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Title: E-ENABLING MAINTENANCE, REPAIR AND OVERHAUL (MRO)
OPERATIONS FOR AN AFRICAN AIR TRANSPORT OPERATOR: A CASE STUDY

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Abstract:

Air transport remains a highly competitive sector, with the global economic downturn adding to the already challenging operational environment. The International Air Transport Association (IATA) forecast heavy losses of around \$9 billion in 2009 but in reality these losses amounted to \$6 billion in the first half year alone (Seattle Times, 2009). According to Maple (2001), maintenance, repair and overhaul (MRO) costs typically account for 10-20 per cent of aircraft-related operating costs, as they are process-intensive and controlled at all levels of the product life cycle in order to meet robust certification requirements. Current methods of managing MRO are limited due to their inherent legacy structures, restricted visibility and reactive modes of operation, leading to excessive operating costs. Such costs account for lost revenue when measured in terms of aircraft downtime. The objectives of this research are to propose new methods of e-enabling MRO operations in global aerospace supply chains.

Introduction

According to Knotts (1999) the airline industry is one of the most unique businesses. Complexities associated with the aerospace sector and the difficulty in achieving competitive advantage is evident in the small percentage of new operators that manage to remain in business 2 years after their inception. According to Rosen (1995) as cited in Rhoades and Tiernan (2005), over 200 start-ups went out of business since US deregulation in 1978 until 1995. However, recent figures pertaining to the number of air transport operator bankruptcies published in recent months since the latest economic downturn indicate a startling view; over 85 air transport operators ceased operations in the last year alone (Flight International, 2009 and Financial Times, 2008). Both the passenger and air cargo sectors in particular are vulnerable to social, political, economic, environmental and health triggers and events, such as the 9/11 terrorist attacks, the H1N1 pandemic outbreaks and more recently the economic downturn in global markets. In economic terms, it could be argued that the development models used for the air transport sector are inherently constrained by the very fuel that powers the product itself. Fuel costs continue to account for roughly a quarter of operating costs of existing airlines, although many future models are focusing on achieving non-reliance on traditional sources of energy (Michaelides, 2009). New generation aircraft, such as the Boeing 787, “promises 20% improvement in operating margins, 30% reduction in maintenance costs (compared to a Boeing 767) and doubling of time needed between heavy maintenance checks” (Aerospace International, 2010). Such impressive gains are achieved not only through performance but also through operational efficiencies, such as extending MRO times between heavy inspections. In the UK there are signs of a trend towards the increasing operation of all-cargo services, dedicated to the carriage of freight and mail. According to Keynote (2004), “the UK air freight market was worth £726.1m in 2004, most of which is attributed to international services”.

Objectives

This research focuses on e-enabling maintenance, repair and overhaul -MRO operations for an international air transport operator in the dedicated airfreight/cargo sector. The company is based in Africa and has a small fleet of dedicated cargo jet aircraft. According to Keynote (2004), the majority of freight services are non-dedicated, i.e. being provided as a by-product of scheduled passenger air services in the belly holds of aircraft. This model may apply well to continents or regions with suitable air transport infrastructures, such as Europe or North America, where scheduled services are frequent, reliable and effective. However, many African operators are constrained by resources and have traditionally relied on either foreign international air carriers or dedicated international freight carriers, such as UPS to service this sector. In more recent years, a number of home-grown operators have emerged with varying success. Since many such company's typically operate older out-of-production aircraft, the challenges of managing MRO operations in the most cost effective and reliable manner are key drivers to enabling such companies to offer competitive services and rates, thus helping maintain market presence. The objectives therefore of this research are to develop an e-enabled MRO system that helps to manage operations in a safe as well as cost-effective manner.

Scope

The aerospace industry ranks between the largest manufacturing industries worldwide; it makes sense therefore to utilise cutting edge technologies not only in the design of new products but also in the improvement and maintenance of existing ones. Through the past years air transport operators around the world have been expanding their use of information technology (IT) especially in key area such maintenance , engineering and flight operations. The use of IT systems, such as e-MRO, can tighten up the interval utilisation losses for all

checks, through better co-ordination and timing of maintenance visits, availability of facilities and other resources (Tsilivakou, 2009). Better interval utilisation between maintenance checks would also improve aircraft operational efficiency and increase availability, leading to optimised operations (Aircraft Commerce, 2004).

Operational efficiency requires system integration throughout an airline’s operations. The objective here is to e-enabled the systems environment in order to integrate real-time data with an air operators maintenance planning and reliability systems (Tsilivakou, 2009). This level of integration enables just-in-time adjustments to planning, record management, and airline cost accounting, with the objective of maintaining an “as-flying” aircraft configuration (Rencher 2009). The scope of the e-MRO system development aims to achieve and maintain a similar “as-flying” configuration as described above, through integration of maintenance programmes, maintenance plans and manufacturing execution.

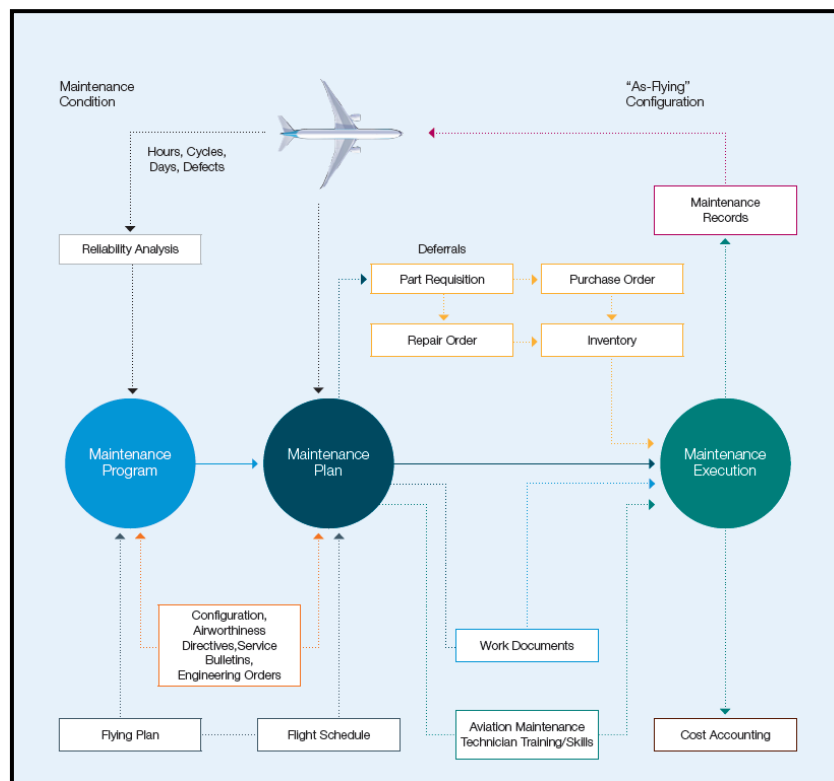


Figure 1: Elements of real time visibility into airline operations (source: http://www.boeing.com/commercial/eromagazine/articles/qtr_01_09/article_04_1.html)

Case Study Methodology

Case study research was carried out with an African air transport operator, leading to the development of a new system to manage the MRO operations in an integrated, aligned and proactive manner. The DOMAIN 3-stage methodology was adopted for this work; see Michaelides (2003), reference Figure 2. This follows the modified waterfall method and starts with the value proposition (or e-proposition/to-be analysis), followed by the prototype development stage (e-prototyping using RAD –rapid application development tools and Internet technologies) and finally the e-Analysis stage involving comparative and qualitative analysis of business benefits.

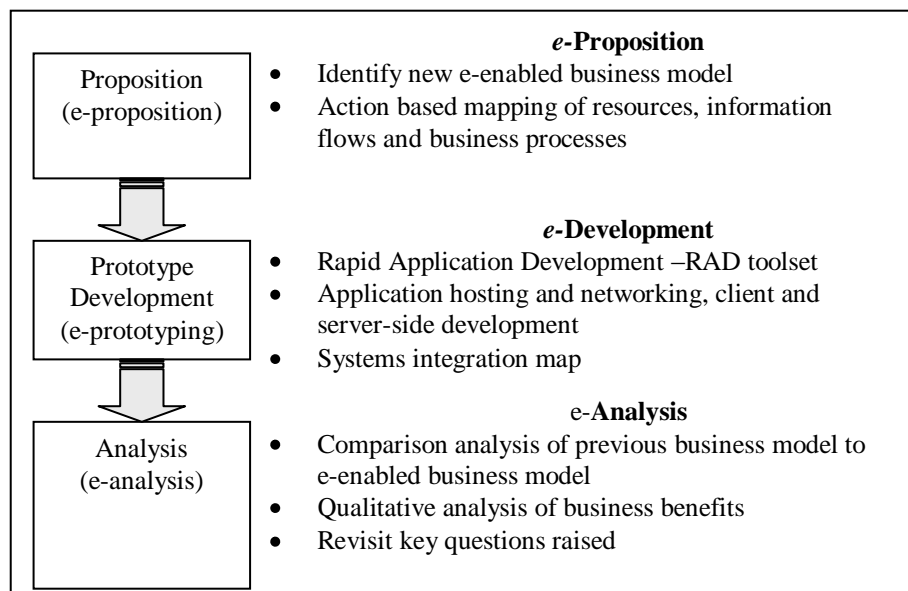


Figure 2: The DOMAIN research methodology map, Michaelides (2003).

E-Proposition

The e-MRO system will provide many benefits to the company and contribute to its long-term strategy of maintaining a competitive market presence. By using the web-based solution, the company will be in a better position to optimise its maintenance and overhaul activities, whilst integrating its procurement and supply functions. In addition, it shall be able to forecast its maintenance needs more accurately and better identify downtime requirements. Scheduling will also be improved resulting in more efficient maintenance operations. Through the introduction of relevant performance and condition monitoring

programmes, such as engine parameter monitoring, the e-MRO system will assist the company to achieve maximum utilisation of its aircraft fleet and resources whilst operating at safe limits.

The proposed solution will provide a holistic system view, that will provide benefits to the company, its employees, as well as its partners and suppliers. The system will also aim at improving current business processes by removing non-value adding activities that are currently present. It is further proposed that the company view this as an opportunity to re-engineer its current operations, in a similar manner that enterprise resources planning - ERP systems use business process re-engineering - BPR to implement lean thinking methods.

E-Prototype Development

The prototype application was developed using Rapid application development – RAD methods. Internet-enabled technologies were used to extend the functionality of the existing legacy systems and to integrate the company's suppliers and partners. Figure 3 illustrates the proposed architecture for the e-MRO solution. The prototype system was based on the three-tier client/server architecture. Open source systems were largely used, such as PHP 4 for scripting language and MySQL for the database layer. However, the first production version used the .NET framework with Microsoft SQL server, which was selected for its robustness and ease of development.

The system was designed to ensure ease of maintainability and scalability. All pages use cascading style sheets (CSS), templates and includes. This minimises the time needed to update pages and improves consistency throughout the application. Many system functions are modularised as this can simplify the process of making changes to the new system. This also enables a user with appropriate access rights to add and update information.

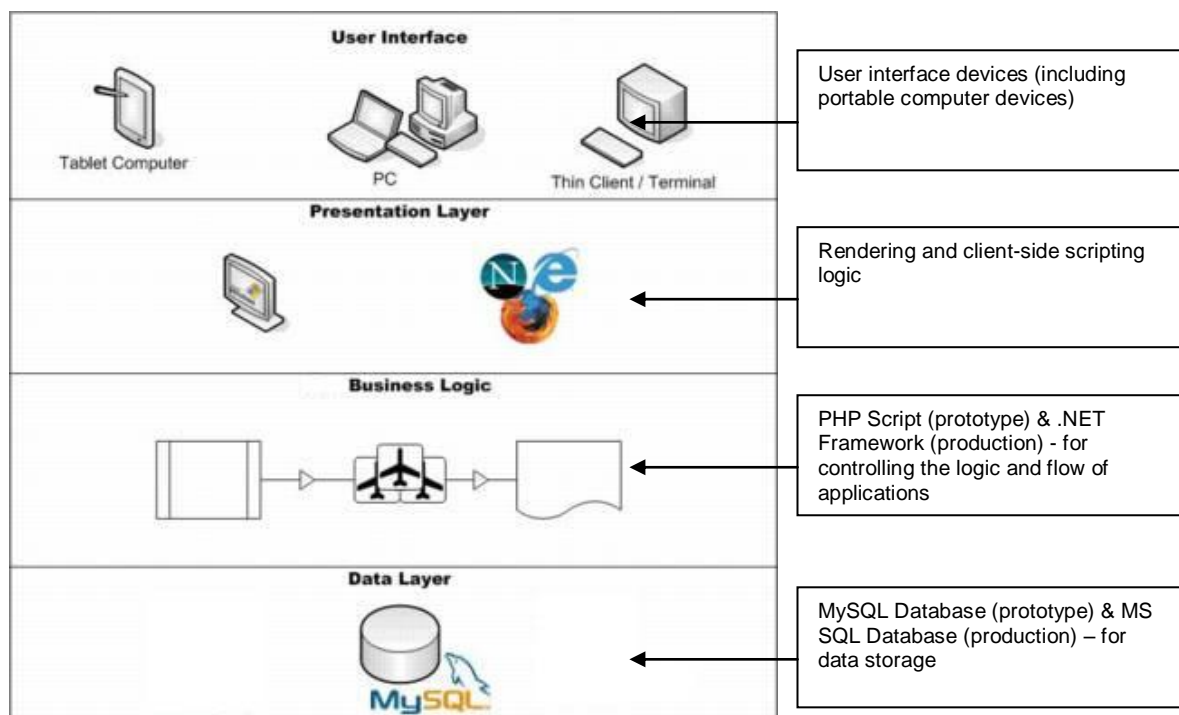


Figure 3: e-MRO system three-tier architecture (adapted from Butler 2006)

Functionality

Users are able to add scheduled maintenance checks for aircraft by selecting the type maintenance check to be completed, the maintenance company completing the check (if contracted to a 3rd party maintenance organisation) and the maintenance check start/end date. Once new aircraft maintenance checks are scheduled, all appropriate information is made available internally of to the 3rd party maintenance organisation, in order to plan, schedule and prepare all necessary resources and ensure the maintenance activities are completed on time. All work cards and supporting documents are available electronically and these can be assigned and accessed at any location, without the need for paper-based material.

The proposed solution offers data integration throughout all the system functions. The e-MRO system queries data from various database tables to provide the user with the required information. If the user updates information on the system, this information it then updated throughout the related database tables, thus ensuring complete data and system integrity.

All maintenance records and maintenance task cards are raised, cleared, released and approved electronically, resulting in better visibility and control of the task. In addition, post-maintenance work is minimised as records are directly maintained and archived electronically. All maintenance task cards are accounted for through tally sheets, which maintain records of any outstanding cards or individual tasks or records. In the interests of safety, it is not possible to close-off maintenance checks with any outstanding items still present.

Integrated Flight Parameter Management (IFPM)

The ability to accurately and effectively track the lifecycle parameters for aircraft lies at the very core of all MRO operations. Therefore systems that control such critical information have to conform to the highest standards of safety.

The Integrated Flight Parameter Management (IFPM) module was specifically developed during this case study (Muller 2009), and was the subject of future research in previous e-MRO system developments. This area of the system was designed to track and maintain the key flight parameters, such as flight hours and flight cycles for the aircraft, its engines, as well as components within each engine, such as engine discs, see Figure 4.

A/C Reg. No. – Engine Disc Sheet- #1										
Displayed Plane: _____ Total Cycles: 24162 Total Hours: 73262 h 2 min Last Recorded Flight: 11/17/2009 10:21:00 AM										
Position	Serial	Model	On-Wing Date		Total Cycles	Total Hours				
1	671425	JT3D-7	1/1/2008 1:00:00 AM		19425	46906 h 12 min				
Engine Serial	Engine Model	Hour Limit	Cycle Limit	Date Limit	Historic Cycles	Historic Time				
671425	JT3D-7	0	0		19519	46498 h 0 min				
Position	MFGsPN	DiscSerial	DateLimit	HourLimit	Total Hours	Time Left	CycleLimit	TotalCycles	Cycles Left	Comment
C-1	739201	5A6232		0	31693 h 35 min	-	14000	13291	709	Cycle2ndLimiter
C-2	629302	220293		0	31612 h 35 min	-	20000	15835	4165	-
C-4	719404	J49917		0	16866 h 35 min	-	30000	7800	22200	-
C-5	719505	J49821		0	27587 h 35 min	-	30000	11167	18833	-
C-6	7196066	KD4439		0	16866 h 35 min	-	30000	7800	22200	-
C-7	726907	H52945		0	23296 h 35 min	-	30000	11168	18832	u

Figure 4: Engine disc sheet

The IFPM module provides core data for all other modules within the e-MRO system environment, such as life-controlled items, airworthiness directives and other utilisation and calendar controlled parameters. The functionality for this module includes all the facilities to effectively manage and monitor the flight data. This includes entering, editing and deleting flights as well as managing engines and engine discs. It also includes all the functionality that supports these functions, such as validation and interface utility. The IFPM module addressed the issues of the prototype system by using a different data structure for tracking flights as well as for input validation. The input validation includes both logical validation as well as format. The system was fully tested and demonstrated its ability to track aircraft key parameters in a robust and accurate manner.

Data verification algorithms

Data verification algorithms within the system are designed to maintain data integrity and eliminate input errors. Examples of this include the controlling of flight sector time durations and airport code identification. In the example below, reference the relevant input screen of the e-MRO application, the system has detected that the current departure airport code is different to the last arrival airport code. A warning is generated and the system does not allow the incorrect data entry to be recorded, see Figure 5.

The screenshot shows the 'New Flight' form in the e-MRO system. At the top, there are navigation tabs for 'Overview', 'Flights', 'Engines', 'Aircraft', and 'Users'. The 'e-MRO' logo is in the top right corner. The form title is 'New Flight'. A red prohibition sign icon is next to an error message: 'There was a problem inserting the Flight: The flight records state that the location of this plane on the 18.06.2009 09:08:00 was NCL'. The form fields are as follows:

FlightNumber	ACE817
DepartFrom	MLA
DepartTime	Date: 18/6/2009 Time: 09:08
ArrivalTo	NCL
ArrivalTime	Date: 18/6/2009 Time: 12:38
Log Number	089
IsVoid	<input type="checkbox"/>

At the bottom of the form, there are 'SAVE' and 'CANCEL' buttons.

Figure 5: Edit Flight Data User Rights

Modelling e-MRO system

In order to model the e-MRO system application development, use case diagrams were developed and used. According to Bennet et al (2005), a use case is part of the Unified Modelling Language (UML), a visual language that provides a way for people who analyse and design object-oriented systems to visualise, construct and document the artefacts of software systems and to model the business organisations that use such systems. UML is a visual modelling tool that enables developers to capture a perspective of a system. The visual model can be used to communicate the system to clients, developers, programmers, etc, using diagrams to represent multiple views of the system (Butler, 2006). It should be pointed out that UML is neither a language such as a human language nor a programming language; nevertheless it is subject to set of rules that determine the use of the language. Most of the elements of UML are graphical and promote the understanding of the illustrative representation of a system and its activities by users that are perhaps not familiar with programming languages (Tsilivakou, 2009).

However UML is not to be thought as a method or methodology or software development process. In many cases some software modelling tools may take a UML model and generate a programme code in different language from it but in those cases the developer would still have to write a code to implement the methods (Tsilivakou, 2009). An example of a use case diagram for the specific function of editing a flight record is illustrated in Figure 6.

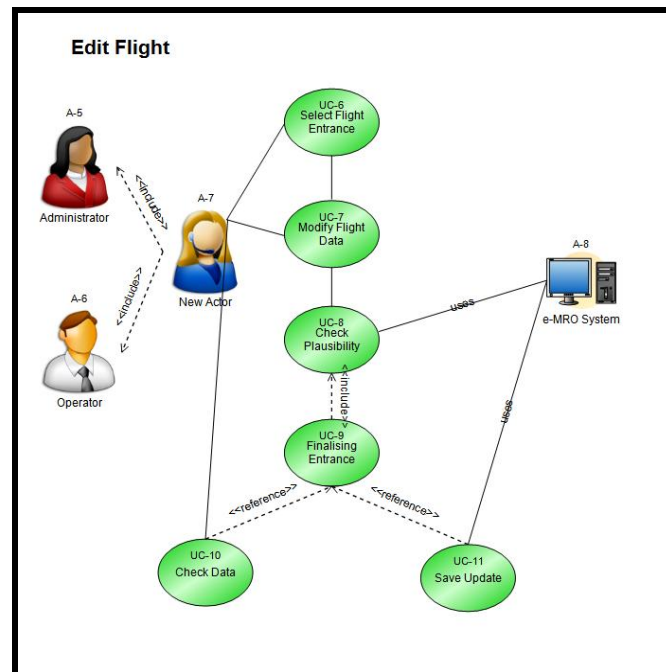


Figure 6: Edit Flight Data User Rights

E-Analysis

Previous methods of managing e-MRO operations can be described as demanding, particularly so for small air transport operators within the air cargo sector operating from less developed parts of the world whilst using older aircraft. The ongoing challenges of being competitive whilst maintaining high airworthiness standards can be daunting. For many company's operating in markets dominated by large international carrier's means that opportunities are scarce and profits are often marginal. Legacy cargo carriers are often forced to operate further from their catchment areas and forced to settle for more challenging conditions. Operationally effective and cost effective MRO operations have the potential to keep legacy carriers in business for longer, and enable them to operate safer and not so close

to margins often imposed upon them. One of the advantages of using e-MRO systems is that they improve operating baselines, since such systems manage MRO operations in a cost-effective and efficient manner. E-MRO systems therefore offer far more than just superseding paper-based systems; they are increasingly valuable tools for ensuring safe and efficient operations. It is ironic that the sector most in need of such systems is the legacy type operators, such as the company described herein, who also constitute the group with the least uptake of electronic-based maintenance program adaptation.

Conclusions and future work

This paper has described the development of an e-MRO system for an African air transport operator in the cargo/air-freight sector. It has presented the objectives of the system and outlined the benefits of utilising such e-enabled maintenance, repair and overhaul systems to achieve competitive advantage through task optimisation. In addition, integration of the maintenance programme, maintenance plan and manufacturing execution elements were demonstrated through the functionality of the e-MRO system. The case study has further shown that use of the e-MRO system has led to enhanced operational visibility leading to better integration with suppliers and partners. The system has also improved resource utilisation and availability through advanced sourcing and scheduling of supplies and service requirements. Furthermore, the system has allowed for a more proactive approach to maintenance philosophy through the inclusion of reliability and condition monitoring programmes. Finally, this work has introduced development of the IFPM-integrated flight parameter monitoring, an application which provides enhanced functionality for managing and maintaining aircraft utilisation data, such as aircraft flight hours and flight cycles. In achieving this, the e-MRO system development has been upgraded from PHP 4/ MySQL open source software to the .NET Framework/ MS SQL, further demonstrating its scalability and enhancing its functionality.

Future research is conducted by the University of Liverpool Aerospace Management Systems Group – ASMG and involves:

- further expansion of the e-MRO system to accommodate multi-aircraft fleet types and operators,
- introduction of mobile enterprise applications for fleet optimisation, and
- development of aligned collaborative frameworks for linking-up operators, regulators, suppliers and manufacturers through common networks.

Additional future research involves:

- the use of global positioning software – GPS, and radio frequency identification – RFID technologies for enabling automatic data transfer and uploads to the e-MRO system.

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