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# Prioritization Schemes of the Air Force Logistics Reparable Pipeline

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# PRIORITIZATION SCHEMES OF THE AIR FORCE LOGISTICS REPARABLE PIPELINE

THESIS

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# OF THE AIR FORCE LOGISTICS REPARABLE PIPELINE

THESIS

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Brigham Briggs

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## Abstract

This study describes the prioritization schemes utilized in the Air Force logistics reparable pipeline. The reparable pipeline is defined and illustrated with flowcharts. A literature review examines previous research conducted on the reparable pipeline, including analytic and conceptual pipeline models, and pipeline management studies. In addition, the topic of prioritization as defined in the production/operations management academic discipline is reviewed. Prioritization schemes of the reparable pipeline are reported in tabular format in addition to descriptions of the various prioritization schemes. Recommendations for pipeline improvement and further research form a basis from which pipeline operation may be improved.

PRIORITIZATION SCHEMES

OF THE

AIR FORCE LOGISTICS REPARABLE PIPELINE

# I. Introduction

## Air Force Logistics

Air Force Doctrine Document 40, *Logistics*, states, "The purpose of Air Force logistics is to create and sustain force generation capabilities whenever and wherever needed to conduct military operations" (1994:3). This logistics function is accomplished through eight interactive logistics processes (see Figure 1). The first four - definition, acquisition, maturation, and integration - combine to create weapon systems; the final four processes - distribution, preservation, generation, and disposition - sustain weapon systems. Although Figure 1 depicts the processes as discrete steps, some processes may overlap or be concurrent (Logistics, 1994:4).

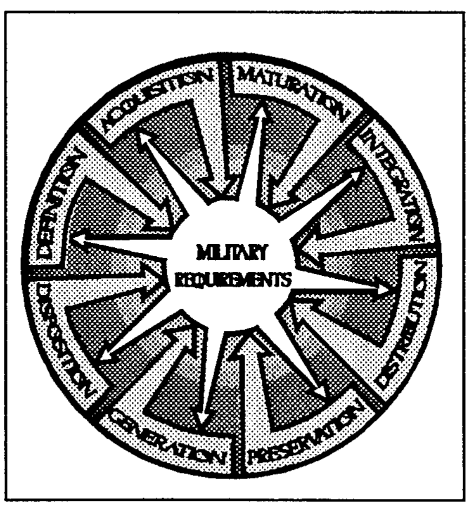


Figure 1. Logistics Processes (Logistics, 1994:4)

## Pipelines

A key concept in supporting Air Force operations is the logistics pipeline. As recognized in AFDD 40,

> Successful sustainment of forces requires a logistics pipeline to link a weapon system with its associated resources. This link makes it possible to sustain weapon systems with the resources needed for continuous operation as well as for retrograde movement. (Logistics, 1994:8-9)

Two classes of items which flow through the logistics pipeline are consumables and reparables. *Consumables* are items which are expended, consumed, or used up beyond recovery in the process of the use for which they were designed or intended (Air Force Compendium, 1981:158). Examples of consumables include fuel, lubricants, nuts, bolts, and rivets. *Reparables* are defined as items that may be reconditioned or economically repaired and restored to a serviceable condition. The term *reparable* denotes the logistics status of an item rather than the condition of an item. The term *repairable* is used to describe the condition of a reparable item which is inoperative and requires repair (Air Force Compendium, 1981:581). Examples of reparables include avionics, landing gear, and flight control surfaces (ailerons and rudders). The term *carcass* refers to an unserviceable reparable which can be restored to serviceable condition.

## Reparable Pipeline

Reparables receive special management in the logistics pipeline because of their high cost and ability to be reconditioned for reuse. When a consumable item fails, it is discarded. Failed reparable items, however, are treated differently. In general, a failed reparable will be routed through base maintenance who determines whether the part can be repaired locally. If so, the repair is made and the part is placed in inventory at base supply. This process is known as the base repair cycle. If local repair is not feasible or authorized, the item will be turned into base supply. Base supply processes the reparable, then forwards it to base transportation where it is prepared for shipment. Once a carrier has been selected, the reparable is moved to a depot where it is evaluated and repaired or discarded. Serviceable parts flow from the depot to base supply to base maintenance. This flow of reparable assets is known as the reparable pipeline, illustrated in Figure 2. The reparable pipeline will be the focus of this study.

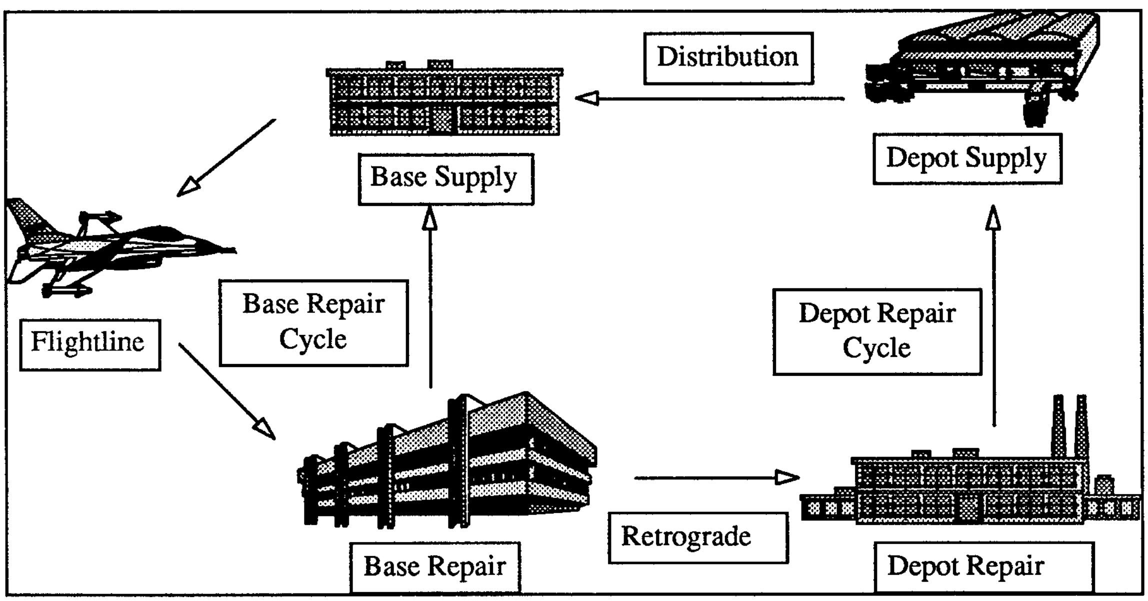


Figure 2. Reparable Pipeline (Adapted from McCormick, 1996:8)

## Logistics Philosophy

The logistics system of the past 30 years was focused on supporting military operations designed to counter the threat from the Soviet Union and the Warsaw Pact nations. This logistics orientation has been described as the *mass logistics paradigm*, which "placed heavy emphasis on three mechanisms for providing logistics support: 1) *functional bureaucracies*, 2) *large inventories*, and 3) *special management actions*" (Girardini and others, 1995:18). Although the mass logistics paradigm served in the past, analysts found these mechanisms "inefficient, often ineffective, and not particularly well-suited to provide the responsiveness and flexibility required of future military logistics operations..." (Girardini and others, 1995:19). Changing threats, different operational requirements, and shrinking budgets dictate changes in the way logistics support is provided. AFDD 40 recognizes these changes: "Logistics processes and the pipelines linking those processes to military forces need to be flexible and secure in order to support one or more conflicts in any region of the world" (Logistics, 1994:9).

Lean Logistics

The actions the Air Force has taken to develop flexible and secure logistics processes can be grouped under the Lean Logistics umbrella. Lean Logistics (LL) refers to a wide range of activities such as the application of successful business practices to logistics processes, re-engineering actions, and process improvement. The objective of LL is to "maximize operational capability by using high velocity, just-in-time processes to manage mission and logistics uncertainty in-lieu of large inventory levels--resulting in shorter cycle times, reduced inventories and cost, and smaller mobility footprint" (LL Master Plan v4.0, 1996:2). Lean Logistics requires a system-wide management approach:

> Developing a logistics strategy to achieve that goal [meeting user needs at least cost] depends upon an integrated approach among component functional areas. Inherent in this system are tradeoffs between functional areas that cause changes in policy and decision making when viewed from a

> corporate rather than a functional perspective. Traditionally, functional areas attempted to optimize individual functional performance without assessing the impact on total logistics performance. (LL Master Plan v3.0, 1995:13)

In order to optimize system performance, it is imperative to clearly understand the components of a system and their relationships. The reparable pipeline has numerous interrelated activities and processes which must be understood before they can be effectively managed.

Lean Logistics initiatives will significantly alter the reparable pipeline. However, these initiatives are being implemented over a period of several years. This evolution results in several coexistent versions of the reparable pipeline, depending on the part, which depot is responsible for its repair, and which phase of LL is being implemented (LL Master Plan v4.0, 1996).

Prioritization

Because assets in the reparable pipeline are competing for limited resources, decisions must be made regarding transportation and repair of reparables. *Prioritization* is the assignment of precedence in obtaining supplies, services, or facilities (Webster's, 1989:1145). In order to manage the reparable pipeline as a whole, transportation, supply, and maintenance actions must be prioritized across the entire pipeline. The goal of this thesis is to facilitate development of this capability by describing the existing prioritization schemes throughout the reparable pipeline. Specifically, this thesis will answer the question, "What are the prioritization schemes currently employed in each segment of the reparable pipeline?"

Investigative Questions

In order to provide a sufficient response to the above question, the following investigative questions must be answered.

1. What are the segments that comprise the reparable pipeline?
2. What are the characteristics of the environment within which the prioritization schemes are employed in the pipeline?
3. What are the characteristics of the job context (factors affecting job processing) within which the prioritization schemes are employed in the pipeline?
4. What prioritization rules are employed in each of the pipeline segments?
5. What are the characteristics of the managerial guidance under which the prioritization schemes are employed in the pipeline?
6. What are the implications of the integration of the prioritization schemes used in the various pipeline segments?

Benefits of the Research

The Air Force has an immense financial investment in the reparable pipeline. Recent reports estimate that the Air Force has a $33 billion reparable parts inventory (GAO, 1996:29). Other studies estimate that at any given time, the dollar value of assets in the reparable pipeline is approximately one-half billion dollars, and that a one-day reduction in pipeline time could save between $16 and $25 million (Kettner and Wheatley, 1989:4; Silver, 1993:iii). Air Force officials have said the Air Force can no longer continue its current logistics practices (GAO, 1996:30). Implementation of LL practices, including improved management of the reparable pipeline, could generate substantial savings, and improve logistics support and responsiveness.

## Summary

This chapter presented an overview of the Air Force logistics system, introduced the concept of a reparable pipeline, and identified the purpose of this thesis. The next chapter presents the results of a literature review, which provides pertinent background information about the reparable pipeline and prioritization schemes, and determines the efficacy of previous research on prioritization in the reparable pipeline.

# II. Literature Review

## Introduction

A literature review was performed in order to discover what comprises the reparable pipeline and determine the scope and utility of previous studies on the subject of reparable pipeline prioritization. In addition, this chapter reviews the topic of scheduling and prioritization, an academic discipline with applications in the business sector. A simple model of the reparable pipeline was presented in Chapter I (Figure 2). While this model is an accurate depiction of the overall reparable pipeline, it does not account for all the processes affecting reparable assets in the pipeline. This chapter begins by reviewing what previous pipeline models have contributed to the development of the reparable pipeline model used in this thesis, which is presented in Chapter IV.

## Pipeline Models

There are two categories of models commonly associated with the reparable pipeline: analytic and conceptual. In general, analytic models of the reparable pipeline are equations or systems of equations that seek to provide a specific answer, such as an optimal stock level or where to distribute a reparable. Conceptual models describe processes affecting reparables and relationships between organizations in the pipeline. They are designed to convey an understanding of how the pipeline functions.

Analytic models of the reparable pipeline have been used by the Air Force for several years. The seminal analytic model of the reparable pipeline is the METRIC model developed by Dr. Craig Sherbrooke. METRIC, Multi-Echelon Technique for Recoverable

Item Control, is a mathematical model of a multi-echelon supply system capable of determining base and depot stock levels for a group of recoverable items (Sherbrooke, 1966).

Following the development of METRIC, several adaptations and improvements were produced to model the reparable pipeline more accurately. These models included Mod-METRIC which accounted for sub-assemblies (Muckstadt, 1972); Dyna-METRIC which accounted for the effects of wartime parts demand surges (Hillestad, 1982); the Aircraft Availability Model, based on METRIC, which seeks to optimize a measure of aircraft availability (O'Malley, 1983); VARI-METRIC, a correction of a faulty assumption in the original METRIC model (Miller and Abell, 1995); and DRIVE, Distribution and Repair in Variable Environments, based on Dyna-METRIC, which seeks to allocate spare parts where they are needed most (Miller and Abell, 1995). Table 1 summarizes the purposes of these models.

Table 1. Analytic Model Comparison

| Model | Purpose |
|---|---|
| METRIC | Determine base and depot stock levels |
| Mod-METRIC | Account for sub-assemblies |
| Dyna-METRIC | Account for unpredictable demand |
| Aircraft Availability Model | Relate stock levels to aircraft availability |
| VARI-METRIC | Correct a faulty assumption in METRIC |
| DRIVE | Allocate spares where they are needed most |

These models do not precisely specify activities in the reparable pipeline that impact the number of parts in the pipeline, such as the activities required to move an asset from an aircraft to the back shop, to base supply, to base transportation, to the carrier and finally to the depot. A different sort of model was required that would be useful for management decisions and policy analysis: the conceptual model.

## AFIT Research

At the behest of Major General Skipton, Assistant Deputy Chief of Staff, Logistics and Engineering and the Assistant Deputy Undersecretary of the Air Force for Logistics, Oscar Goldfarb, Major David K. Peterson began a stream of research aimed at defining and analyzing the reparable pipeline. Under his tutelage, Captains Craig A. Bond and Marvin E. Ruth undertook the task of developing a comprehensive conceptual model of the Air Force logistics reparable pipeline. In their master's thesis at the Air Force Institute of Technology (AFIT), they reviewed the analytic models and found them to be unsatisfactory conceptual representations of the reparable pipeline. They produced their own conceptual model, as seen in Figure 3, based on the Exchangeable Flows Model of the Logistics Management Institute (Bond and Ruth, 1989:173).

Bond and Ruth proceeded to provide detailed descriptions of each segment of the pipeline. These descriptions consisted of flowcharts which attempted to account for the flow of assets through the pipeline and the decisions that directed movement of reparable items. Figure 4 is one such flow chart.

## Refinements

Following this groundbreaking effort, several AFIT theses expanded and modified the baseline model proposed by Bond and Ruth. These efforts include Kettner and Wheatley's model of the depot subsystem (1991); Davis, Platte, and Stafford's model of the base subsystem (1992); Mireles and Pearson's model of reparable movement from the base to the depot (the intransit segment) (1993); and Hites and Schultz' investigation into the base-processing element of the intransit segment (1993).

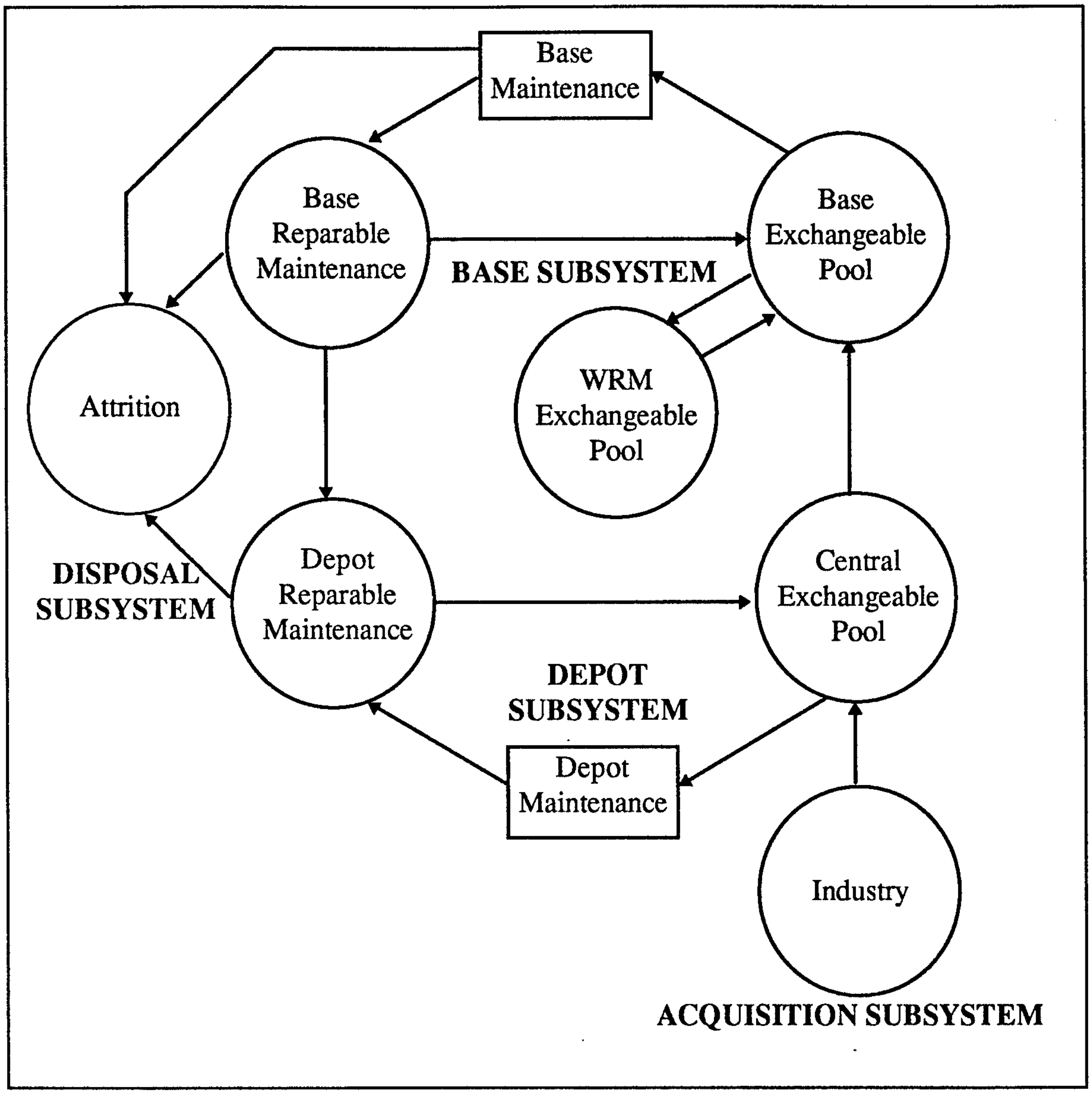

Figure 3. Exchangeable Flows Model (Adapted from Bond and Ruth, 1989:173)

In each of these studies, flowcharts similar to Figure 4 were used to describe the paths, processes and decisions affecting assets in the reparable pipeline.

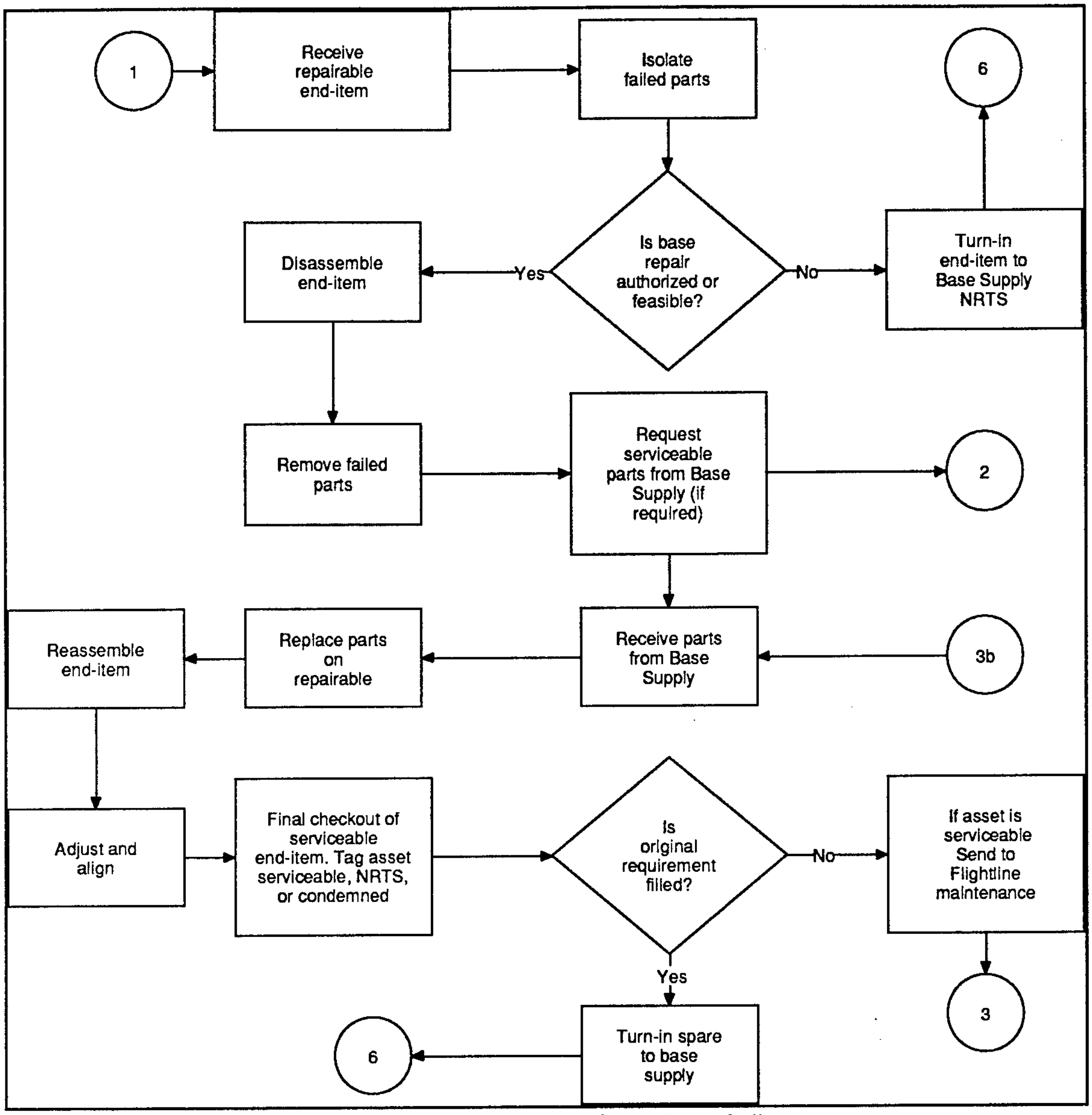


Figure 4. Base Maintenance Shop Repair Process
(Adapted from Bond and Ruth, 1989:177)

These conceptual models are very explicit representations of the reparable pipeline. They effectively describe the pipeline in detail, providing both a macro- and micro-level picture of the processes, asset flow, and functional responsibility. The base-level model proposed by Davis, et al is of note because they actually proposed three models: one generic pipeline, a Tactical Air Command (TAC) pipeline, and a Strategic Air Command (SAC) pipeline (Davis and others, 1992). Mireles and Pearson reported that there is no consensus among logisticians concerning the exact definition of the intransit segment of the pipeline (Mireles and Pearson, 1993:47). In fact, each of the theses after Bond and Ruth's initial report concluded that there was some ambiguity or inaccuracy in existing conceptual models which warranted further clarification and research.

Another issue with these models is the time at which they were developed. Since the late 1980s, the logistics system has undergone significant changes such as the elimination of LOGAIR shipments, the merger of SAC and TAC into ACC, numerous base closures, and reduced funding. Lean Logistics initiatives such as two-level maintenance, consolidated serviceable inventories, and emphasis on premium transportation have further altered the existing logistics system. Although the previously mentioned models are somewhat dated, they still provide an excellent picture of the reparable pipeline, and contribute much to its comprehension.

### AFLMA Pipeline Studies

The Air Force Logistics Management Agency (AFLMA) completed *An Analysis of the Depot Repair Process* in 1993. The study was based on the Recoverable Consumption Item Requirements System (D041) used at the depot. The D041 system defines the pipeline as five processes: 1) base processing days, 2) reparable intransit time, 3) supply to maintenance days, 4) shop flow days, and 5) serviceable turn-in time. The authors then described each process in detail through the use of flowcharts, in a manner similar to the AFIT theses (Silver and others, 1993).

The AFLMA study is also a very detailed and specific description of the reparable pipeline. However, it is the pipeline as seen by the D041 system, which, as noted by the authors, does not reflect reality in all cases. Because the pipeline is defined in terms of the D041 requirements system, the model does not represent the time it really takes the depot repair system to respond to requirements placed on it (Silver and others, 1993:38).

There are many other conceptual models of the reparable pipeline. Reparable items which have been subjected to LL initiatives have a unique pipeline structure (LL Master Plan v4.0, 1996:17). Various reports analyzing some function of the logistics system have representations of the reparable pipeline which are very similar (GAO, 1996; Miller and Abell, 1995). However, none of the above models are appropriate for the purpose of this study. In order to complete a description of the prioritization schemes used in the pipeline, a model of the reparable pipeline will have to be developed which accurately depicts the processes and decision points which are subject to some form of prioritization scheme. This pipeline model will be presented in Chapter IV.

## Previous Prioritization Studies

Despite the scrutiny to which the reparable pipeline has been subjected in recent years, few studies have addressed the prioritization schemes utilized by pipeline managers. In their study of the intransit segment of the reparable pipeline, Mireles and Pearson presented conflicting standards and priorities. In addition to the previously mentioned ambiguity regarding the actual definition of the intransit segment, they found different measures pertaining to the intransit segment from Air Force regulations, the D041 system, and Department of Defense directives. Air Force Regulation 75-1, Transportation of Material, assigned a 2 - 8 day standard for the time of receipt of an item until the item is loaded on a selected carrier, depending on the assigned transportation priority. The D041 system utilized a specific average intransit pipeline time, derived from actual, estimated, and computed values of intransit movement. The Uniform Materiel Movement and Issue Priority System (UMMIPS) established a priority system between depots and base-level organizations. However, at that time, UMMIPS priorities did not apply to Not Repairable This Station (NRTS) items, which are a source of future serviceable assets (Mireles and Pearson, 1993).

While this study may have been accurate at the time, recent occurrences have altered the landscape. Defense Management Review Directive 915 eliminated the three-priority system for transportation (described by Mireles and Pearson) and established a two-priority system (Silver and others, 1993:20). All retrograde movements are now either priority or routine (Cargo Movement, 1994:4). Existing proposals are aimed at revising UMMIPS time standards and priority systems (Logistics Strategic Plan, 1995:14). Despite these changes, the information provided by Mireles and Pearson was valuable because of the insights it provided regarding prioritization in the in-transit segment of the pipeline.

In the previously mentioned *Analysis of the Depot Repair Process*, the authors at AFLMA highlighted some problems with the priority rules used at the depot. Their findings "suggest that the priority reflected in the wholesale [depot] system does not always appear to be appropriate" (Silver and others, 1993:iii). This shortcoming is linked to problems with the process which gives the bases disposition instructions for unserviceables including condemnation direction, shipping destination, and transportation priority. This process, the Reparable Item Movement Control System (RIMCS), was investigated by the AFLMA and found to have numerous problems, including system disconnects, antiquated hardware, training deficiencies, and procedural deficiencies (Coley, 1994:19). The report indicated that many of the deficiencies would be corrected by improved interface systems between the bases and depots.

Neither the thesis by Mireles and Pearson nor the studies by the AFLMA were directed specifically at the prioritization schemes employed in the reparable pipeline. As a result, they make references to them only in the context of their larger studies, the intransit segment or depot-level segment of the reparable pipeline.

## UMMIPS

Because UMMIPS currently plays a central role in the prioritization and movement of assets in the reparable pipeline, it will be beneficial to briefly describe it here. UMMIPS is described in the Department of Defense Materiel Management Regulation, DoD 4140.1-R, and applies to all branches of the military. AFM 67-1, Volume I, Part One, Chapter 24 describes the Air Force implementation of UMMIPS. (AFM 67-1 is in the process of being updated as AFM 23-110. Not all volumes had been completed at the time of this writing). UMMIPS establishes a priority system between depots and base-level organizations using numeric codes, called priority designators. Priority designators are determined from the Force/Activity Designator (FAD) code assigned to the requesting unit (Tables 2 and 3) and the Urgency of Need Designator (UND) specified by the individual who requests the item (Table 4). Priority designators are consolidated into priority groups (Table 5) and time standards are established for each priority group in each pipeline segment (Table 6). Prioritization according to UMMIPS is based first on the priority group and second on the age of the requisitions within each group. The oldest requisition in the highest priority group is satisfied first, but all requisitions are to be satisfied within the applicable time standard.

Table 2. FAD Assignment Authority

| Precedence Rating | Force/Activity Designator Code | Assignment Authority |
|---|---|---|
| 1-1 thru 1-20 | I | JCS |
| 2-1 thru 7-20 | II | HQ USAF |
| 8-1 thru 13-20 | III | HQ USAF |
| 14-1 thru 19-20 | IV | HQ USAF |
| 20-1 thru 25-20 | V | HQ USAF |

Table 3. Force/Activity Designator (FAD) Codes

| I | II | III | IV | V |
|---|---|---|---|---|
| COMBAT | COMBAT READINESS | DEPLOY READINESS | ACTIVE & RESERVE | OTHER |

Table 4. Urgency Of Need Designators (UND)

| A | B | C |
|---|---|---|
| CANNOT PERFORM MISSION | MISSION CAPABILITY IMPAIRED | FIRM RQMT & STOCK REPLENISHMENT |

Table 5. UMMIPS Priority Matrix

| | UND | | |
|---|---|---|---|
| FAD | A | B | C |
| I | 1 | 4 | 11 |
| II | 2 | 5 | 12 |
| III | 3 | 6 | 13 |
| IV | 7 | 9 | 14 |
| V | 8 | 10 | 15 |
| | ←PRIORITY→ | | |

| Priority Groups | |
|---|---|
| Priorities 1 - 3 | Group 1 |
| Priorities 4 - 8 | Group 2 |
| Priorities 9 - 15 | Group 3 |

Table 6. UMMIPS Time Standards
(Adapted from DoD 4140.1-R, DoD Materiel Management Regulation, 1993)

| | Time Standards in Calendar Days for UMMIPS Priority Designators (1) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Expedite | | | | | | | | | | Routine | | | | |
| | TP-1 PD 01-08 | | | | | TP-2 PD 01-08 (01-15 for 444) | | | | | TP-3 PD 01-15 | | | | |
| Time Segment | RDD of 999, N__, E-- | | | | | RDD of 444, 555, 777 | | | | | Blank RDD | | | | |
| A. Requisition Submission | 1 | | | | | 1 | | | | | 2 | | | | |
| B. Passing Action | 0.5 | | | | | 1 | | | | | 1 | | | | |
| C. ICP Availability Determination (5) | 1 | | | | | 1 | | | | | 1 (3) | | | | |
| D. Depot Storage Site or Base Processing and Packaging (5) | 1 | | | | | 1 | | | | | 5 | | | | |
| E. Transportation Hold and CONUS Intransit | 4 | | | | | 4 | | | | | 10 (4) | | | | |
| Area (2) | CONUS | 1 | 2 | 3 | 4 | CONUS | 1 | 2 | 3 | 4 | CONUS | 1 | 2 | 3 | 4 |
| F. POE and/or CCP Processing and Intransit to Carrier | N/A | 1 | 1 | 1 | 3 | N/A | 1 | 1 | 1 | 3 | N/A | 10 | 10 | 10 | 21 (4) |
| G. Intransit Overseas | N/A | 1 | 1 | 2 | 3 | N/A | 1 | 1 | 2 | 3 | N/A | 10 | 15 | 25 | 30 |
| H. POD Processing | N/A | 1 | 1 | 1 | 1 | N/A | 1 | 1 | 1 | 2 | N/A | 3 | 3 | 3 | 5 |
| I. Intratheater Intransit | N/A | 1 | 1 | 1 | 1 | N/A | 1 | 1 | 1 | 1 | N/A | 5 | 5 | 5 | 5 |
| J. Receipt Takeup by the Requisitioner | .5 | .5 | .5 | .5 | .5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| K. Total Order and Ship Time | 5 | 9 | 9 | 10 | 13 | 9 | 13 | 13 | 14 | 18 | 22 | 50 | 55 | 65 | 83 |

NOTES:

Required Delivery Date (RDD):

- 999 Indicates expedited handling required for NMCS overseas customers or CONUS customers deploying overseas within 30 days.
- N__ Indicates expedited handling due to NMCS requirement CONUS customer.
- E__ Indicates expedited handling due to anticipated NMCS requirement CONUS customer.
- 555 Indicates exception to mass requisition cancellation, expedited handling required.
- 777 Indicates expedited transportation required for other than the above reasons.
- 444 Indicates handling service for customers collocated with the storage activity or for locally negotiated arrangements.
- Specific date indicates handling to meet that date of delivery.
- Blank RDD indicates routine handling.

(1) Pipeline standards for materiel delivery exclude weekends and holidays except for segments D and E for requirements with RDDs 999, N__, or E__. Storage activities and transportation managers may combine the times for segments D and E as long as the combined time is not exceeded. The pipeline time standards are service level targets; they shall be met or improved upon whenever subsequent savings in time and improved service can be achieved.

(2) Areas:

1. To Alaska, Hawaii, Guam, Caribbean, and Central America.
2. To United Kingdom and Northern Europe.
3. To Japan, Okinawa, Korea, and western Mediterranean
4. Hard lift areas and all other destinations not listed in areas 1-3 (for example, South America, eastern Mediterranean, North Atlantic, Africa, Diego Garcia) as determined by USTRANSCOM Current information on air and surface hard lift areas is available for the Service clearance authorities.

(3) For manually submitted requisitions or requisitions requiring manual review, 1 day for PDs 01-08 and 3 days for PDs 09-15.

(4) Combine segments E and F as a single segment when a SEAVAN is loaded at the source or when cargo is moved breakbulk to the POD.

(5) Measurement or intra/inter-Service lateral support or distribution begins at segment C or segment D (installation level).

## DRIVE

More recently, the DRIVE system has been considered as an alternative to the UMMIPS prioritization system. DRIVE uses data from many sources to determine which item is the 'next best' item to allocate to the base which provides the greatest gain towards its assigned availability goal. Key data elements are:

1. Relationship to other items as well as the relationship to the end weapons system (single or multi-indenture).
2. Usage per flying hour.
3. Serviceable and unserviceable asset balances at each location.
4. Repair capability at the base and depot.
5. Number of aircraft and flying hours per unit.
6. Priority (goal) of the unit (Neumann and others, 1992:5).

Studies by the Logistics Management Institute and AFMC/XPS both recommended that DRIVE be used to determine which items to repair and where to distribute them (Culosi and Eichorn, 1993; Neumann and others, 1992). In May 1993, the

Air Force was granted a waiver to the UMMIPS item release procedures, so that DRIVE distribution priorities could be used to determine the item release sequence for Air Force customers. Under the terms of this waiver, Air Force backorders would be released as follows:

1. JCS Project Coded MICAP requisitions.
2. Air Force MICAP items (UMMIPS priority 01-03).
3. All other requisition in DRIVE specified order (DRIVE Primer, 1996:3).

Despite this waiver, DRIVE has been adopted slowly, and only by certain depots for certain items. Because DRIVE does not specify time standards for distributing assets, UMMIPS time standards still applied.

Prioritization

Because the focus of this thesis will be to describe the prioritization schemes employed in the reparable pipeline, it is valuable to review the body of knowledge regarding prioritization from the academic and business worlds.

Prioritization of work activities has been studied extensively by researchers in the production management and operations management discipline (referred to as production/operations management or POM). POM is the "systematic direction and control of the processes that transform inputs into finished goods and services" (Krajewski and Ritzman, 1993:3). Within POM literature, the terms scheduling, sequencing, prioritizing, and dispatching are often used synonymously (Panwalker and Iskander, 1977:46). In the interest of clarity and precision, these terms will be used separately and defined as follows:

*Dispatching*. Determining which job to process next when a work station becomes available.

*Prioritizing*. Assigning a number or value to each waiting job. Typically the job with the lowest value or number is selected next. (Example, priority 1, 2, 3, etc.). Prioritizing is used to aid the dispatching process.

*Sequencing*. Determining the order of succession for jobs in a production process.

*Scheduling*. Utilizing one or more prioritization rules in conjunction with dispatching procedures to match resources and tasks with reference to time. Scheduling goes beyond sequencing by assigning start and completion times to activities, thus facilitating estimates of job completion (Simons, 1996).

*Expediting*. Making an exception to the established prioritization technique so that a particular job's flow through the production process is accelerated, given increased priority, or other special treatment (Krajewski and Ritzman, 1993:731; Panwalker and Iskander, 1977:46; Simons, 1996).

In order to better understand scheduling and prioritization, it is beneficial to describe the environment in which the scheduling is taking place. Graves proposes a broad, five-tiered classification system which encompasses a wide variety of production scenarios: 1) requirements generation, 2) processing complexity, 3) scheduling criteria, 4) nature of requirement, and 5) scheduling environment (1981:647-649). Examination of this classification system will provide common ground for characterization and analysis of the various segments of the Air Force reparable pipeline.

Production Environment

Requirements Generation. Requirements may be generated directly by customer orders or indirectly by inventory replenishment decisions. An *open shop* is defined as one in which all production orders are generated from customer requests and no inventory of finished goods is stocked. In a *closed shop*, all customer requests are satisfied from inventory, and production tasks are generally a result of inventory replenishment decisions. Although a pure open or closed shop is rare, Graves suggests that most production environments are either primarily open or primarily closed (1981:647).

Processing Complexity. This distinction is concerned with the number of processing steps associated with each production task. *One-stage* tasks require only one process for completion. *Multi-stage* tasks require processing at a set of distinct machines or work-stations, where typically there is a strict sequence of operations that must be followed. The following is a common breakdown for this dimension.

*One-stage, one-processor.* All tasks require one processing step which must be done on the one production facility (machine).

*One-stage, parallel processors.* Each task requires one processing step which may be performed on any of the parallel processors.

*Multi-stage, flow shop.* All tasks are to be processed on the same set of facilities with an identical sequence of operations.

*Multi-stage, job shop.* The most general production environment; there are no restrictions on the processing steps for a task, and alternative routings are permitted (Graves, 1981:648).

Scheduling Criteria. Two classes of scheduling criteria are *schedule cost* and *schedule performance*. Schedule costs typically include the fixed costs of machine setups, variable production costs and overtime, inventory holding costs, stockout costs, and expediting costs. Schedule performance is commonly measured by utilization rates, percentage of late tasks, and maximum flow time for a set of tasks (Graves, 1981:648).

Nature of Requirement. The specification of the requirements may be deterministic or stochastic. For example, the processing time for each step of a given task may be known (deterministic), or may be a random variable with a specific probability distribution (stochastic) (Graves, 1981:649).

Scheduling Environment. The scheduling environment is commonly classified as either static or dynamic. As Graves explains,

> In a static environment, the scheduling problem is defined with respect to a finite set of fully specified requirements; no additional requirements will be added to this set nor will any of the specifications be altered. As a contrast in a dynamic environment, the scheduling problem is defined not only for the known requirements, but also with respect to the anticipations for additional requirements and specifications generated over future time periods. (1981:649)

A simple case of the static scheduling environment is a weekly scheduling meeting. Once the production decision has been made, no event (such as a new order) will alter the decision for that week's production. A dynamic environment would take the new order into consideration.

Once the production environment has been determined, specific prioritization techniques can be characterized. When characterizing prioritization schemes, it is important to remember that prioritization schemes do not consist of single decision rules, but rather the integration of several contextual factors and management policies. As seen in Figure 5, the inputs to the prioritization scheme may be grouped into three categories: 1) Management Direction, 2) Job Context, and 3) Prioritization Rules. Table 7 shows that several dimensions exist within each category. The presentation of the categories is not meant to be exhaustive, but provides a means whereby prioritization schemes of the reparable pipeline can be classified and discussed according to well recognized and documented parameters.

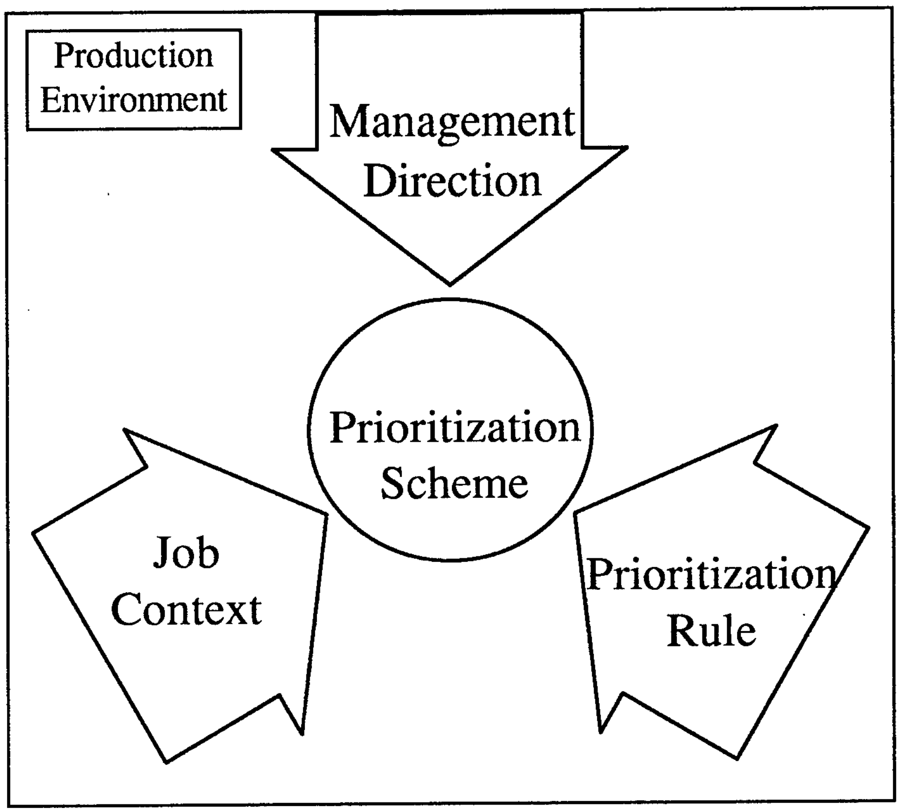


Figure 5. Prioritization Scheme Inputs

Table 7. Prioritization Scheme Inputs

| Job Context | Prioritization Rule | Management Direction |
|---|---|---|
| Order Release Mechanism | Static vs. Dynamic | Constraints |
| Loading Logic | Global vs. Local | Secondary and Tertiary Rules |
| Batching | Cardinal, Ordinal, or Dichotomous | Hidden Priority Schemes |
| Sequence Dependency | Operating Characteristic | Performance Measures |
| | Expediting | |

## Job Context

Order Release Mechanism. An order release mechanism helps control production by determining which job to release to the production floor and when to release it. This determination can be based on capacity levels or queue length for example (Melnyk and Ragatz, 1989:1081-1082).

Loading Logic. This characteristic refers to the reasoning behind the decision to assign a job to a specific queue or resource. For example, a shop might have several machines on the shop floor, some of which can handle all jobs, others of which can only process specific jobs. If the next job is one that all machines can process, loading logic must be used to determine the machine to which the job will go.

Batching. Batching refers to the process of allowing jobs to accumulate until specified conditions are met, whereupon the batch of jobs is released to the shop floor, machine, or work-station. Generally this is done to reduce the number of set-ups for repetitive, identical operations. Batching can affect prioritization as illustrated in the following scenario. A shop processes two types of jobs: low-cost items and high-cost items. Low-cost items will be processed as soon as a batch size of 50 is reached. Otherwise, high-cost items are processed first-come, first-served.

Sequence Dependency. Prioritization rules might consider how the sequence of operations affects set-up times or overall processing times. Consider a shop where jobs must receive processing at stations A, B, C, and D. Operations A, B, and C may be completed in any order, but must be completed before D. The flow time for a part going from A to B to C is five minutes, while the flow time for a part going from A to C to B is twenty minutes. This shop might want to minimize flow times by prioritizing jobs through the A, B, C sequence to take advantage of the flow time dependence on sequence.

Prioritization Rule

Static vs. Dynamic. Jackson differentiates between static and dynamic prioritization rules, defining static priority rules as those in which the job priority value does not change as a function of the passage of time (1957:287).

Global vs. Local. Conway and Maxwell describe local priority rules as those that require information only about those jobs that are waiting at a machine or workstation (1962). Global rules base a job's priority assignment on information from other workstations in addition to the one being scheduled (Krajewski and Ritzman, 1993:731).

Operating Characteristic. An operating characteristic is an attribute of the job, work-station, or machine which will serve as the basis for prioritization, such as processing time or due date. Table 8 specifies several operating characteristics with examples of each.

Table 8. Operating Characteristics

| Characteristic | Example |
|---|---|
| processing time | shortest processing time; longest remaining processing time |
| due date | earliest due date; earliest operational due date |
| number of operations | fewest number of remaining operations; most remaining operations |
| cost | highest dollar value; highest cost penalty for tardiness |
| setup time | minimum setup time, least setup time relative to job just completed |
| arrival time | first-in-first-out; first-in-system-first-out; last-in-first-out |
| slack | least slack (time before due date minus duration of remaining operations) |

(Panwalker and Iskander, 1977:47-48)

Cardinal, Ordinal, or Dichotomous. A cardinal scale is one which contains information about the magnitude of the difference between points. An ordinal scale ranks items in sequence or order (e.g. 1, 2, 3) but does not contain information about the degree or magnitude of the difference between points. When prioritizing, knowing the magnitude of the difference between jobs can be valuable. Consider a shop that prioritizes based on shortest processing time. Jobs awaiting processing may have processing times of 5, 12, and 120 minutes. Knowing the difference in value of the processing times might prove valuable to managers, as opposed to just knowing the priority (1, 2, and 3). A dichotomous scheme will only designate a job as priority or routine.

Expediting. Circumstances may dictate that the existing priority scheme be temporarily waived, or an exception to the rule be made. For example, a plant may follow the first-come-first-served rule, unless a job will be late (as determined by the duration of remaining operations). Prioritization schemes may or may not specify the conditions under which exceptions or expediting is permitted. For example, it may be an unwritten rule that jobs are processed on a first-come-first-served basis; but if the shop foreman directs otherwise, that instruction is followed.

Management Direction

Constraints. Constraints are factors which directly affect the employment of a prioritization scheme. For example, a shop may operate under the longest remaining processing time rule unless the processing time will run past the end of a shift (labor is the constraint). Other constraints which may affect prioritization rules include machine or work-station availability, raw material availability, or direct and indirect inputs and outputs. For instance, a shop may select a lower priority job over a higher priority job if the waste generated by processing the higher priority job would exceed the maximum amount permitted by law for a given time period.

Secondary and Tertiary Rules. Two or more jobs may have identical priorities based on the primary prioritization rule. Therefore, secondary and tertiary rules might be used as tie-breakers. For example, a shop might use the following hierarchy of prioritization rules: 1) shortest processing time, 2) time in queue, 3) item cost.

Hidden Prioritization Schemes. A production plant may profess to follow a standardized prioritization rule, but may actually prioritize in a manner other than that envisioned by the rule-maker. A shop which services internal and external customers might be a candidate for this type of rule. The stated rule may be earliest due date. However, workers in the shop may be able to differentiate between products for internal vs. external customers and consciously select jobs for internal customers. While it may prove difficult to determine hidden prioritization schemes, their existence is common knowledge.

Performance Measures. Organizational or individual performance measures may cause workers to ignore or manipulate prioritization rules. If a shop's performance measure is number of jobs completed, it is likely that workers will find a way to improve work center performance on this dimension, despite an accepted prioritization rule which does not optimize the rate at which jobs may be completed.

In addition to providing a helpful glossary of POM terminology, these classifications and categorizations will help in the analysis of data collected on the reparable pipeline. Comparing prioritization rules discovered through research with the categories just described may elicit more clearly the exact operation and relationships of the prioritization schemes of the pipeline and the environment in which they operate.

## Summary

This chapter presented the development of models of the reparable pipeline. Analytic models are still widely used, but are not well-suited to decision making and policy analysis. Conceptual models are better-suited for this purpose, but existing models are unsatisfactory for the purposes of this thesis. A model of the reparable pipeline suitable for describing the segments of the pipeline subject to prioritization activities must therefore be developed.

Previous studies on prioritization schemes in the reparable pipeline were considered, and found to be limited to certain segments of the pipeline rather than the pipeline as a whole. In addition, prioritization schemes were not thoroughly addressed. Finally, a review of POM literature was presented in order to facilitate the data collection and analysis accomplished in the remainder of this thesis.

Chapter III, Methods, will outline the processes by which data about the pipeline will be collected, the prioritization schemes described, and the interactions of the various segments determined.

# III. Methods

## Research Design

In order for the results of this research to be reliable and valid, it is imperative that a rigorous and scientific method be used to conduct the research. The nature of the problem indicates that a qualitative method is most appropriate. Merriam specified conditions which indicate that a qualitative approach is required, including:

> 1. Research concerned primarily with processes, rather than outcomes or products.
> 2. The researcher is the primary instrument for data collection and analysis.
> 3. Qualitative research is descriptive in that the researcher is interested in process, meaning, and understanding gained from words and pictures.
> 4. The process of qualitative research is inductive in that the researcher builds abstractions, concepts, hypotheses, and theories from details. (1988:19-20)

In addition, Creswell notes that qualitative methods are most appropriate when conducting exploratory research where the variables are unknown (1994:9). The literature review confirmed that a qualitative method is best suited for this thesis topic.

## Data Collection

The data collection method will consist of document analysis, in-depth interviewing, and elite interviewing. According to Cooper and Emory, document analysis is "to evaluate historical or contemporary confidential or public records, reports, government documents, and opinions" (1995:119). They describe an in-depth interview as "conversational rather than structured", and an elite interview "for information from influential or well-informed people in an organization" (Cooper and Emory, 1995:118-9).

Document Analysis. There are ample source documents which will be analyzed for prioritization schemes, including Air Force Instructions, message traffic, master plans, and strategic plans. As mentioned in Chapter II, some priorities are specified in regulations, which may conflict with other written guidance. These conflicts will be discovered and reported through document analysis.

Interviewing and Validity. In order to enhance the validity of the conclusions reached from the document analysis, in-depth and elite interviews will be conducted with relevant managers from each segment of the reparable pipeline. To ensure reliability and validity, a single model of the reparable pipeline will be used for each interview. Thus, all respondents will be answering questions from the same source. In addition to formal questions regarding prioritization in the pipeline, questions will be posed to elicit responses concerning the actual workings of the system versus the prescribed workings of the system. It is common for written guidance to be subverted for one reason or other, such as satisfying personal favors or meeting short-term requirements. Prioritization decisions also tend to be influenced by organizational and individual performance metrics and reward systems. These factors must be accounted for because they have a tangible impact on the reparable pipeline.

## Data Analysis

The data analysis method employed will include elements of grounded theory and case study methodology. In *grounded theory*, the researcher attempts to derive a theory by using multiple stages of data collection and the refinement and interrelationship of categories of information. In *case studies*, the researcher explores a single entity or phenomenon bounded by time and activity (a program, event, process, or institution) and collects detailed information by using a variety of data collection procedures (Creswell, 1994:12).

Strauss and Corbin describe steps for grounded theory data analysis, including the generation of a categorical matrix or taxonomy (1990). For case study research, Yin suggests data be analyzed through *explanation building* in which the researcher looks for causal links and/or explores plausible or rival explanations (1989).

Derived from the factors discussed in Chapter II, the prioritization scheme classification matrix shown in Table 9 has been developed as a tool to facilitate analysis of the reparable pipeline. Applying this classification matrix to the data may highlight or identify effects of the rule that were unknown, or not intended. Identifying characteristics in this manner will provide a basis for formulating responses to investigative questions two through five. Additionally, classifying Air Force priority rules according to terms accepted in the literature may facilitate further exploratory research or simulation studies. Defining the specialized terminology used in the Air Force pipeline in terms familiar to POM researchers will help them determine appropriate experimental and analytical tools.

## Nature and Form of Results

The results of this study consist of the description of the reparable pipeline developed for this research, the prioritization schemes employed in each segment of the pipeline, the advantages and disadvantages of each prioritization scheme, and any conflicts amongst the schemes. Data regarding pipeline prioritization schemes is presented in Chapter IV. These results consist of a description of the prioritization schemes used in the pipeline, along with appropriate explanation and commentary. Chapter V, Analysis, presents analysis of the pipeline classification matrix and deduction of the logical or rational characteristics of the prioritization schemes.

Table 9. Prioritization Scheme Classification Matrix

| | Segment | | | | | |
|---|---|---|---|---|---|---|
| | Base Repair | | Retrograde | | Depot Repair | Distribution |
| | Flightline Maintenance | Backshop Maintenance | Supply Processing | Transportation Processing | | |
| **Production Environment** | | | | | | |
| Requirements Generation | | | | | | |
| Processing Complexity | | | | | | |
| Scheduling Criteria | | | | | | |
| Nature of Requirement | | | | | | |
| Scheduling Environment | | | | | | |
| **Job Context** | | | | | | |
| Order Release Mechanism | | | | | | |
| Loading Logic | | | | | | |
| Batching | | | | | | |
| Sequence Dependency | | | | | | |
| **Prioritization Rule** | | | | | | |
| Static or Dynamic | | | | | | |
| Operating Characteristic | | | | | | |
| Global or Local | | | | | | |
| Cardinal, Ordinal or Dichotomous | | | | | | |
| Expediting | | | | | | |
| **Management Direction** | | | | | | |
| Constraints | | | | | | |
| Secondary and Tertiary Rules | | | | | | |
| Hidden Schemes | | | | | | |
| Performance Measures | | | | | | |

# IV. Results

## Introduction

The first step in describing the prioritization schemes of the reparable pipeline was to construct an appropriate conceptual model. After a satisfactory model of the pipeline had been developed, interviews were conducted with those who had experience working in various segments of the pipeline. The purpose of these interviews was to determine which regulation or combination of regulations dictated the operations of the segment under consideration, focusing specifically on guidance affecting prioritization. For example, after interviewing managers from the transportation segment, it was determined that Air Force Instruction 24-201, *Cargo Movement*, governs retrograde reparable processing and prioritization. Each of these governing documents was thoroughly analyzed to determine the prioritization schemes and related inputs, as suggested by the prioritization scheme classification matrix, Table 9. After analyzing the appropriate documents, more interviews were conducted to verify the data, as well as to gather additional data to complete the classification matrix. The conceptual model of the reparable pipeline will be presented first, followed by the completed prioritization scheme classification matrix.

## Air Force Reparable Pipeline Conceptual Model

Using the basic model shown in Figure 6 as a starting point, a conceptual model of the reparable pipeline was developed by condensing and combining pipelines from previous research, most notably Kettner and Wheatley and Silver and others.

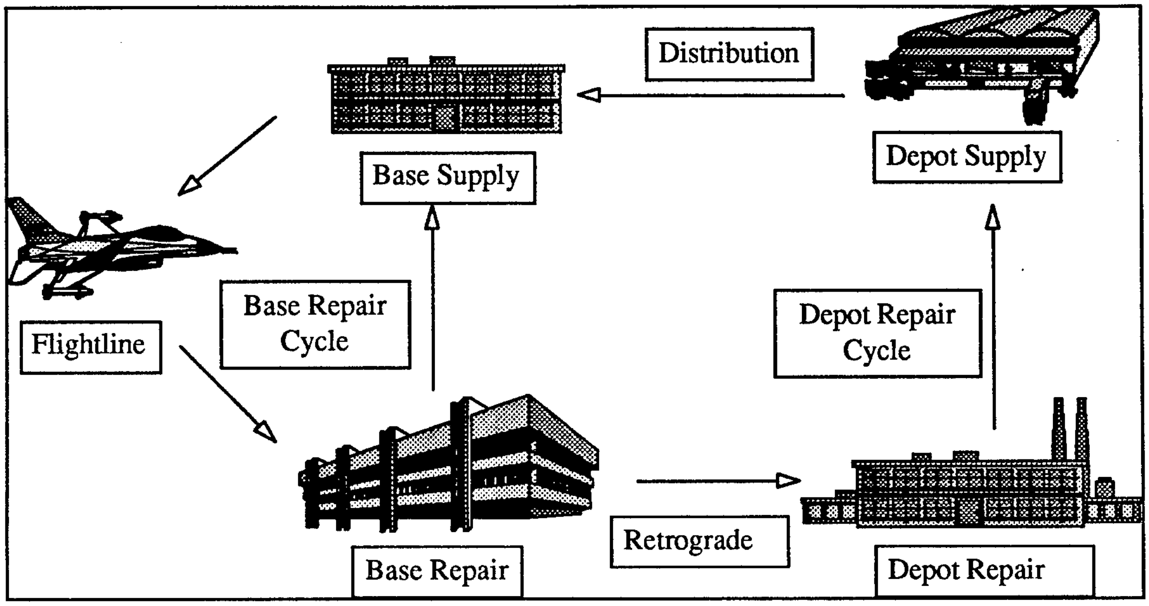


Figure 6. Reparable Pipeline (Adapted from McCormick, 1996:8)

The level of detail in the pipeline model was selected to accurately portray pipeline segments and the activities in those segments which have a direct effect on prioritization. A preliminary model was constructed and presented to pipeline managers for critique, modification, and improvement. It should be noted that this conceptual model is intended to represent the reparable pipeline from an Air Force-wide perspective. It does not attempt to account for pipeline variations associated with specific major commands, bases, or special processing associated with specific reparables. The pipeline model used in this thesis is presented in Figures 7 through 11. Shaded areas indicate the primary points in the pipeline where prioritization is taking place.

Base Maintenance Segment (Figure 7). When a reparable fails, maintenance personnel determine whether the item can be repaired on the flightline. If so, decisions must be made regarding the timing and precedence of repair for that item. It is at this point that prioritization takes place on the flightline. If the item cannot be repaired on the flightline, the reparable is taken to the appropriate maintenance backshop for repair. If backshop personnel determine the item cannot be repaired locally, they also prioritize that job in relation to the other work already in the shop. If the item cannot be repaired, it is declared Not-Repairable-This-Station (NRTS), and moved to base supply. There are occasions when reparables can be declared NRTS by the flightline maintenance organization. Items in this category bypass backshop processing and are moved directly to supply.

Retrograde Segment (Figure 8). Prioritization occurs primarily at two steps in the retrograde segment. Supply organizations prioritize the processing of reparables based on the status of the item as noted on the condition tags. When reparables are processed by the supply function, the Standard Base Supply System (SBSS) generates a shipping document which contains the required delivery date (RDD). After completing the necessary actions in the supply organization, the carcass is moved to the transportation function. When preparing and planning the shipment, the transportation organization uses the RDD to determine the priority given to the reparable for movement to the depot. Once the item arrives at the depot, it is either taken for immediate repair, or stored for repair at a later date.

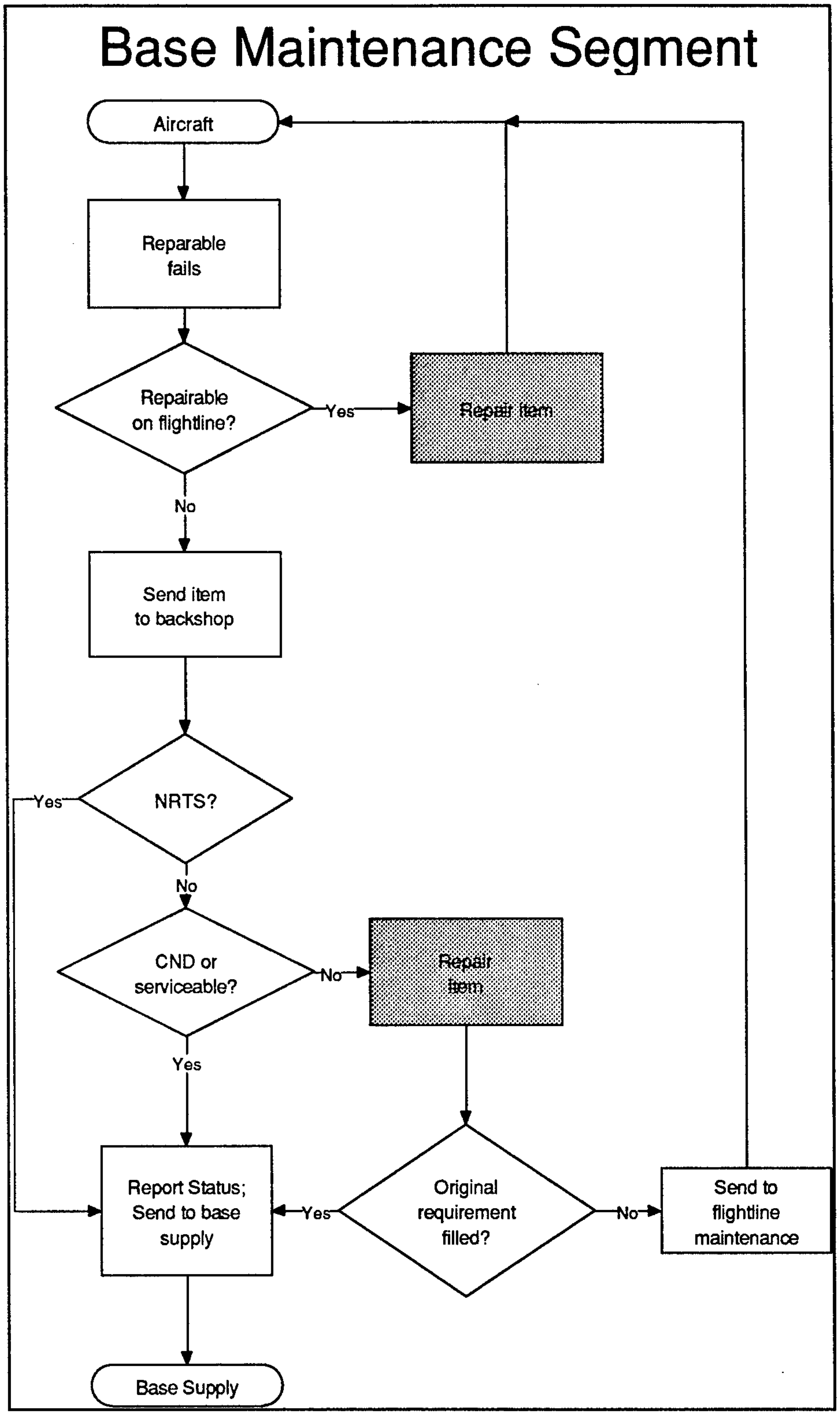

Figure 7. Base Maintenance Segment

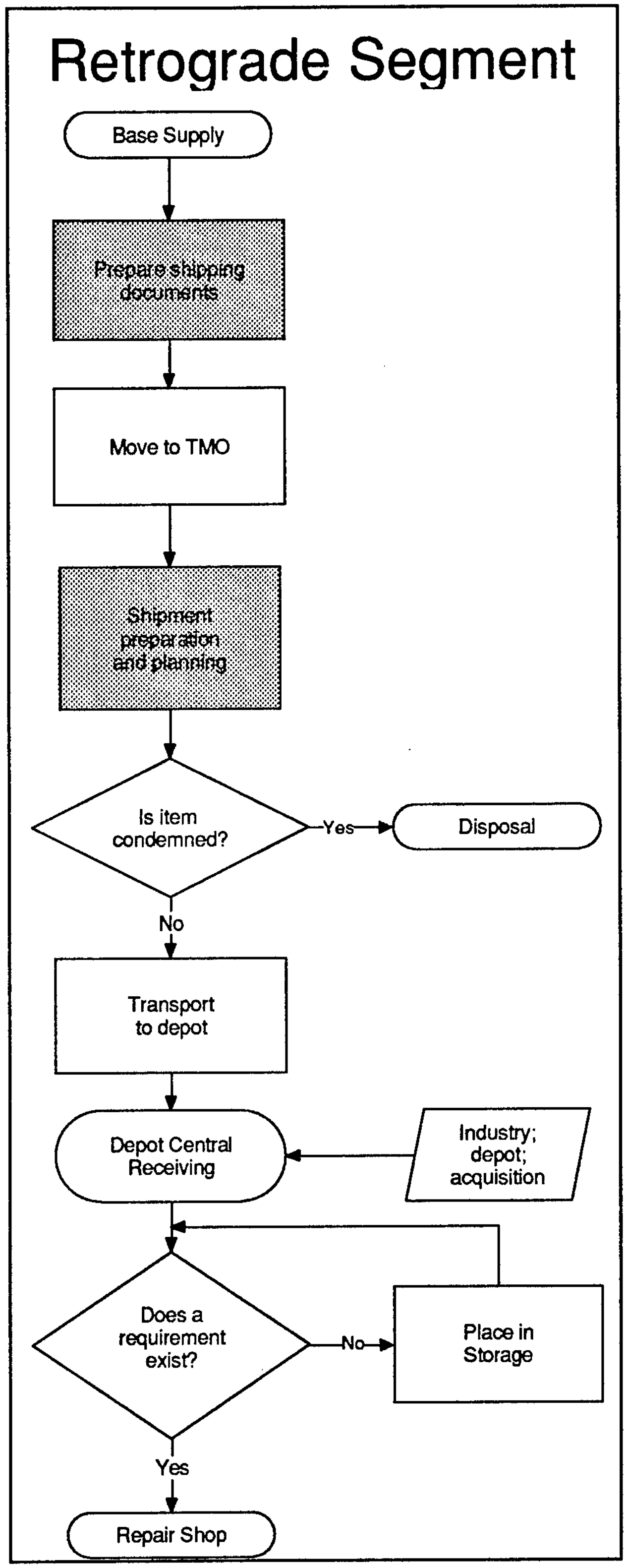

Figure 8. Retrograde Segment

Depot Repair (Figure 9). The components that are repaired at the depot vary widely, as do the steps required in the repair of the individual items. No attempt was made to account for the variations found in each depot repair shop. For the sake of this study, the important steps in regards to prioritization occur when the decision has been made to induct an item into the shop for repair, and when deciding which items to repair and in what order.

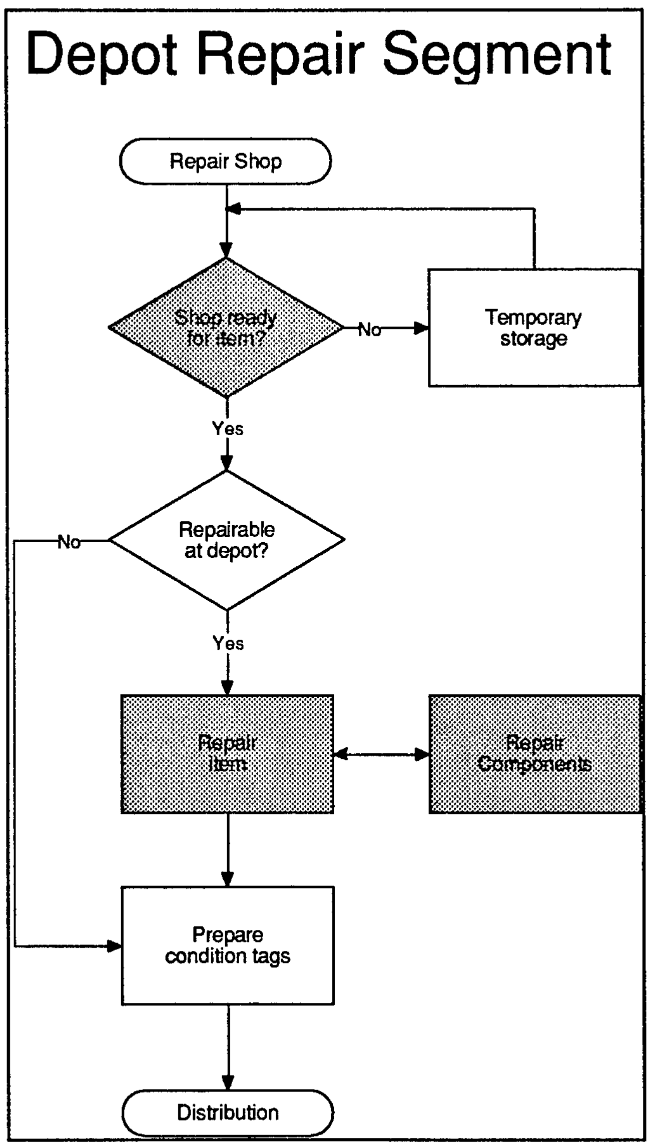


Figure 9. Depot Repair Segment

Distribution (Figure 10). This segment of the pipeline is commonly referred to as Order and Ship Time, reflecting D041 terminology. It is more accurate to label this segment distribution, because that is what is taking place. The first action which requires prioritization is filling a customer requirement. This is performed by UMMIPS, DRIVE, or some other system. Once the consignee has been determined, prioritization next occurs when preparing the shipment. Reparables are requisitioned by base supply using priorities determined by the base maintenance organization. These requisitioning priorities determine the RDD and therefore mode and priority in the distribution segment. The reparable is delivered to the maintenance organization after being received and processed by base supply.

Disposal Segment (Figure 11). This segment was included to complete the reparable pipeline. Once an item enters the disposal segment, it is no longer a viable source for future serviceable items, nor does it compete with other reparables for repair or transportation resources. Prioritization actions in the disposal segment are beyond the scope of this thesis.

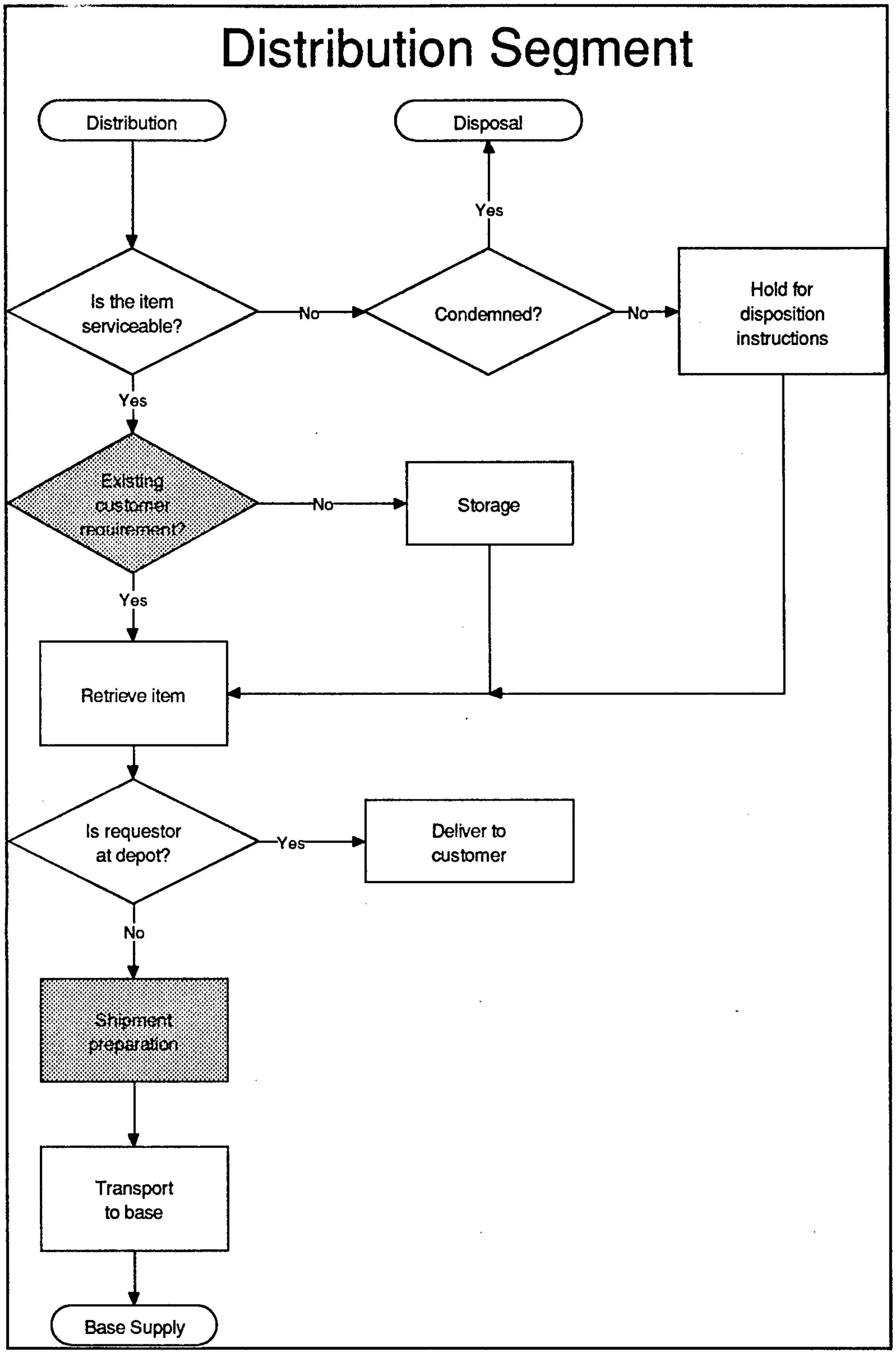


Figure 10. Distribution Segment

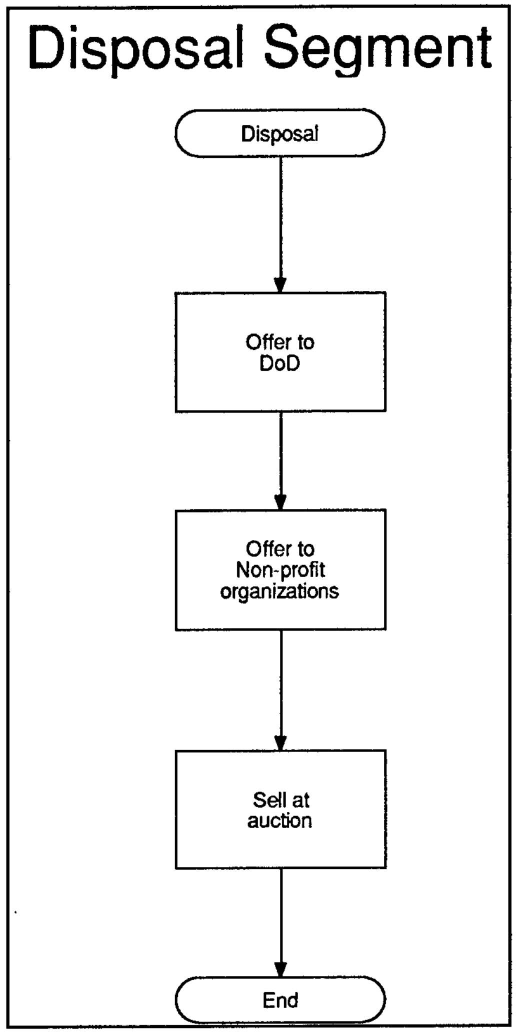

Figure 11. Disposal Segment

Prioritization Scheme Data

Each characteristic of the prioritization schemes of the pipeline segments is described in this chapter in the following order: Production Environment, Job Context, Prioritization Rule, and Management Direction. In addition to reporting the findings of the research, preliminary analysis of the characteristic as it applies to each segment is included as the data is reported. Applicable portions of the prioritization scheme classification matrix are presented with each prioritization scheme input for easy reference.

The completed prioritization scheme classification matrix, Table 15, is found at the end of this chapter (page 60).

Production Environment

Table 10 presents in summarized form the data collected about the production environment of the reparable pipeline.

Table 10. Production Environment Characteristics

| Pipeline Segment | Requirements Generation | Processing Complexity | Scheduling Criteria | Nature of Requirement | Scheduling Environment |
|---|---|---|---|---|---|
| Flightline Maintenance | Open | 1 stage, multi-proc | Schedule Performance | Stochastic | Dynamic |
| Backshop Maintenance | Open | 1 stage, multi-proc | Schedule Performance | Stochastic | Dynamic |
| Supply Processing | Open | 1 stage, multi-proc | Schedule Performance | Stochastic | Dynamic |
| Transportation Processing | Open | 1 stage, multi-proc | Schedule Performance | Stochastic | Dynamic |
| Depot Repair | Open and Closed | Flow Shop | Schedule Performance | Stochastic | Static |
| Distribution | Open | 1 stage, multi-proc | Schedule Performance | Stochastic | Dynamic |

Requirements Generation. Processing of reparables in the flightline maintenance segment begins with the failure of a reparable. Similarly, in the backshop maintenance, supply processing, transportation processing and distribution segments, resources are assigned to jobs only when they arrive at the shop for processing. Production decisions are based on customer requisitions and not on stock replenishment decisions, characteristic of an open shop. There are some notable exceptions however. Some maintenance units prepare limited spares (such as a spare gun) for quick replacement in the event of a failure. Production decisions in these instances are more typical of the stock replenishment decision of a closed shop environment. However, closed shop production decisions are the exception, not the rule.

Depot repair actions are governed by either the quarterly negotiation process or systems such as DRIVE or the Automated Induction System (AIS). In the quarterly negotiation process, a quantity of items to be repaired is determined. This repair quantity is divided into 2-week quantities, or buckets. Because repair actions governed by this process are taken to satisfy a pre-determined quantity of serviceable items, these shops exhibit characteristics of a closed shop. In depot repair shops using DRIVE or AIS, repair actions are taken to satisfy customer orders. This is characteristic of an open shop. However, even these types of shops repair items to fill stock levels in the consolidated serviceable inventory, characteristic of a closed shop environment.

Processing Complexity. The processing complexity of the majority of the pipeline segments is characteristic of one-stage, multi-processor environments. Although there may in reality be several steps within a process, the process as a whole can be considered to be one-stage because the items are treated identically within the process and the pipeline is not affected by the lack of specific detail. There are, however, some notable exceptions to the one-stage, multi-processor environment. Some base backshop maintenance is multi-stage, multi-processor, such as an engine shop. In this situation, the reparable flows through some or all processing cells. The processing depends on the condition of the asset, which varies by item. Transportation functions have a similar possibility of exception to the one-stage, multi-processor environment. Some reparables require processing at packing and crating before being moved by a carrier, others do not.

Depot repair shops tend to be more flow shop oriented, with some actually being job shops.

Scheduling Criteria. Schedule performance is the dominant scheduling criterion across the pipeline. Resources and facilities are focused on time criteria, such as meeting deadlines, or responding in the shortest possible time. Many of the costs associated with processing reparables are sunk costs, such as personnel, equipment, facilities, etc. Schedule cost considerations are not absent however. Shipment planners are directed to choose the least expensive transportation modes and carriers if delivery times are equal amongst the options (Cargo Movement, 1994:6). Depot repair shops are driven to produce the quantity of reparables inducted into the shop for repair, usually in two-week buckets. Although capacity and cost limitations are accounted for in the quarterly negotiation process, shop scheduling is concerned primarily with producing the quantity of reparables inducted. Should the repaired quantity not match the quarterly negotiated quantity at the end of the quarter, the quantity could be re-negotiated to match the number produced.

Nature of Requirement. Processing times in the pipeline are stochastic. That is, the time required to process a reparable varies according to the condition of the asset being considered. Some pipeline segments have deterministic components of overall stochastic processes. For example, once a carrier takes possession of a reparable in the transportation segment, delivery may be guaranteed in a certain number of hours. However, the total processing time is still stochastic.

Scheduling Environment. The pipeline exists in a dynamic scheduling environment. The only exception to this rule is the two-week bucket system associated with depot repair governed by the Management of Items Subject To Repair (MISTR), or G019C, system. Once the repair quantity has been determined for the two-week period, no additional requirements are considered (MISTR, 1989).

It should be noted that the majority of previous research in the POM academic discipline has dealt primarily with static, deterministic environments. With the advances in computer technology and simulation applications, more research is being conducted on dynamic, stochastic environments. Although POM research may have had limited applicability in the past, it is likely that improvements in pipeline performance could be gained from such research and analysis.

Job Context

Table 11 presents in summarized form the data collected about the job context of the reparable pipeline.

Table 11. Job Context Characteristics

| Segment | Order Release Mechanism | Loading Logic | Batching | Sequence Dependency |
|---|---|---|---|---|
| Flightline Maintenance | None | Skill Level | None | None |
| Backshop Maintenance | None | Skill Level | None | None |
| Supply Processing | None | None | None | None |
| Transportation Processing | None | None | Present | None |
| Depot Repair | AIS, DRIVE, EXPRESS | Skill Level | Present | None |
| Distribution | None | None | Present | None |

Order Release Mechanism. There is no requirement for production operations to have order release mechanisms. Management decides whether order release mechanisms are to be used, perhaps to enhance control and timing of operations. Few such mechanisms were discovered in the pipeline.

Some depot repair shops utilize computer programs, such as AIS and DRIVE, which function as order release mechanisms. Both of these programs link induction of reparables for repair with customer requisitions. However, DRIVE functions in support of the quarterly negotiations process, and does not completely control induction of reparables for repair.

A recent LL initiative, PACER LEAN, employs a new tool to induct assets for repair called the Execution and Prioritization Repair Support System, or EXPRESS. Using logic very similar to DRIVE, EXPRESS identifies customer requirements, determines the order in which items are to be repaired to satisfy those requirements, determines whether repair of those items can be supported by the appropriate depot repair shop, and produces distribution recommendations prioritized on the basis of aircraft availability (PACER LEAN, 1996:53).

Loading Logic. Loading logic was only reported in segments of the pipeline responsible for maintenance actions. Typically, pipeline maintenance managers consciously select a worker with known mechanical ability, or skill-level, for a job. This decision is often made according to the subjective judgment of segment managers. In a time-critical situation, a job might be assigned to a highly-skilled worker. Alternatively, a manager might assign a less-skilled worker to a difficult task to provide breadth and depth of experience. Skill-level was the only loading logic detected.

Batching. Batching is most prevalent in the depot repair process and is used primarily to take advantage of perceived cost avoidance or reduction associated with fewer machine setups. Because batching requires accumulation of assets before processing occurs, its use generally makes the pipeline less responsive, especially where reparables are in short supply.

In the transportation segment, AFI 24-201, *Cargo Movement*, directs consolidation when consistent with delivery requirements and UMMIPS time standards (Cargo Movement, 1994:5). While this is not batching in a strict sense (batch size is not specified), it represents a situation which alters the flow of reparables to take advantage of potential cost reductions.

Sequence Dependency. No shops which accounted for the impact of the sequence of operations on processing times were observed.

## Prioritization Rule

Table 12 presents in summarized form the data collected about the prioritization rules of the reparable pipeline.

Table 12. Prioritization Rule Characteristics

| Segment | Static or Dynamic | Operating Characteristic | Global or Local | Cardinal or Ordinal | Expediting |
|---|---|---|---|---|---|
| Flightline Maintenance | Dynamic | Earliest Due Date | Local | Cardinal | Present |
| Backshop Maintenance | Static | AFI 21-101 | Local | Ordinal | Present |
| Supply Processing | Static | AFM 23-110 | Local | Ordinal | Present |
| Transportation Processing | Static | Transportation Priority | Local | Ordinal | Present |
| Depot Repair | Static | Various | Local | Cardinal | Present |
| Distribution | Static | Transportation Priority | Local | Ordinal | Present |

Static or Dynamic Prioritization Rule. Prioritization in the flightline maintenance segment is decidedly dynamic. As events occur over time, the priority attached to a reparable could change as other reparables fail or spare aircraft are substituted in the flying schedule. Occasionally, the prioritization rule becomes static, such as at shift change or the end of a week of flying.

Other pipeline segments use static prioritization rules. This is due to the fact that the backshop repair priority, supply priority, and transportation priority are determined externally, usually by guidance from regulations. For example, a reparable asset's transportation priority is based exclusively on its required delivery date (RDD) (Cargo Movement, 1994:4). The RDD is determined when the item is processed through supply. As far as the transportation function is concerned, the priority is fixed and does not change simply as a function of time.

Operating Characteristic. For the majority of pipeline segments, the operating characteristic is a numerical priority assigned by regulation (see Table 13). In the flightline maintenance segment, AFI 21-101, *Maintenance Management of Aircraft*, directs the production superintendent to assign priorities to meet the flying and maintenance schedules, and to aggressively work non-mission capable (NMC) aircraft (1994:12). Because prioritization decisions are based on the time an aircraft (and therefore reparable) is required in the flying or maintenance schedule, earliest due date is the operating characteristic used in the flightline maintenance segment.

Table 13. Pipeline Segment Regulations

| Segment | Regulation |
|---|---|
| Flightline Maintenance | AFI 21-101 Maintenance Management of Aircraft |
| Backshop Maintenance | AFI 21-101 Maintenance Management of Aircraft |
| Supply Processing | AFM 23-110 Basic Air Force Supply Procedures |
| Transportation Processing | AFI 24-201 Cargo Movement |
| Depot Repair | AFLC 65-296 Management of Items Subject to Repair |
| Distribution | DoD 4500.9-R Defense Transportation and Traffic Management |

The operating characteristic used by base maintenance backshops is a numerical maintenance priority as specified in AFI 21-101 (1994:14-15) (see Appendix D). It should be noted that the backshop does not determine the repair priority. That determination is made by the flightline organization.

Supply organizations processing carcasses in the retrograde segment do not have processing priorities directed by regulation. As a result, retrograde movements in this portion of the pipeline are generally processed first-in, first-out.

A brief explanation of the transportation processing segment is required to understand how priorities are assigned in this segment, and to understand what operating characteristic is used for prioritization actions. Retrograde transportation functions use priorities specified by AFI 24-201, *Cargo Movement*. Assignment of the transportation priority (TP) hinges on the RDD. The RDD is

> a calendar date that specifies when material is actually required to be delivered to the requisitioner... RDD also refers to a code indicating the speed of transportation processing, e.g., 999, N--, E--, 777, 555, 444, or blank RDD. (Cargo Movement, 1994:18)

In accordance with guidance from the UMMIPS priority system (Table 6), the shipment planner assigns the TP based on the RDD code printed on the shipping label.

Shipments with an RDD of code 999, NMCS, or MICAP are assigned TP-1, Expedite. Shipments with RDD code of 777, 555, or an actual RDD of 7 days or less for intra-continental U. S. or intra-theater, or 21 days or less for international destinations, are assigned TP-2, Expedite. TP-3, Routine, is assigned to shipments which do not have a valid expedite indicator in the RDD field (Cargo Movement, 1994:4). AFI 24-201 requires the transportation function to move shipments to the destination within time standards shown in DoD 4140.1-R, *DoD Materiel Management Regulation*, Chapter 5, part F, UMMIPS (Cargo Movement, 1994:4). These standards are shown in Table 6, page 18. Transportation organizations process items in accordance with the TP, which is the operating characteristic. The distribution segment, although governed by DoD 4500.9-R, *Defense Transportation and Traffic Management*, also uses transportation priorities and UMMIPS time standards, and thus uses TP as its operating characteristic (1996:202-14).

Unlike the other pipeline segments, depot repair does not have specified operating characteristics. A variety of operating characteristics, many of which are used to maximize a performance measure such as shop efficiency or revenue, are employed to determine which item to repair next. Most depot repair actions are governed by the MISTR system, which only requires that the negotiated quantity is produced.

Global or Local Prioritization Rule. When workcenters in the pipeline process items, information about the job is relevant only to the workstation being considered at the time. For example, flightline maintenance technicians only need information about the job currently being worked. Similarly, transportation personnel only need to know the TP associated with each asset. Information about other workstations is not required. This is characteristic of local priority rules.

Cardinal, Ordinal, or Dichotomous. As stated previously, the operating characteristic used in the flightline maintenance segment is earliest due date. Because flightline maintenance managers know the scale and magnitude of the different due dates, their prioritization rule is cardinal. For example, jobs might be prioritized 1, 2, and 3, but the production superintendent knows the time requirements associated with each. Items 1 and 2 might be due on the hour, while 3 is not due until 0800 the next day. A cardinal scale is useful because it includes information about the relationship between jobs, with which managers can make better decisions.

Depot repair prioritization rules are also cardinal. Shop foremen have information associated with the decision to repair an item, such as the duration of repair or the cost of the repair. This information is used to select an asset for repair, frequently to maximize a metric or performance measure.

All other workcenters in the pipeline do not know the magnitude of the operating characteristic used to prioritize actions, due to the fact that the priority is determined externally. This is characteristic of an ordinal prioritization rule.

Expediting. Not surprisingly, expediting is present in each segment. Expediting is to be expected because the logistics system is designed to operate under a broad set of circumstances. As situations change, expediting allows managers to intervene to achieve goals that would go unmet if the system were allowed to operate without intervention. Examples of expediting include ‘red-balls’ in the flight-line maintenance segment, special processing in supply, or item-manager directed repair at the depot. There are no specified criteria under which expediting is permitted; it appears that managers make the determination using subjective and localized criteria.

Management Direction

Table 14 presents in summarized form the data collected about the management direction in the reparable pipeline.

Table 14. Management Direction Characteristics

| Segment | Constraints | Secondary Rules | Hidden Schemes | Performance Measures |
|---|---|---|---|---|
| Flightline Maintenance | RCT, 2LM/LL standards | Proximity | Present | MC, Schedule Deviations |
| Backshop Maintenance | RCT, 2LM/LL standards | FIFO, SPT | Present | RCT, PBR, NRTS |
| Supply Processing | RCT, 2LM/LL standards | FIFO, SPT | Present | Issue, Stockage Effectiveness |
| Transportation Processing | UMMIPS, 2LM/LL standards | Cost, Weight | Present | UMMIPS Standards |
| Depot Repair | Negotiated Repair Quantity | SPT, Cost | Present | Efficiency, cost |
| Distribution | UMMIPS standards | FIFO, SPT | Present | UMMIPS Standards |

Constraints. Each segment has constraints placed upon it, most frequently in the form of time standards. Common time standards include repair cycle times, two-level maintenance (2LM) and LL evacuation standards, and UMMIPS time standards. Repair cycle time (RCT) is a measure of the time required for a failed reparable to be repaired in the base maintenance cycle (removal from aircraft, routing to the appropriate repair shop, troubleshooting, and repair). Lean Logistics initiatives (one of which is 2LM) have been applied only to specific assets and their related base and depot repair shops. 2LM/LL assets have unique project codes associated with them which work through the SBSS to automatically generate a retrograde RDD of 777 on the shipping label. The evacuation time standards associated with 2LM/LL items are deadlines by which an item must be moved from the flightline, through base supply and transportation, and to the depot (see Appendix A). 2LM/LL movements are tracked to determine the effectiveness of the 2LM or LL initiative. RCT and 2LM/LL time standards apply to the flightline maintenance, backshop maintenance, base supply, and transportation processing. For non-2LM/LL items in the retrograde segment, UMMIPS standards apply to supply and transportation processing actions. UMMIPS standards act as constraints in the distribution segment.

No explicit time constraints in the depot repair segment were discovered. Although the negotiated quarterly repair quantity was divided up into 2-week buckets, it was not apparent whether the 2-week time frame acted as a firm or consistent constraint.

Secondary, Tertiary Rules. While secondary and tertiary rules are often used as tie-breakers, few segments actually have specific rules stated explicitly. The first-in, first-out (FIFO) and shortest processing time (SPT) rules are common secondary rules in backshop maintenance, supply, and transportation processing. Transportation segments also employ the low-cost carrier rule as a tie breaker if two modes deliver the item within acceptable time standards. Depot repair shops often select items for repair which improve measures of cost or schedule efficiency. For example, a job which takes less time to repair than the standard repair time might be selected for processing. The quick repair increases the shop's measure of schedule efficiency (Simons, 1996). It was not clear whether secondary and tertiary rules in use were necessarily in harmony with the goals of the organization.

Hidden Schemes. Hidden prioritization schemes were ubiquitous, but difficult to document comprehensively. After interviewing three experienced transportation officers with significant aerial port experience, one hidden scheme was discovered in the transportation segments using Air Mobility Command (AMC) aerial ports and aircraft. Reparable assets labeled MICAP were given the same transportation priority (TP-1), but AMC personnel made a conscious effort to move AMC MICAPs first. The logic behind this behavior was that AMC aircraft had to be kept mission capable, or no other parts could be moved.

Performance Measures. Performance measures are also ubiquitous in the pipeline. While they are not prioritization rules, they may significantly impact prioritization actions. For example, flightline maintenance prioritization decisions are influenced by attempts to maximize flying scheduling effectiveness and maintenance scheduling effectiveness (minimize schedule deviations), and mission capable rates, all of which are performance measures.

Backshop maintenance performance measures include repair cycle time, percentage of base repair (PBR), and NRTS rates. PBR and NRTS rates are intended to measure the ability of base repair shops to repair items, and are used in determining the number of spares required in the reparable pipeline. Every attempt is made to repair items at the base, in order to avoid delays caused from ordering assets from off base.

Until recently, little attention was given to processing NRTS items through the base. However, 2LM/LL evacuation times are now being tracked, which affects the base maintenance and retrograde segments. For supply organizations, issue and stockage effectiveness are common performance measures applied to reparables requested by maintenance organizations. In addition, delivery times specified by AFM 23-110 are closely measured, and significant efforts are expended to meet the prescribed times, especially with regard to MICAP items. Both the transportation processing and distribution segments measure compliance with UMMIPS standards.

Prioritization schemes are significantly affected by performance measures at the depot. One common performance measure is called efficiency or effectiveness. This metric is used to measure the actual number of repair hours versus the standard number of repair hours, or the actual repair cost versus the standard repair cost. Shop managers sometime choose easier units to repair (i.e. cherry picking) to improve such performance measures.

One aspect of prioritization unique to depot repair is the practice of job routing. Job routing is the decision by a work center to route a component or sub-assembly through a depot shop for repair, rather than obtain it through supply. If a work center orders the item from supply, it is charged for the item. However, if the shop routes the item for repair at a depot work center, it is not charged for the repair. This presents an area for potential conflict. On one hand, job routing is attractive because the repair is not charged to the originating work center. On the other hand, job-routing assets delays repair of the higher assembly. In addition, repair of the job-routed sub-assembly is not accounted for in the quarterly negotiation process of the sub-assembly repair shop. The sub-assembly repair shop is under no direct obligation to repair job-routed assets, since its primary obligation is to produce negotiated repair quantities. In fact, it may be at a disadvantage to do so because of the costs associated with repairing job-routed assets, and because its capacity and funding levels are based on quantities from the quarterly negotiation process. Often, there is an informal understanding that the sub-assembly shop will repair job-routed items, to avoid negative publicity associated with delayed production from the higher-visibility, higher-cost main assembly shop (Simons, 1996).

## Summary

This chapter reported the data collected about prioritization schemes in individual pipeline segments. Where appropriate, relevant contextual information and preliminary analysis was also included. Table 15, Completed Prioritization Scheme Classification Matrix, summarizes the data collected about the prioritization schemes in the reparable pipeline. The next chapter presents the results of analysis pertaining to multiple pipeline segments, or the interaction of prioritization schemes of the entire pipeline.

Table 15. Completed Prioritization Scheme Classification Matrix

| | Segment | | | | | |
|---|---|---|---|---|---|---|
| | Base Repair | | Retrograde | | Depot Repair | Distribution |
| **Production Environment** | **Flightline Maintenance** | **Backshop Maintenance** | **Supply Processing** | **Trans Processing** | | |
| Requirements Generation | Open | Open | Open | Open | Open | Open |
| Processing Complexity | 1 stage, multi-proc | 1 stage, multi-proc | 1 stage, multi-proc | 1 stage, multi-proc | Flow Shop | 1 stage, multi-proc |
| Scheduling Criteria | Sched Perf | Sched Perf | Sched Perf | Sched Perf | Sched Perf | Sched Perf |
| Nature of Requirement | Stochastic | Stochastic | Stochastic | Stochastic | Stochastic | Stochastic |
| Scheduling Environment | Dynamic | Dynamic | Dynamic | Dynamic | Static | Dynamic |
| **Job Context** | | | | | | |
| Order Release Mechanism | None | None | None | None | AIS, DRIVE, EXPRESS | None |
| Loading Logic | Skill Level | Skill Level | None | None | Skill level | None |
| Batching | None | None | None | Present | Present | Present |
| Sequence Dependency | None | None | None | None | None | None |
| **Prioritization Rule** | | | | | | |
| Static or Dynamic | Dynamic | Static | Static | Static | Dynamic | Static |
| Operating Characteristic | Earliest Due Date | AFI 21-101 | AFM 23-110 | Transportation Priority | Cost, Proc Time | Transportation Priority |
| Global or Local | Local | Local | Local | Local | Local | Local |
| Cardinal, Ordinal or Dichotomous | Cardinal | Ordinal | Ordinal | Ordinal | Cardinal | Ordinal |
| Expediting | Present | Present | Present | Present | Present | Present |
| **Management Direction** | | | | | | |
| Constraints | RCT, 2LM/LL times | RCT, 2LM/LL times | RCT, 2LM/LL times | UMMIPS, 2LM/LL | Repair Quantity | UMMIPS Standards |
| Secondary and Tertiary Rules | Proximity | FIFO, SPT | FIFO, SPT | Cost, weight | SPT, Cost | FIFO, SPT |
| Hidden Schemes | Present | Present | Present | Present | Present | Present |
| Performance Measures | MC, Schedule Deviations | RCT, PBR, NRTS | Issue, Stockage Effectiveness | UMMIPS Standards | Efficiency, Cost | UMMIPS Standards |

# V. Analysis

## Introduction

Whereas the previous chapter presented the data collected on the prioritization schemes in the reparable pipeline with some preliminary analysis and contextual information, this chapter will present analysis of the interaction of the prioritization schemes and other characteristics that apply to more than one segment or include more than one classification category. The chapter begins by discussing the environmental similarity of the pipeline segments, followed by the issues of capacity, time standards, and performance measures. The relationship between cardinal and ordinal prioritization rules and global and local prioritization rules is then considered.

## Environmental Similarity

As noted in the completed prioritization scheme classification matrix, Table 15, many of the segments operate in a similar production environment. In fact, most of the organizations in the pipeline are nearly identical, with the only exception being depot repair functions. Organization similarity is to be expected because they are all governed by the same Department of Defense and Air Force regulations. Consequently, if, through testing and analysis, it is found that pipeline operations in a particular segment can be improved, it is likely that the same techniques could be applied to other segments which operate in a similar environment.

Capacity

Prioritization schemes seek to make the best possible use of existing capabilities. However, their ability to ensure mission accomplishment is limited by the total capability made available by longer-term funding decisions. Air Force flying operations can be supported only by maintaining sufficient capacity for all contingencies, stockpiling spares, or a combination of these two options. Maintaining large amounts of spares is very expensive. The Air Force has moved away from this option in favor of improved and streamlined repair processes. The Air Force is therefore dependent upon proper capacity design to be able to support operations. Capacity must be addressed on at least two points: 1) What is the appropriate level of capacity to maintain to support operations given budget constraints, and 2) What degree of flexibility should be designed into the pipeline to augment periods of increased demand, should capacity prove insufficient? In addition, since each function serves only as a segment of the total pipeline, the determination of appropriate capacity would seem to make sense only to the extent that it supports reparable asset flow through the rest of the pipeline.

Time Standards

Time standards were previously identified as constraints on pipeline processes, rather than prioritization rules. The most common time standards reported were those imposed by UMMIPS (Table 6), with applications in the supply processing, transportation processing, and distribution segments. 2LM and LL time standards were also encountered when preparing and moving reparables in the retrograde segment (see Appendix A).

Time standards are currently being used to ensure movement of reparables. While collecting data about the pipeline and time standards, there appeared to be few, if any, analyses performed to determine the appropriateness of time standards. In the case of 2LM/LL time standards, it appeared that time standards were somewhat arbitrarily applied as a result of the recognition of the potential savings associated with reduced pipeline times. There was some debate among pipeline managers as to the appropriateness of the 2LM/LL time standards (see Appendix B).

A simple example may illustrate some of the potential problems associated with time standards. Consider the familiar experience of taking a car to a maintenance facility for repair. The problem is diagnosed as faulty spark plugs, which require replacement. Assume the facility uses time standards both for repair and billing. According to facility guidelines, spark plug replacement has an associated time standard of one hour. In this example, there are only three easily accessible spark plugs to be replaced, requiring just 15 minutes to complete the repair. However, the customer is told that the repair will take approximately one hour, and will be billed for the standard repair time. The customer is needlessly without the use of his car for 45 minutes, and charged for an hour's labor instead of one quarter of the hourly rate. In contrast, another vehicle requiring spark plug replacement may be more difficult to repair, requiring 90 minutes to complete the repair. Nevertheless, the customer is told the repair will take about an hour and will be billed for the standard labor rate. In this case, the customer is unable to use the vehicle when promised. In addition, the repair facility loses the use of repair resources for 30 minutes longer than anticipated, and receives payment for less than the amount of labor expended.

From this example it can be seen where inefficiencies can arise with the inappropriate use of time standards.

Because time standards are constraints or deadlines, they may also drive undesirable behavior. In order to meet approaching deadlines, low priority items which have less time remaining until their deadline may be processed before high priority items which have more time left. If the system is intended to process high priority items before low priority items, this influence of time standards can have the effect of negating the prioritization rule.

When used properly, time standards can be tools to determine system inefficiencies. Returning to the previous automobile repair example, if the repair time for a simple, three spark plug replacement procedure consistently exceeds its standard, managers can use this fact to investigate the cause more closely. It is not evident that time standards, UMMIPS or 2LM/LL, are being used in this manner. Fortunately, UMMIPS time standards have been identified for replacement with the phased implementation of improved logistics response time standards (Logistics Strategic Plan, 1996:14), and 2LM/LL time standards are being considered more closely (see Appendix B). However, in the short term, time standards would seem to encourage satisficing rather than improvement (i.e. if the standard is being met, nothing need be improved).

## Performance Measures

Performance measures have the ability to affect prioritization decisions. This research indicated that production and prioritization decisions were sometimes made in order to maximize a performance measure, or make the shop look good. In the base maintenance segment a variety of data is collected on the production effort, much of which is reported to the major commands as performance measures. Flightline maintenance managers routinely work to maximize these measures, even if they have no control over them. For instance, it was observed that maintenance managers used every means at their disposal to minimize the amount of time an aircraft was not-mission-capable-supply (NMCS), even though they had almost no control over the availability of reparable or consumable parts.

Lean Logistics brings with it its own set of metrics, including soon-to-be-implemented Logistics Response Times (LRT). LRT measurement is intended to comply with the Government Performance and Results Act of 1993, significantly increase asset visibility and improve responsiveness to customers (Lee, 1996). Appendix C describes the LRT in more detail. In addition, the LL office at the Air Staff has begun publishing a metrics book, detailing pipeline duration times. Pipeline duration times found in the metrics book are reported using the Reparable/Serviceable Item Pipeline Data Analysis Tool (RIPDAT), and are based on data collected from ATAC-AF system (Advanced Traceability and Control - Air Force), the depot D035K system, and individual shop tracking tools (Metrics Book, 1996:5). Conversations with personnel at Air Force headquarters responsible for LL initiatives revealed that many metrics were being developed with the intent to directly influence behavior (McCauley, 1996). However, because the metrics were in their infancy, it was not known if the metrics would ultimately achieve their desired result.

Cardinal vs. Ordinal Prioritization Rules

In the flightline maintenance segment of the pipeline, a cardinal prioritization rule is used. However, when a reparable is moved into the backshop maintenance, supply, and transportation segments, an ordinal prioritization rule is used. Similarly, depot repair shops use cardinal prioritization rules for repairing items, but the distribution segment uses an ordinal prioritization rule. When changing from a cardinal prioritization rule to an ordinal prioritization rule, the resultant loss of the information associated with a cardinal scale may be a liability. With the limited information conveyed by an ordinal scale, pipeline managers may make decisions that are appropriate, given the information they have. However, it is likely that pipeline managers could make better decisions if they had the information associated with a cardinal scale.

Consider the flightline maintenance segment. AFI 21-101 states that the production superintendent uses a daily maintenance and flying schedule to prioritize personnel and equipment to meet the schedule. In addition, the production superintendent assigns priorities to identified deficiencies for rapid repair and optimum availability, based on mission requirements and the maintenance schedule (Maintenance Management of Aircraft, 1994:14). Prioritization of jobs on the flightline is therefore left to the training and judgment of the production superintendent. He has all the information necessary to prioritize jobs and assign resources. It is reasonable to assume that if other pipeline segment managers were given the information required to make decisions about prioritization actions in their segment of the pipeline (including information contained in a cardinal prioritization rule), they could use their judgment and expertise to direct pipeline operations in a manner consistent with organizational goals. Currently, pipeline managers using ordinal scales are not explicitly relied upon to use their judgment and expertise to prioritize jobs.

It should be noted that the type of prioritization actions described above are currently only used where the prioritization rule is a local rule. This is an important point because global prioritization rules were beginning to be used in the pipeline, as discussed in the next section.

## Global vs. Local Priority Rules

During this study, a high degree of segmentation was observed in the pipeline. In other words, it was very clear which organizations were responsible for which actions in the reparable pipeline. Many pipeline managers were highly knowledgeable about their segment and how it operated. However, there were few pipeline managers who had multi-segment experience or understood how the segments interacted. Pipeline managers employed local prioritization rules and were often unconcerned with the performance of other pipeline segments or the impact of their local prioritization rules on other segments. Recent systems such as DRIVE and EXPRESS have been developed and implemented which take a more global perspective of pipeline prioritization events. Although still in the demonstration phase, EXPRESS takes into consideration carcasses in the retrograde segment when making depot repair decisions, an example of a more global prioritization rule. It appears that more global prioritization rules will be employed as the pipeline becomes more integrated. Since this is the direction the pipeline is moving, data systems which are able to communicate information about the pipeline must be in place to support the use of global prioritization rules. In addition, managers will have to have a better understanding of the reparable pipeline and how the segments interact.

One example of the lack of accurate and timely information was reported in the system used to communicate carcass retrograde priority from the depot to the base. A report by the AFLMA noted system disconnects, antiquated hardware, training deficiencies and procedural deficiencies in the Reparable Item Movement Control System (RIMCS) data flow. In simple terms, RIMCS is the means whereby item managers at the depot determine the disposition of unserviceable reparables in the field. Item managers communicate retrograde information to the bases via RIMCS, in effect determining the required delivery date. Unfortunately, the AFLMA report found that base records matched RIMCS master records only 47 percent of the time. This inaccurate data caused some reparables to be moved with faster, more expensive carriers when it was not warranted, or moved via slower, less expensive modes when fast transportation was required. Correction of these problems would save the Air Force approximately $750,000 per year in transportation costs (Coley, 1994). As this study illustrates, accurate and timely information is a necessary prerequisite if global prioritization rules are to be employed effectively.

While some information systems such as the Global Transportation Network (GTN), Cargo Movement Operations System (CMOS), and ATAC-AF may improve communication in the pipeline, the cost and technical difficulties associated with bringing these systems on-line are significant. Nonetheless, efficient data and communication systems are required if the reparable pipeline is to operate as efficiently as possible.

Expediting

Expediting is prevalent throughout the reparable pipeline. However, the criteria used for expediting are subjective and inconsistent. Frequently, expediting occurs at the direction of pipeline managers, such as production superintendents and item managers. Expediting can be a useful tool, but if expediting occurs too frequently or is used because of arbitrary and unsubstantiated reasons, it may undermine the prioritization scheme applied in the segment. This is especially true of cases where a shop has been carefully designed to operate efficiently in pursuit of an objective, such as minimizing late orders. If expediting is a frequent occurrence, it may signal that the existing prioritization scheme is unsatisfactory and requires modification, or some other inadequacy such as personnel training, improper capacity, or equipment shortages.

Summary

This chapter presented some of the findings of the interaction of prioritization schemes in the reparable pipeline. The next chapter answers in condensed form the investigative questions proposed in Chapter I, identifies limitations of the research, and suggests areas for further research.

# VI. Conclusions

## Introduction

Having completed the data collection and analysis, it is helpful to refocus attention on the purpose of this research and summarize the findings. In addition, it provides an opportunity to specify limitations of the research, as well as suggest areas for further research. Each of these topics will be considered in order.

## Research Objectives

The objective of this research was to determine the prioritization schemes employed in each segment of the reparable pipeline. This goal was to be accomplished principally by responding to six investigative questions. These questions and responses to them are summarized below.

Investigative Question 1. What are the segments that comprise the reparable pipeline? After reviewing pertinent literature and interviewing pipeline managers, it was determined that the reparable pipeline could be described as five aggregate functions: base maintenance, retrograde movement, depot repair, distribution, and disposal. In order to capture the processes in which prioritization took place, the pipeline was further segmented into functional responsibilities: flightline maintenance, backshop maintenance, supply processing, transportation processing, depot repair, and distribution. Flow charts illustrating these processes comprise Figures 6 through 11. For the purpose of this thesis, the disposal segment was not investigated further.

Investigative Questions 2 - 5. These questions, repeated below, were answered by use of the prioritization scheme classification matrix. The completed matrix is presented at the end of Chapter IV (see Table 15 on page 60). A detailed discussion of the prioritization scheme characteristics is found in Chapter IV.

2. What are the characteristics of the environment within which the prioritization schemes are employed in the pipeline? Requirements in the reparable pipeline are generated by customer requisitions, characteristic of an open shop. The majority of the segments are one-stage, multi-processor arrangements. Depots resemble flow shops, with some actually being job shops. All pipeline segments use schedule performance as their primary scheduling criterion. The duration of jobs being processed in the pipeline is stochastic, and the scheduling environment is predominantly dynamic.

3. What are the characteristics of the job context within which the prioritization schemes are employed in the pipeline? The only order release mechanisms in the pipeline are the AIS, DRIVE, and EXPRESS systems used in the depot repair segment; other segments do not use order release mechanisms. In the flightline maintenance, backshop maintenance and depot repair segments, skill or worker ability is used as loading logic. No loading logic was observed in the retrograde or distribution segments. The practice of batching was noted in the transportation and distribution segments in the form of shipment consolidation. Some depot repair shops use batching, although its use is becoming less prevalent. No other segment practices batching. Finally, sequence dependency was not found in any segment of the reparable pipeline.

4. What prioritization rules are employed in each of the pipeline segments? The flightline maintenance segment is the only segment to employ dynamic prioritization rules;

all other segments use static prioritization rules. The operating characteristic used in the flightline maintenance segment is earliest due date, while backshop maintenance and supply organizations use numerical priorities prescribed by regulation. Transportation processing and distribution segments use numerical transportation priorities based on the required delivery date, as prescribed by regulation. The depot repair segment uses multiple operating characteristics in the context of producing the quarterly negotiated repair quantity. Each pipeline segment utilizes local prioritization rules, although global priority rules are being tested at the depots. Flightline maintenance and depot repair segments employ cardinal prioritization rules, while the other segments use ordinal prioritization rules. Expediting is common throughout the pipeline.

5. What are the characteristics of the managerial guidance under which the prioritization schemes are employed in the pipeline? Time standards such as repair cycle times, 2LM/LL evacuation times, and UMMIPS time standards are constraints in the pipeline. Secondary prioritization rules, found throughout the pipeline, are often not specified by management. A variety of secondary rules are employed, with shortest processing time and first-in, first-out being common examples. Hidden prioritization rules exist in all pipeline segments. A wide variety of performance measures are in place, specific to each pipeline segment.

Investigative Question 6. What are the implications of the integration of the prioritization schemes used in the pipeline segments? Chapter V contains the analysis of the prioritization schemes from a system point of view. There are seven major findings:

1. Despite a broad range of operating locations, functional responsibilities, and task differentiation, pipeline segments exhibit a high degree of environmental and

operational similarity. This suggests that techniques that improve operations in one segment might easily have the same result in other segments.

2. Since the Air Force is moving away from maintaining large stocks of spare parts, the capacity and flexibility of the reparable pipeline will determine the degree to which operations can be supported by the logistics system.

3. Time standards are found throughout the pipeline. The overwhelming majority are intended to be prioritization tools, but instead act as constraints. Tools such as AIS, DRIVE, and EXPRESS are slowly replacing UMMIPS to determine which items to repair and where to distribute them, but do not affect UMMIPS shipping time standards. Fortunately, efforts are underway to replace UMMIPS shipping time standards. Other time standards, however, remain in effect. Time standards should be understood for what they are — constraints — not prioritization rules.

4. There are numerous and varied performance measures employed throughout the reparable pipeline. In some cases, prioritization decisions were altered to optimize performance measures. While the scope and depth of such behavior was not discovered, it was observed that metrics and performance measures have a tangible effect on individual and work center behavior, and thus on overall pipeline performance. Following appropriate study and analysis, performance measures should be verified to ensure they accurately gather meaningful data and influence desired behavior.

5. The flightline maintenance and depot repair segments are the only pipeline segments to use cardinal prioritization rules. The remaining segments use ordinal prioritization rules. The information lost when changing from a cardinal rule to an ordinal rule is a potential liability for pipeline managers. Pipeline managers could make improved

decisions using a cardinal rule. The decisions made in this manner are most effective when prioritization rules are local, not global.

6. Although the segments in the pipeline use local prioritization rules, new systems such as EXPRESS use more global rules. If global rules are to be used in the reparable pipeline, data systems must communicate accurate and timely information to pipeline managers. Further, pipeline managers must understand the pipeline as a whole and the relationships between pipeline segments, in addition to being knowledgeable about their own pipeline segment.

7. Although expediting is a common occurrence in the pipeline, the criteria under which expediting is permitted are subjective and inconsistent. If expediting occurs too frequently or because of arbitrary and unsubstantiated reasons, it may undermine the prioritization scheme applied in the segment.

## Suggestions For Further Research

Research Scope. The research presented in this thesis is very broad, covering all segments of the reparable pipeline. Time limitations prevented in-depth research into the pipeline segments. Interviews were conducted with pipeline managers via telephone, electronic mail, and in person when possible. Field studies and site visits were not made to collect data. Additional research efforts could be directed at studying the segment processes in more detail. After collecting appropriate data on individual shop operations, simulations could be run to determine optimal shop setup, sequence or prioritization schemes for the various pipeline segments, thus improving pipeline performance. Given the number and similarity of pipeline functions, improvements gained from close analysis of one function might be easily applied to other functions.

Depot Repair. Depot repair operations are quite diverse. Because of this variability, there are many opportunities for focused research, as each shop will likely have its own optimal operating solution. Field studies could be conducted to capture the exact practices of a repair shop. In addition, the number of reparables repaired by contractors is growing. The performance of this aspect of the pipeline should be studied as well.

Distribution. The Defense Logistics Agency (DLA) is now responsible for storage and distribution activities at the depot. They are not an Air Force agency, and are not governed by Air Force regulations as is the remainder of the pipeline. Although pipeline mangers are working closely with the DLA to achieve Air Force goals and implement LL initiatives, the degree to which the two organization's goals, practices, and policies are compatible is an area for potential investigation.

Expediting. As mentioned previously, expediting is a common occurrence in the pipeline and the criteria under which expediting is permitted are not well defined. Inasmuch as excessive use of expediting can undermine a given prioritization scheme, research should be conducted to determine 1) the extent to which expediting occurs in the pipeline, 2) the criteria under which expediting is permitted, and 3) the effect of expediting on the established prioritization scheme.

Global vs. Local Prioritization Rules. This thesis reported that local prioritization rules were used in the various segments of the reparable pipeline, but that global prioritization rules were being implemented at the depots. It was not clear that this decision had been made based on the merit of global prioritization rules. Rather it appeared that EXPRESS, which uses global prioritization rules, had been selected as the repair and distribution system for all depots. Determining whether global rules are more effective than local rules in the reparable pipeline is a topic which merits further research.

Lean Logistics. LL initiatives will continue to be phased in at bases and depots over the next few years. As these programs alter the nature and function of the reparable pipeline, pipeline performance must be studied and analyzed to determine the efficacy of LL efforts. Although LL managers have agencies and metrics by which to gauge the success of LL initiatives, an objective review of LL programs is certainly warranted.

## Appendix A. 2LM Evacuation Time Standards Message

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SUBJECT: LEAN LOGISTICS (LL) PHILOSOPHY, GUIDANCE AND RETROGRADE STANDARDS

1. "LL IS AN AF PROGRAM THAT INCLUDES A NUMBER OF COMPLEMENTARY INITIATIVES, ALL FOCUSED TOWARD IMPROVING OPERATIONAL CAPABILITY BY INTEGRATING AND APPLYING STATE-OF-THE-ART BUSINESS PRACTICES ACROSS ALL LOGISTICS FUNCTIONS AND PROCESSES. LL WILL RADICALLY ALTER LOGISTICS FUNCTIONS IN THE AIR FORCE BY IMPROVING AND STREAMLINING POLICY, PROCESSES, AND MANAGEMENT STRUCTURES THAT DRIVE COSTS AND INVESTMENTS IN LOGISTICS INFRASTRUCTURE." TO BE SUCCESSFULL, IT WILL REQUIRE A TEAM EFFORT ACROSS THE ENTIRE AIR FORCE LOGISTICS COMMUNITY.

2. ANY LOGISTICS INFRASTRUCTURE IS HIGHLY DEPENDENT ON A RESPONSIVE SUPPLIER; IN TURN, THIS IS WHERE THE REAL FOCUS OF LEAN LOGISTICS IS TODAY. MANAGEMENT OF REPARABLE (RSD) ASSETS HAS THE MOST IMPACT ON OUR WEAPON SYSTEMS. AFMC AND THE DEPOTS RECOGNIZE THIS AND FOR OVER A YEAR NOW THEY HAVE BEEN DILIGENTLY WORKING SIX RE-ENGINEERING PROJECTS THAT SPAN THE ENTIRE DEPOT PROCESS. MY STAFF IS ACTIVELY INVOLVED IN ALL THESE EFFORTS TO ENSURE YOUR CONCERNS AND NEEDS ARE ADDRESSED. IN SHORT, WHAT THE DEPOTS BUY AND REPAIR MUST BE DIRECTLY LINKED TO MAXIMIZING AIRCRAFT AVAILABILITY AT OUR BASES.

3. LL ALSO REQUIRES US TO CHANGE THE WAY WE DO BUSINESS. LL MEANS FAST. FAST BASE REPAIR; FAST EVACUATION AND SHIPMENT OF UNSERVICEABLE ASSETS TO THE DEPOT; FAST DEPOT REPAIR; AND, FAST SHIPMENT OF SERVICEABLE ASSETS BACK TO BASES. LL ASSETS ARE IDENTIFIED BY TWO PROJECT CODES: 879 FOR LL SPECIFIC, 858 FOR TWO-LEVEL MAINTENANCE

(2LM). THE ONLY DIFFERENCE IN THESE PROJECT CODES IS THAT BASES DO NOT RETAIN INTERMEDIATE LEVEL MAINTENANCE (ILM) CAPABILITY FOR 2LM ASSETS.

4. ACC BASE REPAIR CYCLE STANDARDS ARE ESTABLISHED. ONCE THE DECISION IS MADE TO NRTS AN ASSET, MAINTENANCE PERSONNEL SHOULD TAKE NO LONGER THAN 4 HOURS TO MOVE THE UNSERVICEABLE ASSET TO SUPPLY FOR PROCESSING. TO FURTHER CLARIFY 2LM (PROJECT CODE 858) PROCESSING, ONCE A REPLACEMENT PART HAS BEEN REQUESTED FROM SUPPLY; MAINTENANCE PERSONNEL (BOTH FLIGHTLINE AND BACKSHOP) HAVE 48 HOURS TO ACCOMPLISH CANNOT DUPLICATE SCREENING (CND) AND/OR CONDUCT MINOR REPAIRS AND MOVE THE ASSET TO SUPPLY FOR PROCESSING. ONCE SUPPLY RECEIVES THE UNSERVICEABLE 2LM ASSET IT SHOULD ARRIVE AT THE DEPOT OR APPROPRIATE REPAIR FACILITY WITHIN 3 DAYS (PARA 5). TOTAL 2LM BASE PROCESSING AND SHIPMENT TIME IS 5 DAYS.

5. ONCE BASE SUPPLY PROCESSES THE TURN-IN, UNSERVICEABLE ASSETS WITH PROJECT CODES 858 AND 879 (RDD 777) SHOULD ARRIVE AT THE DEPOT OR APPROPRIATE REPAIR FACILITY WITHIN 3 DAYS FOR CONUS SHIPMENTS. THIS ALLOWS NO MORE THAN ONE DAY TOTAL FOR SUPPLY MOVEMENT AND TMO PROCESSING AND TWO DAYS INTRANSIT. FOR OCONUS BASES, EXPRESS TRANSPORTATION SHOULD BE FOUR BUSINESS DAYS. ALL LL ASSETS (PROJECT CODE 858 OR 879) WILL BE SENT TO THE DEPOT OR REPAIR ACTIVITY USING EXPRESS TRANSPORTATION.

6. CONCURRENT WITH THIS MESSAGE, A PACKAGE HAS BEEN SENT TO ALL CHIEF'S OF SUPPLY AND TRANSPORTATION SHOWING RETROGRADE TIMES FROM MAY THROUGH NOVEMBER 1995 FOR ASSETS CODED AS LL (PROJECT CODES 879 AND 858) AND MEASURES THE TIME FROM WHICH THE UNSERVICEABLE ASSET WAS PROCESSED INTO THE SBSS UNTIL THE TIME IT WAS RECEIVED AT THE DEPOT. HOW THESE FLOW TIMES WERE OBTAINED ARE EXPLAINED IN THE PACKAGE. WE RECOMMEND YOU USE THE RESULTS AS A BASELINE TO CONTINUE IMPROVING REPARABLE ITEM MOVEMENT AND PROCESSING. DURING THIS PERIOD (MAY-NOV 95) THE OVERALL ACC CONUS AVERAGE WAS APPROXIMATELY 9 DAYS;

WE CAN DO BETTER. WE MUST DO BETTER!

7. EFFECTIVE IMMEDIATELY, I NEED ALL BASES TO START TRACKING LL METRICS (PROJECT CODES 879 AND 858) AND REPORT THIS DATA EACH MONTH TO HQ ACC/LGP AS PART OF THE 9302 REPORT. THE FIRST METRICS ARE DUE APR 96. ADDITIONALLY, THESE METRICS SHOULD BE AN AGENDA ITEM ON MONTHLY INTERMEDIATE REPAIR ENHANCEMENT PROGRAM (IREP) MEETINGS. AT THIS TIME, YOU ARE ONLY REQUIRED TO REPORT SUPPLY AND TMO PROCESSING AND CARRIER TIME. ONCE WE WORK A CHANGE TO THE ACC 203 REPORT OR THE ADVANCED TRACEABILITY AND CONTROL-AIR FORCE SYSTEM (ATAC-AF) IS FULLY ON LINE, NRTS PROCESSING TIME FOR 2LM SPECIFIC ASSETS WILL BE INCLUDED. THE FOLLOWING ARE DEFINITIONS OF EACH SEGMENT:

A. BASE SUPPLY TO TMO. TIME THE SHIPPING DOCUMENT WAS PRODUCED TO THE TIME THE ASSET WAS RECEIVED BY TMO. INFORMATION CAN BE OBTAINED FROM CMOS.

B. TMO TO CARRIER. TIME TMO INCHECKED THE ASSET FROM BASE SUPPLY UNTIL IT WAS RELEASED TO THE CARRIER. INFORMATION CAN BE OBTAINED FROM CMOS.

C. CARRIER TIME. TIME THE ASSET WAS RELEASED TO THE CARRIER UNTIL ACTUAL DELIVERY AT THE DEPOT. THIS IS DEFINED AS TAILGATE TIME. CARRIER DELIVERY TIMES CAN BE OBTAINED FROM COMMERCIAL EXPRESS CARRIER DATA SYSTEMS (POWERSHIP, MAXISHIP, ETC).

TO ASSIST YOU, THE ACC 225 REPORT WILL INDENTIFY THOSE ASSETS WITH PROJECT CODES 879 AND 858 THAT ARE CURRENTLY LOADED IN YOUR SBSS. BASE SUPPLY (LGSC) WILL BE RESPONSIBLE TO PROVIDE THE 2LM NRTS DATA ONCE IT IS AVAILABLE FROM ACC 203 REPORT. BASE TRANSPORTATION (LGTT) WILL BE RESPONSIBLE FOR A, B, AND C ABOVE. LGTT AND LGSC WILL GIVE THIS INFORMATION TO THE BASE MAINTENANCE ANALYSIS UNIT NLT THE 5TH WORKDAY OF EACH MONTH FOR THE PREVIOUS MONTH. EXPECT LL TO BE A SPECIAL INTEREST ITEM ON STAFF ASSISTANCE VISITS.

8. IN SUMMARY, WE MUST DO OUR PART TO MAKE LL WORK. IN THE FY 97 POM, THE ORDER AND SHIP TIME STANDARD USED TO COMPUTE DEPOT BUY REQUIREMENTS WILL BE REDUCED FROM 17 DAYS TO 11 DAYS. THIS MEANS

THERE WILL BE LESS ASSETS AVAILABLE TO SUPPORT BASE NEEDS. THEREFORE, DELAYS IN SHIPPING UNSERVICEABLE ASSETS BACK TO THE DEPOT WILL DELAY THE DEPOT'S ABILITY TO SATISFY YOUR DEMAND. ADDITIONALLY, BASE USERS MUST ENSURE THE REQUIREMENTS THEY PLACE ON THE SUPPLY SYSTEM ARE VALID.

9. WE APPRECIATE YOUR CONTINUED SUPPORT. OUR POC'S ARE MAJ BANKS, HQ ACC/LGTT, DSN 574-2639, E-MAIL BANKSC@HQACCLG.LANGLEY.AF.MIL (LOWER CASE) OR CAPT BENSON, HQ ACC/LGSIP, DSN 574-7819, E-MAIL BENSONR@HQACCLG.LANGLEY.AF.MIL (LOWER CASE).

BT

#0890

## Appendix B. 2LM Time Standard Discussion Message

R 041600Z MAR 96

FM HQ USAF WASHINGTON DC//LGM-2//

UNCLAS

SUBJECT: 2LM BASE EVACUATION "STANDARD"

1. ONE DISCUSSION AT THE FEB 96 LL USERS GROUP MEETING RAISED THE ISSUE OF CHANGING BASE EVACUATION TIMES FOR 2LM ITEMS FROM 48 HOURS TO 72 HOURS. DISCUSSION CENTERED ON THE ISSUE THAT THE CURRENT 48 HOUR GOAL, COVERING THE TIME FROM PART REMOVAL FROM THE AIRCRAFT TO SHIPMENT FROM THE BASE, DID NOT ALLOW MAINTENANCE PERSONNEL ENOUGH TIME TO CND SCREEN THE PART AND MAKE THE PROPER DECISIONS. AS A RESULT, THE USERS GROUP REQUESTED THIS TIME BE INCREASED BY 24 HOURS. DISCUSSION AT THE O-6 LL STEERING GROUP WAS BRIEF AND APPROVAL APPEARED APPROPRIATE. HOWEVER, A RECENT TRIP TO ONE MAJCOM SEEMED TO INDICATE THAT APPROVAL WOULD BE PREMATURE AT THIS TIME. UNITS WITHIN THIS MAJCOM WERE MEETING THE 48 HOUR GOAL WITH NO PROBLEM.

2. REQUEST ADDRESSEES RESPOND NLT 18 MAR 96 INDICATING PROBLEMS WITH THE 48 HOUR GOAL, SO AN INFORMED DECISION CAN BE MADE ON THE ISSUE.

Appendix C. Logistics Response Times (Lee, 1996)

| Process/Function | Measure |
|---|---|
| Requisition Submission Time | Elapsed time from the date on the requisition to the date the requisition was received at DAAS. DAAS compares the requisition date to the date on the AUTODIN batch header to determine the lapsed days. |
| DAAS Processing Time | Elapsed time from receipt of a requisition at DAAS to the transmission of AO_ message to an ICP. |
| Initial Source Processing Time | Elapsed time from transmission of AO_ message by DAAS to receipt by DAAS of supply action |
| Depot Processing Time (Distribution Depot Storage Processing and Transportation Time) | Elapsed time from release of materiel by container consolidation point until release by shipper. |
| Depot to Containerization Point Transportation Time | Elapsed time from shipment of materiel from depot to arrival of materiel at containerization point. |
| Containerization Point Processing Time | Elapsed time from receipt of materiel by container consolidation point until release by shipper. |
| CONUS In-Transit Time | Elapsed time from release of the shipment to the carrier until receipt by the CONUS consignee or the port of embarkation of OCONUS shipments |
| Port of Embarkation Processing Time | Elapsed time from receipt at port of embarkation until the shipment is lifted to the port of debarkation. |
| In-Transit to Theater Time | Elapsed time from lift at the port of embarkation to receipt at the port of debarkation. |
| Port of Debarkation Processing Time | Elapsed time from the date the material is received at the port of debarkation until it is released, or shipped, to the consignee. |
| In-Transit, In-Theater Time | Elapsed time from release by the port of debarkation until the date the material is received by the consignee. |
| Receipt Take-up Time | Elapsed time from receipt by the consignee to posting in the consignee's stock records or issue to the ultimate customer. |

Appendix D. Maintenance Repair Priorities
(Maintenance Management of Aircraft, 1994:14)

Use this table as a guide to establish maintenance repair priorities. Raising or lowering priorities will not necessarily require a corresponding change in the supply delivery priority. The maintenance repair priority and the supply delivery priority are normally identical. Use a less responsive supply delivery priority when the need time or date for a part does not justify the delivery time specified.

**Priority 1. Supply delivery: ASAP.** Use for primary mission aircraft within 12 hours of a scheduled launch on the following missions:

- Presidential directed missions supporting US. forces in combat and national emergency plans and special weapons movement missions.
- Aircraft alert status.
- Related AGE, munitions, and munitions equipment assigned to these missions.

**Priority 2. Supply delivery: ASAP.** Use for:

- Primary mission aircraft and related AGE, munitions, and munitions equipment for first 8 hours after landing or start of recovery or within 6 hours of a scheduled launch or alert.
- During simulated generation of operational readiness inspection.
- Primary special weapons movement mission aircraft 48 hours prior to a scheduled launch.
- Air evacuation rescue, and weather mission aircraft and related AGE, munitions and munitions equipment.
- All transient Federal Aviation Administration aircraft.
- Aircraft and equipment or related AGE requiring repair which is preventing or delaying student or maintenance training.

**Priority 3. Supply Delivery: Not later than 1 hour.** Used for:

- Primary mission air vehicles, engines and related AGE, munitions and munitions equipment, undergoing scheduled or unscheduled maintenance.
- Transient air vehicles not otherwise listed.
- Administrative aircraft within 8 hours of scheduled flight or on alert status with standby crews.
- Time change requirements for nuclear weapons.
- Scheduled and unscheduled maintenance of munitions which if not performed will prevent or delay mission accomplishment.
- Precision measurement equipment (PME) requiring emergency repair or calibration, the lack of which will prevent or delay mission accomplishment.
- Spares not available in supply.
- Critical end items and reparable spares or supply designated "priority repair" spares.

- Routine maintenance of air crew or missile training simulator, or other training devices or related AGE or sites and aircraft or equipment used for maintenance training.
- Avionics shop electronic AGE and automated test stations.

**Priority 4. Supply Delivery: Not later than 4 hours.** Used for:

- Routine or extensive repair of primary mission air vehicles, related AGE, and repair cycle assets.
- Administrative aircraft undergoing scheduled or unscheduled maintenance.
- Routine maintenance of AGE not otherwise listed above.
- WRM items due maintenance or inspection.
- Inspection, maintenance, and TCTO compliance of MSK or MRSP material.
- Scheduled calibration and unscheduled repairs on PME not listed above.
- Extensive repair of air crew or missile training simulator, or other training devices or related AGE.

**Priority 5. Supply Delivery: Not later than 4 hours.** Used for:

- Non-tactical or non-primary mission aircraft undergoing extensive repair.
- Fabrication and repair of aeronautical items not carrying a higher priority.
- Time change requirements on non-nuclear items.
- Bench stock requirements.

**Priority 6. Supply Delivery: Not later than 12 hours.** Used for fabrication and repair of non aeronautical items, equipment, and other aeronautical requirements.

**Priority 7. Supply Delivery: Not Applicable.** Used for spares excess to base requirements.

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This study describes the prioritization schemes utilized in the Air Force logistics reparable pipeline. The reparable pipeline is defined and illustrated with flowcharts. A literature review examines previous research conducted on the reparable pipeline, including analytic and conceptual pipeline models, and pipeline management studies. In addition, the topic of prioritization as defined in the production/operations management academic discipline is reviewed. Prioritization schemes of the reparable pipeline are reported in tabular format in addition to descriptions of the various prioritization schemes. Recommendations for pipeline improvement and further research form a basis from which pipeline operation may be improved.

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