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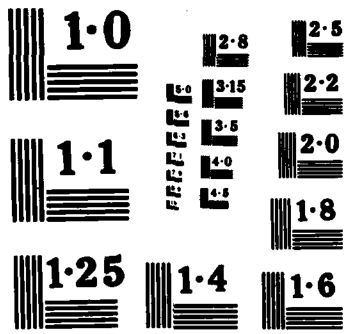

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

MANAGEMENT CONTROL OF AIRCRAFT
MAINTENANCE IN THE INDONESIAN
AIR FORCE'S LOGISTICS SYSTEM

by

Mukhtar E. Lubis

March 1985

Thesis Advisor: Dan C. Boger

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A155 579	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Management Control of Aircraft Maintenance in the Indonesian Air Force's Logistics System		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; March 1985
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Mukhtar E. Lubis		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		12. REPORT DATE March 1985
		13. NUMBER OF PAGES 64
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Aircraft maintenance; Management control; Standardize maintenance procedures; Automatic inventory control.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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This thesis studies the aircraft maintenance logistics system. The first part of the thesis analyzes the factors which cause the problems. The second part consists of proposals to standardize

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S N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Abstract (cont'd)

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Management Control of Aircraft Maintenance in the Indonesian Air Force's Logistics System

by

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

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ABSTRACT

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This thesis studies the aircraft maintenance logistics system. The first part of the thesis analyzes the factors which cause the problems. The second part consists of proposals to standardize maintenance procedures for all types of aircraft and the third part is a proposal to automate the inventory control system.

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I. INTRODUCTION

A. PURPOSE OF THESIS

The focus of this thesis is on the TNI-AU (Tentara Nasional Indonesia Angkatan Udara), or the Indonesian Air Force, where aircraft maintenance is the main factor to support the readiness of the aircraft as weapon systems. In supporting the aircraft maintenance operations, the TNI-AU is experiencing a continued shortage of spare parts, components, equipments, and technical skills. The purpose of this thesis is to analyze the problems which would cause aircraft maintenance not to be performed as scheduled and to make recommended solutions by introducing standardized aircraft maintenance, development of a management information system, and automation of inventory control techniques so that the Indonesian Air Force can solve their maintenance problems.

B. SCOPE OF THE THESIS

The thesis is divided into five chapters. The first chapter is background which covers Indonesian geography, the Indonesian development plan, and the development of the Indonesian Air Force. The second describes the problems of aircraft maintenance in the Indonesian Air Force such as: aircraft types, maintenance facilities, inventories, and personnel. The third chapter explains maintenance management of the aircraft. The fourth chapter contains a proposal to automate inventory control. The last chapter contains conclusions and recommendations to automate inventory control and to develop new logistics concepts for the aircraft maintenance system.

The proposal to computerize the inventory system is not a universal solution and may be only one of many ways to solve the existing problems in aircraft maintenance. It is hoped that the proposed system can provide a way of thinking that will eventually help the reader recognize the aircraft maintenance problems and the importance of a computerized inventory system within the Indonesian Air Force's supply system. Obviously, other appropriate changes and modification must be made to solve other aircraft maintenance problems.

II. BACKGROUND

A. GEOGRAPHY

Indonesia stretches some 5,120 kilometers from east to west across the equator, the greater part being below the equator (see Figure 2.1). It is the largest archipelagic nation in the world, encompassing 13,677 islands and having a land and sea area of 4.8 million square kilometers, of which only approximately 1.9 million square kilometers are land. Laid over a map of the United States, the archipelago would considerably overlap the distance from New York to San Francisco.

Its geographic location at one of the world's major crossroads has made Indonesia strategically important in the context of regional and super-power rivalries. The country forms natural barriers separating the Indian Ocean, the South China Sea, and the Pacific Ocean. With Malaysia, it commands the Strait of Malacca, one of the world's busiest waterways. Through its islands also pass other important sea routes from the Suez Canal and the Persian Gulf to China, Japan, and North and South America, including the passages of Selat Sunda (the Sunda Strait), Selat Lombok (the Lombok Strait), and the Makassar Strait. Travel between Australia and East Asia, as well as to North America, must also traverse the archipelago [Ref. 2].

The country incorporates the territory of the former Netherlands Indies and Portuguese Timor. It shares land borders with Malaysia on the northern part of the Kalimantan island (Borneo) and it shares a border with Papua New Guinea on the island of Irian (New Guinea).

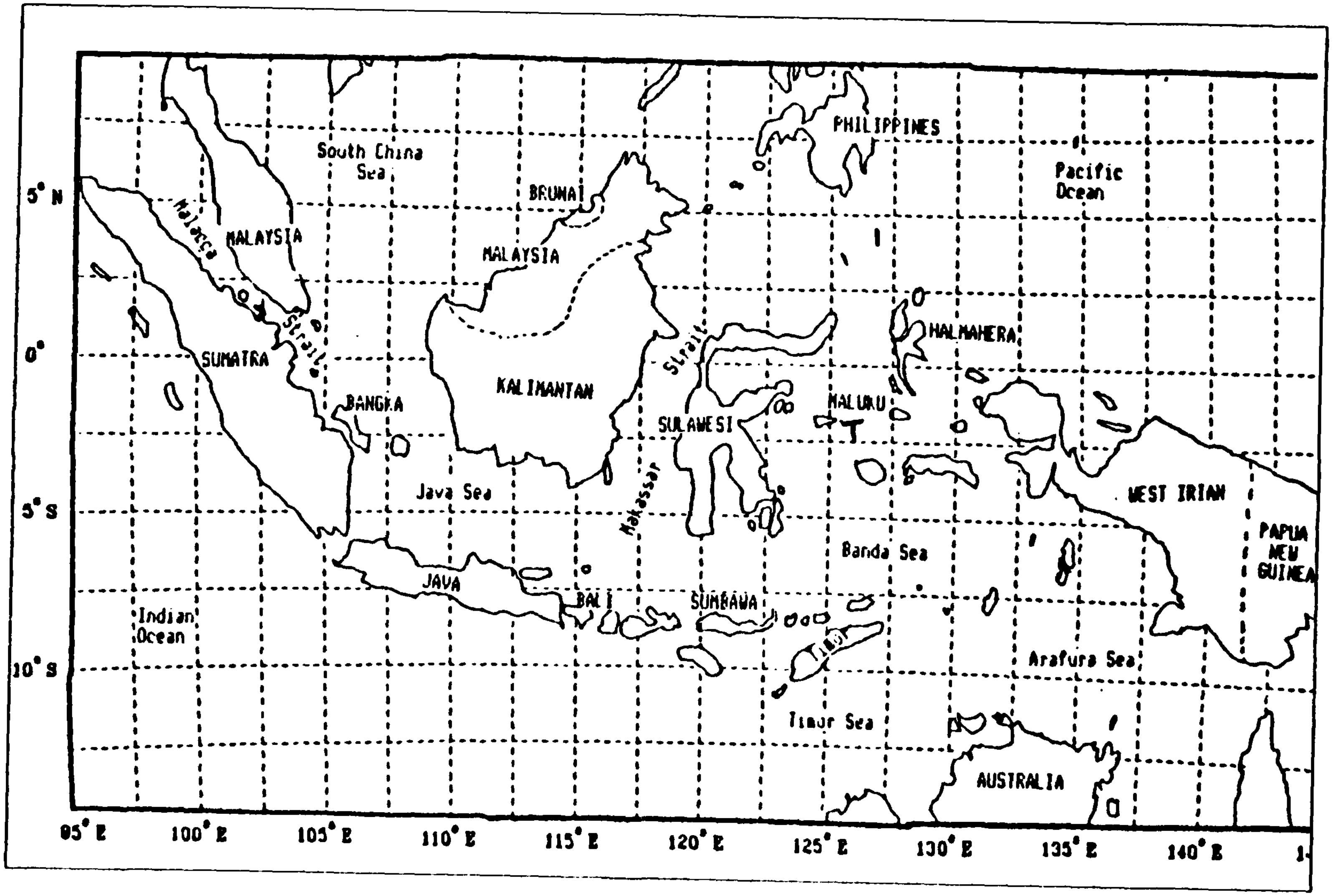

Figure 2.1 Map of Indonesia

Indonesia is separated from Malaysia by the Strait of Malacca, from the Asian continent by the South China Sea, from the Philippines by the Celebes Sea, and from Australia by the Timor Sea and Arafura Sea. Because of its strategic position, Indonesia, historically, politically, and economically, has always been strongly conditioned by geography.

Indonesia's land area is approximately 60 percent covered by thick tropical forests, and its climate is distinctly seasonal, with dry monsoons from June through September and wet monsoons from December through March. These geographical conditions aggravate problems of transportation, distribution and warehousing; and in the utilization of weapon systems and equipment, including their maintenance systems, they become dominant factors.

B. THE INDONESIAN DEVELOPMENT PLAN

After the abortive communist coup of 1965, the new government, for the first time in its history, drew up a development plan. This Development Plan was divided into six consecutive Five-Year Development Plans. The first was launched in 1969, focusing on agricultural development, especially in food grains. The second emphasized agriculture and economy. The third plan which began in 1979, generally expected that the Department of Defense and Security (DODS) would receive greater emphasis. These Plans demanded each governmental department to submit its program and, for this purpose, the DODS adopted a Planning, Programming and Budgeting System (PPBS) to implement what needed to be accomplished [Ref. 11].

Efforts to keep the armed forces as effective as possible and to provide responsive support to operating forces requires good planning, execution, and control, if authorized budgets are not to be wasted and goals are to be reached. Thus, a good Air Force Logistics System becomes one of these elements. A good Defense Logistics system became a necessity so that the DODS and each component service might efficiently implement the expected provisions of the third of the Five-Year Plan, beginning in 1979.

C. THE INDONESIAN AIR FORCE DEVELOPMENT

1. Air Force History

The Indonesian Air Force was established in 1946 and evolved from the aviation division of the People's Security Army. Upon becoming a separate organization, its personnel included only a few pilots. Nonetheless, it assumed responsibility for the air defense of the Republic, taking over all existing Dutch airfields and equipment. Until the late 1950s, the Air Force remained fairly small and flew mostly United States and European-made aircraft. In 1958, however, Indonesia purchased 60 MiG-17 jet fighters and IL-28 bombers from Czechoslovakia. Over the next eight years, the stock of Soviet-designed military aircraft was more than doubled, and the number of personnel was considerably augmented, making the Indonesian Air Force the best equipped air arm in Southeast Asia by the early 1960's.

The influence and capability of the Air Force fell sharply after the 1965 attempted coup by the PKI (the Indonesian Communist Party). A sharp drop in defense expenditures, initiated under Soeharto, and the anti-communist orientation of the new government prevented the purchase of needed spare parts and maintenance assistance and led to the rapid grounding of almost all East European-made equipment.

During the early 1970's the nation purchased some refurbished military aircraft previously used by Australia and by the United States, but significant equipment modernization did not get under way until the late 1970's.

2. Air Force Development

Parallel with the development of national defense and security (in the Third of the Five-Year Development Plans), the Indonesian Air Force purchased the following aircraft types: A-4 Skyhawks, F-5 E/F Tiger IIs, OV-10F Broncos, C-130 Hercules, T-34 Turbo-Mentors, etc. All of these planes were manufactured by the U.S. In addition, a squadron of British Aerospace T-53 Hawks was used for advanced training.

According to the new organizational structure, the Indonesian Air Force has two area commands. The area command I is West sector and the area command II is East sector. Most combat aircraft were based in Java. In 1980, the Air Force expressed its intentions to pursue a forward defense strategy that would necessitate building or upgrading bases off Java, especially in Sumatera, Sulawesi (Celebes), and Irian Jaya (West New Guinea). In the early 1980s, work began on upgrading an airfield on Natuna Island to provide the Air Force with improved coverage of the South China Sea.

D. MAINTENANCE AND READINESS

Maintenance is all actions necessary for retaining an item in, or restoring it to, a serviceable condition. Maintenance includes all of the following procedures in regards to aircraft: service and repair, modification, modernization, overhaul, inspection, and condition determination [Ref. 9].

Readiness is defined as the "ability of military forces, units, weapon systems, equipment, and personnel to perform functions for which they have been designed, organized, or trained" [Ref. 8].

Maintenance of military weapons and equipment is an integral part of defense capability. In today's world, the ability of military forces to react instantaneously is essential to national survival. This ability cannot exist unless an optimum quantity of mission-essential equipment is maintained in a mission-ready state. For this reason, equipment maintenance capability is provided for in the organizational structure of every military unit designed for combat or combat support. Maintenance capability consists of trained people, adequate tools, equipment, facilities, technical data, supply support, and materials. Maintenance managers are provided to insure the effective use of maintenance capability in attaining and retaining the required mission equipment readiness.

Maintenance capability is developed to sustain a specified state of equipment readiness for a tactical unit. The measure of maintenance success is the operational availability of the aircraft. Thus, it becomes a primary factor in determining unit capability. This places the maintenance manager in a position of great importance and explains the command interest in maintenance operations.

III. PROBLEMS AND ANALYSIS

A. DEFINITION

Stoner has defined a problem as a situation that prevents any organization from achieving one or more of its objectives [Ref. 17]. Most problems which happen in aircraft maintenance are caused by several factors. In the Indonesian Air Force the factors are caused by varied aircraft types, inadequate maintenance facilities, poor inventory control, and lack of skilled personnel for maintenance.

B. AIRCRAFT TYPES

1. Aircraft Types in Early 1966

After all the Russian and Eastern European-made aircraft were grounded in 1966 (as explained in Chapter II Section C.1), the majority of the aircraft in the Indonesian Air Force inventory were from the United States of America, with the rest from France (Helicopter Alleuete) and other western countries [Ref. 15]. Aircraft types from the U.S. are shown in Table I.

2. Air Force Development

During the Development of the National Defense and Security Department (the third of the Five-Year Development Plans), the Indonesian Air Force purchased many types of aircraft. The current types of the Indonesian Air Force's aircraft are shown in Table II [Ref. 4].

TABLE I

Aircraft Types in Early 1966

a. Training aircraft:	
T-33 (T-birds)	turbo-jet engined,
T-34 (Mentor)	piston engined,
T-41D (Cessna)	piston engined.
b. Transport aircraft:	
C-47 (Dakota)	piston engined,
C-130B (Hercules)	turbo-prop engined,
Cessna series	piston engined,
c. Helicopter:	
S-55 (Sikorsky)	turbo-prop engined,
d. Fighter aircraft:	
F-86 (Sabre)	jet engined

If Table I and Table II are compared, it can be seen that the aircraft types increased sharply during the development of the Indonesian Air Force. The different aircraft types also require different maintenance procedures, and therefore, differing aircraft maintenance systems.

TABLE II

The Current Aircraft Types

a. Training aircraft:	
MK-53 (Hawks)	turbo-jet engined,
AS-202 (Bravos)	piston engined,
T-34C (Turbomentors)	turbo-prop engined.
b. Transport aircraft:	
C-130B/H/H-30 (Hercules)	turbo-prop engined,
L-100-30 (Hercules)	turbo-prop engined,
BOEING 737-200	turbo-jet engined,
C-160 (Transall)	turbo-prop engined,
C-212 (Aviocars)	turbo-prop engined,
F-27 (Fokker Friendships)	turbo-prop engined.
c. Helicopters:	
Bell-204 Bs	piston engined,
Bell-47H (Siouxs)	piston engined,
S-61As	turbo-prob engined,
BO-105 Cs	piston engined,
SA-330 (Pumas)	turbo-prop engined.
d. Fighter aircraft:	
A-4 (Skyhawks)	turbo-jet engined,
TA-4 (Skyhawks)	turbo-jet engined,
F-5 E/F (Tigers)	turbo-jet engined,
OV-10 (Broncos)	turbo-prop engined.

Some aircraft periodical inspection are based on flight hours operations, some on calender days, and some on a progressive performance check system.

The author's experience indicates that the large numbers of aircraft types was one of the elements which could cause problems for aircraft maintenance in the Indonesian Air Force. There is no standardized maintenance system for all types of aircraft. For example, in periodical inspection a certain number of flying hours determines when maintenance is required. This maintenance is to check the performance of the aircraft equipments after 25, 50, and 100 hours of operation. Major servicing is required after 300 or 1000 hours. An overhaul is required after 4000 hours. For aircraft using the calender system, maintenance is performed after 30, 60, and 90 days to check the performance of aircraft equipments. Major servicing occurs after 6 months and 1 year and overhaul occurs every four years.

The difference between aircraft maintenance systems become extreme problems when a unit (squadron) is equipped with more than one type of aircraft. Because of the different types of aircraft, maintenance departments must maintain a heavy complement of military specialists of different skill levels. In addition, it is a problem for the maintenance officer to schedule maintenance for many different types of aircraft requiring differing maintenance programs. For example, periodical maintenance sometimes requires three to five days to perform. While one aircraft is being maintained, other squadron aircraft may go down because of required maintenance, but can not be repaired because lack of maintenance capability to check more than one type of aircraft at a time.

Each aircraft in a squadron is an integral part of the defense capability. So, aircraft awaiting maintenance affect the Air Force capability in providing the national defense.

C. MAINTENANCE FACILITIES

Maintenance facilities consist of the physical plants (i.e. hangars, intermediate shops, and depot facilities) to support the operation and maintenance functions associated with the aircraft.

Before its recent growth, the Indonesian Air Force had enough maintenance facilities to completely support the maintenance of its aircraft. However, these facilities are not modern enough to support current aircraft, because of their advanced technology. For example, the current aircraft are equipped with modern avionics systems. These systems are computerized, but the maintenance facilities cannot test or check these systems. Specifically, a failure of the computerized aircraft systems and the inability to repair them affects readiness.

D. INVENTORY

Inventory of spares is one of the most important elements of the Indonesian Air Force's logistics system. It strongly affects the effectiveness and efficiency of aircraft maintenance.

Each aircraft type is generally spared at a 20 percent level of the aircraft inventory. With this 20 percent of spares an 80 percent availability is desired. This objective cannot be attained with the 20 percent spares under the existing maintenance system. This is caused by a poor inventory system and a lack of capability to repair the repairable spares. The value of the spare component can be extended by repairing it. With the proper facilities this repair could be achieved at low cost, if compared with having to buy a new spare. The availability of components in the inventory system are dependent on the length of time required to repair the components. In logistics terminology this is called turn around time. The longer the time to repair components, the greater the stock level required. (See Figure 3.1)

It is obvious that the availability of <u>spares</u> is one of the main factors in achieving availability goals. It often happens that aircraft maintenance must be delayed as a result of lack of spare parts. This lack of spares problem exists because: (1) Military aircraft are complex and have a high rate of failure. (2) Failure rates are higher than planned, therefore more parts were required and stock outs could not be avoided.

Equipments which can not be repaired within the maintenance system of the Air Force are normally returned to vendors which takes long period of time (from 12 months to 24 months).

Hadley and Whitin have defined order cycle or procurement lead time for an inventory system as:

> The interval between the time when the stocking point decides that an order for replenishment should be made and the time that the order arrives [Ref. 10].

This includes time for order transmittal, processing, preparation, and shipping [Ref. 5]. The long lead time necessitates that for replacable items (parts or components which are not repairable) a high inventory level should be maintained because of long ordering and procurement process (from Guhar to Guharpus, Guharpus to Skamat, Skamat via WINGMAT to KOMATAU, KOMATAU to Vendor and from vendor back to Guhar), which normally requires more than 12 months. (See Figure 3.2)

The Indonesian Air Force's logistics system requires a high inventory stock level for non-repairable components, as a result of the long procurement process. This long

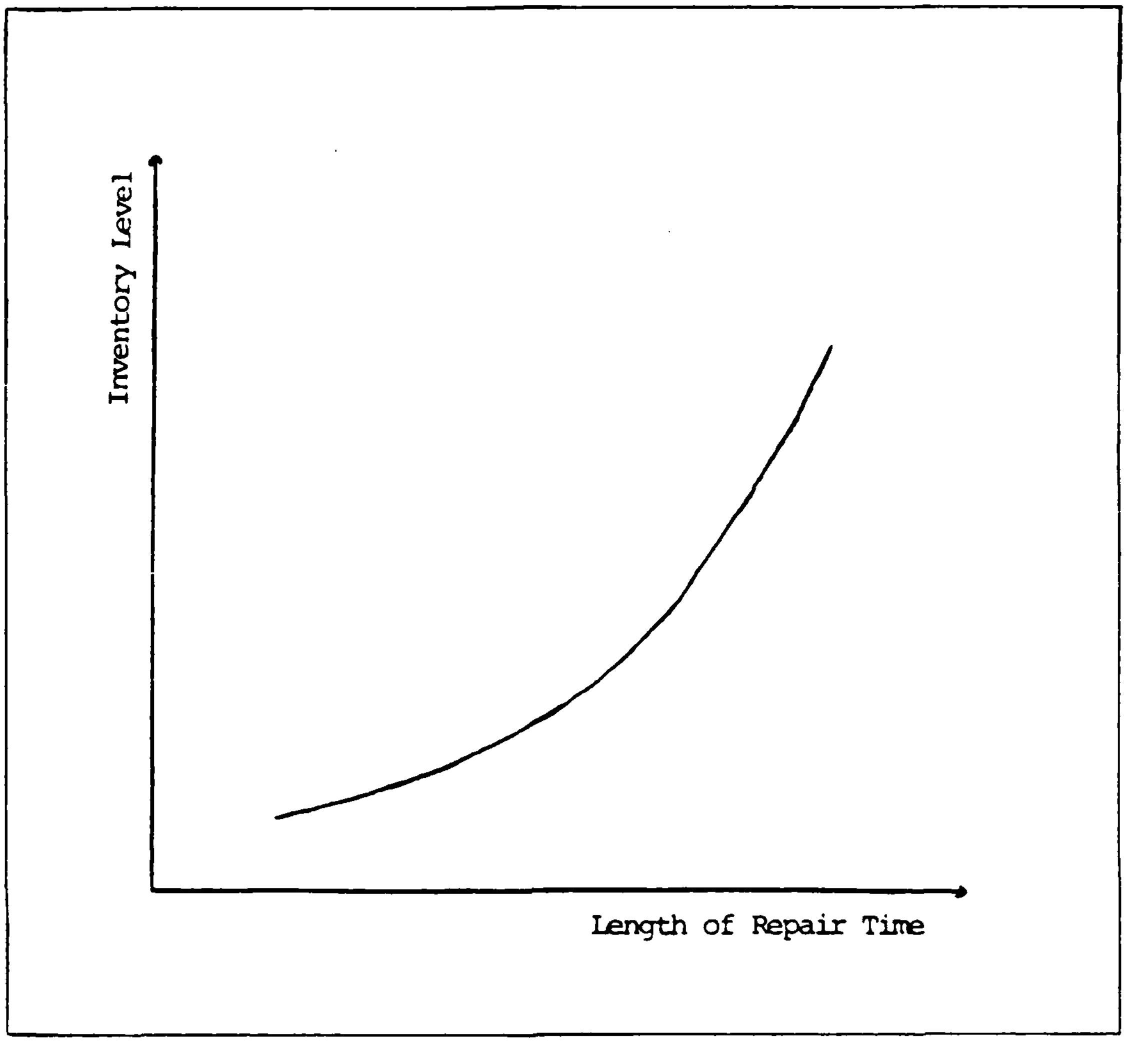

Figure 3.1   Turn Around Time

procurement process is complicated because stock levels are not accurately maintained by supply personnel and procurement status is not accurately tracked. In other words, stock status does not match inventory records.

The above problem is being analyzed in this thesis. The author has listed several the causes for the weakness of inventory in the Indonesian Air Force's Logistics system. In summary this weakness has two causes. (1) Organizational

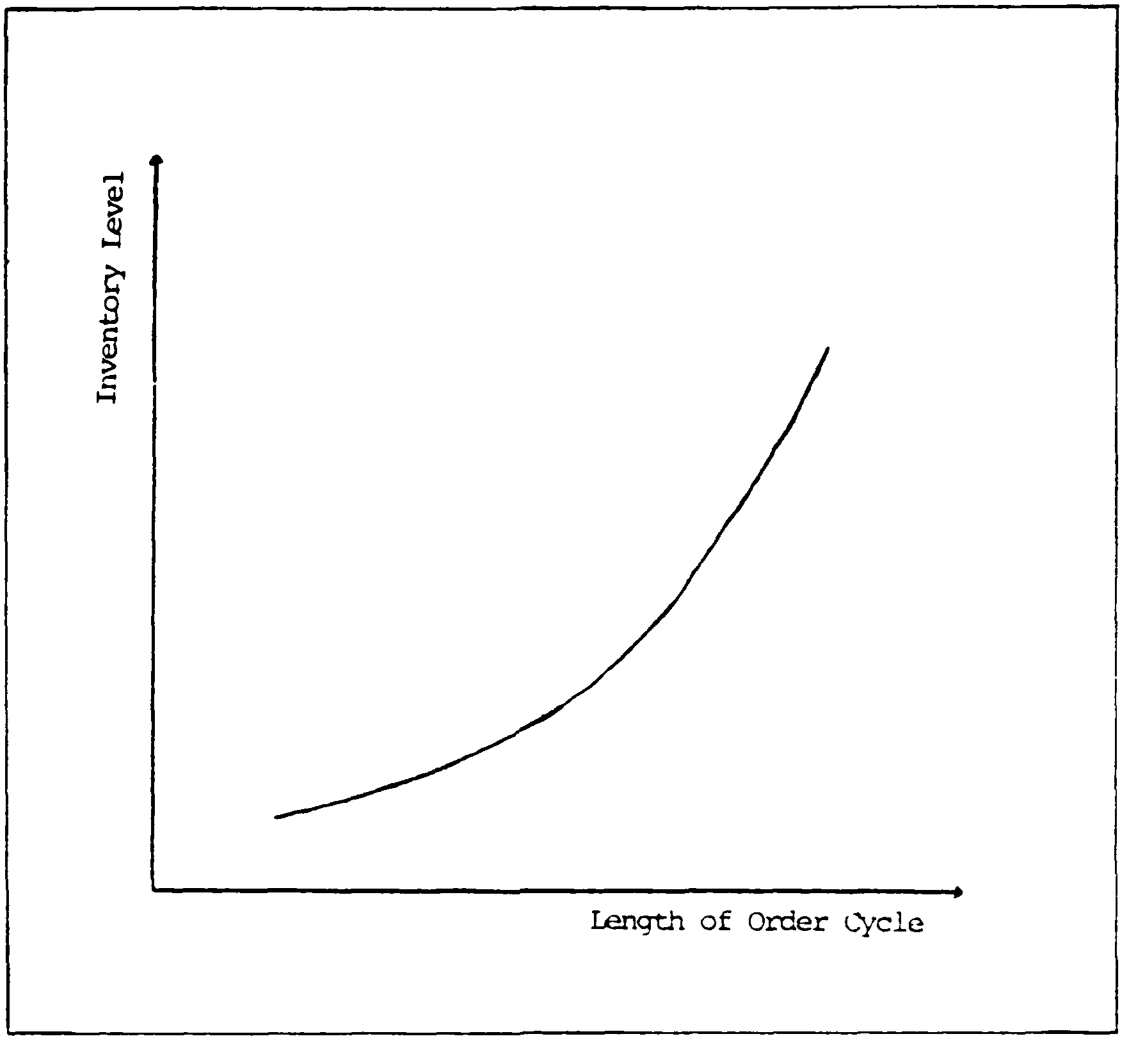

Figure 3.2 Order Cycle Time

structure, (2) Inventory handling. These causes will analyzed below.

1. <u>Organizational Structure</u>

KOMATAU (komando material alat utama angkatan udara), the Air Force Material Command, is composed of several WINGMATs (Wing material) or material wings. Air Force Material Command functions as the inventory control point (ICP). The Material Wing functions as a stock point (SP) to support the spare parts and components for aircraft maintenance. The Material Wing is not located at the bases where the Operational Wings are stationed. All spare parts or components which have been ordered by Air Force Material Command are stored in the Material Squadron's warehouses at the Material Wing. Also the parts or components which can not be repaired within the Indonesian Air Force are stored at Material Wing before being sent to the vendor by Air Force Material Command.

Up to now, the Indonesian Air Force's Logistics System has followed a three levels provisioning system: Skamat, Guharpus and Guhar. (See Figure 3.3)

a. Skamat

Skamat (gudang skadron material), or material squadron warehouses, function as stock points for spares ordered by KOMATAU (Air Force Material Command) from vendors.

b. Guharpus

Guharpus (gudang pemeliharaan pusat), or Wing Operational's maintenance warehouses, function as a distribution point, to support the availability of spare parts or components for each Guhar at the air squadrons or technical squadrons.

c. Guhar

Guhar (Gudang pemeliharaan), or squadron's maintenance warehouse, functions to support the aircraft maintenance at every air squadron or technical squadron. All spare parts or components that are available at Guhar are normally ready for issue. The defective parts, components, or equipments (from aircraft), are sent to Guharpus and from

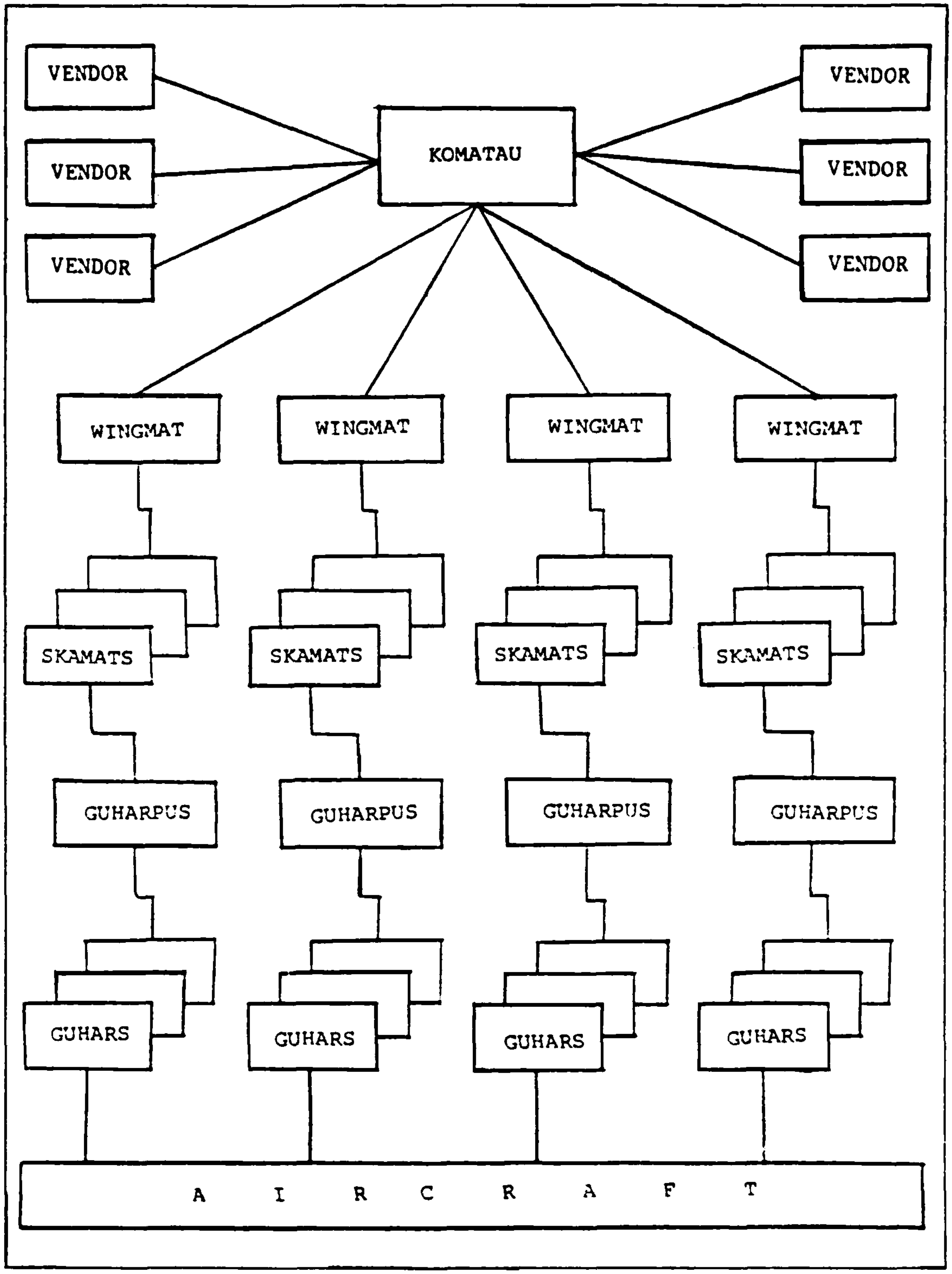

Figure 3.3 Levels of Storage

Guharpus to Material Squadron (SKAMAT) or Technical Squadron (SKATEK).

The warehouse levels at GUHARs cannot be maintained by the Indonesian Air Force's Logistics System because so many levels involved in handling and replacement or repair of spares [Ref. 1].

2. Inventory Handling

The ordering process for parts or components from inventory distribution to the next level takes a long period of time. For example, to order the components from GUHARPUS to SKAMAT normally requires more than one week, because all processes are manual. So, it is obvious that the probability of mistakes in recording the parts or components are very high, and the process is time consuming.

KOMATAU now uses mini computers to handle their problem. The computers which are available at KOMATAU are not able to solve inventory problems at the stock points and inventory distribution points. SKAMATs and GUHARPUSes are not equipped with compatible computers yet.

E. PERSONNEL

New aircraft for the Indonesian Air Force has new capabilities and technologies. New capabilities bring new problems. The aircraft weapon systems bring new, unexplored failure modes and require new procedures and skills for maintenance (inspection and repair). The advanced aircraft technology, complexity of systems, and increasing sophistication of components and repair methods require increased training and additional educational level for the people who maintain them at organizational (field), shop, and depot levels.

At the current time, the Indonesian Air Force's Logistic System lacks maintenance personnel. This condition is indicated by the declining number of maintenance personnel at all maintenance levels because of attrition of experienced personnel. The number and skills of personnel are out of balance with current aircraft technologies. According to a survey and research that has been done by the Air Force [Ref. 1], these conditions are the results of: (1) no new recruitment of enlisted personnel, (2) promotions through the ranks, (3) the retirement of personnel and (4) the gap of existing skills to those needed.

1. No New Recruitment of Enlisted Men

For more than six years, starting in 1966, the Indonesian Air force did not recruit new enlisted personnel for maintenance because all of the Russian and Eastern European-made aircraft were grounded. This policy was set at the time, because the Indonesian Air Force had only a few types of aircraft and the personnel who maintained these aircraft were more than what was required.

2. Promotion

The personnel who had good technical skills later became NCO's (Non Commissioned Officers) and some of them were even promoted to officers. But all who were promoted normally became staff members whether at their unit or at a new assignment, and so left their maintenance jobs.

3. The Retirement of Personnel

Personnel who have Non Commissioned Officer rank and not promoted to Officer generally retired from service because of their age. The Indonesian Air force has special regulations for enlisted personnel, i.e., personnel who are 48 years old and have not been promoted to Officer must retire from service. The personnel who have been retired, cannot be rehired as civilians to perform air force maintenance, as in the United States.

4. Gap of Skills

Recruitment, training, and normal replacement of maintenance personnel are problems of great concern to the Air Force because of the increasing technological sophistication of its aircraft.

Maintenance skills must constantly be reinforced by training. Large and small technical innovations never cease, and they necessitate constant skill updating to insure that the entire working team is current [Ref. 3]. Therefore, in addition to the above reasons, the constant need for training new personnel causes large problems. It is extremely difficult to close the gap between senior and junior enlisted men's skills for aircraft maintenance.

IV. MAINTENANCE MANAGEMENT

In the previous chapter the author discussed non standard maintenance procedures, which contributes to inefficiency of maintenance activities. The purpose of this chapter is to discuss ways the maintenance system's inefficient can be corrected and to present a proposal which would correct the maintenance system deficiencies.

A. MAINTENANCE ORGANIZATION

Maintenance organizations are designed to provide the degree of aircraft readiness required to accomplish the assigned mission. To do this, maintenance is expected to perform three basic functions:

1. Preventative maintenance -routine scheduled attention to equipment, to keep it safe and effectively operable;
2. Corrective maintenance -repairing or rebuilding to rectify failure, malfunction, or damage;
3. Qualitative maintenance -approved modification, alteration, or retrofit, to improve safety, or to improve or change performance characteristics to meet mission requirements [Ref. 13].

The management of this maintenance effort is extremely important. Management must determine the priorities necessary for the correct application of maintenance resources. To do this, management must clearly understand the unit's mission. Further, management must communicate the mission and mission needs intelligibly to all personnel involved directly or in a support role.

Maintenance in the Indonesian Air Force has been organized on a three-level basis, as is the rest of the Air Force's organization. The three levels are organizational, intermediate, and depot levels [Ref. 15]. Organizational maintenance is provided by the unit in the field or on the flight line, intermediate maintenance may also be provided by the operational unit, but usually in a shop context, and depot maintenance typically occurs at centralized maintenance facilities. The level of maintenance activity is important because it determines the type of personnel who perform the maintenance.

For the purpose of this thesis, the autc..r only considers the maintenance organization for periodical (flight hours based) maintenance. The TNI-AU (Indonesian Air Force) intends to standardize all aircraft periodical maintenance around flight hours.

1. Organizational Maintenance

Organizational maintenance is usually performed within the operational squadrons. The maintenance tasks are performed by the personnel of the squadron involved with the operation and use of equipment. They are limited to:

a. Pre-flight checks and visual inspection/functional checks;

b. Periodic checks of equipment performance (after every 25, 50 and 100 hours of operation);

c. External adjustments (such as fuel regulation system adjustments);

d. Removal and replacement of some components (such as tires) and;

e. Cleaning and some servicing.

The personnel assigned to this function are usually not skilled in specialized maintenance. They do not repair any removed equipment, but instead forward it to the intermediate maintenance level.

2. <u>Intermediate Maintenance</u>

Maintenance tasks that cannot be performed by organizational levels due to limited personnel skills and test equipment are performed at the intermediate level. Intermediate maintenance personnel are better equipped and more skilled than those at the organizational level.

Equipment may be repaired by the removal and replacement of major modules, assemblies, or unit parts. Scheduled maintenance requiring equipment disassembly may be performed only at specified intermediate maintenance areas that have the necessary skilled intermediate maintenance personnel. As a consequence, the turn-around times are not as rapid as in the organizational maintenance units. The tasks of intermediate maintenance include:

a. Detailed inspection and system check out;
b. Major servicing (after every 300 and 1,000 hours of operation);
c. Complicated adjustments and component repair;
d. Limited calibrations.

For emergency purposes, semi-mobile units can provide close support to the operational site. The mission of such units is to provide close, on-site maintenance beyond that accomplished by organizational units, in order to facilitate the return of the aircraft to its full operational status on an expedited basis.

3. <u>Depot Maintenance</u>

Depot maintenance is the highest level of maintenance. This level of maintenance includes:

a. Complicated "factory" adjustments;
b. Complex equipment repair and modifications;
c. Overhaul and rebuilding;
d. Detailed calibrations; and

e. Work overloads from intermediate levels of maintenance.

Depot facilities exist only at certain locations. Equipment requiring this level of maintenance must be transported to those locations. Each depot maintains its own inventory (called depot level stock). In addition, there is one logistics depot whose sole mission is to supply support for the entire Air Force including the transportation and distribution of materials to the maintenance depots and other unit organizations [Ref. 15].

B. MANAGEMENT CONTROL OF AIRCRAFT MAINTENANCE

1. The Meaning of Control

Earl P. Strong and Robert D. Smith have described the need for control as:

> There are a number of conflicting view points regarding the best manner in which to manage an organization. However, theorists as well as practicing executives agree that good management requires effective control. A combination of well-planned objectives, strong organization, capable direction, and motivation have little probability for success unless there exists an adequate system of control [Ref. 16].

2. Management Control

> Management control is a systematic effort (1) to set performance standards with planning objectives, (2) to design information feedback systems, (3) to compare actual performance with these predetermined standards, (4) to determine whether there are any deviations and to measure their significance, and (5) to take any action required to assure that all corporate resources are being used in the most effective and efficient ways possible in achieving corporate objectives [Ref. 12].

According to this concept (Mockler's definition), the management control of aircraft in the Indonesian Air Force needs systematic efforts to set readiness objectives and ways to measure whether or not those objectives are being achieved.

In this chapter we consider the unit commanders as the managers, and they have the responsibility to establish and carry out the maintenance plan.

Maintenance management may be judged for its clean shops and its ability to plan and schedule and to fully employ assigned personnel. However, the ultimate question, which, paradoxical as it may seem should be the first question, is: "Does the maintenance plan produce the standard of equipment readiness that meets programmed operational requirements?" Regardless of the many yard-sticks available, the final evaluation as to whether or not maintenance is effective will depend upon the answer to that question, "are operational readiness objective being achieved"?

The Indonesian Air Force program (to standardize maintenance system based on flight hours) will establish the logical sequence that reliability of the hardware determines the basis for maintenance. Dess and Kunstel have stated that:

> Maintenance management must manage a weapon support system concept, and that the prime evaluation of maintenance is based on its ability to provide mission-ready systems. Once effectiveness has been determined, the cost of the resources expended to accomplish the attained state of rediness must be determined. Thus, maintenance efficiency can be expressed in terms of cost per hour of operation of the weapon/support system, or cost per hour of availability, or cost per hour of readiness compared to acceptable cost standards for the condition, use, or availability. Briefly the axiom can be stated as, first be effective, and then determine the efficiency or cost of being effective [Ref. 7].

C. MAINTENANCE MANAGEMENT INFORMATION

Management information should help the Commander and Maintenance Officer (1) to plan what to do, (2) to execute plans, and (3) control the unit activity to assure that the maintenance schedules are accomplished. The Commander and Maintenance Officer's information needs include all the maintenance activities.

The sequence of management requires adequate sources of information by which the effectiveness and efficiency of maintenance can be measured.

The Indonesian Air Force maintenance program requires the basic informational needs, as a minimum, for maintenance management as: (1) maintenance data, (2) maintenance categories, and (3) maintenance cost. It is within these information requirements the commander and maintenance officers have the data to answer the questions and provide the information base for the decisions.

The commander and maintenance officers of an aircraft unit should have the knowledge of technical (performance) and production aspects of the equipment given to them to perform their mission. Maintenance Data Collection System (MDCS), originating at base level and flowing up through all levels, should provide the information required at each level. A lengthy discussion of who does what is not necessary, but the significant features of the system can be presented. Figure 4.1 [Ref. 7] illustrates an analysis pattern of how a commander and maintenance officers may use maintenance data. The remaining sections of this chapter will discuss this pattern for analysis.

D. MAINTENANCE DATA

Maintenance data are recorded by the mechanic and provides the commander or maintenance officers with

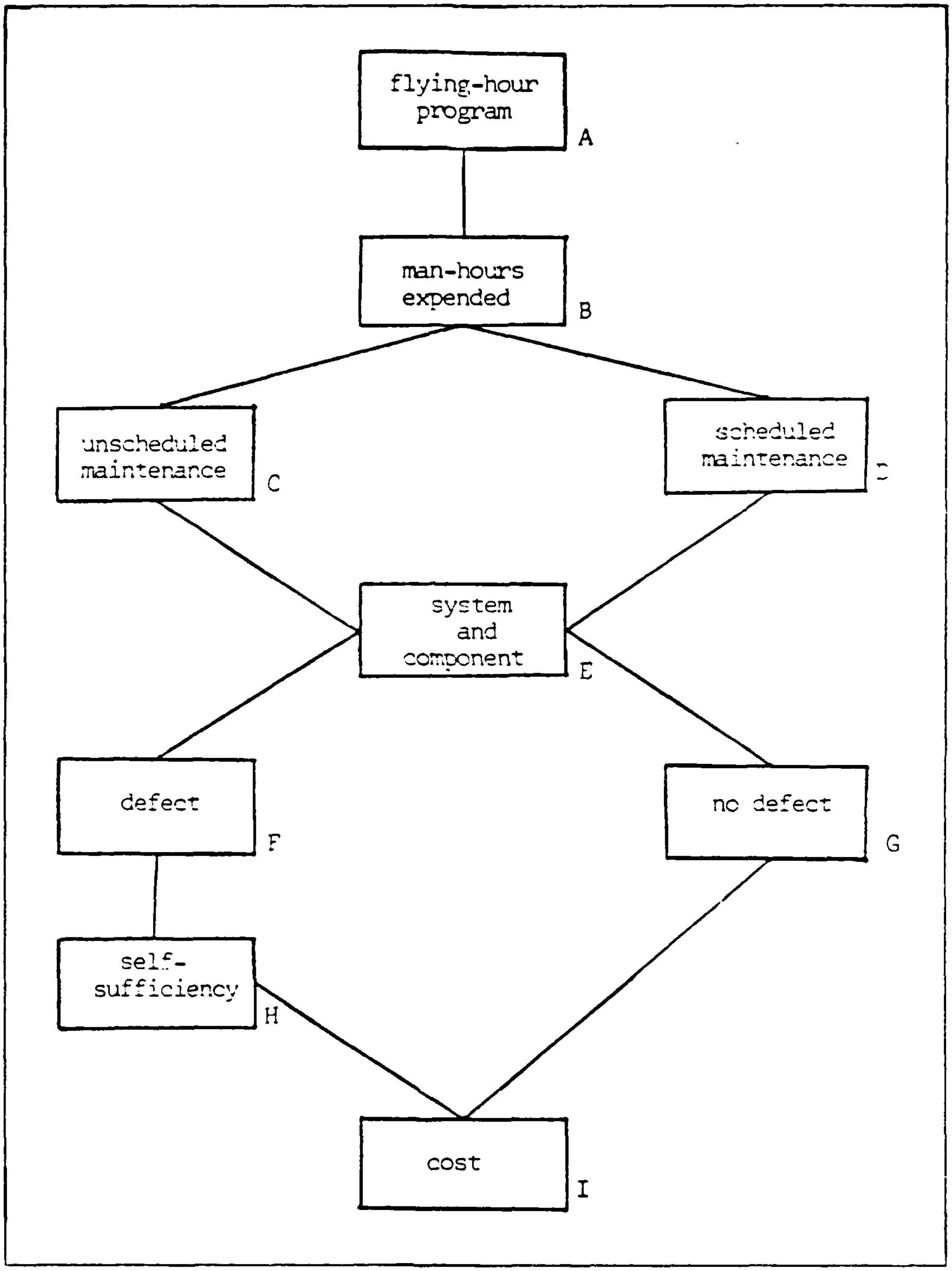

Figure 4.1 A Logic Path for using Maintenance Data

(1) the maintenance man-hours spent to support a flying hour program, (2) the causes for the maintenance effort, and (3) what equipment or part caused the expenditure. The data also identifies the malfunction, when the maintenance need was discovered and by whom, the parts used, and the maintenance actions that occured.

The maintenance data system, by showing how many maintenance hours were expended for a type of equipment, pinpoints how these hours were spent (Item B, Figure 4.1). Also, using these data and established standards, deviations from the norm can be identified for action by the manager.

E. MAINTENANCE CATEGORIES

Maintenance falls into two categories: scheduled -those maintenance inspections as specified in the inspection manuals applicable to the equipment (Item D, Figure 4.1); and unscheduled -all work accomplished on equipment or components except scheduled maintenance (i.e.: servicing, cleaning, and movement etc.), see item C, Figure 4.1. If standards in terms of man-hours were established and compared with man-hours expended the manager could from the totals determine efficiency of maintenance personnel in performing their maintenance tasks. Also the ratio of scheduled hours to unscheduled hours could be determined. There will always be unscheduled maintenance because things will break or wear out. However, the relationship of scheduled to unscheduled maintenance for the type of equipment should be established. Generally, a ratio of more than 50 percent [Ref. 7] unscheduled to scheduled maintenance may be a problem, caused by ineffective periodic or phase inspection, training problems, improper work-load schedules, or failure to recognize significant nonmaintenance factors such as inadequate design criteria or operational abuse of equipment. As a minimum effort, the managers should investigate increasing ratio trends in these areas as means of anticipating or avoiding problems.

Within the category of unscheduled maintenance, it should be determined which equipment system or components are problems (Item E, Figure 4.1). The analysis section in the maintenance organization can identify the system or components causing the problems. This analysis can identify the high consumption of man-hours, frequency of malfunctions causing aborts or removal from operationally ready status, which could seriously affect mission capability.

When a problem is identified, the commander should know what the maintenance officers are doing to solve it and whether the problem is local or Air Force-wide. If service-wide, KOMATAU can help in this regard.

Another major concern of the commander involves expenditures of maintenance man-hours on malfunctions which are finally classified as "No defect" (Item G, Figure 4.1). The importance here is the expenditure of resources for no apparent reason. The problem could be an operator problem, caused by his lack of understanding of the system, or it could be a maintenance problem.

Thus far we have traced a logic path (Figure 4.1) from flying-hour program evaluation to maintenance man-hours expended whether for scheduled maintenance or unscheduled maintenance, and then to the determination of validity of reported malfunction in a component or part.

The next item to consider is the repair of the "broken" item. The manager should know whether items are repaired or not repaired and, if not repaired, the reasons. The impact of this status is the utilization of available resources in relation to what an organization is authorized to repair, what the rationale is, and what actions the Repair Capability Evaluation Section has taken on items that should be repaired. This data provides the identity and quantity of items repaired and those condemned or shipped off-base in the category of "Not Repairable This Station (NRTS)." Items shipped NRTS are also grouped into numbered categories or reasons for the NRTS actions: i.e., "Repair Not Authorized," "Lack of Equipment, Tools, Facilities," "Lack of skills," "Lack of Parts," etc. Specific attention should be given to what maintenance has done about "Lack of Skills," "Shop backlog," "Excess Requirements," and "Condemned parts." Corrective action needed is then more readily apparent and local control more likely.

The managers can examine maintenance actions relative to training, proper shop scheduling techniques, whether or not equipment requirements are monitored, and whether or not proper procedures are in effect locally.

F. MAINTENANCE COSTS

Cost considerations are mandatory, not because of Air Force instruction, but because management universally relates maintenance to a cost basis. If this is not done, an effort to evaluate and compare the many parts of management efforts will be a continuous process of mixing "apples and oranges".

The cost data can be compared to determine whether maintenance should be performed at organizational (field) level or intermediate (shop) level or if it should be transfered to depot level.

In Chapter V the author will discuss inventory in the TNI-AU logistics system. This Chapter will explain the avoidance of stock outs, the flow of inventory within the TNI-AU Logistics organizations, and the importance of the computer for inventory management and control.

V. INVENTORY SYSTEM

Inventory is one of the most important elements for the aircraft maintenance, the existing inventory problem in the Indonesian Air Force strongly affects the effectiveness and efficiency of aircraft maintenance. In this chapter the author wants to introduce the economic order quantity model, safety stock level, and propose to automate the inventory control system.

A. GENERAL

1. Inventory Definition

Render and Stair have defined:

> An inventory is any stored resource that is used to satisfy a current or future need [Ref. 14].

Spare parts, components, test equipments, and all GSEs (ground support equipments) are examples of inventory for support of aircraft maintenance. Inventory levels of parts and components are a direct function of aircraft maintenance. Once we determine the requirements for parts to complete aircraft maintenance tasks, it is possible to use this information to determine how many of the items are available to perform the task. All the TNI-AU organizations have some type of inventory planning and control system.

2. Inventory Planning

Figure 5.1 illustrates the basic sequences of a inventory planning and control system. The planning phase is primarily concerned with what inventory to be stocked and

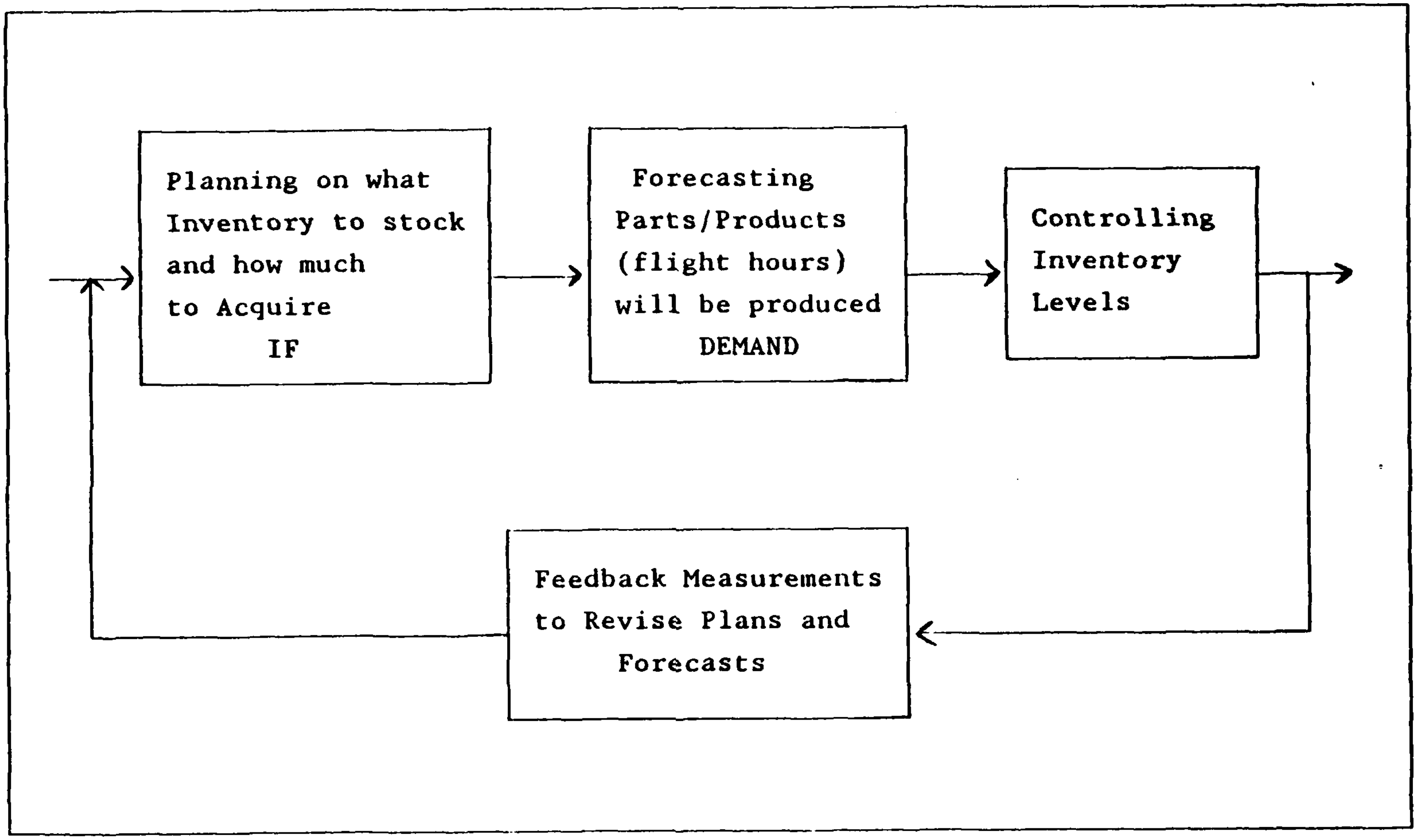

Figure 5.1 Inventory Planning and Control

how it is to be acquired (make, repair, or buy). This information is then used in forecasting demand for the inventory and in controlling inventory levels. The feedback loop in Figure 5.1 provides a way of revising the plan and forecasting requirements based on allocation of flight hours (how many flying hours will be produced by each air squadron) for the next fiscal year. The technical data (data about parts or components in aircraft that will be changed or replaced after a certain number of flight hours) are collected by maintenance officers according to the TO (technical order) for specific aircraft.

3. Inventory Control to Avoid Stock outs

The one important function of supply is to avoid shortages or stock outs. If the supply is out of stock that implies that the maintenance is delayed. To solve these problems good inventory control and stock forecasting techniques are necessary.

The safety stock is additional stock that is kept on hand for emergency use. If safety stock for a part or component is fifty units, supply would maintain a stock of fifty units above those required for routine scheduled and unscheduled maintenance. When aircraft maintenance demand is unusually high (for example, more tactical operations or more aircraft equipment problems than anticipated), then the KOMATAU could utilize the safety stock instead of encountering stock out. (See Figure 5.2) The main purpose of safety stock is to avoid stock outs when the demand is higher than expected. To maintain a given safety stock level, the use of a reorder point (ROP) is necessary. This can be accomplished by adding the number of units of safety stock, as a buffer, to the reorder point. The model for the ROP is as follows:

$$\text{Reorder point} = ROP = d \times l \qquad \text{(eqn 5.1)}$$

d = Daily demand

l = Order lead time or number of working days it takes to deliver an order.

With the inclusion of safety stock, the reorder point becomes

$$ROP = d \times l + ss \qquad \text{(eqn 5.2)}$$

ss = Safety stock.

To determine the safety stock we can use historical data from the previous year. As a consequence of introducing the safety stock, the TNI-AU must maintain high inventory on hand. This stocking could be automated through use of a computerized supply system. This can be handled by installing the computers at every echelon in Figure 3.3.

4. The Inventory Decision

The decision that must be made for the thousands of the items in Air Force's inventory are:

a. How much to order and
b. When to order.

If these inventory models are efficient they will avoid stockoutages in so far as economically possible. Since inventory stock levels increase when demand is low, the cost of storing and handling inventory also increases. By the same reasoning, when the Indonesian Air Force orders too little too often the cost of procurement and shipping go

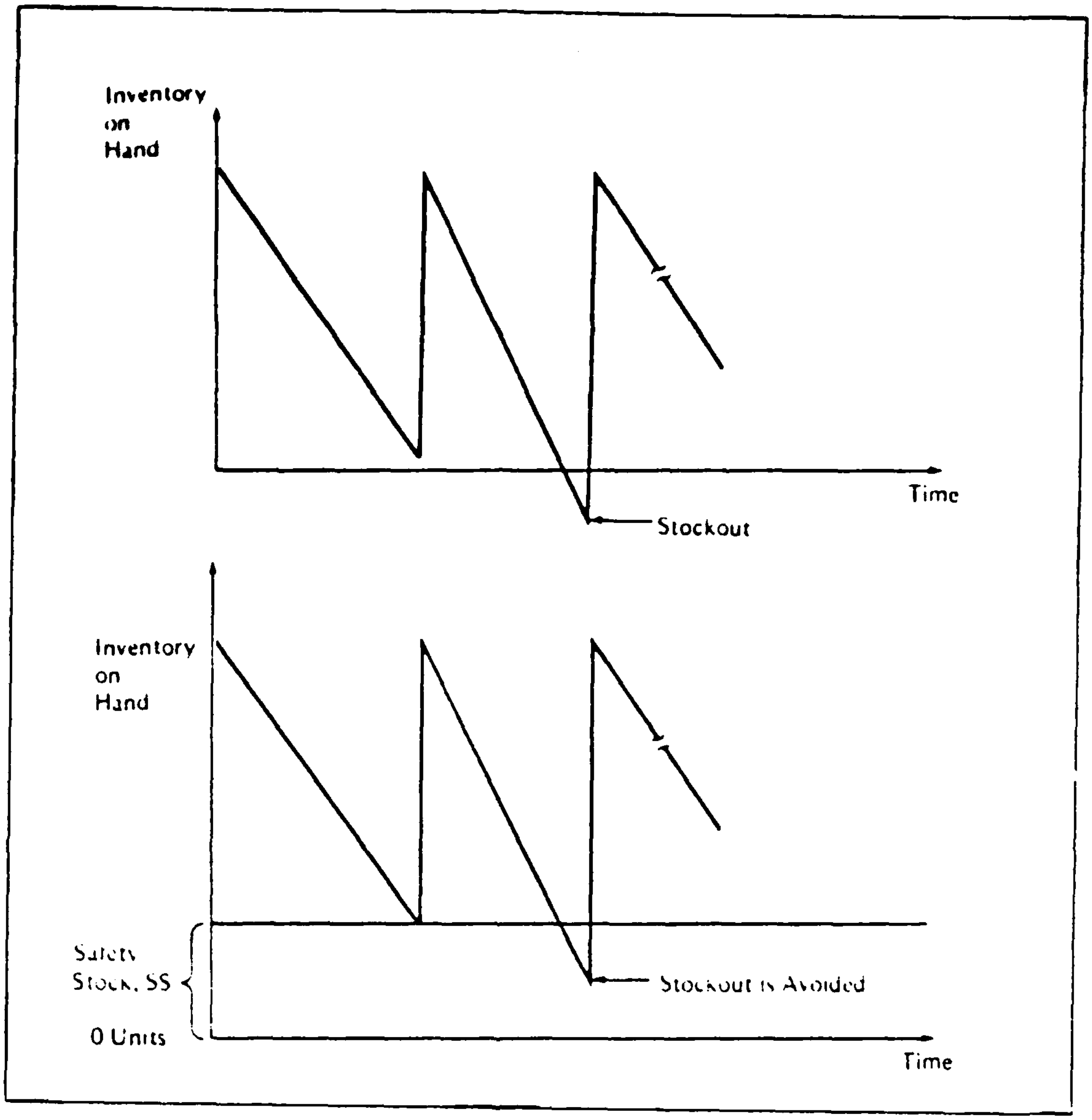

Figure 5.2 The Use of Safety Stock

up thereby off-setting inventory cost savings. It is important, therefore, to have inventory models that are realistic forecasters of need in order that Indonesian Air Force can avoid stockouts while minimizing inventory cost, while providing some predetermined safety stock.

In summary the objective is to derive a model that minimizes total cost of inventory while avoiding stockoutages.

5. Inventory Cost

The objective of most inventory models is to minimize the total cost. In this case the Indonesian Air Force can make the following assumption. The significant costs are the ordering cost and carrying cost. Other costs, such as the cost of inventory itself, are constant [Ref. 14]. Thus, if the Indonesian Air Force establishes inventory models based on the above stated premises, they should minimize the sum of the ordering and carrying cost, and would also be minimizing the total cost. (See Figure 5.3.)

6. Economic Order Quantity

Economic order quantity is the point that minimizes the total cost, where total cost is the sum of ordering cost and carrying cost. Figure 5.3 indicates graphically that the optimal order quantity was at the point where the ordering cost was equal to the carrying cost. The economic order quantity equation is:

$$Q^* = \sqrt{\frac{2DC_o}{C_h}}$$

Where:

Q = Number of pieces per order
Q* = Optimum number of pieces per order
D = Annual demand in units for the inventory item
Co = Ordering cost for each order
Ch = Holding or carrying cost per unit per year.

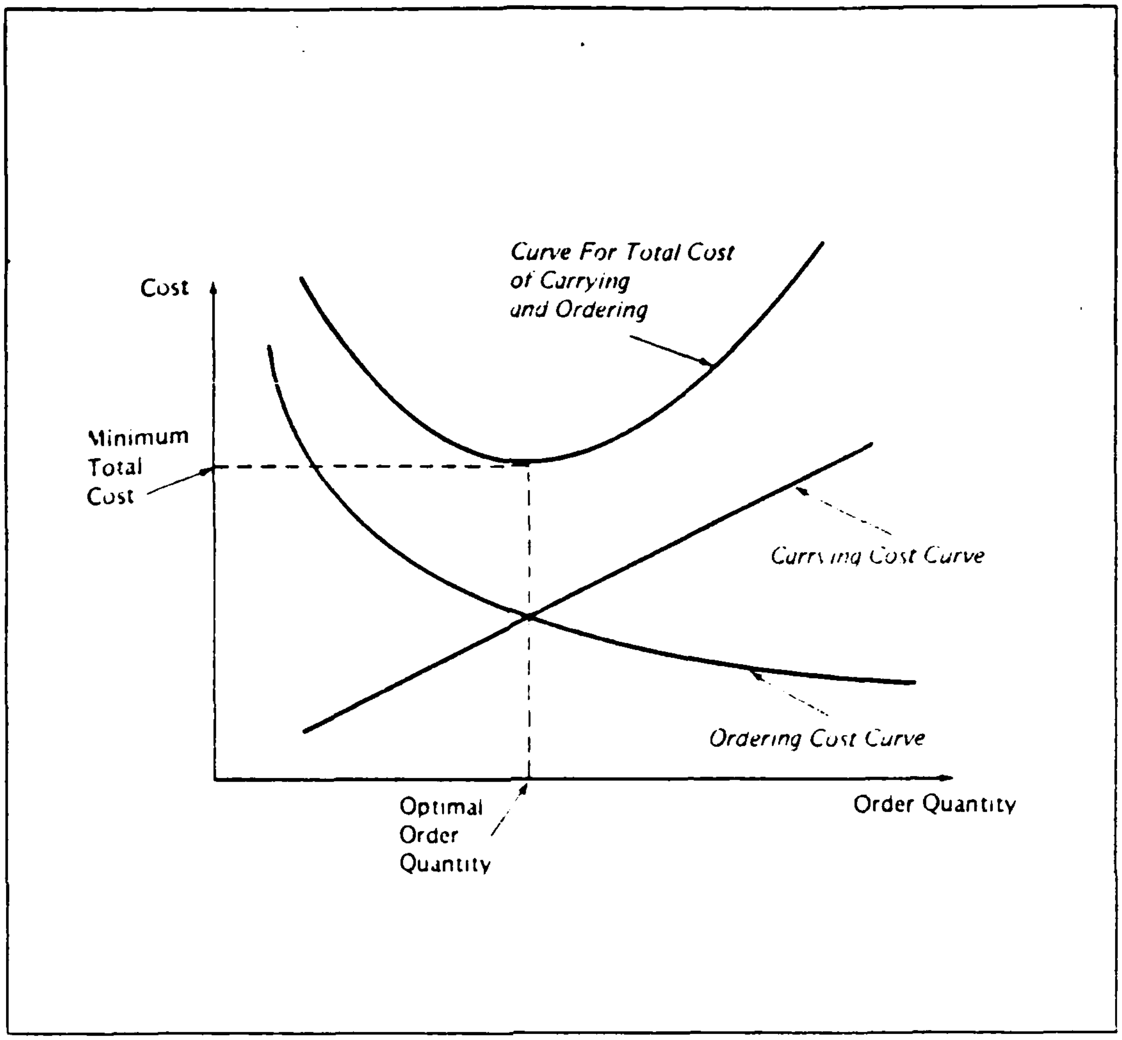

Figure 5.3 Total Cost as Function of Order Quantity

The following is step-by-step procedure to develop the components of the economic order quantity equation:

1. Annual ordering Cost

= (No. of orders placed/year) X (Order cost/order)

$$= \frac{\text{Annual demand in units}}{\text{No. units in each order}} \text{ X (Order cost per order)}$$

= (D/Q) X Co (eqn 5.3)

2. Annual holding or carrying cost

= (Average inventory level) X (Carrying cost/unit/year)

= (Ordering Quantity/2) X (Carrying cost/unit/year)

$$= (Q/2) \times Ch \qquad \text{(eqn 5.4)}$$

3. Optimal order quantity is found when

Ordering cost = Carrying cost

$$(D/Q) \times Co = (Q/2) \times Ch \qquad \text{(eqn 5.5)}$$

4. To solve for Q*, simply cross-multiple terms in equation 5.5 and isolate Q on the left of the equal sign.

$$Q = Q^* = \sqrt{\frac{2DCo}{Ch}} \qquad \text{(eqn 5.6)}$$

Now that the equation for the optimal order quantity, Q*, has been derived, it is possible to solve inventory problems [Ref. 14] by implementation.

B. INVENTORY HANDLING METHOD

1. General

The Indonesian Air Force inventory encompasses spare parts, ammunitions, equipments, and facilities. There is a requirement to handle the inventory items efficiently so that maximum benefits are achieved. At the present time the inventory is handled manually. The manual processing and lack of system standards result in undue delays as previously explained in chapter III page 23. The purpose of this section is to discuss ways of decreasing delays and improving accuracy of inventory accounting.

2. Procedure for Inventory Control

The Indonesian Air Force's inventory control procedures need revising and should based on material categorization and value.

a. Material Categorization

(1) Expendable Items. The control activities should be geared toward the effort of supplying items and maintaining there location prior to issue and to whom issue.

(2) Non Expendable (Repairable) Items. The control is meant to track the size of the inventory, amount of inventory in stock, inusage, and in repair along with location and stock condition.

(3) General Support Equipment. Control activities maintain location, and material condition.

(4) Facilities. The control activities maintain records of condition, status and capability.

b. Material Value

Material value will determine the intensity of control, and will be directed toward the effort of supplying adequate economic inventory together with the location and material status.

3. The Accountability of the Component Processing and Spare Parts

The justification of expendable items are completed after the material is issued. For the non-expendable items, the justification is completed when the item is deleted from inventory because of improper use or not economical to repair. Therefore, the control of expendable items are limited to GUHARPUS level, and for non-expendable items control encompasses the life of the item.

By identifying logistics problems within the TNI-AU, it was evident that the methods to improve control movement and efficiency of the supply system were necessary in order to provide for prevention of stock outages and for minimizing cost of inventory. At the present time the major portion of the inventory is handled manually. This results in a long procurement and delivery time, plus problems with control, location and status. The improvement of computer at KOMATAU and the installation of computers (at SKAMAT and GUHARPUS) for inventory control and requisitioning would not only result in a saving of manpower but would also provide faster, more accurate and more efficient delivery, location, and status of material.

C. PROPOSE PROCEDURES

1. Receipt

Upon receipt of material from vendors, a receipt inspection is performed, the item is then receipted into inventory and forwarded along with its paper work to the item stock point for storage/issue. The responsibility for thes actions is assigned to SKAMAT 82 [Ref. 1]. The following are the procedure for performing the receipt process:

a. In order for SKAMAT 82 to perform the receipt inspection procedures, they must maintain copies of requisitions, material procurement contracts, and shipping and receipt documents.

b. SKAMAT 82 must also maintain documentations on distribution of material and for whom it is intended within the Air Force.
c. The inspection of items must be carried out by the material inspectors present within SKAMAT 82 material receipt area. This prevents delays in the process of making inspections and acceptance or rejections of new material or repaired material arriving at the dock from vendors.
d. The validation of all receipted material is the responsibility of SKAMAT 82. If the material does not meet contract specifications then a non-validation form is sent to commanding general, KOMATAU for further action.

If this process were computerized the enormous work-load of maintaining the documentation would be minimized and validation or non-validation actions could be completed in a much shorter period of time thus decreasing material delays.

2. Storage

Storage entails warehousing, preserving, and management of inventory in accordance with Air Force directives. Specific procedures are to:

a. Maintain files on inventory.
b. Update inventory files as material is received.
c. Maintain warehouse layout and environmental storage conditions according to Air Force directives.

3. Issuance of Material

The management of the issue function entails:

a. Completing issue documents and updating files.
b. Issuance of material.
c. Reporting issues to the inventory control point.

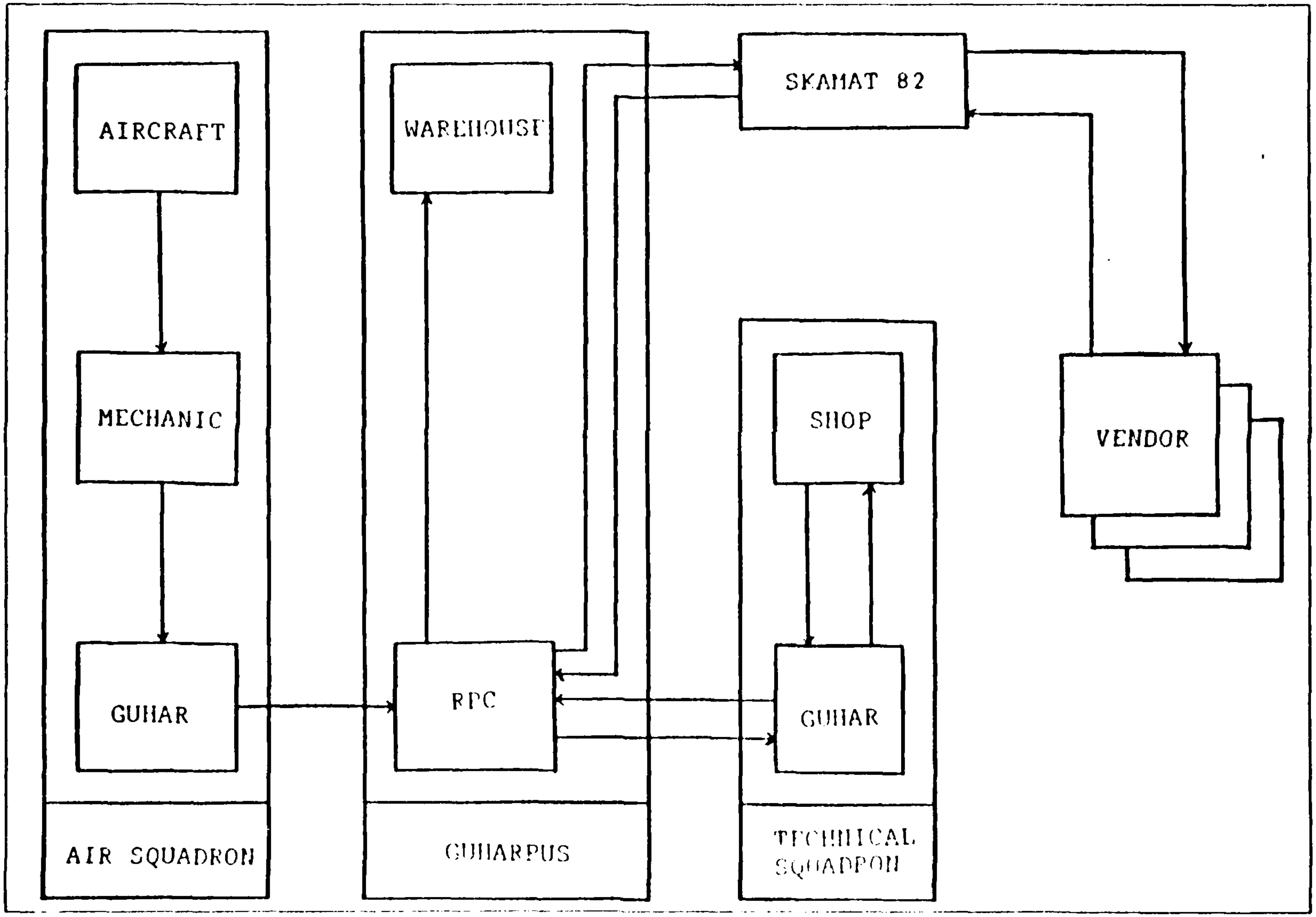

Figure 5.4 Component Repair Process

4. Component Repair

Repair of repairables can either be accomplished by Air Force intermediate or depot maintenance facilities; or by vendors within Indonesia or by vendors in foreign countries. Repair procedures are listed in the appropriate Air Force directives. (See Figure 5.4)

D. MATERIAL FORMS

The forms requisition, receipt, storage and issue should be standardized throughout the Air Force supply system. This would simplify inventory management and automation of the system.

1. To Simplify Inventory Control

To simplify the control of inventory, the following steps must be fulfilled:

a. Material form containing all data on materials specification.
b. Material form containing the authority to validate the material transaction so that it will not be contradictory with the valid certification or stipulation.
c. Material form being used so it also functions as a material transaction report.
d. Material form that does not have too many types and having the characteristic "single item document number" that is geared toward computerization. Thus, the above mentioned forms can be used by all echelons within the perimeter TNI-AU and for only one single item.

2. Material Forms that are Needed:

a. Warehouse cards to be found in every material storage warehouse.
b. Supply cards, to be found in Guharpus and Skamat.
c. Supply control cards, to be found in KOMATAU.
d. Material request and issue forms valid for components and spare parts.
e. Request and restitution for repair of component form.
f. Report of material receipt.
g. Inventory report.

E. ORGANIZATION

In order that the procedures can be applied smoothly and the inventory control function can be executed well, the existing organization structure (See Figure 5.5) needs to be arranged to encompass all functions that were connected with the inventory management. The following concepts are needed at the inventory control point and inventory stock points.

1. Inventory Control Point

a. Inventory Manager

The inventory manager would be responsible for the following:

(1) Determining and controlling the level of spare.
(2) Determining the number of components (together with the component manager) that must be possessed by the TNI-AU.
(3) The issue and transfer of spare parts.
(4) The procurement of the spares.
(5) To maintain purchase order contracts with vendors for purchase of spares.
(6) Monitoring of the stocking of spares.

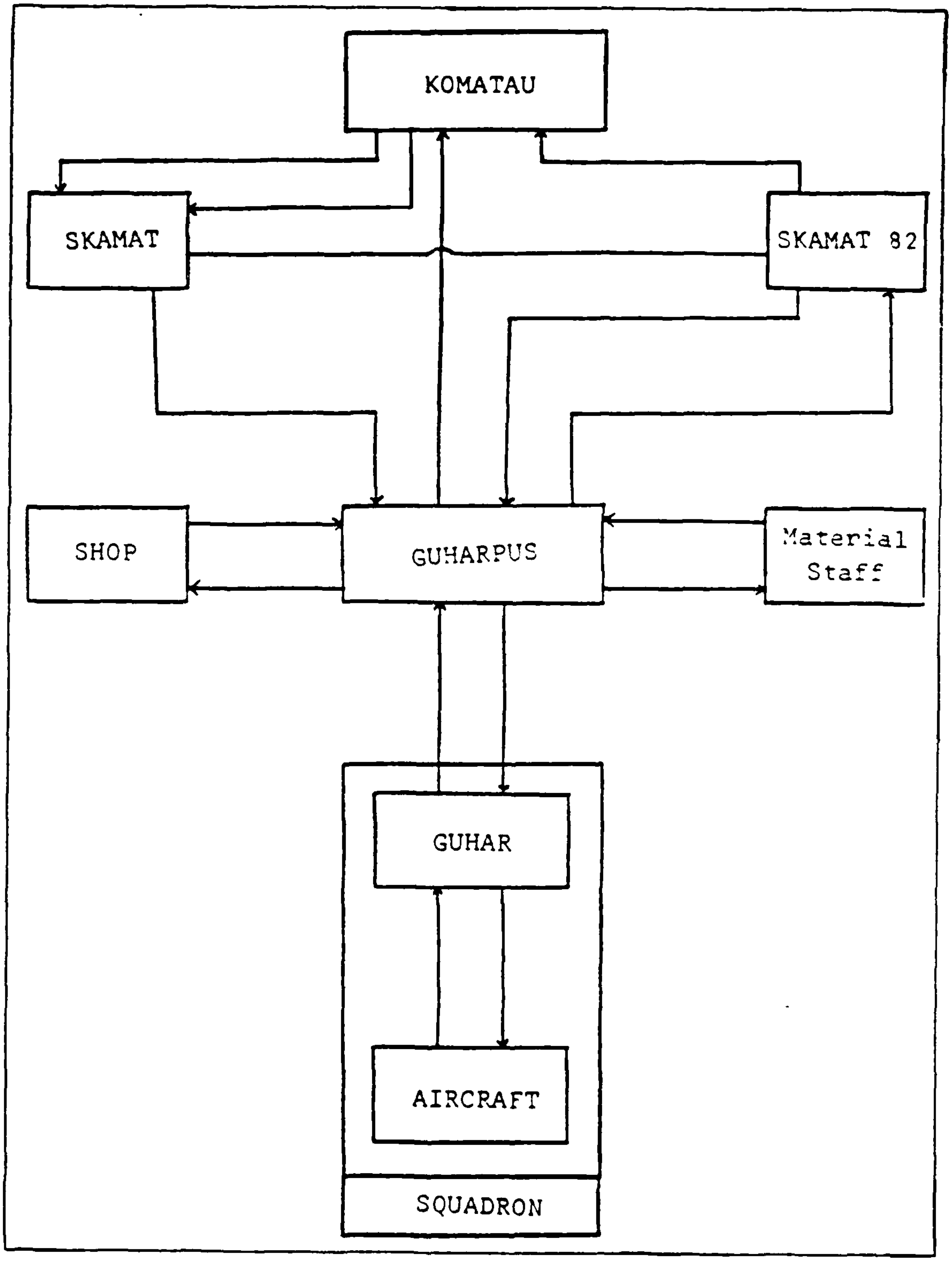

Figure 5.5 Process Requisition, Receipt, and Issue

b. Component Manager

Component manager is responsible for:

(1) To management of assigned components, monitoring of component status, storage, usage, and repair within or outside the TNI-AU.

(2) To provide usage informations and component status to System Manager.

c. Document Control Manager

The document control manager is responsible for:

(1) Monitors and controls status of procurement.

(2) Maintain all supply documentations to ensure rapid processing and delivery.

(3) Insure document standardization.

2. Inventory Stock Point

SKAMAT functions as the manager of stock points for the inventory and as such SKAMAT is responsible to:

a. Report inventory status to inventory control point.

b. Distribute receipted material to GUHARPUS.

c. Collection and shipment of repairables to appropriate maintenance activity or vendor.

3. Inventory Distribution

GUHARPUS is the distribution points and as such are responsible for:

a. Issue of material.

b. Maintenance of stock levels necessary to support operational units.

c. Forwarding requisitions for material not in stock to inventory control point.

d. Receipt documentation and forwarding to appropriate maintenance activities repairables that have been turned in as result of issues.

4. Issue Point

GUHARs are responsible to maintain operational stocks necessary to support squadrons. As such they are responsible for:

a. Issue material to squadron.
b. Receive and document turn-in of repairables.
c. Process supply requisitions initiated by squadrons.
d. Account for usage of material issued.

F. COMPUTERIZATION

1. General

In view of the maintenance problems due to inventory discussed in chapter three, the inventory control point must improve the present capability to process orders, and direct shipments throughout the supply system. With a range of items which constantly increases in size, the existing manual system, in terms of speed, accuracy, and reliability is already at its limit of capability without room for further expansion. Solutions to inventory control problems, such as those which exist within this system can be solved relatively easily through computerization. Since there already exists a limited computer technology in use by the Indonesian Air Force the natural progression is to a system offering the next level of sophistication. Included in this step would be improvements in hardware and software capability as discussed below.

2. Hardware

Presently, KOMATAU has a limited computer capability through use of a mini computer which receives and transmits data concerning material requisition to SKAMAT-82. This is admitedly a very narrow application of computer capability. In addition to the requisition of materials, the mini system is used to complement the remaining material supply system which is a totally manual operation. Daily reports are required from GUHARPUS listing materials issued to the squadrons. This data is entered into the computer which update particular line item status. Additionally, when conditions at the squadron supply point (issue point) reach pre determined levels, notification to SKAMAT, indicating material needed at the squadron level, is sent via letter mail or telephone, depending on the urgency of the situation. The system never reflects the true real time inventory level and suffers from severe "garbage in, garbage out" effects.

What is proposed is a distributed data network with a host computer at the inventory control point. Replacement of the mini at KOMATAU will be necessary to handle the following improvements. At each SKAMAT is envisioned terminals with limited processing capability and additional printing capability. The same hardware assets would be installed at GUHARPUS. The accuracy of inventory status would be greatly increased, not only in terms of actual item count, but in terms of real time reliability. Stock shortages would be greatly reduced as the central control would be able monitor all inventory assets quickly, without concern for updates enroute to KOMATAU. The data link for the units would be through the use of existing telephone lines. Further, the recommendation for "SMART" terminals at the various inventory stock points are necessary to provide a backup capability in the system. Should the computer at KOMATAU become unavailable for any reason, each activity must be able to monitor and update their respective inventory control information. This individual capability will require the addition of appropriately sized storage hardware, a combination of disk units for real time information processing, and magnetic tape units for storage and transmission of data.

3. Software

Software needs will be fairly significant, not only in converting and facilitating data input and manipulation, but also system software which enables the distributed network to communicate effectively. Because the present inventory accounting system is a recreation of the inventory control system used by the United States Air Force, the majority of costs will involve requisition and application, rather than development of an entire new software package. Programming material currently available does not enable the system to operate automatically, but will involve some effort to tailor the programs to the new hardware set up. The programs allowing communication between the hardware stations will require more development than operating software, as the physical layout will be individualized to suit KOMATAU.

G. SUMMARY

This chapter explained the use of economic order quantity model, by using this model it is hoped that the stockoutages of spares and components can be solved. Presently, the TNI-AU has limited computer capability, the proposal to automate the inventory control system is a necessary if efficiency is to be achieved. This chapter explains how such a system can be structured and the benefits of automation in inventory control.

VI. CONCLUSION AND RECOMMENDATIONS

The objective of this thesis is to review the management of aircraft maintenance and inventory control in the Indonesian Air Force's Logistics System. Aircraft maintenance is an essential element to enable the Indonesian Air Force to perform National defense. From the analysis of the maintenance and inventory systems several conclusions and recommendations are recommended.

A. CONCLUSIONS

Indonesia is the largest archipelagic country in the world. Its geographical location has made Indonesia strategically important in the context of regional and super-power rivalries. Because of this strategical importance and the country's geography high mobility for national defense is required. Therefore, the Indonesian Air Force has to maintain the capability to perform a highly mobile mission. In the performance of this mission, there are several problems with aircraft maintenance and supply which hamper the Indonesian Air Force in attaining aircraft weapons systems readiness goals. The problems are primarily caused by lack of aircraft maintenance standardization and poor inventory control.

B. RECOMMENDATIONS

Unit Commanders and maintenance officers must understand the objectives and goals of their organization and determine the priorities necessary for correct application of maintenance resources.

All inventory levels should have automated information and control systems to enable rapid response on material requests and to improve material distribution and communications between inventory stock points.

The Indonesian Air Force's Logistics System should implement the economic order quantity model (Figure 5.3) and use a safety stock level (Figure 5.2) to avoid stock out problems.

If these recommendations are implemented, the inventory manager at the inventory control point, by interacting with the automated system, could answer the following questions:

1. What kind of parts are needed and for what types of aircraft?
2. When are the parts and components needed and when to order?
3. How much are the parts going to cost?
4. From what source should they be ordered?
5. What is the lead time?
6. What are inventory levels at each storage point?
7. What are the anticipated usage factors?
8. What are the actual usage factors?
9. How often should parts be ordered to prevent stockoutages?

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