Express air mode only	N/A
Selection of lowest cost mode	N/A
Quantity of total mode selections	839
Quantity of LTL mode selected	839
Percentage of LTL mode selected	100 %
Quantity of express air mode selected	-
Percentage of express air mode selected	-

Exclusive selection of the LTL mode to move shipments weighing over 150 pounds resulted in an aggregate transportation cost of 64,720 dollars. In this event, 839 shipments weighed more than 150 pounds. These results are not significant by themselves; however, these results will be useful to determine aggregate transportation costs in proceeding analyses.

Results of the Third Analysis

The third event consisted of a modal analysis of all shipments weights and consolidation was not considered. The results of this analysis are represented in Table 9.

Table 9. Third Analysis – Aggregate Results of Shipments of All Weights (no consolidation)

LTL mode only	$215,756
Express air mode only (includes LTL portion for shipments greater than 150 lbs)	$137,811
Selection of lowest cost mode	$122,713
Quantity of mode selections	3,372
Quantity of LTL mode selections	1,371
Percentage of LTL mode selected	36.7 %
Quantity of express air mode selected	2,361
Percentage of express air mode selected	63.3 %

Exclusive selection of the LTL mode resulted in an aggregate transportation cost of 215, 756 dollars, the highest of all three modal selection conditions. Again, this high cost occurs since shipments were not consolidated and minimum LTL charges were additive. Exclusive use of the express air mode provided a lower aggregate cost: 137,811 dollars. This cost included aggregate LTL mode costs for shipments weighing over 150 pounds. The best aggregate cost performance resulted from the selection of the lowest cost mode for each individual shipment: 122,713 dollars—a 36.1 percent reduction from exclusively selecting the LTL mode and a 43.1 percent reduction from exclusively selecting the express air mode. Of the 3,372 shipments, 1,371 shipments or 36.7 percent were moved by the LTL mode and 2,361 shipments or 81.6 percent were moved by the express air mode.

Results of the Fourth Analysis

The third event consisted of a modal analysis of all shipments weights and

consolidation was not considered. The results of this analysis are represented in Table 9.

Table 10. Fourth Analysis – Aggregate Results of Shipments of All Weights (consolidation considered)

LTL mode only	$ 62,748
Express air mode only (includes consolidated LTL portion for shipments greater than 150 lbs)	$119,147
Selection of lowest cost mode	$ 60,977
Quantity of mode selections	866
Quantity of LTL mode selected	420
Percentage of LTL mode selected	48.5 %
Quantity of express air mode selected	446
Percentage of express air mode selected	51.5 %

Exclusive selection of the LTL mode resulted in an aggregate transportation cost

of dollars, the highest of all three modal selection conditions. Again, this high cost

occurs since shipments were not consolidated and minimum LTL charges were additive.

Exclusive use of the express air mode provided a lower aggregate cost: dollars. This cost

included aggregate LTL mode costs for shipments weighing over 150 pounds. The best

aggregate cost performance resulted from the selection of the lowest cost mode for each

individual shipment: dollars—a percent reduction from exclusively selecting the LTL

mode and a percent reduction from exclusively selecting the express air mode. After

consolidation of the 3,372 shipments, 866 modal selections resulted. Of those modal

selections, 420 or 48.5 percent were moved by the LTL mode and 446 or 51.5 percent

were moved by the express air mode.

Results of the Fifth Analysis

The fifth analysis reviewed all four previous analysis events and illustrated how making modal choices between LTL and express air in the movement of the historical shipment data affects resulting aggregate transportation costs and modal mixes.

Table 11. Fifth Analysis – Synopsis of Four Modal Analysis Events

	LTL only	Express Air only	Lowest Cost Mode	# LTL	% LTL	# Ex Air	% Ex Air
(1) Less than 151 lbs (no consolidation)	$151,720	$73,810	$58,676	534	18.4%	2,361	81.6%
(2) More than 150 lbs (no consolidation)	$64,072	-	$64,072	839	100%	-	-
(3) All weights (no consolidation)	$215,756	$137,811*	$122,713	1,371	36.7%	2,361	63.3%
(4) All weights (consolidated)	$62,748	$119,147**	$60,401	420	48.5%	446	51.5%
* Includes LTL portion for shipments greater than 150 lbs							
**Includes consolidated LTL portion for shipments greater than 150 lbs							

The first two analyses, (shipments less than 151 pounds and shipments more than 150 pounds) provide verification of aggregate transportation costs in the third analysis:

Less than 151 pounds (Express Air Only) $ 73,810
More than 150 pounds (LTL only)   + $ 64,072
                                          $137,882
                          is approximately equal to:
All weights-no consolidation
        (Express Air Only) $137,811

Since shipments of all weights moving via express air mode include some LTL charges for weights greater than 150 pounds, the two figures should be and are nearly equal.

Additionally, the aggregate transportation costs resulting from the *Lowest Cost Mode* method in the first two analyses verified the *Lowest Cost Mode* method aggregate transportation cost in the third analysis.

Less than 151 pounds (Lowest Cost Mode) $ 58,676
More than 150 pounds (Lowest Cost Mode)   + $ 64,072
                                         $122,748
                            is approximately equal to:
         All weights-no consolidation
             (Lowest Cost Mode) $122,713

Again, here the two figures are nearly equal.

Most significant, however, is the aggregate transportation cost ($60,401) of *Lowest Cost Mode* method for shipments of all weights in conjunction with the consolidation strategy. A 62,312 dollar, or 50.8 percent decrease in aggregate transportation costs is realized over the transportation costs ($122,713) of *Lowest Cost Mode* method when a consolidation strategy is not employed.

Limitations of the Analyses

The historical shipment data collected was not complete and a portion of the shipment data was rendered useless due to omitted fields and undeterminable origins, destinations and weights. It is suspected that the volume of shipment data is understated; however, the results are still considered useful and representative of nature of results had the data been complete.

Some retrograde distribution lanes of other origins and destinations may possess enough shipment volume to result in advantage under any consolidation strategy. Furthermore, this research was limited to consolidation of shipments at each origin each shipment day. Further consolidation of more days or more origins could result in further cost reductions.

V. Conclusions

Thesis Objectives Restated

This thesis reviewed the Air Force logistics pipeline system and the retrograde portion of the pipeline. The logistics processes and policies that drive modal choice for shipments of reparable assets moving within the CONUS were discussed. Additionally, the thesis reviewed previous research that was performed relevant to modal choice in the Air Force forward logistics pipeline and review modal choice theories in the civilian sector.

Historical retrograde shipment data and relevant modal choice conditions were analyzed to compare the extent of efficiencies that resulted between utilizing premium transportation and LTL modes in different combinations at equal service levels. Additionally, the consolidation of shipments was considered in some of these events where LTL modes were used as the transportation mode.

Conclusions

Use of the *Lowest Cost Mode* method in conjunction with a one-day, each origin consolidation strategy resulted in a decrease of 62,312 dollars or 50.8 percent in aggregate transportation costs over the *Lowest Cost Mode* method without any consolidation strategy. The former is not outperformed by the exclusive selection of only one of the two modes either. The 62,312 dollars cost benefit may seem insignificant at first glance. However, historical data observed is only a small part of Air Force retrograde shipment volume that occurred during that six month period. Roughly, the

observed historical data represents just one-eighth of the Air Force's volume of retrograde shipments during that period. Thus, an annual cost benefit of at least 996,992 dollars could result if the Air Force modal selection process for the retrograde movement of reparable assets was performed by comparing the lowest cost mode between express air and LTL modes in conjunction with a consolidation strategy. Furthermore, the sheer magnitude of the DoD's annual volume of retrograde shipments of reparable assets could push the cost benefit significantly higher if applied to all of the DoD services and agencies.

Synchronization of supply, transportation, and repair depot prioritization schemes can further discern the required transit time service levels of reparable assets so the appropriate modal choices can be made by transportation coordinators. Additionally, relaxing the regulation of modal and carrier choice in Small Package Express Shipping programs will allow for the proper application of consolidation strategies under LTL modal choices.

It is suspected that the content of historical shipment data is lacking the accuracy and precision required to perform effective evaluations of past performance and reliable decision analysis for future process improvement of the logistics pipeline. However, it is unknown to this author to what extent this problem exists.

Exclusive use of just one mode does not result in the most effective and efficient logistics pipeline. However, modal selections of both express air and LTL modes and exploitation of each mode's strengths of speed and consolidation, respectively is an effective tool to manage velocity of fast transportation in the Air Force logistics pipeline. Two factors contributing to the appropriate mode selection are the actual velocity

required to get the asset to the repair depot in time to begin the repair process and whether the volume of shipments between origins and destination depots can be benefited by consolidation if the LTL mode will facilitate the required velocity. In the retrograde logistics pipeline there are hundreds of origins and four primary depots: Robins AFB, GA; Tinker AFB, OK; San Antonio, TX; and Hill AFB, UT. Depending on shipping volumes between the many origins and four destinations, use of the express air mode and LTL mode with consolidation strategies can provide a means to maximize operational capabilities through high-velocity, time-definite processes. Furthermore, more efficiency and effectiveness could be realized by consolidation of shipments over multiple origins and destinations and over multiple days. Although, the resulting optimal solutions would become more complex, information technology could make the modal selection task more manageable and is an inexpensive tool compared to the potential cost savings.

Recommended Research

This study only focused on modal selection in the retrograde shipment of reparable assets in the Air Force from CONUS four origins to one CONUS depot. Further research could be accomplished on other distribution segments of the retrograde logistics pipeline: positioning of reparable assets after repair is complete, induction of new assets into the pipeline, condemnation of assets, and forward logistics of assets from the stock position to the using activity, movement of assets within international locations and to the CONUS. Furthermore, other assets could be considered, such as consumables. The synchronization of CONUS LTL modes with arrival of assets into military aerial ports and seaports could also be another area for potential research.

At the time of this writing, the DoD announced a new initiative regarding the procurement of domestic freight services in the form of tailored transportation contracts (TTC). This initiative permits the DoD to procure long-term recurring freight transportation services under the auspices of the Federal Acquisition Regulation (FAR). Under the FAR, open competition and performance-based contracts are allowed. Open bidding and increased competition should result in significantly improved service levels among surface freight carriers since surface freight carriers will be competing hard for DoD business based on past performance. As surface freight carriers continually improve their services levels, this mode of transportation will become increasingly more attractive as an alternative or supplement to premium transportation. In time, an analysis of these effects could determine if service levels have increased and it could possibly uncover opportunities for better performance of this mode in the logistics pipeline.

More research and analysis could be conducted on the information and decision support system infrastructure between distribution and repair pipeline segments. Further real-time connectivity between local base supply points with repair depots could provide better assignment of movement priorities, modal choice, and repair induction scheduling decisions. This information system would also be the basis for exclusive *intransit* visibility of reparable assets in the retrograde pipeline.

Further research could be conducted to determine the time elapsed from when a reparable asset is received by a repair depot and when the asset is actually inducted into the process for repair. Furthermore, this research could determine what supply and transportation priorities and which mode was utilized in the shipment from the user to

repair depot and conclude whether the priorities and modes were appropriately assigned according to this time the asset sat idle.

Research could be conducted to determine if transportation coordinators perceive express air shipments easier to coordinate than LTL shipments. If there is evidence that this may be so, further research could also determine if LTL underutilized because of this perceived convenience and if it occurs at the expense of efficiency of the logistics pipeline.

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Vita

Captain Michael P. Kossow graduated from Custer Senior High School in
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His first commissioned officer assignment was as a Transportation Officer, Chief
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1996, he was assigned to the 414th Combat Training Squadron (Red Flag), Nellis AFB,
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14. ABSTRACT

  Transportation modal choice for the Air Force retrograde movement of reparable assets within the CONUS is inflexible and is not synchronized with the depot repair process. Additionally, transportation coordinators are compelled by unsynchronized priorities and shipping policies to use express air modes in all cases when the use of LTL modes may be available to meet actual service level requirements at a lower cost. There may be cases where the retrograde shipments of reparable assets via an alternative transportation mode, such as LTL, can still meet fast transportation requirements at an even lower cost than can premium transportation.

  The methodology used analysis of modal selection of retrograde shipments of reparable assets within the Continental United States. Service levels were held equal between modes; historical retrograde shipment data of reparable assets was analyzed in terms of dollars to determine efficiencies resulting from various modal choices between express air and LTL modes. Additionally, the feature of consolidation was explored in portions of the analysis when LTL modes were selected.

  The *Lowest Cost Mode* method of modal selection in conjunction with a consolidation strategy whenever LTL was used resulted in a 62,312 dollar or 50.8 percent cost benefit of aggregate transportation costs over a *Lowest Cost Mode* method without a consolidation strategy. Just the consideration of either LTL or express air modes in each shipment significantly reduced aggregate transportation costs.

15. SUBJECT TERMS
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