

Prerequisites for a Business-oriented Fleet Availability Assurance Program in Aviation

Alireza Ahmadi
Luleå University of Technology
Division of Operation and
Maintenance Engineering
SE-971 87 Luleå, Sweden
+46 (0)920 49 10 00
Alireza.ahmadi@ltu.s

Ramin Karim
Luleå University of Technology
Division of Operation and
Maintenance Engineering
SE-971 87 Luleå, Sweden
+46 (0)920 49 23 44
ramin.karim@ltu.s

Javad Barabady
University of Tromsø
Department of Engineering and safety
N-9037 Tromsø, Norway
+46 776 60389
Javad.barabady@uit.no

ABSTRACT

The air transport business is a large, integrated, automated and complex domain with high requirements on safety, security and dependability. In order to achieve customer satisfaction and gain a global competitive advantage, provision of services is essential. In air transport business with an extensive competition, the consequences of unreliable services become more critical which may increase cost of operation and reduce productivity. Furthermore, occurrence of unreliable services might also lead to annoyance, inconvenience and a lasting customer dissatisfaction that can create serious problem with regarding the responsible company's marketplace position. Hence, it is crucial for air transport companies to continuously improve the quality of the services they provide to customer. In the context of air transport, maintenance process and maintenance-related services have a high impact on effectiveness, productivity and costs. Maintenance departments are required to ensure that their fleet is expected to meet, or continues to meet, airline's established availability performance goals (e.g. operational readiness, dispatch reliability and cost affectivity) and to ensure that demands for deliveries will met. One way to align maintenance decisions and business objectives and at the same time highlight where the potential weakness in the systems and maintenance performance can be expected, is through Fleet Availability Assurance Program (FAAP). However, an effective implementation of FAAP needs adaptation to the usage context. Hence, the purpose of this paper is to present an availability assurance program in airline industries, in which the essential functional elements of such a program are discussed. The paper also proposes an integrated information logistic infrastructure for this management system.

Keywords

eMaintenance, Availability Assurance Program, aviation maintenance, maintenance program.

1. INTRODUCTION

Air transport business is large, integrated, automated, and complex, in which, providing a safe, dependable, and best in class services have become a strategic issue, in order to meet customer requirements and also to gain a global competitive advantage. When dealing with complex technical systems and in an extensive competition, the consequences of unreliable services become more critical which may increase cost of operation and reduce

productivity. These can also lead to annoyance, inconvenience and a lasting customer dissatisfaction that can create serious problem with regarding the responsible company's marketplace position. This consequences are crucial since a company (e.g. air carrier) can rapidly be branded as unreliable after providing poor service, whereas building up a reputation for reliable services takes a long time. Therefore, air carriers are constantly trying to achieve high standards of safety and services at minimal cost (Sachon & Pate, 2000).

Over the past decades also, significant improvements in airline services have taken place. However, passengers still expect an affordable service and punctuality has become one of the most significant factors for defining a passenger's satisfaction with an airline (Herinckx & Poubeau, 2000).

A report released by Euro Control (2004), four scenario-based forecasts of air traffic demand for the next 20 years. In the highest growth scenario, the annual demand rises up to 21 million flights a year with more than 60 airports congested, the top 20 airports being saturated at least eight to ten hours a day. Given this forecast, it is obvious that an operational disruption would have deeper operational and economical consequences than today (Eggenberg et al., 2010).

Hence, with a global rise in air travellers' market demand and restrictions in capital investment budget, higher operation performance (flight operation) is expected. This requires management of availability performance of operational resources for flight operation with accepted level of uncertainty. Examples of operational resources include airport slots, flight routs, crew, passenger terminals, gates and aircraft itself which is considered as resource of interest in this study.

Therefore, air carrier's maintenance departments are required to ensure that their fleet is expected to meet, or continues to meet, airline's established performance goals (e.g. operational readiness, dispatch reliability, cost affectivity, etc.) and to make sure that demands for deliveries will met. It is also needed to identify any deviation from established goals, to recognize the need for any corrective actions and to find the cost-effective improvement solutions. This will help airlines to sustain their fleet operation capability, to meet demands for deliveries and to confirm that their strategic business objectives and performance goals are met at minimum cost, setting ambitious and very challenging issues.

Therefore, air carrier's maintenance departments are required a formal Fleet Availability Assurance Program (FAAP) (supportability book page 9.10: fleet availability) for availability performance management, that contributes to the alignment of maintenance decisions and business objectives and at the same time highlight where the potential weakness in the systems and maintenance performance can be expected. It should also facilitate the identification of opportunities and cost-effective ways to implement and execute availability improvement actions that are needed to modify and sustain aircraft availability performance, resulting in reduction of business risks and uncertainties, and improve profits, and efficiency. Such program should also include an Integrated Information Logistics System (IILS) which assures the collection of important information about their performance, and directs the use of this information in the analysis and decision making processes.

Hence, the purpose of this paper is to present the concept of FAAP, in which the essential functional elements of such a program are discussed. The paper also discusses the development of information services for the management of a typical FAAP from different perspective.

2. AVAILABILITY PERFORMANCE

Availability Performance is the ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided (IEC, 2007). Availability might also be described as the measure of the degree a system is in the operable and committable state at the start of a mission when the mission is called for at an unknown random point in time (Blanchard, 1992). It can be formulated as:

$$A = \frac{UpTime(MTBF)}{UpTime(MTBF) + MeanDownTime(MDT)}$$

Availability performance level is recognized by the equipment inherent design characteristics i.e. its reliability, maintainability performances, and maintenance support performance of the organisation providing maintenance (IEC, 2007). However, it should be noted that both reliability and maintainability are also influenced by operating context, and maintenance support performance

Reliability performance is the probability that an asset will perform its intended function for a specified period of time under specified operating conditions. In fact, reliability is a function of time/load and the operating environment of a product, which comprises factors such as the surrounding environment (e.g. temperature, humidity and dust), condition-indicating parameters (e.g. vibration and pressure), and human aspects (e.g. the skill of the operators) (Ghodrati, 2005). The maximum reliability of an item/unit can achieve is built in to it during its design phase and manufacturing process and is called Inherent reliability. Hence, by Maintenance we may increase an item's operational reliability, but not its inherent reliability. Therefore, organisation providing maintenance plays an important role to achieve inherent reliability of aircraft at the lowest possible cost in its service life. Examples includes selecting proper subcontractor, using skilled crew for correct removal and installation, repair and testing, proper inventory environment and packaging schemes, etc.

Maintainability performance, is the ability of an item under given conditions of use, to be retained in, or restored to, a state in which it can perform a required function, when maintenance is performed under given conditions and using stated procedures and resources (IEV 191-02-07). High maintainability performance and in turn, high availability performance is obtained when the system is easy to maintain and repair. In general, the maintainability is measured by the mean repair time, often called Mean Time To Repair (MTTR), which includes the total time for fault finding, and the actual time spent carrying out the repair. Some design features of maintainability characteristics includes Interchangeability, easy accessibility, easy serviceability, diagnostic and prognostics capabilities. Inherent maintainability is primarily determined by the design of the equipment and can be greatly enhanced if fault detection, isolation, and repair procedures are worked out during the design stage itself in advance (Blanchard, 2008).

Incorporation of diagnostic and prognostics such as PHM reduces the active maintenance time through an improved maintainability performance of the technical system. This is achieved through improved testability and fault diagnosis, i.e., improved fault recognition, fault localization, and cause identification.

Maintenance support performance is defined by IEC (2007) as: "the ability of a maintenance organization, under given conditions to provide upon demand the resources required to maintain an item, under a given maintenance policy".

In general, the resources needed for the successful completion of every operation and maintenance task could be grouped in to Supply support, test and support equipment, transportation and handling, personnel and training, facilities, data, computer recourses (Kumar, 2000). The time to support the resources or logistic delay time (LDT) is defined as the time spent waiting for facilities, equipment, man power, and spares. According to Kumar (2000), LDT is a random variable and has an unpredictable nature, being the rest of the variability and complexity of all the influential factors to the restoration process, together with the provision of support resources. However, the randomness in support time is caused due to the factors listed below:

- Maintenance factors: these are related to the management of the maintenance process, in particular its concept, policy and strategy.
- Location factors: the influence of the geographical location of the items, communication systems, or transport.
- Investment factors: these influence the provision of support resources (spares, tools, equipment, and facilities)
- Organisational factors: these factors determine the flow of information and support elements.

However, in practice, due to dynamic behaviour of market demand, and the long list of contributory factors on availability performance and the randomness regarding their nature of occurrence and influence, management of availability performance to meet established performance goals is a huge challenge.

3. A PROPOSED FAAP

Considering Figure 1, management of availability performance of an airline fleet in order to meet established performance goals is a

huge challenge due to dynamic behaviour of market demand, and long list of contributory factors on availability performance and the randomness regarding their nature of occurrence and influence. Therefore, this study proposes FAAP.

Fleet Availability Assurance is a program for the systematic monitoring and evaluation of the various aspects of technical activities and services (maintenance), to ensure that the fleet is expected to meet, or continues to meet, airline's established availability performance goals and to make sure that demands for deliveries will met in a systematic and reliable fashion. Based on the fact that any services should be suitable for the intended purpose, FAAP refers to planned and organized processes that

provide confidence in technical service's suitability. It is a set of activities intended to ensure that established availability performance requirements are met. In the operation phase, observations of the Fleet Availability performance should be used to evaluate the need for corrective actions, i.e. modifications, and improvements. The necessary feedback should identify:

- i) How well the fleet is performing in comparison to established goals and requirements.
- ii) Where and why the deviations occur, if the performance goals and requirements have not been achieved,
- iii) How to define cost-effective solutions to achieve the necessary improvements.

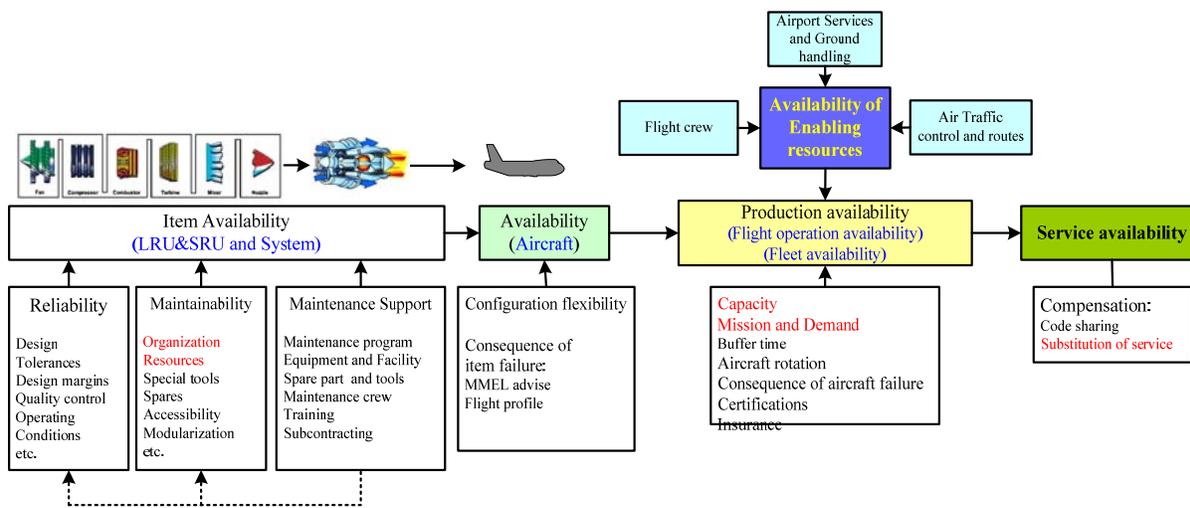


Figure 1. Relationship between flight operation availability and some of influencing factors

3.1 FAAP Objectives

FAAP is a formal management system, which assures the collection of important information about fleet performance throughout operation phase, and directs the use of this information in the implementation of analytical and management processes which are specifically developed to meet three specific objectives:

- Confirm that the fleet is expected to meet, or continues to meet, the established availability performance goal such as fleet safety, operation capacity, operational readiness, Flight deliverability, dispatch reliability, cost affectivity, etc.
- Identifying any deviation from established goals, and to recognize the need for corrective actions,
- Guide the search and implementation process for cost effective improvements either to enhance fleet availability performance or reduce total business risk.

3.2 FAAP PREREQUISITES

According to the literature review as well as discussions with a number of experts in the area, a typical FAAP can be expected to have the following prerequisites:

3.2.1 Goal setting and performance criteria

The FAAP requires the definition and assignment of a broad set of high level fleet performance goals and performance criteria which can be used for comparison with actual or predicted plant

performance. The goals and criteria may be either deterministic or probabilistic.

In order to implement the FAAP, the starting point is the definition of FAAP goals, criteria, and requirements. The task of transforming overall goals to specific requirements is complicated. When it comes to cost, effect on safety, and other concerns, it is almost impossible to know what the proper requirements should be without knowing what such requirements imply and mean. Establishing the FAAP requirements can be subdivided into:

1. Identifying different functions/activities; and
2. Translating goals into requirements for each function/activities.

The focus should be on the functions of design elements instead of the design elements themselves. This is because a particular design element can perform several functions and the consequences of the failure of one function are likely to be quite different from the consequences of the failure of another function. Furthermore, the primary focus should be on establishing the FAAP requirements for each function that is important for achieving the production plant goals and then on translating these requirements to the systems designed to accomplish these functions.

When the FAAP requirements are established, a primary design is developed to meet these requirements. This design is then evaluated to see if the FAAP requirements are being met and to

identify critical functions and design elements. If the results indicate that the FAAP requirements are not reached, then the manager must decide whether the FAAP requirements are attainable. If so, the existing design should be revised to fulfill the FAAP, and the revised design should be re-evaluated to check if it meets the FAAP requirements. This process needs to be repeated until the evaluation demonstrates that the requirements can be met. If the result of evaluation shows that the FAAP requirements are not attainable, they should be revised. If these requirements can not be revised in a satisfactory way, then the FAAP goals should be either revised or cancelled.

3.2.2 Planning and implementing procedures:

In order to ensure that a FAAP produces consistent and effective results, a plan and implementing procedure (as guidance) need to be defined in order to support managers, engineers and decision makers in implementation of FAAP. Barabady and Aven (2007) suggests a methodology for application of a typical production assurance program for engineering projects, which can be used as a bases for application of FAAP. Such implementation procedure includes FAAP activities that should be carried out step by step, as part of a FAAP, in the various life cycle phases of an air transport business. Examples of such Activities are given in Table 1. As an example, a management program shall serve as a management tool in the process of achieving FAAP objectives by cost-effective means and should be a continuous activity throughout all phases of a production plant. The following two management tasks need to be performed to ensure that the FAAP becomes an effective tool:

- i) Develop, maintain, and implement an FAAP plan, expressing what to do, how to do it, and who is to do it.
- ii) Establish and maintain an FAAP review process.

It includes monitoring the overall availability performance level, management of reliability, maintainability, and capacity performance of critical components, and continuous identification of the need for different activities. A further objective of FAAP management is to contribute practical technical or operational recommendations, including in the maintenance and organizational areas. In order to clarify and discuss different activities which are necessary for implementation of FAAP, we refer you to ISO 20815 (2008).

3.2.3 Analytical tools and investigative methods

The question is how the system will perform in the future from the availability point of view. Analysis of the system and modelling will increase the knowledge and hopefully reduce uncertainties. The availability analyses provide a basis for decisions concerning choice of solutions and measures to achieve an optimum economy within the given constraints. Therefore an FAAP uses a set of investigative and analytical and/or simulation methods and approaches to calculate and maximize the reliability, availability and capacity of important systems, subsystems or components. Table 1 lists several effective FAAP-related tools for different FAAP activity.

Table 1. Examples of FAAB activities and tools

<i>FAAP Activities</i>	<i>FAAP tools</i>
Management	FAAP program plan, FAAP review process
Modelling and Analysis	Reliability block diagram, FMECA, FTA, ETA, Markov analysis, Cause-consequence analysis, Maintenance-engineering analysis, Life-cycle cost analysis, Tolerance analysis, Part-count analysis
Data Collection and Analysis	Generic data development, Failure reporting,
System Design and Logistics	Redundancy and diversity, Modularity and diagnostics, Reliability vs. maintainability trade-off studies, Part control program, RAM procurement specifications, Preventive maintenance program, Corrective maintenance program, Spare part program

3.2.4 Information management and logistics

The effectiveness of the FAAP depends on the quality and accessibility of the information used to provide the feedback to the management systems about how well the system is performing and where to obtain improvements. Collecting data is costly and this effort needs to be balanced against the intended uses and benefits. A typical data collection process may consist of collecting data from different sources into one database where type and format of data are pre-defined.

Therefore, provision of information to the FAAP’s stakeholders is essential in order to achieve overall efficiency and effectiveness. An effective information provisioning is highly dependent on underlying mechanism which can be provided by an appropriate information logistics. The main aim of information logistics is to provide just-in-time information to targeted users and optimization of the information supply process, i.e. making the right information available at the right time and at the right point of location (Heuwinkel et al., 2003; Haseloff , 2005).

Solutions for information logistics need to deal with: I) time management, which addresses when to deliver; II) content management, which refers to “what to deliver”; III) communication management, which refers to “how to deliver”; and IV) context management, which addresses “where and why to deliver” (Heuwinkel et al., 2003; Haseloff , 2005).

FAAP requires information produced during a system’s whole lifecycle such as design, development, production and construction, utilization and support, and retirement. However, the establishment of appropriate information logistics through all phases of a system’s whole lifecycle is a great challenge since necessary information is often hidden among vast quantities of data, stored for other purposes, at different places, in different formats, and generated throughout the whole life cycle of a system (Tsang, 2002).

Development of platform for information logistics related to FAAP requires: I) identification of information sources and services which have impact on the system availability and II) selection of a proper process for development of necessary information system. The identification of FAAP-related information services can be carried out through any combination of quantitative and qualitative approaches. Karim (2008) provides a methodology and a supporting tool based on a model and simulation approach that is combined with Design of Experiment

(DoE) principles. Hence, the methodology draws on the benefits of multivariate data analysis, where multiple factors can be

altered simultaneously (for more discussion see Karim 2008).

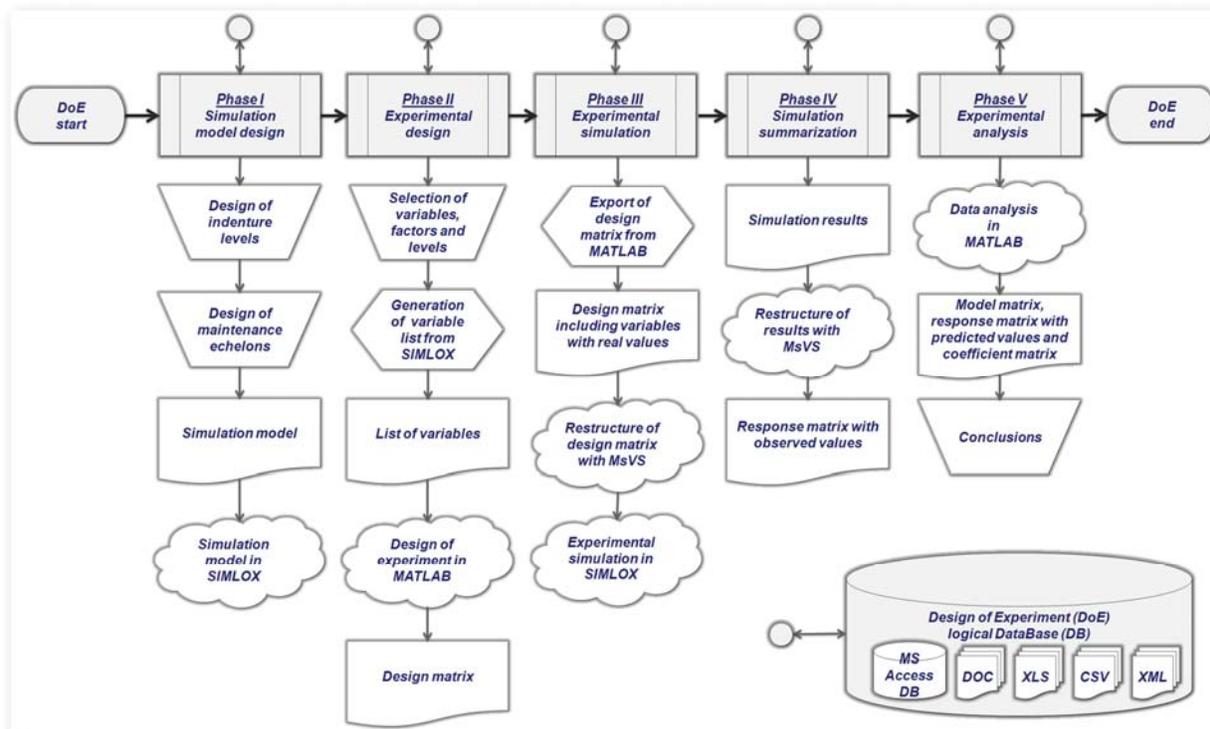


Figure 2. Illustration of the phases of the proposed methodology and its supporting toolbox (Karim, 2008).

Such methodology can be used as a basis for development of a platform for information logistics related to FAAP. The methodology consists of the five phases, as illustrated in Figure 2. During the Phase I ‘Simulation model design’ – in this phase the structure of the system-of-interest and their support systems are defined. Phase II ‘Experimental design’ – provides a detailed design of experiment. Within the Phase III ‘Experimental simulation’ – the designed set of runs are executed. In Phase IV ‘Simulation summarization’ - data from the conducted experiment are collected and compiled. Finally in Phase V ‘Experimental analysis’ –the results from the experiments are analyzed. In the context of FAAP, in order to face the challenges related to development of information logistics, several contributions have been provided. The result from the information service identification related to FAAP can be used for the development FAAP information services. However, aspects related to the development of information services related to FAAP need to be discussed.

3.3 Development of information services for FAAP

Development of information service for FAAP is an important issue and can play a significant role in successful implementation of FAAP which need to be clarified. However, aspects related to the development of information services for a typical FAAP can be considered from different perspective such architecture, infrastructure and content (Karim, 2008). These aspects are

emphasised in the proposed FAAP, since they are essential in development ICT-based software as support to information logistics.

3.3.1 Aspects related to software architecture

There are several contributions related software architecture that might be applied within the development of information logistics for FAAP. One contribution is the concept of a common database, i.e. an integration at the data level for provision of the needed flexibility for different working areas (e.g. maintenance), as support to strategic, tactic and operational decision making (Kans, 2008). Another contribution to an architecture is a client-server approach (Han & Yang, 2006). This client-server architecture is based on two subsystems: I) a server which is intended to be tailored to the needs of the company through cooperation among the various areas (e.g. maintenance); and II) local client, which implements and evaluates the system provided by the server. Another architecture approach relies on a star-like layered architecture (Bangemann et al., 2004, 2006). One way to realize this star-layered architecture is to use a platform that utilizes the Web services technology upon the existing maintenance applications to provide function and data integration.

However, the Web services technology is only one way to realize a Service-Oriented Architecture (SOA). SOA presents a vision of a world where resources are cleanly portioned and consistently represented (Erl, 2006). SOA is gaining momentum worldwide by

promising agility, mobility, interoperability, reuse and better alignment with business objectives (Erl, 2006; Pulier & Taylor, 2006). In the context of software architecture, SOA represents a model where business logic is de-composed into smaller elements that can be distributed (Erl, 2006). One of the benefits of such elements is that they are autonomous and can be individually distributed (Erl, 2006; Pulier & Taylor, 2006). Another benefit is that these elements are unified by the term service, in order to reduce their dependency on underlying technology and emphasize their target, i.e. the business processes (Erl, 2006; Pulier & Taylor, 2006). The Organization for Advanced Standards for Information Society (OASIS) describes SOA as a collection of best practices, principles and patterns related to service-aware, enterprise-level and distributed computing (OASIS, 2008). Their efforts are focused on support to agile computing by providing concepts for workflow management, translation coordination, orchestration, collaboration, loose coupling, business process modelling and other related concepts.

Hence, a software architecture based on a service-oriented approach is believed to increase the flexibility and adaptability of FAAB-related services to stakeholders' needs of information.

3.3.2 Aspects related to software infrastructure

Establishment of SOA requires underlying infrastructure that supports a service-oriented approach. Service-Oriented Infrastructure (SOI) is considered as the platform that aims to provide features for the enterprise production environment. SOI can be considered as a set of technologies and tools that are required to meet needs and requirements when services, according to SOA, are developed, implemented and managed in an enterprise (Erl, 2006; Microsoft, 2008; OASIS, 2008). It can be concluded that SOA, with support of SOI, is aimed at facilitating enterprise application integration. However, the implementation is also an important phase when considering the establishment of an eMaintenance solution. There are several generic existing efforts that contribute to the implementation phase of a solution. An example of these efforts is the guideline provided by Eriksson & Mirijamdotter (2008) that proposes ten precepts for implementation of information systems. They state that this guideline addresses the last three phases, i.e. the planning, execution and evaluation, of the total five key phases related to the idealized design of organizations described by Ackoff (1981). However, SOA has implications on all processes and their actors

related to software, e.g. development, evolution, maintenance and support, discussed by Kajko-Mattson et al. (2007).

3.3.3 Aspects related to content management

The ultimate goal of information logistics is to provide an effective and efficient content sharing capability within a given context (Karim et al., 2009a). Content is one of the most fundamentals in information logistics, since it addresses issues such as data ontology, data taxonomy, data warehousing, data exchange and content format.

The proposed FAAP does not provide any specific methodologies or technologies, but it relies on existing contributions related to information logistics. Some of these contributions including inherent artefacts that intend to support operation and maintenance management from a content management perspective are summarised in Table 2.

The first column of Table 2, "Content Management Related Contributions", lists some of the contributions that are relevant for content management within FAAP, e.g. AeroSpace and Defence Industries Association of Europe (ASD). The second column, "Application Domain", highlights if a contribution addresses a specific application domain, e.g. aerospace, or if it is generic. The third column, "Service Domain", indicates which type of services within the application domain that the contribution addresses, e.g. technical publications. Finally, the fourth column, "Examples of Artefacts", provides examples of technologies, methodologies and tools related to a contribution, e.g. the standard S1000D. The remaining part of this section provides a more detailed description of the contributions listed in Table 1.

4. CONCLUSIONS

In fact, the ability to sustain and improve the availability performance and capability of aircraft to meet demand for deliveries of air carriers is the key to gain higher market share, achieve market competitiveness, profitability, and for airlines future business success. This paper introduces the concept of FAAP which is a program, not only for documenting of the performance of airline, but also for providing decision support for development and optimization of the fleet performance to improve availability performance, reduce risk and uncertainties.

Table 2. Examples of contributions related to content management related to FAAP(adapted from Karim, 2008).

Content Management Related Contributions	Focus Area	Maintenance Specific	Application Domain	Service Domain	Aspects of Information Logistics	Examples of Artefacts
AeroSpace and Defence Industries Association of Europe (ASD)		Yes	Aerospace	Technical publication	▪ Content	S1000D
Business to Manufacturing Markup Language (B2MML)		No	Automation, manufacturing, maintenance etc.	Generic	▪ Content	IEC/ISO 62264
Center for Intelligent Maintenance Systems (IMS)		Yes	Generic	Maintenance, e.g. proactive maintenance and maintenance decision support	▪ Content ▪ Context ▪ Time ▪ Communication	Device-to-Business, Watchdog Agent
Document Management Applications (ISO/TC 171)		No	Generic	Quality control & integrity	▪ Content ▪ Context ▪ Time	ISO 19005-1:2005, ISO 32000-1:2008, ISO 24517-1:2008
DYNAMITE		Yes	Generic	Health monitoring, prognostics etc.	▪ Content ▪ Time ▪ Communication	DYNAMITE-platform
Industrial Automation Systems and Integration (ISO/TC 184)		No	Industrial automation	Generic	▪ Content ▪ Context ▪ Time	ISO-10303, ISO-15531, ISO-18435
Information and Documentation (ISO/TC 46)		No	Generic	Libraries, documentations, publishing etc.	▪ Content ▪ Context	ISO 15836:2003, ISO 2709:2008
Information Technology (ISO/JTC 1)		No	Information management	Generic	▪ Content ▪ Context ▪ Time ▪ Communication	ISO/IEC 2382-17:1999, ISO/IEC 2382-4:1999, ISO/IEC 15940:2006, ISO/IEC 9075-1:2008, ISO/IEC 9075-14:2008
ISA-95		Yes	Manufacturing	Enterprise & control systems	▪ Content	Models & Terminology, Object Models & Attributes
Machinery Information Management Open System Alliance (MIMOSA)		Yes	Manufacturing, fleet & facility environments	Operation & maintenance	▪ Content ▪ Context ▪ Time ▪ Communication	OSA-EAI, CRIS
Materials, Equipments and Offshore Structure for Petroleum, Petrochemical and Natural Gas Industries (ISO/TC 67)		No	Petroleum & gas	Maintenance etc.	▪ Content ▪ Context ▪ Time ▪ Communication	ISO-14224
Mechanical Vibration, Shock and Condition Monitoring (ISO/TC 108)		No	Generic	Mechanical vibration & shock	▪ Content ▪ Context	ISO-13374
Organization for Advancement of Structured Information Standards (OASIS)		No	Generic	Generic	▪ Content ▪ Context ▪ Time ▪ Communication	PLCS & PPS
PROTEUS		Yes	Generic	Maintenance	▪ Content ▪ Communication	PROTEUS-platform
System for Mobile Maintenance (SMMART)		Yes	Generic	Remote information exchange, maintenance, logistic planning etc.	▪ Content ▪ Communication	SMMART-platform
Technologies And Techniques for nEW Maintenance concepts (TATEM)		Yes	Aerospace	Health monitoring & management, Aircraft operability assessment , process-oriented maintenance etc.	▪ Content ▪ Context ▪ Time ▪ Communication	TATEM-platform
Technical Product Documentation (ISO/TC 10)		No	Technical products	Publications	▪ Content ▪ Context ▪ Time	ISO 128-1:2003, IEC 82045-1:2001, IEC 82045-2:2004, ISO 7573:2008
Tele-maintenance platform (TELMA)		Yes	Manufacturing	Prognosis & aided decision-making	▪ Content ▪ Context	TELMA-platform
The Object Management Group (OMG)		No	Generic	Generic	▪ Content ▪ Context ▪ Time ▪ Communication	UML, Corba
World Wide Consortium (W3C)		No	Generic	Generic	▪ Content ▪ Context ▪ Time ▪ Communication	XML, XML Schema & RDF

5. REFERENCES

- [1] Ackoff, R.L. (1981). *Creating the Corporate Future: Plan and be Planned for*. Wiley, New York.
- [2] Bangemann, T., Rebeuf, X., Reboul, D., Schulze, A., Szymanski, J., Thomesse, J-P, Thron, M. and Zerhouni, N. (2006). PROTEUS - Creating distributed maintenance systems through an integration platform. *Journal of Computers in Industry*, vol. 57, no. 6, pp. 539–551.
- [3] Bangemann, T., Reboul, D., Szymanski, J., Thomesse, J-P and Zerhouni, N. (2004). PROTEUS - An Integration Platform for Distributed Maintenance Systems. *Proceedings of the Intelligent Maintenance Systems (IMS) 2004 International Conference*, 15-17 July 2004, Arles, France.
- [4] Barabady, J. and Aven, T. (2008). “A methodology for the implementation of production assurance programmes in production plant”. *Journal of Risk and Reliability*. Vol. 222, No. 3, p. 283-290.
- [5] Blanchard, B.S., (2008). *System Engineering Management*. John Wiley and Sons, New Jersey.
- [6] Campbell, J.D. and Jardine, A.K.S. (2001). *Maintenance Excellence: Optimizing Equipment Life-Cycle Decisions*,
- [7] Eggenberg N., Salani M. and Bierlaire M. (2010), Constraint-specific recovery network for solving airline recovery problems, *Computers & Operations Research*, 37 (6), pp. 1014–1026.
- [8] Erl, T. (2006). *Service-Oriented Architecture: Concepts, Technologies, and Design*. Pearson Education Inc., Upper Saddle River, New Jersey, USA.
- [9] Eriksson, D.M. and Mirijamdotter, A. (2008). *Ten Guidelines for the Implementation of Information Systems: Research in Progress*. *Proceeding of the 31st Information Systems Research Seminar in Scandinavia*, 10 August 2008, Åre, Sweden.
- [10] EUROCONTROL (2004), *Challenges to growth report*, /www.eurocontrol.intS.
- [11] Ghodrati, B. (2005). *Reliability and Operating environment based spare parts planning*, Doctoral thesis, Lulea University of Technology, Lulea Sweden
- [12] Han, T. and Yang, B-S (2006). Development of an e-maintenance system integrating advanced techniques. *Journal of Computers in Industry*, vol. 57, no. 6, pp. 569–580.
- [13] Haseloff, S. (2005). *Context Awareness in Information Logistics*, Doctoral Thesis, Elektrotechnik und Informatik der Marcel Dekker, New York.
- [14] Heuwinkel, K., Deiters, W., Königsmann, T. and Löffler, T. (2003). “Information logistics and wearable computing”, *Proceedings of the 23rd International Conference on Distributed Computing Systems*, 19-22 May 2003, pp. 283–288, 2003.
- [15] Herinckx, E. & Poubeau, J.P., 2000. Methodology for analysis of operational interruption cost. Airbus Industries:Toulouse.
- [16] IEC, (2007). *International Electrotechnical Vocabulary (IEV)*, Online, Chapter 191: Dependability and quality of service, Access, November 2007, www.electropedia.org
- [17] IEC 60300-3-10. (2001) *International Standard IEC 60300-3-10: Dependability Management – Part 3-10: Application guide – Maintainability*. International Electrotechnical Commission (IEC). Geneva.
- [18] IEV 191-02-07. (2007). *International Electrotechnical Vocabulary (IEV) Online*, Chapter 191-02-07: Dependability and quality of service. <http://www.electropedia.org> (accessed April 2010).
- [19] ISO/CD 20815. (2008). *Petroleum, petrochemical and natural gas industries-Production assurance and reliability management*. Published in Switzerland.
- [20] Kans, M. (2008). *On the utilisation of information technology for the management of profitable maintenance*. Doctoral thesis, Växjö University, Växjö, Sweden.
- [21] Karim, R., Candell, O. and Söderholm, P. (2009a). “eMaintenance and Information Logistics: Aspects of Content Format”. *Journal of Quality in Maintenance Engineering*, vol. 15, issue 3.
- [22] Karim, R., Candell, O. and Söderholm, P. (2009b). “Development of ICT-based Maintenance Support Services”. *Journal of Quality in Maintenance Engineering*, vol. 15, issue 2.
- [23] Karim R. (2008). *A Service-Oriented Approach to eMaintenance of Complex Technical Systems*, Doctoral Thesis, Luleå University of Technology. Sweden.
- [24] Kumar, U.D., Crocker, J., Kenezovic, J., El-Haram, M., 2000. *Reliability, Maintenance and Logistic Support*. Kluwer Academic Publishers: US.
- [25] Microsoft (2008). SOA. Microsoft, available at: <<http://www.microsoft.com>>, accessed: 25 August 2008.
- [26] Microsoft (2008). SOA. Microsoft, available at: <<http://www.microsoft.com>>, accessed: 25 August 2008.
- [27] Mobley, R.K. (1990). *An Introduction to Predictive Maintenance*, Van Nostrand Reinhold, New York.
- [28] Nowlan, F.S. and Heap, H.F. (1978). *Reliability-Centered Maintenance*, Department of Defence, Washington, DC.
- [29] Pulier, E. and Taylor, H. (2006). *Understanding Enterprise SOA*. Manning Publication Co., Greenwich.
- [30] Technischen Universität Berlin, Berlin, Germany.
- [31] Tsang A., “Strategic dimension of maintenance management”, *Journal of Quality in Maintenance Engineering*, vol. 8, no. 1, pp. 07-39, 2002.
- [32] Sachon, M., Pate, E., 2000. Delay and safety in airline maintenance, *Reliability engineering and system safety*. Elsevier, UK, Vol.67, pp.301-309
- [33] Söderholm, P. and Akersten, P.A. (2002). “Aerospace Diagnostics and Prognostics in a TQM-Perspective”, in *15th International Congress on Condition Monitoring and Diagnostic Engineering Management (2002) COMADEM International*, Birmingham, UK. 80-89.