Journal of Transportation Management

Volume 15 | Issue 1 Article 7

4-1-2004

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

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*The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Air Force, the Department of Defense (DoD) or the U.S. Government.*

## 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, thus 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. A stock-point modeling approach was used, with depot production requirements as a surrogate for demand in calculating shipping priority. Using Warner Robins Air Logistics Center reparable asset production data, this article illustrates potential savings in transportation that are possible utilizing an alternative factor in modal choice decision for the retrograde or reverse portion of the pipeline.

## INTRODUCTION

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* (Department of the Air Force, 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* (Department of the Air Force, 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 (Not Repairable This Station) and concludes when the item has returned to the serviceable inventory (Department of the Air Force, 1998, p. 3).

This is a slightly expanded view of reverse logistics than is normally discussed, which ends when the item is returned to its point of origin. In AFPD 20-3, the Air Force expands the scope of retrograde logistics to include the repositioning of 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 (Department of the Air Force, 1998, p. 1).

The policy directive goes on to direct the "expedited evacuation of reparables by bases…to the source of repair" (Department of the Air Force, 1998, p. 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 policy:

> 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, and Lyle, 2002, p. 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 (Department of the Air Force, 1999, p. 9).

### Transportation Mode Selection

Reliance on transportation to support lower inventory levels and faster cycle times places a premium on transportation mode selection. 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, and Novak, 2000; Liberatore and Miller, 1995; Sheffi, Eskandari, and Koutsopoulos, 1988). But more than that, it is the interaction and synergy between logistics activities that drive costs. Stock and Lambert 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 (2001, p. 28).

The customer service level provided by a mode of transportation is the preeminent factor involved in mode choice. This is not to say that the goal is the highest level of service available. It is the optimal level of service that is desired, once other trade-offs have been considered. 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 and Lalonde, 1977, p. 57). For pre-deregulation this would have to be true, since price was not allowed to be utilized as a competitive weapon.

Other studies (McGinnis, 1990; Murphy and Hall, 1995) have shown this to be true 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, p. 17).

Murphy and Hill (1995), in their analysis using studies published in the early 1990's demonstrated that customer service was still the preeminent factor. However, costs have 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 and Hill, 1995, p. 37).

The goal in modal choice decisions 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 and Lambert, 2001). 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, p. 17).

> Economic and resource constraints mandate that organizations make the most efficient and productive mode and carrier choice decisions possible (Stock and Lambert, 2001, p. 355).

When costs are considered, freight cost should not be analyzed in isolation. Coyle, Bardi, and Novak (2001) note that failure to consider the total picture is hazardous. Simply selecting a low cost mode, while lowering transportation costs, may raise inventory or warehousing costs, and reduce customer service.

**Air Force Transportation Mode Selection**

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 is found in three publications. The first is the *Defense Transportation Regulation* (DTR), Part 2 (Department of Defense, 2000). This document sets time standards and allows for expedited movement of cargo when needed. Second, AFI 24-201, *Cargo Movement* (Department of the Air Force, 1999), is the overarching Air Force transportation regulation. Finally, *Air Mobility Command Freight Traffic Rules*, Publication Number 5 (AMC, 1999), 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* (Department of the Air Force, 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 (Department of the Air Force, 1998, p. 11).

From the guidance on reparable maintenance, instructions require that the NRTS asset be transported off base as quickly as possible. Further, regulations state that the reparable assets should be "moved using fast, time-definite best value transportation..." (Department of the Air Force, 1998, p. 11).

However, as one study of Air Force shipping policies states, "the definitive word comes from AFI 24-201" (Masciulli and Cunningham, 2001, p. 4). This transportation instruction provides Air Force transportation managers with the direct guidance on selecting the mode of transportation for a NRTS asset. Chapter 2 of AFI 24-201 provides the concept of operations for transportation managers.

According to this document, all reparable items will be shipped using commercial express. Explicitly, the directive states:

> Commercial air express small-package delivery service... is the norm for Agile Logistics/2LM/Rapid Parts Movement shipments to meet Air Force sustainment goals (Department of the Air Force, 1999, p. 9-10).

It also sets a rigorous and compressed time standard of 24 hours from the time an item is declared NRTS by maintenance until it is processed through supply to transportation and picked up by the carrier (Department of the Air Force, 1999, p. 10). AFI 24-201 also states that the DoD is a mandatory user of the General Services Administration 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 (Department of the Air Force, 1999, p. 22). Three of the major exceptions include distances under 500 miles, contingency operations, and shipments over 151 pounds.

The overall Air Force policy on transportation mode selection (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 and 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.

Masciulli and Cunningham (2001) analyzed 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 and Cunningham, 2001, p. 4). Of particular interest is the heavy reliance on the use of premium, overnight air to ship items. The data used in this study had several examples of misuse of premium, overnight 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 [that] it is automatically ... used as the carrier for MICAP items and other time-critical shipments without regard to cost, distance or other factors? (Masciulli and Cunningham, 2001, p. 7)

The problem with the current Air Force policies is that they seek to optimize the entire logistics pipeline by optimizing each individual segment in terms of transportation times. The reasoning is, if the part is shipped by the fastest mode in each segment, this will result in the fastest overall order cycle time. However, this view ignores the effects of bottlenecks in one segment that might affect other decisions in that segment or other segments, and is the antithesis of the systems approach to logistics management. 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... (Department of the Air Force, 1998, p. 1).

In addition, Air Force transportation policy, while not dictating mode, further calls for the fast movement of reparable items (Department of the Air Force, 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 repair capacity. In this instance, the rapid movement of an asset to the depot would result in the asset arriving and being added to the backlog of items awaiting repair. This would be an inefficient use of transportation resources.

## ANALYSIS

This article examines the use of depot capacity as a determinant of retrograde mode selection. No previous studies were found that incorporated the use of receiver capacity to process (by repairing or otherwise modifying) the item shipped as a determinant in mode selection. 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 repair capacity are used to determine what service level is required and, where this level could be provided by a lower cost mode, potential cost savings are calculated.

### Supply Data

The supply data were obtained from the depot wholesale and retail receiving and shipping database. The data include two measurements per month from January to July 2002. The depot pipeline data needed from these measurements are the quantities of each national shipping number (NSN) that are in the depot pipeline and are physically at the depot.

Also needed is depot capacity. However, depot capacity data could not be obtained from the air logistics centers (ALC). The Oklahoma City ALC 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 (Oklahoma City, ALC, 2004).

The other depots confirmed this, describing shop capacity as a "floating" or "running" figure based upon budget, manning, and equipment. Therefore, a surrogate measure for depot capacity was developed.

### Depot Capacity and Induction Requirements

In order to determine the shipment priority of a reparable item back to the depot repair station, the time sensitivity of the shipment must be established. The repair schedule, a combination of depot capacity and funded repair authorizations, determines the monthly requirement for the numbers of items to be inducted for repair. A stock point model approach was used to determine time sensitivity. The sensitivity is based upon shipping mode selection in order to prevent "stocking out" of items for induction.

The stock point model approach is based upon maintaining sufficient stocks of an item of inventory in order to ensure an acceptable level of risk of having insufficient inventory to meet demand. In this application, demand is the need for reparable assets to induct for a given production cycle. If the number of such items at the beginning of a production period is already sufficient to meet all of the induction needs for that period, then no shipment is required. If there are insufficient items to meet the production need, then shipments must be scheduled in order to provide items ahead of need in order to assume a limited risk of stocking out.

In this research, the induction needs of the depot repair shop were treated as the "customer demands" for the stock point model. Actual depot capacity sets an upper bound for the number of items that could be repaired in any monthly period. While the lower bound for any period is zero, the funded allocation of repairs per month over the annual budget cycle would set a practical average level of induction in any period. While information on actual depot capacity (upper bound) was not available, actual production counts (demands) were available from historical records.

Depot production data were acquired from Warner Robins ALC. Actual monthly production quantities of national shipping numbers (NSN's) produced by repair shops at Warner Robins from October 2000 to December 2003 (less missing data for April 2002) for approximately 5,500 NSN's were obtained from historical records. Using Microsoft Access, these files were joined together to yield a sample of NSN's with non-zero production counts in each month. Descriptive statistics were calculated for these items to compare against depot stock. While all data samples did not strictly adhere to a theoretical normal distribution, the data were sufficiently symmetrical and mound-shaped, and the samples large enough, to apply the central limit theorem. Under the application of the stock point modeling technique, this data represented "customer demand" for the purpose of calculating risk of stockout and time sensitivity of resupply.

**Transportation Data**

Transportation data came from Headquarters, Air Force Materiel Command's Logistic Support Office (LSO), and the D087T, "Tracker" database. The transportation data required consisted of the trip information and cost data. In addition to actual transportation data, information on an alternate transportation mode is needed to evaluate the effectiveness of mode selection.

**Methodology**

Since only Warner Robins ALC provided production data, the pool of NSN's is limited to those for which this center is either the source of repair (SOR) or source of supply (SOS). To ensure 30 or more observations, only those NSN's that were in all three years of the monthly production data were used. These NSN's serve as a filter for the transportation data. NSN's having fewer than two shipments (air or ground) were also excluded. Of the NSN's remaining, only those with eleven or more shipments were used in this study.

Once the sample was obtained, the methodology became fairly simple in nature. The intent was to evaluate the efficacy of the modal choice made. Throughout the analysis, it involved comparing the depot stock (consisting of condition code F reparable items in depot supply and those in transit to the depot repair shop from depot supply) with the depot production averages calculated from the Warner Robins ALC production data. For this model, 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 was performed on all 3,189 NSN's. Because 14 different production data files were available, each NSN was evaluated for efficiency of modal selection 14 times.

The use of $\mu + 3\sigma$ was decided upon because 99.7 percent 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, 99.85 percent (virtually all occurrences) of the time the depot repair shop production rate will be less than $\mu + 3\sigma$.

The final step is to calculate a potential savings figure using an alternate mode (in this study FedEx ground shipments) for shipments that passed the above mentioned test ($\mu + 3\sigma$). Of the

NSN's remaining after the paring is accomplished, a random sample of 35 NSN's were selected to calculate this cost saving. In Microsoft Access, the results of the modal tests and the transportation data were linked in a query that filtered for shipments of the 35 randomly selected NSN's and for the given date of the production data file, then screened out those that failed the test.

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 saved over standard overnight rates was 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 set of repaired NSN's, the savings from the random sample to the population were extrapolated.

### 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 items in depot supply, and those in transit from depot supply to the repair shop, was calculated for all 3,189 NSN's for all 14 of the production data files and compared with the average monthly production, plus three standard deviations. Table 1 displays the results of this comparison by sample size.

### Potential Savings

After obtaining the results of the modal evaluation analysis, the data were filtered for those shipments on the dates of the production data files from the 35 NSN's whose depot stock allowed for slower transportation. A total of 34 of the 35 sample NSN's had at least one occasion of depot stock exceeding the production rate. These NSN's had a total of 114 shipments on the dates of the 14 data files. The calculation of savings is provided in Table 2.

Calculating what that savings might constitute when extrapolated over the entire set of repaired NSN's was accomplished by assuming that the savings of a larger sample is proportional to the relative sizes of the two samples. Table 3 shows the results of this extrapolation.

Recall that this figure is only for 14 days, assuming the ratios hold throughout. Annual savings would be derived by dividing 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 NSN's and $38,771,413.33 for those managed by Warner Robins ALC. A simple "back of the napkin" sensitivity analysis

**Table 1**
**Results of Modal Evaluation**

| Sample | Trials | Success | % |
|---|---|---|---|
| 35 | 490 | 410 | 83.7 |
| 213 | 2,982 | 2,585 | 86.7 |
| 593 | 8,302 | 6,283 | 75.7 |
| 3,189 | 44,646 | 24,189 | 54.2 |

**TABLE 2**
**SAVINGS FROM ALTERNATIVE MODE**

| | Cost | Savings | % of SO |
|---|---|---|---|
| **Standard Overnight (SO)** | 2,577.96 | | |
| 2 day | 2,202.36 | 375.6 | 14.57% |
| 3 day | 2,071.88 | 506.08 | 19.63% |
| Ground | 1,080.05 | 1,497.91 | 58.10% |

**TABLE 3**
**EXTRAPOLATION OF SAVINGS***

| | Sample Size | Ratio | Savings ($) |
|---|---|---|---|
| Total Repair NSN's | 133,538 | | 5,715,083.02 |
| WR ALC NSN's | 50,732 | 0.380 | 2,171,199.15 |
| NSN's with Production Data | 3,189 | 0.063 | 136,481.00 |
| NSN's 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

illustrates that, even if the results of the interpolation were off by 90 percent, substantial savings would result from a modal selection process that utilized depot capacity and on-hand inventory as decision criteria.

## RESULTS

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 study of this process, most often this means that an NRTS asset is 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. This produces a situation analogous to our military's notorious penchant for "hurry up and wait." In addition, this also results in the over-expenditure of a significant amount of resources for premium air when a slower, cheaper mode would have sufficed.

## CONCLUSIONS

The U.S. Transportation Command'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, p. 15).

While reverse logistics and synchronization may not seem directly germane to transportation mode selection, it is essential that mode selection not be made in a vacuum. The entire system must be considered. 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 (2001, p. 29).

Part of this systemic view entails taking into account what is happening upstream at the source of supply and repair. This research queried whether depot repair capacity should 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 that the 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. It should follow that the depot should be dependent upon fast shipment to maintain production. 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 possessed 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, with the 83.7 percent pass rate of depot stock greater than depot production, the service level can be reduced without impacting production.

Furthermore, this research was conservative in the determination of situations in which 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, at reduced transportation cost. This analysis has not approached the point of synchronization of transportation with repair production scheduling. It was 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 produce a hold signal for 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 more efficient transportation modal decisions will become.

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