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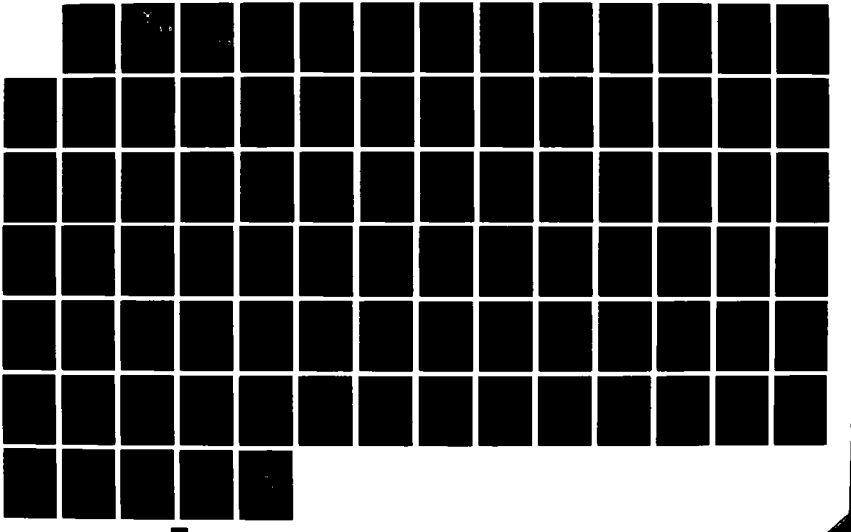

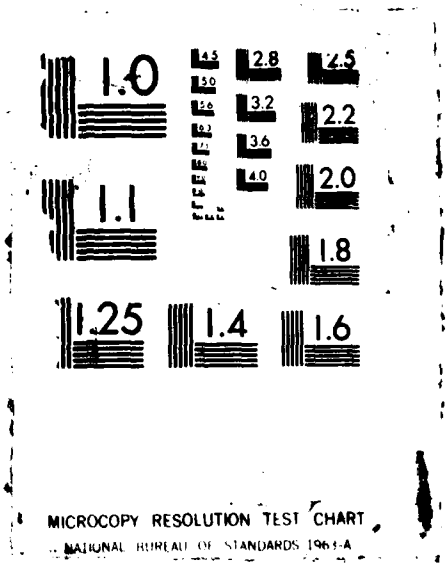
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CONSIDERATION OF USAF LOGISTICS DOCTRINE PRINCIPLES IN A DECISION MAKING FRAMEWORK

THESIS

David W. Wallingford
GS-12, USAF

AFIT/GLM/LSR/87S-82

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Per Capt. Kenneth R. Jennings, AFIT/LSR

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AFIT/GLM/LSR/87S-82

CONSIDERATION OF USAF LOGISTICS DOCTRINE PRINCIPLES IN A DECISION MAKING FRAMEWORK

THESIS

Presented to the Faculty of the School of Systems and Logistics of the Air Force Institute of Technology Air University

In Partial Fulfillment of the Requirements for the degree of Master of Science in Logistics Management

David W. Wallingford, B.A.

GS-12, USAF

September, 1987

Distribution limited to U.S. Government agencies and their contractors; Administrative/Operational Use 16 September 1987. Other requests for this document must be referred to CMDT/AWC.

Preface

This thesis is not a statistical test of a hypothesis. Instead, it offers the reader a perspective on decision making in cases where the costs and benefits of the alternative courses of action are not easily evaluated. Readers are encouraged to read this document with a critical eye and agree or disagree with the conclusions herein, thereby extending the research in this area.

I am deeply indebted to my advisor, Capt Kenneth R. Jennings, and my reader, Lt Col James T. Lindsey, for their efforts and insights which were of inestimable value to me in accomplishing this thesis. In addition, I thank Maj Phil Miller for the assignment which gave rise to this concept and Capt Carl Davis for his enthusiastic support.

Finally, I thank my wife Lynne for her patience and understanding during some stressful times.

David W. Wallingford

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Abstract

The purpose of this study was to assess the feasibility of using a decision making tool to consider alternatives in terms of publicly stated doctrine.

The first section examines the potential difficulties in using U.S. Air Force Logistics Doctrine to assist in making decisions. This is accomplished through a review of current doctrine based on its evolution.

The second section examines several decision tools which are (or could be) in use. Advantages and disadvantages of both quantitative and qualitative frameworks are discussed.

The final element of this thesis is the synthesis of a conceptual framework of a logistics decision support system, using specific models to consider the relative merit of alternatives based on the principles of U.S. Air Force Logistics Doctrine.

CONSIDERATION OF USAF LOGISTICS DOCTRINE PRINCIPLES IN A DECISION MAKING FRAMEWORK

I. Introduction

The support of a weapon system poses an economic problem: "How can the logistics manager maximize operational readiness and at the same time minimize support costs (Schwankman, 1986:33)?" This conflict between operational needs and economic reality has stimulated the study of logistics as an important and distinct field. Much has been written to try to discuss logistics in current practice. Several prior attempts at defining a new logistics doctrine have contributed much to understanding the goals of the military logistics systems. The works of Badalamente (1980), Gorby (1980), McMahon (1985) and McDaniel (1986) have identified many of the principles and goals of logistics systems. These collections of ideas, however, all seem to lack a general framework that will serve to unify their collection of worthwhile ideas.

Background

Any study of a conceptual nature requires both the researcher and the reader to use a vocabulary based on shared understanding of meanings. This is especially true of subject areas where definitive meanings do not exist. Many of the terms used in this research effort have multiple definitions. This background section serves both to define terms operationally and to provide the reader with context as understood by the researcher.

1. Logistics - The basic principles of logistics have not changed appreciably over time; the articulation of those principles has changed frequently.

> The Joint Chiefs of Staff Publication 1, Dictionary of Military and Associated Terms defines logistics ... as follows: Logistics is the science of planning and carrying out the movement and maintenance of forces. (McMahon, 1985:2).

Logistics is considered to incorporate the processes of acquisition, equipment maintenance, training, physical distribution, inventory management, and facilities management (Clark, 1986:1). The military logistics function has also been defined as all the activities necessary to support combat readiness, or even more simply, as "combat support (McDaniel, 1986:11-12)."

2. Management - Early studies of the functions of management centered on the functions defined by Henry Fayol: planning, organizing, commanding, coordinating, and controlling (Donnelly, Gibson, and Ivancevich, 1984:88). In

their text, Donnelly (et al) describe the management function as "planning, organizing, and controlling (Donnelly, Gibson, and Ivancevich, 1984:5)."

3. Logistics Management - Logistics management is therefore, decision-making in planning, organizing and controlling the application of organizational resources in order to maximize combat readiness.

4. Decision making - The primary goal of management is to properly allocate scarce resources in order to best achieve organizational objectives.

> Organizations ... without managers probably will dissipate ... resources in random activity. Effective management ... leads to purposeful, coordinated, goal-directed activity (Hicks and Gullett, 1976:187).

This implies that there are not sufficient resources to accomplish the organizational objective in a haphazard manner. That is, decisions must be made because not all things are possible, or stated another way, the opportunity to "... have one's cake and eat it too" should be considered an infrequent, unusual luxury.

5. Doctrine - Probably the most nebulus of terms in this research effort is "doctrine." While a number of definitions are offered in the literature, the best may also be the simplest: a set of "beliefs that are taught (McMahon, 1985:2)."

Stewart, Badalamente, and Margenthaler (1981:10) offer the following concept of Air Force Doctrine:

> ... the purpose of Air Force Doctrine is to provide decision makers at all levels within the decision structure with principles and guidelines to use in developing more specific policies, strategies, and tactics in pursuing mission goals and objectives. It is intended to imbue Air Force decision makers with the 'corporate' idealogy concerning the appropriate and effective use of aerospace forces.

In essence, Stewart et al present the view that USAF logistics doctrine should provide an effective decision making framework. This research effort begins from that perspective.

A collection of ideas is only useful when their relationships are understood. Both the causal and comparative relationships need to be visible; i.e., it's important to comprehend how items are connected and their relative importance. The bottom line is that all decision-making is based on two questions; one question relates to causal aspects and the other to comparative aspects. The causation question is: "What is the impact?" The comparison question, perhaps the more significant of the two, is: "How important is that?"

The central theme that can put all the prior work into useful perspective is the principle of "PRIORITY". Webster's definition of priority is "... precedence, preference in regard to privilege (Allee, 1972:292)." In layman terminology, priority is the relative importance of one thing to another. A thorough understanding of the actual priorities established by superiors is essential to

adequate combat readiness. As the principle document of belief, USAF Logistics Doctrine should provide the priority framework for decision making.

Logistics doctrine offers a series of principles which serve as the goals for the Air Force combat support effort. It also describes the sequential and iterative combat support process. Air Force Combat Support Doctrine (AFM 1-10) discusses "balance" as an important logistics principle. "One of the great challenges of combat support is effective resource allocation (Dept of the AF, 1987:Ch 3, 3)." The manual does not, however, offer guidance in this area. The decision-maker is faced with responsibility for appropriate resource allocation without being given a system for trading-off costs and benefits. Every individual involved in military logistics must be able to make decisions with respect to causation and comparison.

Performing such a trade-off analysis is complicated at best, but is even more difficult when the measures of cost or benefit are non-commensurate. Non-commensurate measures are those which cannot be used in simple mathematical operations like addition and subtraction. What measure would be used to describe increased reliability at the cost of decreased availability? For the decision maker, how long can the logistics system wait in order to obtain improved reliability? The analysis becomes even more complex when

there are multiple factors to be considered and there is limited time in which to accomplish the decision process.

The complexities of the logistics process preclude the establishment of any single listing of priority or relative importance. The logistics decision must be made in specific context of the combat support requirement and based on the capabilities of the entire logistics system. While logistics decision makers have doctrine to provide the philosophical basis for their decisions, they lack a method for the practical application of doctrine in their specific circumstances.

Problem Statement

What can be done to facilitate logistics managers' use of Logistics Doctrine in their decision-making process?

The goal of this research effort is to document the necessity for, and determine the feasability of establishing a decision making framework in Logistics Doctrine. Such a framework would serve to aid in establishing priority in trade-off analysis and decision making. The purpose of this study is not to debate the merits of the principles, or to promote any particular priority list as superior. The purpose is to develop a framework in which these types of trade-off analysis can be effectively performed. Figure 1 shows the logistics decision making process.

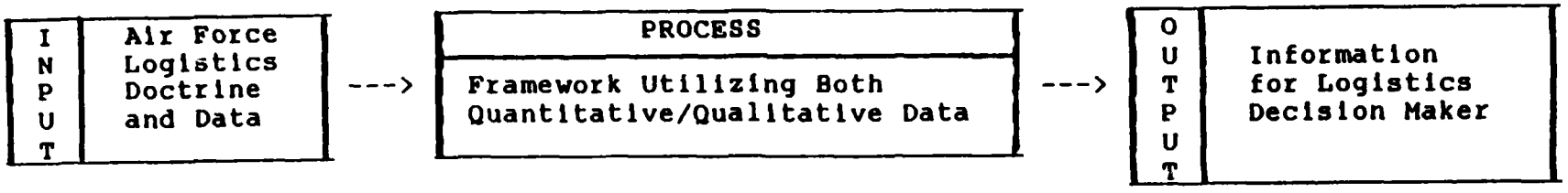


Fig. 1. Proposed Logistics Decision Making Process

The following list of investigative questions have driven the design of this research:

a. What doctrinal guidance exists for Logistics Managers?

b. What shortfalls exist in the doctrinal guidance?

c. What techniques for improved qualitative decision making are available?

d. What model should be applied?

e. How can doctrine be merged with the model?

Chapter II of this thesis addresses logistics doctrine. It provides a historical perspective on Air Force Logistics Doctrine by briefly outlining the major steps in doctrinal development. The current status of logistics doctrine is then described by overviewing Air Force Manual 1-10, Combat Support Doctrine. Current doctrine is then analyzed to determine if there are problem areas in using doctrine to guide a decision maker. The useful elements of doctrine are then recommended for application in a decision making framework. This chapter includes definition of variables and proposes a means of valuing the variables.

Chapter III of this thesis addresses qualitative decision making. It discusses several qualitative techniques which can be utilized by managers. The analysis of the advantages and disadvantages inherent in each of the techniques are briefly summarized. Based on those

characteristics, a framework is recommended in chapter IV for development of a decision making model appropriate to logistics doctrine. Chapter V discusses the apparent validity of applying the proposed framework for decision making and identifies weaknesses of the framework as potential areas for further research.

II. Logistics Doctrine

U. S. Air Force logistics doctrine has a long background that stretches from 1943 to the present. Logistics doctrine has grown from something of an afterthought to Air Force basic doctrine (only addressed in passing) into one of the most critical factors to combat support. Studying the history of logistics doctrine provides insight into its current articulation in Air Force Manual 1-10 as well as insight into its current deficiencies.

Historical Background Prior to 1980

Lieutenant Colonel Gary McMahon, in his Air War College research report entitled "Air Force Logistics Doctrine: Where Is It?" describes early doctrinal efforts. In 1943 the Army Air Corps published their "Logistical Manual." The manual contained data and planning tables with information for the logistician. The Army Air Corps manual evolved into Air Force Manual 400-5, which was considered to be lacking in doctrinal type statements. Use of the manual was discontinued in 1960 (McMahon, 1985:3).

A study entitled "The Development of Air Logistic Doctrine 1948-1956" was published in 1957 by the Mobile Air Material Area. This study was primarily historical in nature and did not provide substantive doctrinal statements

(McMahon, 1985:3). Air Material Command was, however, beginning to formally encourage the development of doctrine.

> In 1955, the Air Material Command established the Advanced Logistics Course at the Air Force Institute of Technology to train logisticians and develop logistics philosophy and doctrine (McMahon, 1985:4).

Despite the formal organization and charter of the Advanced Logistics Course, no logistics doctrine was published for thirteen years.

An important predecessor to Air Force logistics doctrine was Department of Defense Directive (DoDD) 4100.35, entitled "Logistics Support Directive," which was issued 19 June 1964. That directive listed the elements of integrated logistics support as: planned maintenance, logistic support of personnel, technical logistic data and information, support equipment, spares and repair parts, facilities, and contract maintenance (Eccles, 1986:26). DoDD 4100.35 appears to be the basis for all the academic development of Air Force logistics doctrine which followed. The directive requires that "... Trade offs appropriate to the stage of development shall be made that will maximize the effectiveness and efficiency of the support system to a degree that is in consonance with the overall system operational requirement (Badalamente, 1980:Ch 4, 7)." The directive did not define the principles to which logisticians should ascribe.

Air Force Logistics Doctrine, Air Force Manual 400-2, was published in November of 1968. It was the product of two students at the Air Force Institute of Technology's School of Systems and Logistics (McMahon, 1985:4). Although often criticized as outdated (Gorby 1980:25, McDaniel 1986:10, McMahon 1985:1), AFM 400-2 was not updated and was eventually rescinded on 1 January 1986.

The period from 1968 to 1980 was not an active period in the development of logistics doctrine. Research indicates that during that period, fragmented policies were issued and updated in the sub-disciplines of logistics, but little comprehensive study was conducted.

It may be that activity in Southeast Asia preempted most academic activities. Major emphasis appears to have been placed on advancing technology in weapon systems. Effectiveness was obviously the primary concern. "Because survival is at stake, cost [efficiency] cannot be the primary consideration in national security decisions (Dept of the AF, 1987:Ch 3, 2)."

The end of our national involvement in the hostilities of Southeast Asia offered an opportunity to evaluate the performance of our logistics system. In 1974, the U.S. Army published "Vietnam Studies: Logistics Support." Technological advances were being evaluated for application to the systems that support the weapon systems.

At the same time that the military was considering lessons learned from the conflict, the civilian sector was faced with transitioning the Military-Industrial-Complex from a wartime stance into a peacetime stance. "The will of the people ... was to devote all available resources toward improving the peacetime life of the nation (Gansler, 1980:22)." This attitude engendered new emphasis on effeciency and economy in Defense industry. The concept of life cycle cost was introduced. Department of Defense Instruction 5000.1 was issued in 1971 and established the requirement for life cycle cost evaluation. In 1976, the Office of Management and Budget issued circular A-109 which requires life cycle cost analysis in the acquisition of all major systems (Gill, 1985:5).

Changes in the national resolve along with changes in war-fighting techniques and technologies caused a reassessment of doctrine. Air Force Basic Doctrine, Air Force Manual 1-1, was rewritten in February 1979. This provided a baseline for development of a new logistics doctrine.

Specific Contributions Since 1980

Major James D. Gorby. In early 1980, Major James Gorby published an article entitled "Air Force Logistics Doctrine" with the intent "to stimulate the development of a new logistics doctrine for the Air Force (Gorby 1980:24)." When

Gorby's article was published, the editor of the Air Force Journal of Logistics noted that "a revised Logistics Doctrine, AFM 400-2, is scheduled for publication in June 1980 (Gorby 1980:24)." As noted previously, the original AFM 400-2 was not rescinded until 1 January 1986.

Major Gorby articulated nine principles of logistics that he considered critical to doctrine. The principles he outlined appear to be based primarily on historical experience, but can provide a baseline for current logistics thought that can be used as a starting point for the discussion of more recent descriptions of logistics principles. The next several paragraphs provide brief explanations of Gorby's nine principles:

1. OBJECTIVE - "Support the mission (Gorby, 1980:25)." The principle of "objective" has two elements. The first element of the principle is that there must exist an organizational objective; a goal toward which all efforts can be focused. The second element is that there must be a pervasive visibility of the objective throughout the organization; i.e., all units in the organization should be constantly aware of the organizational goal.

2. READINESS - "Keep the equipment ready for war (Gorby, 1980:25)." Readiness is based on preparation for wartime use. Periodic exercise and evaluation of the logistics systems should be under conditions which approximate the expected wartime environment. Real threats

should be considered; real data should be used; real feasability must be assured.

3. SUSTAINABILITY - "Support the mission until it is completed (Gorby, 1980:26)." The logistics system should support protracted military efforts. The logistics system which supports initial readiness may not be sufficient to support extended combat.

4. FLEXIBILITY - "Support the force under all planned conditions (Gorby, 1980:26)." The logistics system should have the flexibility to be able to adapt to a variety of operational scenarios.

5. SYSTEM INTEGRITY - "Logistics is a dyanmic, interrelated, system. We cannot treat logistics as distinct from military operations because they cannot be seperated except to ease analysis (Gorby, 1980:27)." The logistics system must recognize and support operational requirements and the operational system must recognize logistics capabilities.

6. VISIBILITY - "Watch those things most critical to the mission (Gorby, 1980:27)." There are two elements to visibility. The first is that the important resources should be visible to logistics managers at all levels. The second element is that the logistics system must be understood as a productive system composed of inputs, processes, and outputs. That is, the relative position of

important resources in the entire logistics system must be visible to each portion of the system.

7. ECONOMY - "Do the job the cheapest possible way. We must be efficient; money or resources saved in doing one task can be used to buy more of something else or to do tasks that were going undone because resources weren't available to do them (Gorby, 1980:28)."

8. AVAILABILITY - "Get the right thing to the right place at the right time (Gorby, 1980:28)." Logistics resources must be available for proper allocation to support sustainability. Availability is a function of quantity and mobility.

9. SIMPLICITY - "Logistics systems and procedures should be easy to understand and operate (Gorby, 1980:29)." Simplicity is based on two elements. The first is efficiency; i.e., that there be no "fat" in the system which would cause inefficiencies in wartime. The second element is maximum standardization. Systems should be stable, use standardized parts, and be implemented with adequate training to assure that the system is understood (Gorby, 1980:29).

Major Gorby offered these principles as a "target" to serve as a focus for future development of doctrine. Discussion of later doctrinal efforts will be in terms of evolution from this baseline.

Lieutenant Colonel Richard V. Badalamente. The Air Force Institute of Technology was also tasked to examine logistics doctrine, its purpose, and its relationship to basic doctrine. The AFIT effort was approximately parallel to Gorby's analysis and was supposed to result in a revised AFM 400-2. The revision to that manual never materialized; instead, a new doctrinal document was drafted. Lieutenant Colonel Richard Badalamente, AFIT/LSM, distributed a draft of Air Force Logistics Doctrine, AFM 2-18, on 19 September 1980 (Badalamente, 1980:1, Gorby, 1980:24, McDaniel, 1986:10).

Lt Col Badalamente's major contribution to the advancement of logistics doctrine was to include a description of the logistics process. The logistics process was described from the systems viewpoint; that is, that all the subelements are related. This gives the reader the opportunity to see where the principles of doctrine should be put into practice. Badalamente also defined the goal of logistics: "To create and sustain forces in the conduct of offensive and defensive operations in the air anywhere in the world, or in space (Badalamente, 1980:Ch 3, 5)." Badalamente explained the rationale for the set of principles used in the draft doctrine this way:

> In driving toward our goals, it is essential that we know as much as possible about how the logistics system works, including how essential elements in the system are related to each other. As we learn the exact nature of these relationships, we can express them as

'principles.' Using these principles helps us achieve our goals. Thus the final part of logistics doctrine deals with principles of logistics (Badalamente, 1980:Ch 3, 10).

Table 1 shows the relation of Badalamente's principles to Gorby's list of principles.

TABLE I
Logistics Doctrine Concepts

Maj Gorby, 1980	Lt Col Badalamente, 1980
Objective	Objectives and Priorities
Readiness	Response
Sustainability	Sustainability *Survivability
Flexibility	Flexibility
System Integrity	Strategy-Tactics-Logistics Joint Centralized Planning
Visibility	Information *Communication
Economy	*Design to Life Cycle Cost Economies of Scale
Availability	Mobility
Simplicity	Simplicity Standardization
	*Continuous Flow

* Asterisks indicate substantial additions or changes to Gorby's work.

The parallel work of Gorby and Badalamente resulted in many shared concepts which were identified with different

names. There were some significant variations, and these are discussed in the following paragraphs.

In some cases, Badalamente added detail without sufficient distinction to merit identification as separate principles. Where Gorby described economy in general terms and then gave examples of different types of economy, Badalamente described two specific economies. Design to life cycle cost is defined as "... an elaborate system of tradeoffs balancing such things as higher reliability against increased acquisition cost (Badalamente, 1980:Ch 4, 6)." Economies of scale are the efficiencies to be gained by grouping homogenous logistics tasks (Badalamente, 1980:Ch 4, 14).

In the case of standardization, Badalamente provided additional detail which he considered to merit separate definition. Where Gorby only mentions interchangability of parts, Badalamente extends the definition of standardization to include

> the compatibility of plans, policies, procedures, equipment, tools, data, and information systems [which] enhances command, control and communications, speeds up production and maintenance, reduces manpower requirements, and minimizes training (Badalamente, 1980:Ch 4, 8).

This separate analysis of standardization allowed Badalamente to focus on simplicity, as a different principle which he described as "... a function of the interrelationship and interdependence of component parts ...

Simple systems have higher reliability and are easier to maintain (Badalamente, 1980:Ch 4, 7)."

Twice Lt Col Badalamente identified principles which might more accurately be called procedures. "Centralized planning allows forces to be directed towards a central objective (Badalamente, 1980:Ch 4, 3)." Joint centralized plannng appears to be a technique for supporting visibility of resources and orientation toward a common corporate objective.

Continuous flow is described as "the efficient flow of logistics support materials ... by avoidi ıg out-of-line movements, minimizing handling and minimizing interchange of transportation equipment and transfer points (Badalamente, 1980:Ch 4, 11)." Continuous flow is a technique in support of the principle of availability.

Badalamente does add substantial material in the area of sustainability (survivability) and in the area of visibility (communication).

While sustainability is focused on the continued operation of weapon systems, survivability is focused on the continued operation of the logistics system. Badalamente argues that it should be "difficult to destroy or disrupt the logistics systems' capability to perform its essential functions (Badalamente, 1980:Ch 4, 13)." Gorby only briefly mentions protection "from theft, deterioration, or enemy action (Gorby, 1980:28)" as a means of maintaining resource

availability. Survivability and sustainability focus on protection over time; where availability focuses on presence at a given time.

Gorby describes visibility as the knowledge of the status of resources. Badalamente divides this concept into two principles: information and communication. Information is "data that have been processed into a meaningful form (Senn, 1978 :628)." Information systems must provide information which is accurate, timely, relevant, concise, objective, complete, quantifiable, and clear (Badalamente, 1980:Ch 4, 16). Once information is created, it must be communicated. Badalamente states that "communication makes cooperation possible (Badalamente, 1980:Ch 4, 17)." The principle of efficient communication therefore requires maximum transfer of useful (true) information while minimizing message traffic.

Lieutenant Colonel Gary McMahon. Badalamente's idea of putting the principles of logistics doctrine in perspective was extended in 1985. Again, nearly parallel efforts were in process. Lieutenant Colonel Gary McMahon was conducting research at the Air War College and Lieutenant Colonel William McDaniel, Jr. was working in the newly created doctrinal development position in the Logistics Concepts Division of the Logistics Plans and Programs Directorate, HQ USAF.

Lt Col McMahon stressed the idea of stating the principles of logistics doctrine in operational terms. McMahon considered that the formal doctrine at that time was insufficient for any of doctrine's four purposes.

> ... the Air Force does not have a useable logistics doctrine that can be used as the underlying rationale for logistics decisions, as a structure for long range logistics planning, as a means to encourage new thoughts on how to better support combat operations, [or] as a means of educating all Air Force personnel on the importance of logistics in warfighting (McMahon, 1985: 5).

His remedy for doctrine was to orient all logistics principles to specific elements of the logistics process. McMahon related logistics principles to the four traditional stages of the logistics process: requirements determination, procurement, distribution, and maintenance. In addition he defined a fifth element; that of logistics management. "This function should include ... the management beliefs that transcend depot and base logistic systems and the four other logistics functions (McMahon, 1985:11)."

The principles that McMahon describes are arranged strictly by the operational subdivisions of a logistics system. They are shown as the important principles of each operational area. They are not written for theoretical application to the logistics system as a whole. In many cases, McMahon has described a feature of the logistics system without specifically identifying "a principle." The

list of doctrinal principles contained in Table II was extracted by the researcher.

TABLE II
Logistics Doctrine Concepts
Lt Col McMahon, 1985

Logistics Process	Principles of Doctrine
Requirements Determination	Objective Readiness Flexibility
Procurement	Timely Economy
Distribution	Visibility Availability
Maintenance	*Reliability *Maintainability
Logistics Management	Objective Information Comprehensive

* Asterisks indicate substantial additions or changes to prior work.

Lt Col McMahon used operational examples to provide additional detail for some of the earlier principles of logistics. Worthy of particular note are the concepts of reliability and maintainability (R & M). R & M are

considered to be force multipliers, in the case of aircraft, a more reliable or a more maintainable system will be capable of generating more sorties than the same system could otherwise. "The desireability of reliable and maintainable systems has long been recognized (Russ, 1985:122)." McMahon's writing may incorporate the ideas of reliability and maintainability as a response to the HQ USAF policy memorandum of 17 September 1984 which "emphasized the need to increase Air Force operational effectiveness through improved Reliability and Maintainabiliy (R & M) (Dept of the AF, 1985: 1)."

Air Force Regulation 800-18 defines reliability as "The probability that an item will perform its intended function for a specified interval under stated conditions (Hodgson, 1984:10)." Maintainability is defined in DoD Directive 5000.40 as "The ability of an item to be retained in or restored to specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources (Hodgson, 1984:10)."

McMahon's emphasis in proposing an updated logistics doctrine was to operationalize the concepts. He proposed making doctrine accessable to the reader by providing examples of performance factors which could be evaluated. That is, doctrine should provide guidance in terms of measurable performance factors. This is an important element in providing a framework to the decision maker.

McMahon introduced the concepts of reliability and maintainability into logistics doctrine. This new emphasis on reliability and maintainability would give logistics managers a way of identifying and measuring many important aspects of their systems. System performance in these areas can be measured and standard statistical techniques can be use to predict future performance.

McMahon's goal in operationalizing doctrine was to provide a document which would "... educate Air Force officers [who] make critical logistical funding decisions ... [and] be of great value to the Air Commanders who make the final logistics decisions in combat ... [and] help logisticians to make better and quicker decisions (McMahon, 1985:19-20)."

During the period that Lt Col McMahon was studying the shortcomings of existing doctrine, many of the inadequacies came to the attention of Lieutenant General Leo Marquez, Air Force Deputy Chief of Staff for Logistics and Engineering. He tasked Lt Col William McDaniel, Jr. to "resurrect doctrine to a place of influence within the logistics community (McDaniel, 1986:10)." Air Force logistics doctrine had finally received the level of attention that was necessary to formally publish a new Air Force Logistics Doctrine.

Lieutenant Colonel William McDaniel, Jr. Working in the Logistics Concepts Division of the Logistics Plans and

Programs Directorate of HQ USAF, Lieutenant Colonel William McDaniel, Jr. was responsible for the formulation, coordination, publication, and indoctrination necessary to develop and institutionalize a new logistics doctrine for the Air Force. Doctrine was developed through a series of conferences and draft documents (McDaniel, 1986). One of the early changes was the replacement of "logistics" with "combat support." This change was a reaction to the overly narrow concept of logistics throughout the Air Force.

> It was apparent from many diverse readers of the evolving draft that the term logistics had a very narrow connotation in the Air Force. If this document was to bring doctrinal coherency and unification to the Air Force community with an emphasis on the man as well as the machine, then a more descriptive term than logistics had to be found, especially for those involved in personnel, engineering, security, and acquisition activities (McDaniel, 1986:11-12).

For the sake of consistency and readability, the researcher will continue to use the phrase "logistics doctrine" unless referring to the specific title of a document. Air Force Manual (AFM) 2-15, Combat Support Doctrine, was issued 13 December 1985, and the outdated AFM 400-2 was rescinded 1 January 1986. Concurrently, Lt Col McDaniel published a preview of AFM 2-18 in the Air Force Journal of Logistics (McDaniel, 1986:10). That preview was apparently intended to aid in the indoctrination of logistics professionals in the Air Force.

Combat Support Doctrine dated 1 April 1987, was reissued, upgraded to Air Force Manual 1-10. While the

document was basically unchanged, the upgrade reflected the importance of logistics doctrine by elevating it to the level of basic doctrine (1-series manual) from the operational (2-series manual) status. "Today, logistics in one form or another dominates U.S. strategic planning and military procurement (Eccles, 1986:26)."

The only significant differences between Ltc McDaniel's article, AFM 2-15 and AFM 1-10 are the inclusion of additional detail in the manuals. Because of this high degree of similiarity, the remainder of this chapter (unless otherwise noted) reflects logistics doctrine as currently articulated in Air Force Manual 1-10, Combat Support Doctrine.

Current Status

Air Force Manual 1-10 contains three chapters: combat perspective, combat support process, and combat support principles. The first chapter describes the importance of logistics to all facets of combat. The second discusses the specific processes involved in the logistics system. The third chapter lists eight principles explaining "... what makes combat support work best (Dept of the AF, 1987:Ch 3, 1)." Because this research effort is focused on the use of doctrine in decision making, analysis of AFM 1-10 will be limited to chapters two and three of the manual.

The original draft of the revision to logistics doctrine contained a description of the logistics process based on the four traditional functional areas, this time identified as acquisition, distribution, restoration, and disposition. The conference participants decided "that doctrine should be cross-functional and confine itself to basic tasks or processes (McDaniel, 1986:12)." The resulting list of eight processes includes: definition, acquisition, maturation, distribution, integration, preservation, restoration and disposition (Dept of the AF, 1987: iii).

The doctrine in AFM 1-10 now contains more complete and detailed definitions of the logistics processes than any previous edition. Many examples and interrelationships are included. It appears that the authors made a concerted effort to show each logistician how he or she fits into combat support. "In essence, the entire support process encompasses the Air Force life cycle of an aerospace system - its people, materials, facilities, and information (Dept of the AF, 1987:Ch 2, 1)."

The processes described in the second chapter of AFM 1-10 are organized in chronological order as though applied to a single facet of a single aerospace system. This appears to have been done to simplify the concepts and enhance the readability of the manual. The doctrine does caution that

> this support process is exhaustive and iterative, but not necessarily sequential. All of the

> processes are highly interdependent and some take place concurrently. Each process varies in duration, intensity and scope according to the unique characteristics of each aerospace system (Dept of the AF, 1987:Ch 2, 1).

The descriptions include many of the tasks encompassed by each of the processes.

Air Force Manual 1-10 (McDaniel) uses a format similiar to Gorby's to explain each of the eight logistics doctrine principles identified by the conferees. Table III shows the relation of the eight principles of AFM 1-10 to prior statements of logistics doctrine. The following paragraphs briefly list and explain all eight of the principles.

1. OBJECTIVE - "Know what you want to do before you do it and keep reminding everyone until it's done (Dept of the AF, 1987:Ch 3, 1)."

2. LEADERSHIP - "You are the single most important factor in achieving military victory...Leaders are people who first choose to do 'the right thing' and then ensure 'things are done right' (Dept of the AF, 1987:Ch 3, 2)."

3. EFFECTIVENESS - "Do only those things that improve combat capability (Dept of the AF, 1987:Ch 3, 2)." The full description of effectiveness in AFM 1-10 includes a brief mention of affordability, efficiency, productivity, supportability, availability, reliability, maintainability, transportability, and survivability. The doctrine calls for unwavering emphasis on the last four "to reduce the combat support structure... necessary to sustain combat operations.

TABLE III
Doctrinal Principles

Gorby, 1980	Badalamente, 1980	McMahon, 1985	AFM 1-10, 1987
Objective	Objective/Priority	Objective	Objective
Readiness	Response	Readiness	
Sustainability	Sustainability Survivability	Reliability Maintainability	
Flexibility	Flexibility	Flexibility	Flexibility
System Integrity	Strat-Tact-Log Joint Central Plans	Comprehensive	Synchronization
Visibility	Information Communication	Visibility Information	Control
Economy	Economy/Scale	Economy	
Availability	Mobility	Availability Timely	
Simplicity	Simplicity Standardization	Maintainability	
	Continuous Flow		
			Leadership
			Effectiveness
			Trauma/Friction
			Balance

4. TRAUMA/FRICTION - "Understand: War is hell! (Dept of the AF, 1987:Ch 3, 3)." This principle was included based on "a doctrinal need to debunk the myth that the Air Force functions in peacetime as it does in wartime (McDaniel, 1986:13)."

5. BALANCE - "Get the right thing in the right amount to the right place at the right time (Dept of the AF, 1987:Ch 3, 3)." This principle is defined only through the use of multiple examples. A contrary definition might stated as: imbalance leads to inefficiency which limits effectiveness.

6. CONTROL - "Never lose contact with your resources (Dept of the AF, 1987:Ch 3, 4)." Control is achieved through adequate information and communication systems and through an appropriate balance between centralized planning and individual authority.

7. FLEXIBILITY - "Create aerospace forces that can operate in any combat environment ... A flexible combat support structure is elastic, modular and simple (Dept of the AF, 1987:Ch 3, 5)." Mobility, survivability and supportability are complementary to flexibility.

8. SYNCHRONIZATION - "Remember: Combat power equals the combination of combat operations and combat support (Dept of the AF, 1987:Ch 3, 6)." Logistics does not exist in a vacuum. Successful combat support requires integrated objectives and planning.

Lt Col McDaniel can be considered to be the individual author of AFM 1-10 due to his roles as the draft author, conference leader, and focal point for coordination. McDaniel approached the development of the doctrinal manual as "breaking new ground (McDaniel, 1986:11)." While he acknowledged the prior work of Lt Col Badalamente. Lt Col McDaniel appears to have made a special effort to start with a clean slate and develop doctrine based on current and future logistical processes and concerns. Even so, there are four principles contained in Air Force Manual 1-10 that directly related to the work of prior authors.

The principles of "objective" and "flexibility" are presented with additional examples and clarity, but without significant modification from previous doctrinal statements. "Synchronization" more clearly defines the idea of system integrity by showing the critical importance of logistics (combat support) to combat success. "Combat power can achieve its full potential when combat operations and combat support come together in unison (Dept of the AF, 1987:Ch 3, 6)." McDaniel's concept of "control" can be interpreted as showing the previously unstated relationships of the elements of visibility, information and communication in the logistics system.

A primary difference between AFM 1-10 and the prior doctrinal attempts is the increased emphasis on the integral role that people play in the total logistics system. Where

prior works emphasize the advancing technological aspects of logistics, McDaniel encouraged the inclusion of "leadership" and "trauma/friction" as way to incorporate the human element of logistics.

> This was especially important ... because the Air Force has had an inordinately mechanistic, materiel bias in the preparation and conduct of warfare despite a declaratory policy that people always come first ... (McDaniel, 1986: 10).

McDaniel's work was thus based on the principle of logistics contained in Air Force Manual 1-1, Basic Aerospace Doctrine of the United States Air Force, in that logistics involves "... preparing man and machine for combat ... (McDaniel, 1986:10)."

The other principal difference between the current AFM 1-10 and prior logistics doctrine of the USAF is a new emphasis on the role of the decision maker. The logistics decision maker is specifically identified in the principles of balance and effectiveness. In addition, his/her importance is implied in all of the examples of trade-off analysis.

"... Air Force leaders must always extract the greatest return possible for every military dollar spent (Dept of the AF, 1987:Ch 3, 2)." Effectiveness can be achieved through "improving the reliability, maintainability, transportability, and survivability of new and existing aerospace systems ... (Dept of the AF, 1987:Ch 3, 2)." Trade-offs will have to be made; the decision must be based

on increasing effectiveness. "Efficiency is important to the extent it contributes to combat effectiveness ... (Dept of the AF, 1987:Ch 3, 2)." Effectiveness seems to be the ultimate goal of the logistics system.

Balance is suggested as a means of achieving effectiveness. "One of the great challenges of combat support is effective resource allocation (Dept of the AF, 1987:Ch 3, 3)." "... Logistic resources are always limited (McMahon, 1985:10)." This statement clearly indicates that there will be contention for resources. AFM 1-10 explains concept of balancing the satisfaction of contentious needs by listing several examples of one-dimensional trade-offs where either extreme is obviously an inappropriate position. Table IV shows some of the trade-offs which are identified in AFM 1-10.

TABLE IV
Balance in Logistics
per AFM 1-10

Policy Area	Thesis	Antithesis
Resource Utilization	Use	Conservation
Supply Strategy	Centralized	Decentralized
System Acquisition	New Systems	Systems Support
Force Ratios	Quality	Quantity
Personnel Assigment	Specialist	Generalist

It is with respect to balance that the logistician is tasked to make quality decisions in evaluating the wide range of alternative courses of action which are available. "The Air Force can best prepare aerospace forces for combat by giving emphasis to all the support process (Dept of the AF, 1987:Ch 3, 4)." This seems to imply that effective balance requires consideration of all facets of logistics. The scarcity of logistics resources will require that not all areas can be simultaneously optimized. There would appear to be many scenarios in which a logistician could not emphasize all support processes but must select a subset of processes on which to focus attention. Some flexibility is essential to modern combat logistics. (See discussion of the principle of flexibility)

Current doctrine offers the decision maker tremendous amounts of flexibility. So much, in fact, that doctrine serves to provide a logistics philosophy rather than specific guidance to the decision maker. Current doctrine provides the decision maker with a comprehensive list of the goals to be considered in evaluating the adequacy of alternatives. Current doctrine, therefore, appears to satisfy three of the four objectives of doctrine. It provides: a baseline for future, advanced logistics study; a tool for the education of those involved in the logistics mission; and a framework for long range planning (to some extent). Doctrine does not, however, provide a substantial

tool for the logistics decision maker. Instead, it suggests that the logistics decision maker requires an additional tool or framework in which to evaluate alternative solutions to combat support problems. Doctrine can be used effectively to identify the trade-offs which are the basis for all decisions regarding allocation of scarce resources.

III. Decision Making Framework Alternatives

A decision making system generally involves applying a prescriptive model to data that have been determined to be relevant to the decision process. Chapter II discussed the important principles which can be used to analyze the impact of logistics decisions based on current doctrinal statements. This chapter looks at the models or frameworks that can be applied to these principles. The purpose of this chapter is to consider techniques which a logistics decision maker can use to determine proper courses of action in trading-off the sometimes contrary principles comprising logistics doctrine. This chapter examines the models currently in use, evaluates several alternatives, and advocates their use for specific applications of logistics doctrine in the decision making process.

Quantitative Techniques Currently In Use

Logisticians are involved in two types of decisions which require consideration of logistics factors. The system acquisitions decisions and the operation and support decisions. Logistics decision makers currently use a variety of models in these situations. Acquisition decisions often focus on the Life Cycle Cost of the alternatives. Operations and support decisions are based on

the relative productivity of the alternatives with increasing frequency. Both of these techniques are quantitative and based on expected or observed phenomena. Discussion of these techniques is based on actual examples, currently in use.

Life Cycle Cost. Life Cycle Cost is a means of comparing alternatives available to the decision maker. Circular number A-109 from the Office of Management and Budget defines Life Cycle Cost as:

> ...the sum total of the direct, indirect, recurring, nonrecurring, and other costs incurred, or estimated to be incurred in the design, development, production, operation, maintenance and support of a major system over its anticipated useful life span (Office of Management and Budget, 1976:3).

A complete analysis of Life Cycle Cost may reflect several of the principles of logistics doctrine. A Rand Corporation study identified a number of life cycle cost determinants (Gill, 1985: 85). While the list below is for aircraft systems, it shows many logistics factors to be considered in life cycle cost analysis.

AIRCRAFT CHARACTERISTICS
- Reliability and Maintainability
- Physical Characteristics

SUPPORT CONCEPTS
- Maintenance Concept
- Supply Support Concept
- Training Concept
- Aerospace Ground Equipment Concept

OPERATIONS CONCEPTS
- Crew Size and Composition
- Force Size and Activity Rate
- Basing and Deployment Concept
- Mission Type and Profile

Although sometimes quite tenuous, some doctrinal principles of logistics can be reduced to statement in terms of cost to the Government. Increased reliability and maintainability may result in lower Life Cycle Cost through a decrease in support costs (even given higher investment costs). Increased availability may result in increased Life Cycle Cost due to the need for additional quantities (if the operating concept requires redundancy or duplication) and hence, higher total acquisition cost. Life Cycle Cost focuses the decision maker's attention on the monetary costs of the resources required. It does not directly address the benefits of the alternative under consideration. Because of the difficulty in comparing functional benefits (in measures of capability) to monetary costs (in dollars), Life Cycle Cost is most appropriately used when comparing two alternatives that satisfy the same mission need. That is to say, a decision between alternatives with identical benefits can be made on the basis of lowest Life Cycle Cost.

While Life Cycle Cost can address some of the principles of logistics doctrine, it ignores others. The principles of objective, leadership, trauma/friction, balance, control, flexibility and synchronization are not readily convertible to monetary costs factors.

A significant short-coming of the Life Cycle Cost technique can be seen however when attempting to decide between supporting missions in different ways. For example, how can life cycle cost be applied to a decision of whether it is better to acquire additional spare parts or additional fabrication facilities? This type of analysis is not easily accomplished in terms of Life Cycle Cost. To evaluate these alternatives based on life cycle cost would require the decision maker to "enlarge" the system under question until the same system is evaluated with the different alternatives as components of the system. In this example, the system expands to include virtually all of the Air Force, including consideration of its tactical and strategic missions. Life Cycle Cost is an appropriate tool for some selected Air Force logistician's decisions; it will certainly not satisfy all the decision situations.

Productivity Measurement Matrix (Turpin, 1987). In an effort to evaluate disparate alternatives, one approach is to consider the relative merits based on productivity. "In its simplest form, productivity is output divided by input (Turpin, 1987)." Air Force Logistics Command, Directorate of Maintenance is experimenting with the use of a tool called the Productivity Measurement Matrix. Although this tool is currently only in use at the AFLC Air Logistics Centers, it could be applied at higher or lower organizational units.

The Productivity Measurement Matrix is based on the work of Glenn Felix and James Riggs at the Oregon Productivity Center. The model establishes a method of "rolling up" indicators from observable phenomena to produce statistics that can be used as management indicators. At each level of analysis, the Productivity Measurement Matrix supports the calculation of a productivity factor. This factor is based on a 100 point scale. A perfect 100 would represent a system that is fully meeting or satisfing all stated goals. An illustrative example of the Productivity Measurement Matrix is provided in the Appendix.

When this system is implemented, the decision maker identifies the variables he/she wishes to consider. Those variables are then weighted using a formula that totals 100 percent. The identified variables are placed on the horizontal axis of the matrix. The degree of productivity is shown in "levels" on the vertical axis of the matrix. Each cell of the matrix will be used to record performance data used in the analysis. Level 3 is used to identify the current capability of the logistics system component, level 10 is used to identify the ultimate goal of the component. Each variable of the matrix is then completed with a standard for each level. The score for each variable is the level corresponding to the standard of performance that has been achieved. The scores are multiplied by the appropriate weight then summed for the overall assessment. The "roll-

up" feature of the matrix model is shown in figure 2. Figure 2 shows an outline form describing the levels of analysis used at OO-ALC and their relative weights in the

- Maintenance (100)
  - Production/Timeliness (33)
    - Aircraft (9)
      - A-7 requirements
      - A-7 AMREP
      - A-7 flow days
      - B-52 requirements
      - B-52 AMREP
      - B-52 flow days
      - KC-135 requirements
      - KC-135 AMREP
      - KC-135 flow days
      - E-3 requirements
      - E-3 AMREP
      - E-3 flow days
    - MISTR (8)
    - Missles (16)
  - Quality (33)
    - Aircraft (9)
    - MISTR (8)
    - Missles (16)
  - Resources (34)
    - People (12)
      - Manpower utilization (3)
      - Cost of mishaps (2)
      - Number of mishaps (2)
      - OPMD (3)
      - EDP cost (2)
    - Financial (16)
      - Direct labor (2)
      - G&A cost (2)
      - Material cost (2)
      - All other costs (3)
      - Revenue variance (3)
      - Net operating results (4)
    - Equipment/Facilities (6)
      - ACP obligation (3)
      - Preventive maintenance (2)
      - Energy (1)

Fig. 2. BREAKOUT OF FACTORS
numbers in parentheses are percent emphasis

overall evaluation. Different performance indicators are used in many of the variables. This feature allows the decision maker to determine the relevent factors in his/her analysis. The scalar product of the matrix, however, can be used to relate the performance of the missle mission to that of the aircraft mission in the OO-ALC example. Strengths and weaknesses in the maintenance operation can be easily identified. This is a primary strength of the Productivity Measurement Matrix method.

The most notable weakness of the methodology is the heavy reliance on the determination of standards of performance and on the estimation of the relative importance of the variables. This subjectivity can be somewhat minimized in that the tasks of deciding weights and standards are assigned to the managers who will be responsible for attempting to meet the standards. In the same way that the system is made accurate by depending on the managers, it can also be "gamed." That is, important variables can be left out or minimized in the assignment of relative weights.

A secondary weakness is that this method relies strictly on observable data. This means that the Productivity Measurement Matrix can be used to control and improve operations, but is not well suited to application in the prospective (future) decision area.

Qualitative Alternatives

In some cases, reliance on models that measure efficiency can overshadow effectiveness. The question about acquiring tanker aircraft or transport aircraft cannot be answered on purely objective data. In recognition of this fact, certain qualitative techniques have been developed to treat some of the more subjective factors in decision making. Preference analysis and utility analysis are two of the more common.

Preference Analysis. The direct analysis of preference seems, on the surface, to be a simple construct. For example, the preference for one alternative over another may be based on a decision maker's perceived value of each of the alternatives. Preference analysis can be extended to trade-off analysis by developing an indifference curve. The points on the curve are based on the decision maker's concept of satisfaction. A classic example of the indifference curve is the trade-off between unemployment and inflation. The analysis is conducted by determining acceptable levels of unemployment at different levels of inflation. The decision maker is considered to be equally satisfied at all the points on the indifference curve. This technique is especially useful when comparing only two variables. The task of multiple successive comparisons can often be very complicated. The greatest strength of this

method is its ease of application in direct comparison situations. Comparing two alternatives doesn't require any form of quantification. This advantage is also a significant weakness of preference analysis. In order to compare multiple alternatives or two alternatives with multiple characteristics of interest, quantification is required. The reason that quantification is necessary is to prevent "intransitivity." An example of intransitivity is where a decision maker prefers A to B, B to C, and C to A. (Taylor, 1984:69) "The basic reason for the observed violations of the transitivity of preferences is the large number of attributes in the objects to be compared." (Bell et al, 1977:200) The circular nature of the argument just described prevents preference analysis from being an adequate decision making tool. By developing quantitative values for A, B, and C, the decision maker can then establish a maximization or minimization decision criteria and the outcome will be clear.

Trade-off analysis by preference analysis often utilizes standards. Life Cycle Cost is one example of a tool that can be used to convert two alternatives into standard units of measure; e.g. dollars. The decision maker can then choose the alternative that best meets some economic alternative. When quantifiable standards can be identified decisions among multiple alternatives are simplified.

Utility Theory. For some types of decisions, the trade-off cannot be made directly. In these cases, the decision maker must assess the relative utility of each of the alternatives using qualitative criteria. Utility is "the psychlogical value associated with an alternative - the percieved usefulness of its outcome (Taylor, 1984:62)." In utility analyses, the decision maker is asked to determine the relative utility of a number of alternatives.

Even in instances of uncertainty, utility theory can still be useful. Alternative outcomes are assigned probabilities of occurence, which are multiplied by the anticipated value of the outcome and summed for analysis of the decision alternative. This technique is based on the decision criteria called "Bayes' Decision Rule" wherein the alternative with the highest expected value is selected (Lapin, 1973:610). Application of this rule offers the decision maker the chance to introduce probability to uncertain situations.

The previous examples have all used only a single type of outcome. Many complex decisions involve multiple criteria and are more representative of the decision faced by the logistician. In more complex situations, the decision maker is asked not only to assign relative values to each of the attributes, but also to weight the criteria. This weighting technique allows the decision maker to apply utility theory to more complex situations.

Utility theory does have a significant limitation when applied to complex situations in which many layers of subjective judgements are required. Because of the nature of the multiple judgements, some loss of precision is possible. Initially the anticipated value must be determined. Then the liklihood of occurrence must be estimated. Finally the relative weights of the criteria must be established. Bayes' decision rule then calls for multiplying these three subjective measures to result in an expected value. The result is a significant loss of precision. Simply put, increasing complexity can result in decreasing certainty or confidence in the outcome.

Qualitative techniques offer the advantage of structuring important, but not always observable, factors in the decision making process. In situations where these factors must be considered, the decision maker must acknowledge the subjective nature of his/her assessments. There can sometimes be considerable difficulty in achieving consensus in deriving the scale for measurement.

In addition, the qualitative techniques described above require an explicit expression of a "production function." The production function is the mathematical expression which describes the method of compiling the multiple criteria to maximize some benefit. "Unfortunately, frontier production functions are very difficult to derive for complex processes (Clark, 1986:17)." In the arena of logistics doctrine, the

implication of the production function is a specific statement that, for instance, quality is more important than quantity. Some decision makers may not be comfortable with having to make or support this type of statement.

Efficiency Analysis

One of the most useful methods of evaluating non-commensurate alternatives is to evaluate the efficiency of each of the alternatives. "A technical definition of efficiency is easy: the ratio between inputs and outputs (Brewer and deLeon, 1983:335)." Efficiency is, therefore, a measure of productivity. The specific details of the production process itself are irrelevant and can be viewed as a "black box." Efficiency is often expressed as the ratio of output divided by input:

$$\text{Efficiency} = \text{Output} / \text{Input}$$

Treating input and output in this fashion, the production function need not be explicitly specified. Efficiency analysis is conducted by a variety of means, ranging from ratio analysis to data envelopment analysis.

Ratio Analysis. The simplest form of efficiency analysis is ratio analysis. In this technique, outputs are directly related to inputs. For example, three units per dollar spent. The relative efficiency of two or more

alternatives can be evaluated in this way. This technique is inherently attractive in an environment where defense decision makers are charged with getting "more bang for the buck."

The drawback to ratio analysis is its inability to deal with multiple inputs and outputs simultaneously. Deciding between two alternatives that require differing amounts of different inputs to achieve different outputs is computationally difficult using ratio analysis. The relative importance of the ratios must be established relative to the overall system, and this leads back to the problem of articulating a production function. "... As the number of inputs and outputs increases, the problems of weighting and assimilation grow multiplicatively (Clark, 1986:15)."

Efficiency Frontier Analysis. Complex situations with a large number of simultaneous, interrelated inputs and outputs require an efficiency evaluation technique that aggregates all variables in the equation.

> Farrell (1957) provides a satisfactory measure of productive efficiency which takes into account multiple inputs and multiple outputs in a way that would be of use to a wide range of economic statisticians, theorists, policy makers, business persons, and civil servants (Clark, 1986:16).

Farrell's efficiency model is based on the most efficient combinations of inputs to achieve a specified level of output.

While Farrell's efficiency measure can be used in multidimensional space, it is most easily understood by examining the simplest possible form of the multiple variable problem. Figure 3 shows a simple efficiency frontier relating the required input levels of two inputs, X1 and X2 (for example, time and money), to a given level of output, Y. The curve shows the optimal amounts of input

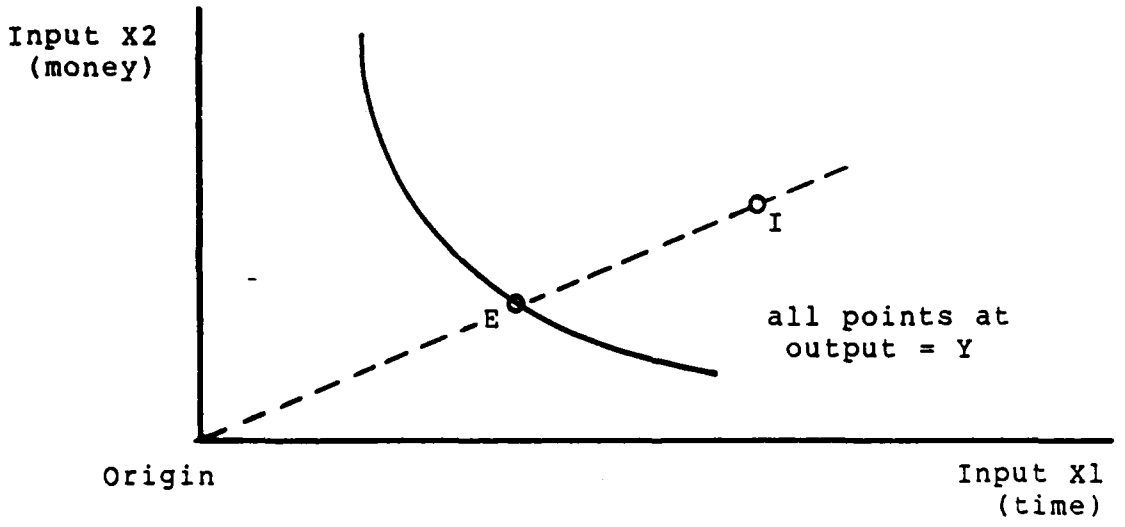


Fig. 3. Farrell's Efficiency Isoquant

required to achieve the desired output. Point E represents an efficient use of the inputs, which can be seen by its position on the curve. Point I is an inefficient use of the inputs, in that it requires more of X1 and X2 to achieve the same level of output as those points on the curve. Point E

represents the most efficient combination of inputs likely to result in the output achieved at point I. The relative efficiency of point I can be assessed by dividing the length of the ray from the origin to point I by the length of the ray from the origin to point E:

$$\text{Efficiency (I)} = \overline{OE} \; / \; \overline{OI}$$

In this way, efficiency ratings can be developed for any number of possible points representing decision alternatives. The ratings will range between zero and one. The rating will be equal to one for those points on the curve and something less for all the points behind the frontier.

Efficiency analysis can be used to develop trade-off concepts at the point of Pareto optimality; that is, the frontier made up of the most efficient data points. Decreases in the amount of one input will necessitate increases in the other.

Data Envelopment Analysis. One specific model of efficiency analysis is Data Envelopment Analysis (DEA). "DEA is a new, empirically based approach that can eliminate or ameliorate some of the assumptions required in traditional benefit/cost analyses to problems of public choice (Bowlin et al, 1986:1)." DEA is based on a linear programming model where the objective function is merely to

maximize the ratio of all outputs divided by all inputs. A constraint reflects each of the alternatives; indicating that it is either optimal or sub-optimal (≤ 1). Solution of the linear program involves an optimization using each of the alternatives as the alternative of interest.

A unique feature of DEA is that alternatives are evaluated in context of the observed (or projected) data and not based on a presupposed efficiency of 100%. In Farrell's words, "it is far better to compare performances with the best actually achieved than with some unattainable ideal (Clark, 1986:17)." The result of this is that the efficient frontier is not a smooth curve, but instead a piecewise linear construction. Figure 4 shows a piecewise construction of the example previously shown in figure 3.

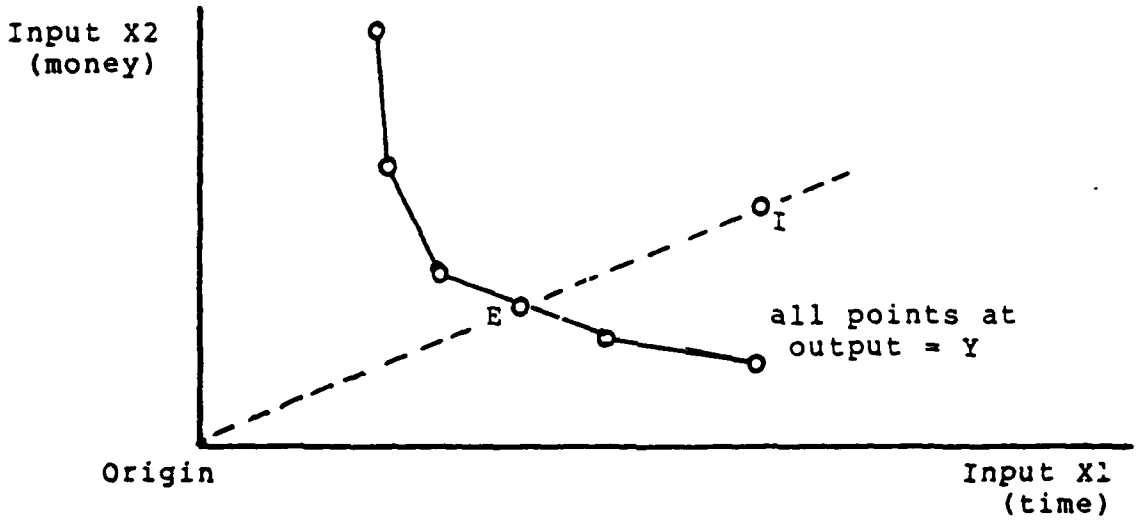


Fig. 4. Piecewise Linear Construction

The efficiency frontier in figure 4 is based on actual observed data points. Note now that point E is not on the theoretically efficient frontier but is instead, an interpolated point between two observed points. Point E is used to represent an attainable level of efficiency for the observation labeled point I.

The efficiency of point I is calculated in the same way that it was originally. This calculated efficiency, based on observed data and the vector to point I is a figure which represents point I in its best light. That is, it is based on optimal performance of the input and output variables in the proportion used by point I.

While this is an advantage of the technique it also constrains the technique in that it requires at least two observations representing decision alternatives for each measure of input or output. A smaller number of observations will result in the determination that all are fully efficient. Statistically, the required degrees of freedom for significance is equal to twice the number of inputs and outputs considered in the calculation. For the example in figures 3 and 4, where there are two inputs and one output, six data points (observations) are required.

Recent advances in the availability of computational resources have allowed researchers to explore the solution of problems with multiple objectives.

The work of Farrell, Charnes, Cooper, Rhodes and others provided major theoretical breakthroughs

> and extensions in frontier estimation and enabled the measurement of relative efficiency without designating (assuming) the form of the industry production function and without requiring that weights be assigned *a priori* to inputs and outputs (Clark, 1986:19-20).

A wide variety of decision making models are available for the logistics decision maker. Each has its own advantages and disadvantages in terms of applicability and precision. The next chapter outlines a framework in which the logistics decision maker can consider the appropriate choice of model, based on the doctrinal principles of interest.

IV. Synthesis

Chapter II of this thesis examined Air Force Logistics Doctrine from the decision maker's perspective. It showed that effective decision making requires an understanding of both the logistics process and the principles which support good logistics. Chapter III considered a number of decision making tools which have been or could be applied to logistics decisions. It identified the advantages and shortcomings of many different quantitative and qualitative techniques. The purpose of this chapter is to integrate the analyses of the previous two chapters to offer a decision making framework to the decision maker.

This chapter presents a discussion of a logistics decision support system (DSS) from a conceptual standpoint. The second section of this chapter discusses the practical problem of measurement; and the final section looks at the role of the DSS in aiding the real world decision maker.

This chapter provides the conceptual framework for a logistics decision support system. Decision support systems are "characterized as ...systems that help decision makers utilize data and models to solve unstructured problems (Sprague and Carlson, 1982:4)." Figure 5 outlines a

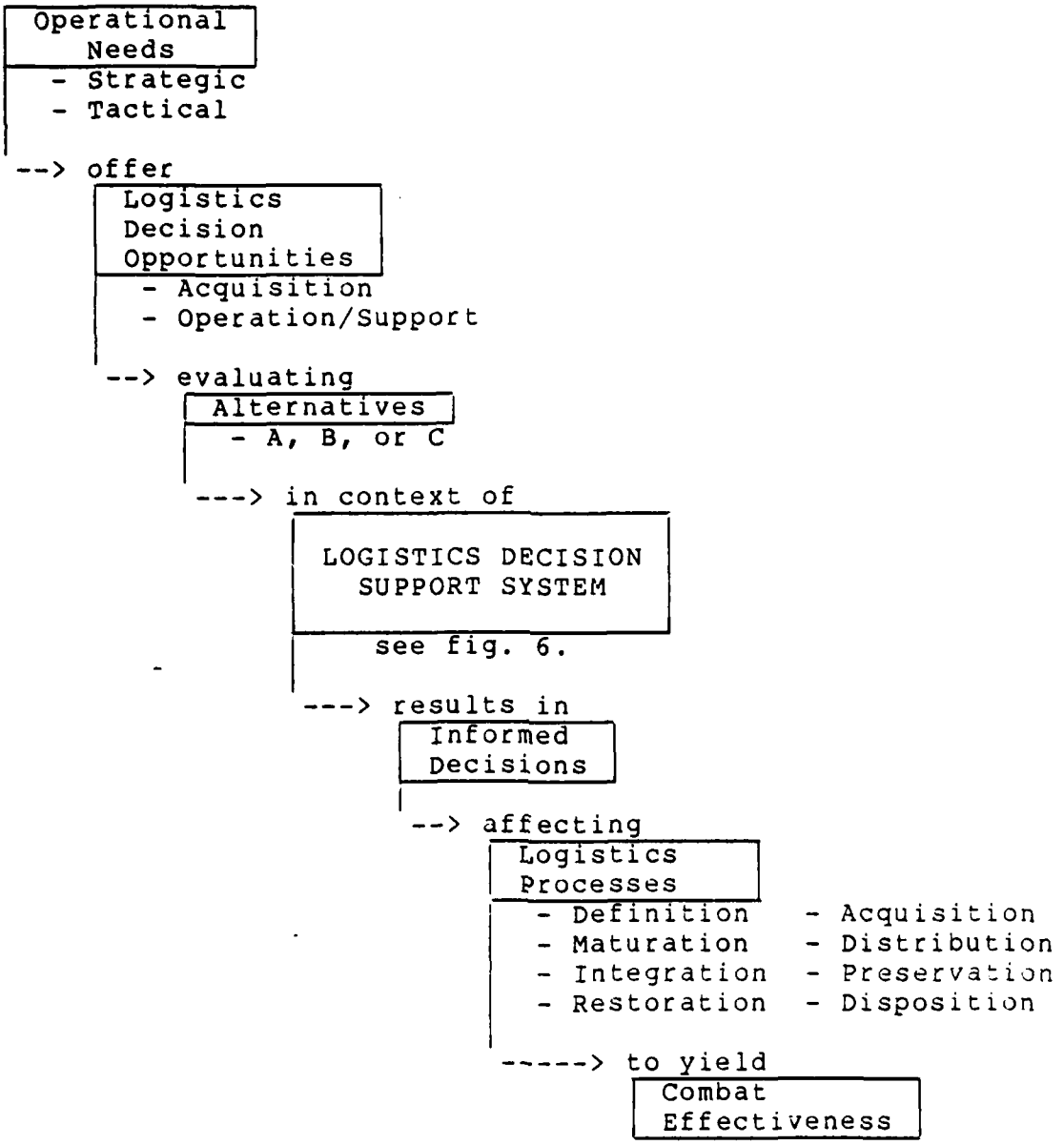


Fig. 5. Consideration of USAF Logistics Doctrine Principles in a Decision Making Framework

conceptual level DSS combining logistics doctrine with an analytical model.

The remainder of this section is an element by element explanation of the decision support system framework shown in figure 5.

Operational Needs

Current Air Force Combat Support Doctrine focuses on the interrelationship between operational and logistical needs. Operational needs drive the logistics process. For example, operational scenarios may require that additional flying hours be imposed on a certain class of aircraft. This operational need will offer the logistician a decision alternative.

Logistics Decision Opportunities

Once an operational need has been stated, the logistician must determine a course of action to satisfy the requirement. This would usually necessitate the choice between alternatives. In the example inititated above, more flying hours might be generated by modifications making the aircraft more reliable or making it more maintainable.

Alternatives

After alternatives have been identified, they may be quantified for comparison. Air Force Manual 1-10 defines

the capabilities of logistics system and the resources consumed to recieve the benefit of the logistics system (Dept of the AF, 1987:Ch 3, 2):

TABLE V
Logistics System Capabilities and Resources

Capability	Resources
Reliability	Manpower
Maintainability	Material
Transportability	Facilities
Survivability	

Once the alternatives have been identified, it is necessary to determine appropriate measures of the capabilities and resources involved. The logistician should obtain data detailing each of the alternatives, either from observation or by projection (estimation).

For example, one modification might make the aircraft more reliable while the other would improve maintainability. Both alternatives would require some amount of manpower, material, and facilities. Because the resulting capabilities are not directly comparable, the decision between them is necessarily complex.

Logistics Decision Support System

When the alternatives under consideration are measured in the dimensions of doctrinal principles, the resulting logistics decision support system could use specific models to evaluate the relative degree of logistics (conformance to the principles of logistics) provided by each of the alternatives. Figure 6 shows the model DSS of this chapter.

LOGISTICS DECISION SUPPORT SYSTEM	
Doctrinal Principles	Models
Objective	Life Cycle Cost
Flexibility	Productivity Matrix
Synchronization	Preference Analysis
Control	Utility Theory
Leadership	Ratio Analysis
Effectiveness	Frontier Analysis
Trauma/Friction	Data Envelopment
Balance	Analysis
using subordinate measures	

Fig. 6. Logistics Decision Support System

This proposed DSS would generate information regarding the relative performance of the alternatives under consideration.

The choice of which doctrinal principles apply and which model is most appropriate are left to the decision maker. This is an essential element of an effective DSS in that every decision made is slightly different. The decision maker needs flexibility in approaching the decision situation.

Informed Decisions

The DSS will not provide the logistics decision maker with a decision, but with information about the alternatives based on the data submitted and the criteria identified by the decision maker. That information may include both relative comparisions and trade-off information. The availability of these types of information will allow the decision maker to make a more informed, rational and supportable decision.

Logistics Processes

The decision made by the logistician will require that some or all of the processes of logistics be called into action. The logistics "process is exhaustive and iterative, but not necessarily sequential. All of the [sub]processes are highly interdependent and some take place concurrently (Dept of the AF, 1987:Ch 2, 1)."

Combat Effectiveness

"Combat effectiveness is the standard for judging all combat support actions... (Dept of the AF, 1987:Ch 3, 3)." The goal of the logistics system is to produce "logistics" and the level of productivity can be measured by efficiency. Combat Support Doctrine requires that "...Air Force leaders must always extract the greatest return possible for every

military dollar spent (Dept of the AF, 1987:Ch 3, 2)." Air Force Manual 1-10 thereby defines the grand measure of efficiency as the ratio of capability divided by resources consumed.

The result of implementing the logistician's informed decision should be an increase in combat operations abilities. The original operational need should be satisfied. An effective decision support system will facilitate the whole process of moving from an operational need to increased combat effectiveness.

The concept of a decision support system is appropriate in the logistics environment. In chapter III it was shown that the relationships among the elements of logistics are relatively clear, although not always able to be stated mathematically. This relatively unstructured trade-off problem is well suited to a decision support system. "A DSS should provide support for decision making, but with emphasis on semistructured and unstructured decisions (Sprague and Carlson, 1982:26)."

In order to make decisions, the decision situation and the likely effects of the accepting each of the alternatives should be known. This data is important to the decision process, but is not always available. In some instances, explicit measures would not be readily available. In those cases, the logistics decision maker may be required to use

subordinate (or even surrogate) measures. Quantified variables are necessary for valid comparison of alternatives. The traditional method for studying the effectiveness of an organization is the degree to which it achieves its goals (Schoderbeck, et al, 1980:234). As shown in the literature review, the goals of a logistics system are diverse and non-commensurate. No single factor adequately describes "combat support." Operational goals, because they focus on activity within the organization, are a valuable source of measurable variables. In this sense, effectiveness can be measured through the use of subordinate indicators of goal achievement, ultimately tied to combat support.

A number of operational factors have persisted in the literature on logistics doctrine. Some of these may readily be used in the decision support system. Table VI details a number of these measures.

As shown in the table, several aspects of logistics can be identified and measured in real terms. Many of the principles of logistics, however, do not lend themselves well to quantification. Neither "combat support" nor any of its eight doctrinal principles can be measured simply by observation. The data currently available are only subordinate data which represent the performance of the logistics decision alternative under consideration. In order for a decision support system to model the likely

result of a given decision, the concept of "combat support" should be described as fully as possible. "Evaluation can only be undertaken in concrete settings (Brewer and deLeon, 1983:331)."

TABLE VI
Operational Logistics Factors

Factor	Measure	Sources
Reliability	Mean Time Between Failure	M,A
Maintainability	Mean Time To Repair	M,A
Availability	System Uptime & Quantity	G,M A
Readiness	Time To Deploy	G,B,M
Economy	Life Cycle Cost	G,B,M,A

Key to Sources: B = Badalamente, 1980
G = Gorby,
M = McMahon,
A = Air Force Manual 1-10, 1987

V. Conclusion/Recommendations

This thesis has examined the difficulties encountered in decision making based on the principles of logistics doctrine. The intent has been to offer a decision maker's perspective in the review of doctrine and to attempt to construct a framework in which logistics decisions can be rationally made.

The analysis began with a review of the current U.S. Air Force Combat Support (logistics) Doctrine. That analysis was performed in the context of an historical perspective. Changes in logistics doctrine were reviewed with particular emphasis on the period from 1980 to present (1987). The work of several authors was reviewed for the purpose of identifying consensus in doctrinal thought. This review showed that, although the terminology has evolved, there is considerable consensus regarding the operational dimensions of logistics. The concepts of availability, reliability, maintainability, economy, and flexibility (among others), are frequently cited.

After identifying the objectives of a logistics system as defined through official doctrine, the next task was to examine decision making tools which were, (or might be) applied to the logistics environment. This examination showed a significant gap in the types of decision making

tools frequently used. They tend to be either extremely data intensive or based to a great extent, on very subjective analyses. The former tend to be useful in management control situations while the latter tend toward high degrees of uncertainty and bias. A decision support system, providing access to a number of models was identified as having the potential to provide logistics decision makers with a means of comparing alternatives which are typically thought to be incomparable, without necessarily introducing high degrees of subjectivity. Thus, decision makers can be aided in their analysis of trade-offs between used of scarce resources.

Data Envelopment Analysis is currently being used in the Air Force in several instances where the data required already exists in highly objective quantified forms. A number of base level maintenance operations have been evaluated in this type of study. This thesis has shown that DSS may be an appropriate tool even in situations where the data of interest are of a less objective nature. DSS can help to identify and quantify the trade-offs which are inevitable when principles of logistics doctrine conflict.

Milton Friedman has stated that "...the only relevant test of the validity of a hypothesis is comparison of its predictions with experience (Charnes, et al, 1981:690)." This thesis has not validated the concept through actual application toward achieving verifiable results. It has,

instead, offered conceptual support for the hypothesis to the degree that is necessary to indicate that future research may be valuable in this area. "...Efficiency analysis does have value for the Air Force, where it can serve as a guide to auditors, budget programmers, managers and others in measuring, evaluating and enhancing efficiency (Bowlin, 1987:127)." This author believes that the uses of efficiency analysis can be extended into a supporting position for management decisions all the way up to and including policy decisions.

Recommendations

1. It is recommended that changes in logistics doctrine continue to be viewed in a historical perspective. This will offer the logistics decision maker the opportunity to know how their field has evolved and to better understand the then current emphasis of logistics in combat support.
2. It is recommended that the principles of doctrine be clarified to eliminate potential overlaps on the concepts.
3. It is recommended that research be undertaken to identify appropriate operational measures for each principle of USAF Logistics Doctrine. This will aid logisticians in evaluating their own performance in the logistics system.
4. It is recommended that efforts be made to distill "real world" experiences into concepts to be included in doctrinal statements and/or decision support systems.

5. It is recommended that the concepts of "expert systems" and artificial intelligence be explored, and their relevance to logistics decision support systems be articulated.

6. It is recommended that, after identifying operational measures of logistics conformance to doctrine, research be undertaken to determine the validity of using those measures as variables in various decision models.

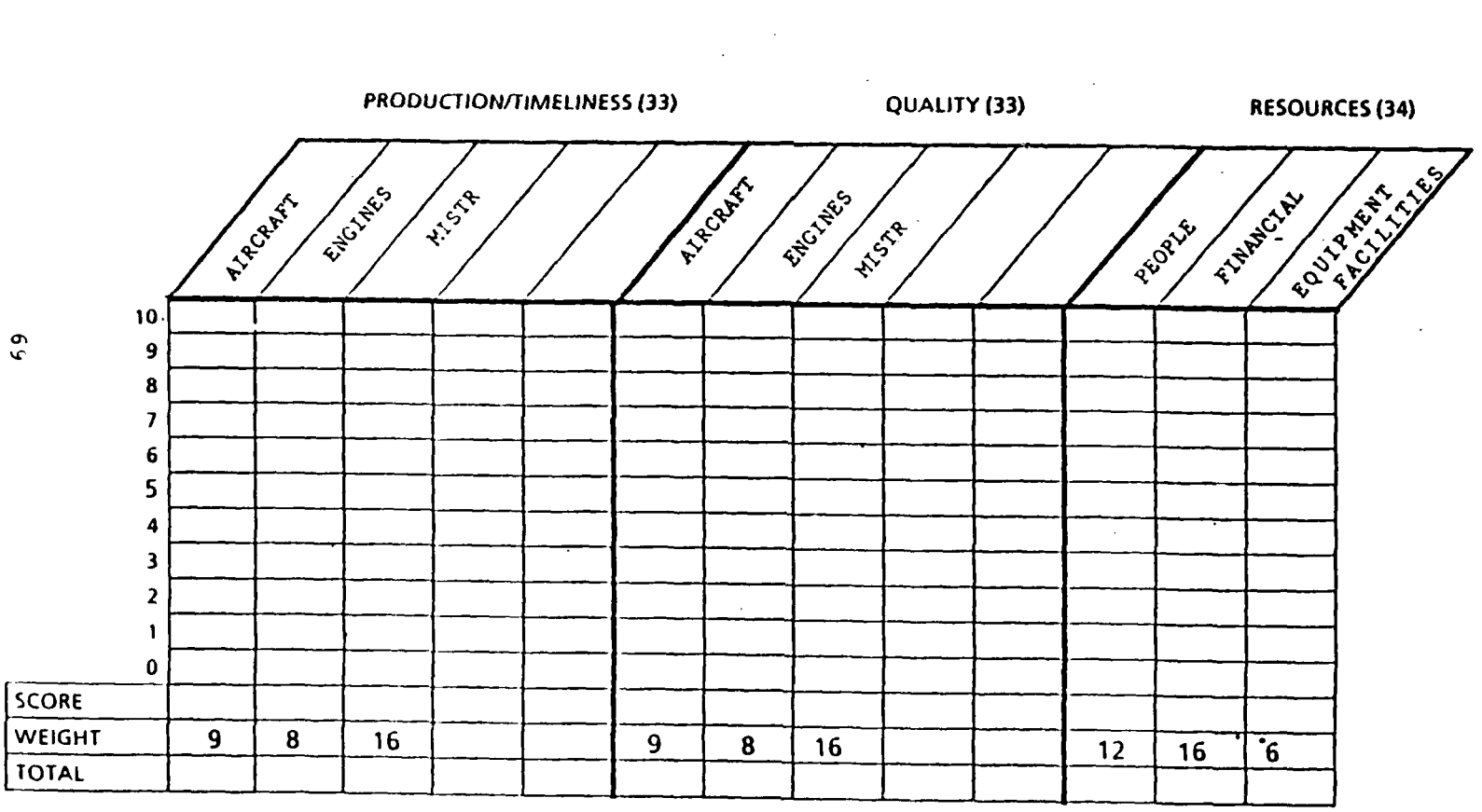
7. It is recommended that the DEA framework discussed in this thesis be evaluated through the process of developing a specific model addressing a specific logistics problem. This should include a identification and validation of the measures of input and output related to the area under investigation.

APPENDIX

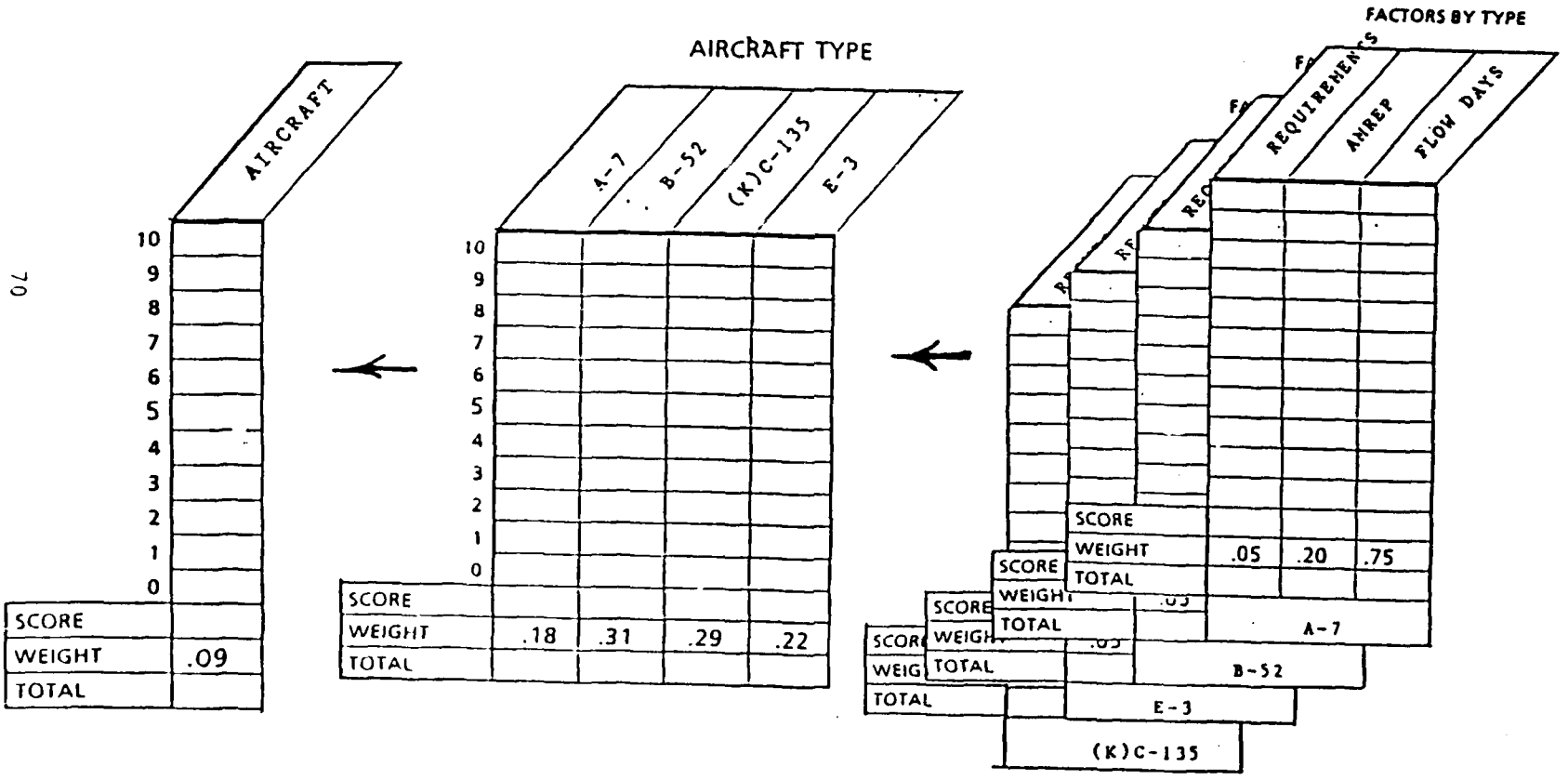
AFLC/MA Productivity Measurement Matrix

3 pages

AFLC/MA
PRODUCTIVITY MEASUREMENT MATRIX



AFLC/MA
PRODUCTIVITY MEASUREMENT MATRIX



AFLC/MA
PRODUCTIVITY MEASUREMENT MATRIX

	A-7			B-52			(K)C-135			E-3		
	A-7 REQMTS	A-7 AMREP	A-7 FLOW DAYS	B-52 REQMTS	B-52 AMREP	B-52 FLOW DAYS	(K)C-135 REQMTS	(K)C-135 AMREP	(K)C-135 FLOW DAYS	E-3 REQMTS	E-3 AMREP	E-3 FLOW DAYS
10												
9												
8												
7												
6												
5												
4												
3												
2												
1												
0												
SCORE												
WEIGHT	.009	.036	.135	.0155	.062	.2325	.0145	.058	.2175	.011	.044	.165
TOTAL												

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Vita

David W. Wallingford was born on 11 May 1958 in Chateauroux, France. He graduated from high school in Dayton, Ohio, in 1976 and attended Wright State University, from which he received the degree of Bachelor of Arts in Communication in March 1981. After working through school as a Procurement Clerk at the 2750th Air Base Wing, he was employed as a Contract Specialist with the same organization. In August 1984, he transferred to Contracting directorate of the Air Force Logistics Command's Logistics Management Systems Center. That organization was absorbed into the Wright-Patterson Contracting Center where he worked until entering the School of Systems and Logistics, Air Force Institute of Technology in June 1986.

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Block 19. Abstract

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Abstract

The purpose of this study was to assess the feasibility of using a decision making tool to consider alternatives in terms of publicly stated doctrine.

The first section examines the potential difficulties in using U.S. Air Force Logistics Doctrine to assist in making decisions. This is accomplished through a review of current doctrine based on its evolution.

The second section examines several decision tools which are (or could be) in use. Advantages and disadvantages of both quantitative and qualitative frameworks are discussed.

The final element of this thesis is the synthesis of a conceptual framework of a logistics decision support system, using specific models to consider the relative merit of alternatives based on the principles of U.S. Air Force Logistics Doctrine.

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