PERFORMANCE DEVELOPMENT METHOD FOR THE AVIATION SUPPLY CHAIN

by

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ABSTRACT

Severe competition in the global market impacts aviation business. Several airlines must adapt themselves to respond to new threat. Passengers and freight forwarders are expected to have lower service prices while being served with higher quality services. To compete with other airlines in the Asia-Pacific region, airlines in Thailand must manage their costs and service quality efficiently. Consequently, several factors that are critical to the airlines operations must be identified and analyzed. The objectives of this research are (i) to study the related factors which are significant to aircraft maintenance service, (ii) to study the Aviation Performance Benchmarking, (iii) to produce the Aviation Performance Development method, (iv) to produce the mathematical model for cost optimization, and (v) to implement the designed aviation supply chain model to four air operators and one aircraft maintenance center in Thailand. Finally, results from this research are used to formulate aviation policy and reported to the government in order to make the proper decision to enhance Thai aviation industry competitiveness.

KEYWORDS
Aircraft Maintenance, Supply Chain, Performance Measurement, Cost Improvement

INTRODUCTION

In business’s world, companies no longer compete with other companies in the same business but they compete in terms of their associate supply chains. All companies in the most effective supply chain win (Christopher, 2005) (Malone, 2007). Consequently, the supply chain performance must be assessed and improved to enhance its competitiveness.

Recently, most airlines face crisis from increasing fuel price and uncertain market demands (Armstrong, 2009). Impacts from fluctuated fuel price and unexpected event result in less numbers of travelers. Under uncertain incomes, airlines require low maintenance cost, effective spare part control, high skilled work force, and high-level inspection services from third parties (Choy, Harry, et al., 2007). Although the nearest maintenance material suppliers are in Singapore, most of Thai airlines buy maintenance materials from other countries far further e.g. USA, UK, France, Australia, and etc. Since several maintenance materials supplied are not available in Singapore. Hence, Thai operators must directly purchase materials from USA and Europe, which result in longer lead-time and higher cost (Cooper, Seiford et al, 2006)

Today, the airline businesses are highly competitive. Thus, airlines must minimize their costs. For military aircrafts, they are required to utilize their limited maintenance budget for all aircrafts. Consequently, the effective performance measurement method must be developed. This measurement method must be able to estimate the future cost pattern and allow the airline management to make a proper decision based on cost minimization.
This research will investigate the critical factors which are significant to aircraft maintenance service, and then establish the effective performance measurement method. Later, the optimum solution to minimize maintenance costs with the best maintenance performance is developed in this research. Finally, decision support algorithm that is able to choose several operating resources which will effect to performance and maintenance costs.

LITERATURE REVIEW

Aircraft Maintenance

It is very important to clearly understand the meaning of aircraft maintenance. There are several definitions of aircraft maintenance by difference expertise in aviation together with aircraft maintenance.

<table>
<thead>
<tr>
<th>Author</th>
<th>Definition</th>
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<tr>
<td>International Civil Aviation Organization (ICAO, 2009)</td>
<td>Maintenance: The performance of tasks required to ensure the continuing airworthiness of an aircraft, including any one or combination of overhaul, inspection, replacement, defect rectification, and the embodiment of a modification or repair</td>
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<td>Federal Aviation Administration, Department of Transportation (FAA, 2009)</td>
<td>Maintenance means inspection, overhaul, repair, preservation, and the replacement of parts, but excludes preventive maintenance</td>
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<td>Kroes and Rardon (Kroes &amp; Raedon, 1993)</td>
<td>Preventive maintenance means simple or minor preservation operations and the replacement of small standard parts not involving complex assembly operations. Alteration refers to changing the design of the aircraft from that originally certificated. Alteration range from major changes in the structure or engine to the addition or removal of relatively minor equipment.</td>
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<td>Knotts (Knotts, 1999)</td>
<td>Maintenance is defined as those action required for restoring or maintaining an item in a serviceable condition, including servicing, repair, modification, overhaul, inspection, and the determination of condition</td>
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<td>(Mobley, Higgins, &amp; Wikoff, 2008)</td>
<td>Maintenance as Art, Science and Philosophy</td>
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<td>(Hessburg, 2001)</td>
<td>Maintenance is the action necessary to sustain or restore the integrity and performance of the Airplane</td>
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<td>(Kinnison, 2004)</td>
<td>Maintenance is the process of ensuring that a system continually performs its intended function at its designed-in level of reliability and safety</td>
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<tr>
<td>(Illman, 1994)</td>
<td>Maintenance means the inspection, overhaul, and repair of aircraft, including the replacement of parts. Its purpose is to ensure that an aircraft is kept to an acceptable standard of airworthiness throughout its operational life.</td>
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<td>Air Force Instruction 21-101 Dated 26 July 2010 (McMahon, 2010)</td>
<td>Aircraft and equipment readiness is the maintenance mission. The maintenance function ensures assigned aircraft and equipment are safe, serviceable, and properly configured to meet mission needs. Maintenance actions include, but are not limited to, inspection, repair, overhaul, modification, preservation, refurbishment, troubleshooting, testing, and analyzing condition and performance</td>
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Importance of Aircraft Maintenance

The regular operation of any systems or equipment is continuous deteriorating and then malfunction which there are two damaged issues.

FIGURE 1
THE NATURE OF THE MATERIALS DETERIORATION

1. The damage from production means damage caused by the production since the agency or the manufacturer that designed and built which caused by the system or equipment has been designed and just applying them. Although manufacturer tested for use but it is likely that the defect was possible. Figure 1, we would see that the damage caused by the production. The “Failure of Weak Items” line show high hazard rate occurred only in beginning of using, but when a system or device has been used to gradually reduce the damage rate.

2. The damage from using is the damage occurred when the system or equipment or may be said that the deterioration which results in decreased performance over time. Therefore, damage or deterioration will depend on time, as seen from the curves wear out. The rate of deterioration of the hazard rate is increases as the time in a manner exponential which will create harmfulness of work, especially when it is much used during first period. The maintenance, care processes insuring by manufacture or high experiences are the way to keep the aircraft secure operation.

3. Externally Induced Failure is component failures which do not occur from operation or production but from others sources. Figure 1, the Hazard rate is steady. It may be happen anytime during using.

So, the maximum component service life or minimum hazard rate is in middle period of it’s throughout lifetime. The owner should perform operation check and service at appropriate time in order to keep longer lifetime or until its design lifetime.

As of previous reasons, once the component is accumulating some using time. It is possible to damage from deteriorating. Owner should plan the maintenance schedule at convenience time by referring the manufacture manual. Without the proper maintenance system will create the problems in operating which may be caused the aircraft lost and fatal. Furthermore; Aircraft, Engine, and installed components are highly value and not capable to procure in short time. So, the maintenance is important to keep aircraft ready for operation. (Kinnison, 2004)

The Benchmarking of Performance in aviation

1. Costs are the expenses of work task which may be in-source or outsource for materials, man power, tools and processes (technical publication). Figure 2, the development of a Performance Measurement System to monitor the effectiveness of the logistics flow in handling various components for rework, maintenance or replacement and benchmark with the best-in-class practice, is crucial in the aviation industry. (Choy, Harry, & Lee, 2007) The operation directly affects the cost of the product or service and thus its purchase price through its direct or indirect control of the supply chain. The higher costs and prices make the lower competitiveness. (Beckman & Rosenfield, 2008)
2. Quality assurance is a system engineering discipline which embodies the process of quality control, inspection, management, policies and oversight procedure which will instill understanding. (Langford, 2006) The Performance Measurement System should also help to identify such gaps and to design effective and efficient improvement strategies. (Gopal, 2002)

3. Reliability is the probability that a system will perform its intended function for a specified interval under stated conditions. Reliability is a significant contributory factor to maintainability. (Langford, 2006) The failure rate dictates the frequency of unscheduled corrective maintenance (or repair) of a system affected by random malfunction. Low reliability indicates frequently failures, which in turn dictate more frequent corrective maintenance, which in turn mandates increased maintenance support in the form of facilities, skilled technicians, tools and supporting stocks of spare components and repair piece-parts. Increased system reliability based on high quality components can greatly extend the intervals of operation between failures and eliminate or minimize corrective maintenance support requirements. (Department of the ARMY, 2007)

4. Maintainability is the ease and speed with which any maintenance activity can be carried out on an item of equipment, may be measured by Mean Time to Repair. It is a function of equipment design, and maintenance task design (including use of appropriate tools, jigs, work platforms etc.). Once a piece of equipment has failed it must be possible to get it back into an operating condition as soon as possible, this is known as maintainability. To calculate the maintainability or Mean Time To Repair (MTTR) of an item, the time required to perform each anticipated repair task must be weighted (multiplied) by the relative frequency with which that task must be performed (e.g. no. of times per year). MTTR data supplied by manufacturers will be purely repair time which will assume the fault is correctly identified and the required spares and personnel are available. The MTTR to the user will include the logistic delay (Langford, 2006)

5. Time is referred as the lead-time since service requested by customer until completely fulfills that requirement. Performance Management System needs to be linked to operational characteristics, as the selection of maintenance logistics providers is part of management of supplier relationship. Flight delay is one issue which makes passengers misses their appointment, business meeting and connecting flight. The on-time performance of an airline is of significant concern to an airline traveller. (Vasanthakumar, 1995)

6. Availability is defined as the percentage of time that a system is available to perform its required function(s). (Department of the ARMY, 2007) It is the measure of the readiness of a system to fulfill its assigned function, and measure the capability of a system to be committed to operation. Availability is sensitive to and determined by the trade-off between system reliability and maintainability. (Langford, 2006)

7. Flexibility/Replaceability is ability of production plant or service provider to switch the planned operation to other process or solution and then meet the customer expectation. (Adegoke, 2005) Supply Flexibility is ability to reconfigure the supply chain, altering the supply of product in line with customer demand. The flexibility is composed of
two dimensions; (1) Resource flexibility which a resource can be applied to a range of alternative uses, the costs and difficulties associated with the switching from one resource to another, and the time required for the switch; (2) Coordination flexibility is flexibility in those processes that redefine product strategies, reconfigure chain of resources to product, and re-deploy those resources needed to produce the product. (Leslie, Robert, & Rhonda, 2003)

THE CONTEXT OF RESEARCH PROBLEM

Figure 3, the aviation industry; there are many airline types (passenger, freighter, special mission, etc.). They have aircrafts in difference model. All aircrafts need to perform maintenance service per safety regulation of International Civil Aviation Organization (ICAO). (Pleumpirom & Amornsawadwatana, 2009)

FIGURE 3
THE SUPPLY CHAIN OF AVIATION

Model

The concept of model formulation is multi-objective optimization linear programming. At first we will start on cost variable, when we success in this variable on all factors we will continue add the following variable until five variables.

There is a fleet of aircrafts which must be provided M maintenance services (Daily check, Weekly check, A-check, C-Check and unscheduled repair) in a year (from January to December). Each service is having N jobs, and each job require aircraft part/material.

Assumption
- \(a_{ij}\) is the selling prices of material for job \(j\) of service \(i\).
- \(b_{ij}\) is the loaning prices of material for job \(j\) of service \(i\).
- \(c_{ij}\) is the repairing prices of material for job \(j\) of service \(i\).

Decision variable:
- \(X_{ij} = 1\) if we choose to buy the material for job \(j\)^{th};
  \(= 0\) otherwise.
- \(Y_{ij} = 1\) if we choose to loan the material for job \(j\)^{th};
  \(= 0\) otherwise.
- \(Z_{ij} = 1\) if we choose to repair the material for job \(j\)^{th};
  \(= 0\) otherwise.
Objective function:

\[
\text{Minimize } z = \sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij}X_{ij} + b_{ij}Y_{ij} + c_{ij}Z_{ij} \quad (1)
\]

Constraints:

\[
X_{ij} + Y_{ij} + Z_{ij} \leq 1 \quad (2)
\]
\[
Y_{ij} - Z_{ij} = 1 \quad (3)
\]
\[
X_{ij} = 0 \text{ or } 1 \forall (i,j) \quad (4)
\]
\[
Y_{ij} = 0 \text{ or } 1 \forall (i,j) \quad (5)
\]
\[
Z_{ij} = 0 \text{ or } 1 \forall (i,j) \quad (6)
\]

The objective function (1) is to minimize to total cost of aircraft parts/material in all maintenance services of all aircraft in fleet for one year. Constraint (2), the logistics manager can choose only one choice of material source for each job \(j\). Constraint (3), if they choose loan they must choose repair.

**CONCLUSION AND EXPECTED CONTRIBUTION**

This research will support commercial aviation industry or the military aircraft fleet in survival under limit cost or certain budgetary. The building model from this research will assist the aircraft operators in decision support of resources selection. The Air Operator could develop the mathematical algorithm in their maintenance to optimize relative benchmarking and continue their best operation to enhance their competitive advantage.

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