Lappeenranta University of Technology
School of Business and Management
Industrial Engineering and Management
Master's thesis

INFORMATION MANAGEMENT IN AIRCRAFT MAINTENANCE

Examiners Professor Tuomo Uotila
University Lecturer Lasse Metso

Supervisors Head of Aircraft Maintenance Juha Ojala
Post-Doctoral Researcher Salla Marttonen-Arola

21.3.2016

Samu Linnimaa

ABSTRACT

Author: Linnimaa Samu

Title: Information Management in Aircraft Maintenance
Faculty: LUT School of Business and Management
Major: Industrial Engineering and Management
Year: 2016
Master's Thesis: Lappeenranta University of Technology
81 pages, 29 figures, 3 tables, 2 appendices
Examiners: Professor Tuomo Uotila
University Lecturer Lasse Metso
Keywords: Information Management, Aircraft Maintenance, Aviation, Maintenance

Well managed information promotes competitive advantage and economic value for the company. The challenge is to use information effectively in complex networks. Decision making in network is complicated due to many independent sources of information. The aim of the present study was to identify and map the internal information flows and used information resourced by functions and roles, to make proposals to the case organization to improve the information management and to improve the situational awareness and process flows.

In the present study, an inductive approach was applied, with the aim to find out gaps and bottlenecks of information flow of an aircraft maintenance organization and its network. The empirical part was conducted with observing the processes and with questionnaires. Theoretical part of this study consists on reviewing relevant literature on maintenance management in aviation and information management in aviation. Together with empirical evidence and the literature used in the study the gaps were found and suggestions for improvements were done. The outcome of this study contributes the organization in its bigger goal to improve the productivity.

The information management of the network is one actor in the field and will pave the way to smoother operation and situational awareness. The lack of rules and requirements for information management and spreading is a challenge in information management. The excessive data overburden may cause problem in the actors' situation-awareness due to non-availability of the right information.

TIIVISTELMÄ

Tekijä:	Linnimaa Samu
Tutkielman nimi:	Tiedonkulun hallinta lentokoneen huoltotoiminnassa
Tiedekunta:	LUT School of Business and Management
Pääaine:	Tuotantotalous
Vuosi:	2016
Diplomityö:	Lappeenrannan teknillinen yliopisto LUT 81 sivua, 29 kuvaa, 3 taulukkoa, 2 liitettä
Tarkastajat:	Professori Tuomo Uotila Yliopisto-opettaja Lasse Metso
Hakusanat:	Information Management, Aircraft Maintenance, Aviation, Maintenance

Tehokas tiedonhallinta ja käyttö edistävät kilpailuetua sekä luovat taloudellista arvoa yritykselle. Nykypäivän yritykset toimivat verkostossa. Verkoston haasteena on tehokas tiedonkulun hyödyntäminen ja käyttö. Verkostossa toimivan yrityksen päätöksenteko on monimutkaista, tietolähteinä toimii yleisesti useita itsenäisiä informaatiolähteitä ja järjestelmiä. Tutkimuksen tavoitteena oli kartoittaa ja tunnistaa erään yrityksen sisäisen verkoston tiedonkulku, käytettävät tiedonlähteet toimijoittain sekä rooleittain ja tehdä suosituksia tapausyritykselle tiedonhallinnan sekä tilannetietoisuuden parantamiseksi.

Tutkimus toteutettiin tapaustutkimuksena, jossa käytettiin induktiivista tutkimusotetta. Tutkimuksessa tutustuttiin lentokonehuolto-organisaation ja sen verkoston tiedonkulkuun ja tiedonhallinnan haasteisiin. Empiria kerättiin seuraamalla prosesseja sekä toteuttamalla kaksi erisisältöistä kyselyä. Teoriaosuus koostuu ilmailun huollon- ja tiedonhallinnasta.

Tutkimuksen tuloksina yritykselle esitettiin suosituksia sen tiedonhallinnan sekä tilannetietoisuuden parantamiseksi. Tutkimuksen tulokset hyödyttävät osaltaan yritystä saavuttamaan tavoitteensa tuottavuuden parantamisessa.

Verkostossa toimivan yrityksen tehokas tiedonhallinta edistää tehokasta ja taloudellista toimintaa sekä parantaa tilannetietoisuutta. Tiedonhallinnalle tulee kuitenkin laatia säännöt sekä on vältettävä ylimääräisen tiedon levittämistä.

Foreword

“In the end, the location of the new economy is not in the technology, be it the microchip or the global telecommunications network. It is in the human mind.” - Alan Webber

The idea of a new adventure started about three years ago. The preliminary plan was to take the studies as a hobby keeping the main focus on work and family. However the meaning of university studies opened rapidly and the hobby was forced to be taken seriously. These three years have given me an education, great experiences, awesome friends and lots of mental capital.

During these three years there have been up- and downhills. The studies included lots of group assignments. I was lucky to find flexible, enthusiastic and committed core group. Without the group’s support and teamwork of the fellow students the studies would not have been in this point so fast. I would especially like to thank Mika, Markku, Jarmo and Juha for the shared journey. We had also fun, occasionally.

My family has had to be flexible throughout my studies. The study time has been taken from the family time. My wife has been keeping the household, looking after the kids and raised them and at the same time encouraged me with the studies. I would like to thank you Piia. Without you this would not have been possible.

I’d also like to thank Juha Ojala who gave me this possibility to make this interesting Master’s thesis for the case company. The subject was extremely motivating and the support was excellent. Special thanks to Salla and Lasse for constructive supervising and support for the thesis.

Porvoo 13.3.2016

Samu Linnimaa

Table of Content

List of Figures

List of Tables

List of Abbreviations

A/C	Aircraft
ACM	Aircraft Maintenance
AMOS	Aircraft Maintenance and Repair Management Software
AOG	Aircraft on Ground
CM	Configuration Management
CMMS	Computerized Maintenance Management Systems
DM	Duty Manager
eLog	Electronic Logbook
ERP	Enterprise Resource Planning
HCC	Hub Control Center
IT	Information Technology
LRU	Line Replaceable Unit
Maint. OPS	Subcontractor Order Software
MC	Maintenance Control
MCC	Maintenance Control Center
MPD	Maintenance Planning Data/Document
MRO	Maintenance, Repair and Overhaul
OC	Operation Control
OCC	Operation Control Center
OPS	Operations Division
PDM	Product Data Management
PLM	Product Lifecycle Management
SRT matrix	Material Management Software
SRU	Shop Replaceable Unit
Snapshot	a short description that tells what particular place or situation is like at a particular time
WP Summary	Work Package Summary

1 INTRODUCTION

Data, information, manage the information, product lifecycle management, eMaintenance are terms and conceptions which are considered to include in modern day efficient industry and linked to decision making activity. Information is everywhere. Well managed information can be used to streamline processes, give real time alternative information to the networks and stake holders, make things better, faster, select the best one(s) and promote competitive advantage and economic value. The challenge is to make effective use of information due the complexity of networks. Product lifecycle management (PLM) integrates people, processes, business systems and information to manage and is considered as a business process in enterprises.

Aviation is strictly regulated and the modern aircrafts are complex technical systems. Airworthiness regulations for civil aircraft oblige excellent operations with strict control procedures. The major challenges the modern aircraft faces are related to maintenance and in-service support. The increasing information flow and system complexity are the challenges for Maintenance, Repair and Overhaul (MRO) as well as other aircraft operation support functions.

Modern aircrafts are equipped with Information and Communication Technology (ICT) solutions and multiplied computerized functions. The support system integration to services and functions like maintenance programmes, maintenance plans, job cards, defect diagnosis support, amendment services, health and usage monitoring, operational feedback, and technical information (publications) are at a low level. Aircraft maintenance providers and support serviced faces challenges to increase service levels in complex technical systems with multiple products and increasingly stringent requirements simultaneously improving quality. The business environment has a great change to become purely digital because of the development of information technology (IT).

Suppliers and customers are forced to face the increasing complexity of the information concerning the level associated with the configuration control and change management, as well as the aircraft and its support system. The high level of complexity of information logistics hampers the effectiveness of action.

The management, support planning, preparation, execution, assessment and improvement are the phases involved to maintenance process.

These phases are activities to interrelated and adapted to fulfill the stakeholder's requirements. The activities performed consume and produce information.

1.1 Background

Efficient decision making of large maintenance systems depends on several independent sources of information and is therefore complicated: The current health status of each device, daily, weekly and monthly plans of maintenance, the condition profile of the machine, maintenance costs i.e. resource, tools, spare parts, etc., and the system configuration and decision options. The system level controller is the most effective to make decisions within the maintenance after having received the information about the aircraft, concerning departments and other information as inputs. These inputs are compared to production requirements that have been set by the company. To boost productivity and increase reliability and responsiveness to change operations in large and complex maintenance activities can be helped by design, control and management. (Ni & Jin 2012, p. 411)

The aircraft maintenance is an important part of flight operation because of its big role in creating customer value. The maintenance value chain promotes the value chain of whole company by creating lifecycle for each phase of the product, and management and control of maintenance and required service and performances, etc. The value chain has to be supported at every level of the product life cycle to reach the objectives to be fulfilled. All objectives shall be supported by business processes that use resources flows to transform input flows into output flows. The value chain will be running well if all the sub objectives are performed. (Levrat, et al. 2008, p. 410)

The value chain and the objectives and sub-objectives need Information management. Information management is closely related to systems and processes which are critical to organizational success. PLM is considered kind of a process where design, planning, production and information are managed in defined and coordinated manner. PLM can also be used as the central repository for other information, like different kind of documents, catalogues, client feedback, plans, schedules and further information about the product. Industries with high safety and control requirements like aviation, medicine and hospitals, nuclear power plants first implemented the PLM concepts (PLM 2014). Information Management in means of effective information sharing and collaboration as well as ease collating and organizing information are the classical benefits of PLM according to Christian (2015, p. 1).

To integrate functions, information systems and processes is challenging for organizations due to complex services and network. The processes operation should be improved to obtain the goals set by the company or the network. Different types of data and formats used within the network causes challenges and obstacles in information management. Compatibility of the IT systems would improve information and workflow within the network and organizational units. (Giachetti 2004, p. 1147) According to Silventoinen et al. (2014, p. 727) the challenge is to develop a shared approach and common information usage, flow, exchange and coordination. Right information in right time gives competitive edge i.e. orders in time, reduces stocks, and makes global action easier to achieve. (Bovet & Martha 2000, p. 23)

IT has revolutionized the connections between airlines and passengers in the last decade. But gains from IT in maintenance hangars have come more slowly and must be pursued much more carefully. Airlines pick their openings cautiously, examine business cases closely and focus IT efforts where gains seem clear. When airlines are investing one of the highest priorities is in maintenance actions and its processes. But business intelligence is only one area where airlines may see prospects for improving operations or cutting maintenance costs with IT. The selected strategy, IT capabilities, fleet and scope of operation have impact to an airline selecting the priorities. (Canaday 2014) In Aviation industry the manufacturers, maintenance and in-service support providers are also facing the increasing information flow. The customer requirements i.e. improved aircraft (A/C) availability and cost effectiveness with 24/7 support and ever increasing complexity of technology requires new types of solutions for handling the processes and information flows. (Candell, et al. 2009, p. 928-937)

The various information integration types, maintenance, eMaintenance, PLM, and Information management are studied from several points of views and angles. Still the overview of theory let the feeling that there are still some research gaps between the combinations of selected theories where the goal could be assumed. eMaintenance tries to catch up the cap between the Information Management and PLM.

1.2 Research objectives and limitations

The case organization have overall goal to improve the productivity. One of the objectives is to gain the maintenance production to world-class level. There are several on-going projects towards the goal.

The situational awareness and the same picture of the ongoing process in different function are vital. The objective of this study is to identify and map the internal information flows and used information resourced by functions and roles. The functions mean the maintenance information users like different departments in the company's network. How the information needs differs by the functions and what kind of deviations there are in snapshot picture of the maintenance production. The interfaces of the information flows between the functions will be examined for getting understanding of the wholeness. With the map is meant to find out development areas and information gaps to improve the situational awareness and process flows and make proposals to the case organization to improve the information management in maintenance process. In addition to that the study is to sort out the essential information in perspective of maintenance production.

The study concentrates to the Information management in maintenance execution process. The meaning of information in the study is the information what are used for the decision making in different levels and functions and roles concerning aircraft maintenance process in Aircraft Maintenance department. In addition to information management in maintenance process the links between the value networks is studied. The information flow which concentrates to maintenance and repair activities within the company's network for smooth and effective air operation is studied. The network in this case means the organizations, functions and roles that need maintenance process information. These interfaces are familiarized in general level to gain understanding of the needs of Information in network actors to provide right information for the networks needs.

1.3 Research questions

The main research question is:

In what ways information management in maintenance process can be developed to get better real time situational awareness in aircraft maintenance process?

The sub-research questions are:

What is essential information in aircraft maintenance in perspective of production?

How does the maintenance information snapshot differ between the networks and units?

How does the information flow between the functions?

1.4 Structure of the thesis report

This is a qualitative study with inductive approach. The qualitative data is analyzed with a systematic procedure in the inductive approach and is derived by specific evaluation objectives. The inductive approach provides research findings to emerge without any restrictions. The raw data leads the findings by structured methodologies (Thomas 2006, p. 238).

This study consists of introduction, theory, empirical, results and conclusion. The progress of the study is shown in the figure 1. The introduction provides an overview of information management in aviation and maintenance management discussions and will present the research questions, objectives and limitations of the study.

The theoretical part deals with the main concepts linked to the subject matter, and precise literary discussions. The theory is divided into two chapters. The first chapter deals the parts of a general overview of maintenance, eMaintenance, product life cycle management information flows and aviation maintenance management. The second chapter handles the information management in aviation and the concepts connected to this work: information management in aircraft maintenance process, Challenges in information management in aircraft maintenance process and Information Network Analysis in maintenance process.

The empirical part describes the used methods in the study and introduces the case organization. The material used in the study is described and reliability of the data is evaluated. In the results is presented the findings of the study, case organizations information network analysis and identified information management. In the results are identified also the findings which will supplement the treated theory.

In the conclusions the theoretical framework the research questions will be answered. In addition to previous the proposed information management model or process will be evaluated to the case organization and propose some implementation hints. Finally there will be some recommendations presented for the further development and research.

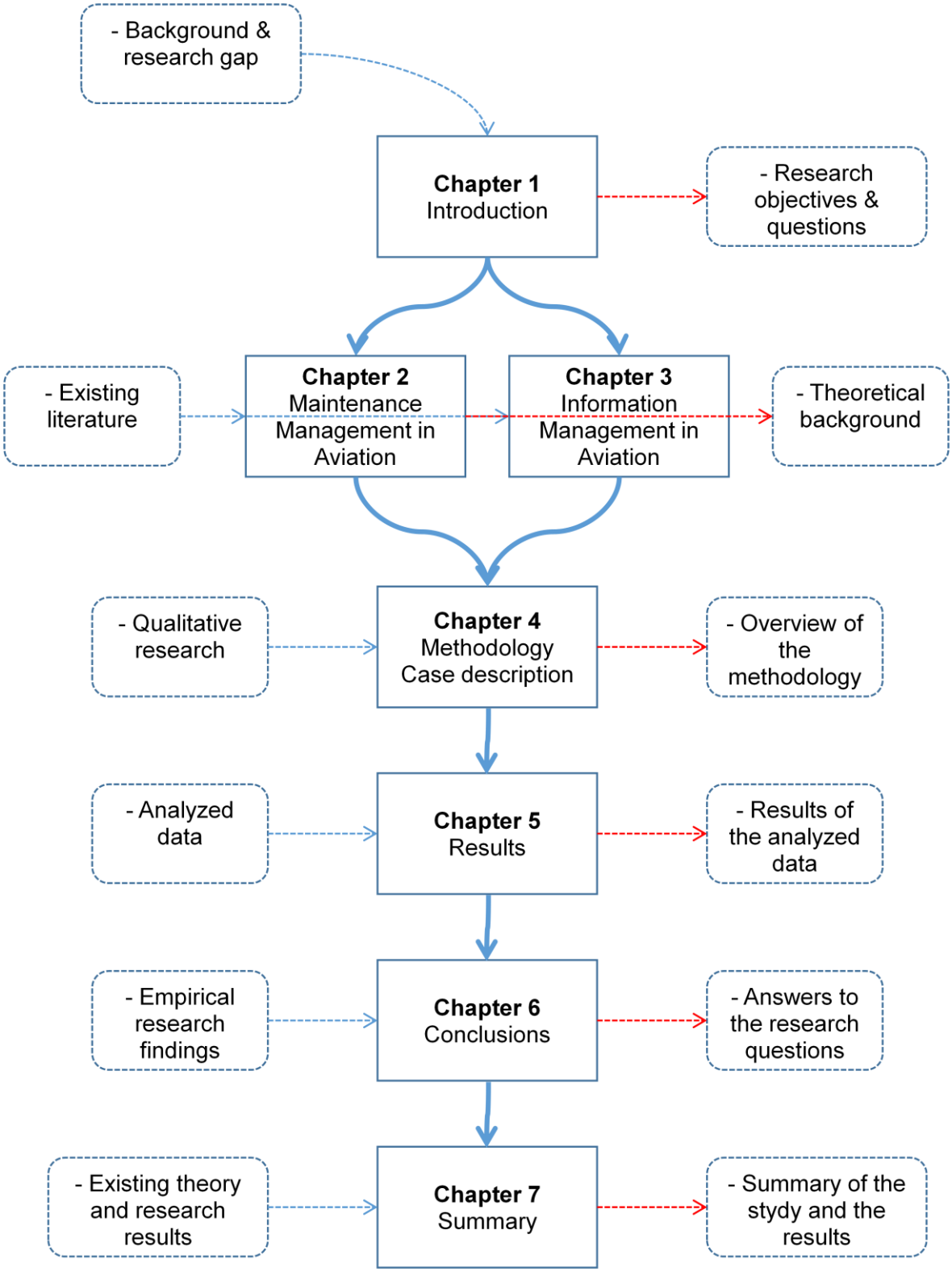

Figure 1. Structure of the study

2 MAINTENANCE MANAGEMENT IN AVIATION

This section is a literature review of maintenance, repair and overhaul, eMaintenance, product life cycle management information flows and maintenance management in aviation in point of view of aircraft maintenance process.

2.1 Maintenance, repair and overhaul in nutshell

Maintenance concept is a broad, complex and higher performance. Maintenance aims to maintain the condition of machinery, equipment and buildings, in order to production can take place under conditions that are the cheapest in net income, safety, environment and quality. Service can be produced in such a way that the customer is satisfied and the relationship between cost and quality as cheap as possible. (OPH 2016)

With maintenance is meant to keep item, device or an aircraft in condition and reliable, and while defect is found repairing it and also managing the environmental and safety risks. In industrial sections like capital- and heavy intensive industries are supported by maintenance for safe and reliable operation condition of items, devices or an aircraft. The maintenance has impact also in term of productivity. Today maintenance is seen as a part of the value chain instead of mandatory action. And it is also considered in has a key role in maintaining the company long-term profitability. (Parida, et al. 2015, p. 3)

Maintenance is mainly split into two main strategies, preventive and corrective maintenance. Preventive maintenance is done normally according to maintenance manuals in certain intervals defined by the original equipment manufacturer. The preventive maintenance maintains the equipment and prevents defects to occur. When a defect is detected the executed maintenance is called corrective maintenance. The aim of corrective maintenance is to put the equipment into on condition again (Järviö et al. 2007, p. 47)

Different forces guide the maintenance operation. The forces are requirements and networks. Maintenance actor need to deal the forces for smooth operation. The forces are shown in figure 2. Maintenance is a balancing between technology, operations and logistics with so that they are in harmony with the production. Technology offers supportive tools and equipments for the maintenance actions. (Pintelon & Parodi-Herz 2008, p. 22.)

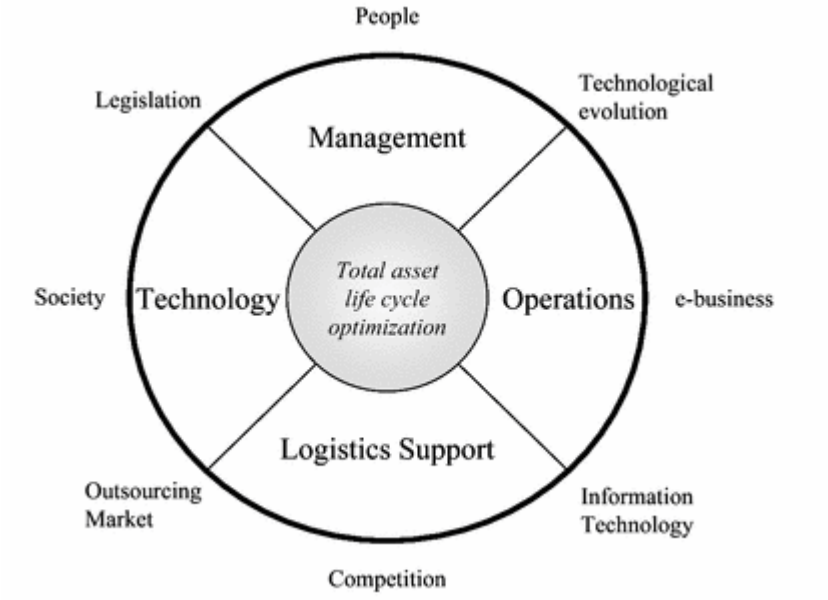

Figure 2. Maintenance in context (Pintelon & Parodi-Herz 2008, p. 22)

To obtain efficient information flow and logistics in maintenance support resources in present eBusiness environment the information systems are vital. Service and maintenance support concepts of complex aircrafts and other technical systems are described to concentrate on the optimization of the two basic and mutually dependent factors. The first factor is the aircraft and its systems that have to be designed with great emphasis of reliability and should retain the shape within the available Life Cycle Cost (LCC) restrictions. The second factor is to find the balance with the design and the support systems. The design should take account the lifecycle phases and the support provided to each phases to support maintenance action. The support system does not necessary affect directly to the operation but must enable the operation of the system during its lifecycle. Maintaining a modern aircraft many Information and Communication (ICT) solutions and multitude computerized functions are exploit on an operational level by the managers and end-users. The support systems are still not well integrated to functions and services. The maintenance programs, maintenance plans, fault and defect diagnosis, job cards, technical publications, operational feedback and health monitoring have mainly own systems and are not linked to each other. (Candell, et al. 2009, p. 938)

To tackle the challenge of building block in maintenance and support systems in present digital environment, product data and information systems the eMaintenance could be considered to be one solution.

eMaintenance collects various kinds of data and information generated by the complex product like health and monitoring data. The collected data and information from the complex product can be used for the decision making by support systems and the different stakeholders. (Candell, et al. 2009, p. 937) The information users and stakeholders need the data and information from the maintenance action. The information should be available anytime for the user at any location and at many levels of the network. The roles should be defined for authorizing the access to the users. (Jantunen, et al. 2010, p. 2).

2.2 Introduction of eMaintenance

The functions and actions have been earlier carried out autonomously. The functions or departments in concern optimized their own actions and procedures regardless of other functional areas in the network. (Galar, et al. 2015, p. 143.) Nowadays eMaintenance is a common term according to the literature. It has emerged since early 2000. Nowadays it is common in the industry to take account the integration of ICT and eMaintenance in the companies maintenance strategy plan to meet the new needs and challenges in constantly changing market. (Muller, et al. 2008, p. 1165) Muller et al. (2008, p. 1167) defined the eMaintenance takes account the standard terminology and the benefits of the excisting and rapidly developing ICT possibilities in complex network organisations and functions.

According to Levrat, et al. (2008, p. 409) the emergence of e-maintenance is linked to two main elements:

1. enabling technology increases the maintenance efficiency and optimizes the work process,
2. need to incorporate operating performance, which sets maintenance area the following criteria: transparency, integration and cooperation with other service providers.

In general Levrat, et al. (2008, p. 209) defined the eMaintenance as a concept of maintenance management where the actions and flows are monitored and managed over the Internet. It gives more transparency and efficiency to whole network and functions involved.

eMaintenance can be taken advance in several levels in the organization hierarchy. On operational level technologies and tools are involved to implement the functions to monitor the maintenance actions and its performance as well as performance indicators. The technology is used monitor the status and availability of the component or equipment for supporting the decision-making of the networks staff. Enterprise Resource Planning (ERP)

systems and Computerized Maintenance Management System (CMMS) as part of eMaintenance provide the surfaces to managers for implementing the maintenance policy. eMaintenance gives the appropriate tools for the company and its managers to implement the maintenance policy to lower levels of the organization. The information from the eMaintenance system supports the decision making within the company.

Today's technology allows implementing and designing the maintenance actions with i.e. electronic publication, health and performance data. Also the transparency of the actions with the systems the cash and stock flows are easily followed. (Jantunen, et al. 2010a, pp. 2-3)

Technological support of eMaintenance consists of internet, intranet and internet components (Iung, et al. 2009, p 221; Levrat, et al. 2008, p 413). Iung, et al. (2009, p. 223) states that innovative communication equipments various troubleshooting and forecasting tools, like virtual reality are critical decision making tools to eMaintenance. WiFi, Bluetooth, RFID Reader and other technologies and applications enables flexibility for maintenance functions to get information on site anywhere.

eMaintenance platform presents the efficiency and transparency into business processes throughout the industry and it may reduce interfaces between the separate IT systems, functions or the staff. The benefit of the eMaintenace is business process integration which paves the way to lean processes, maintenance synchronizing and minimizing the dowtime costs. The integration enhance the communication processes, reduces process errors, accelerate the feedback sysles and improves the overall quality. eMaintenance gives the opportunity to implement an information infrastructure to connect the systems, processes and actors with the existing internet network. (Muller, et al. 2008, p. 1170)

eMaintenance facilitates the data and information flow for all actors and organizational levels from decision making to planning. Concept of eMaintenance, the maintenance management, operations, tools and information becomes available to utilize anytime and anywhere. It supports decision making and business process integration across the enterprise. eMaintenance is considered to be an enabler of internal integration and decision making tool. (Aboelmaged 2014, p. 643; Muller, et al. 2008, p. 1170)

New technologies are considered to support business activities i.e interactive visualization interfaces. But still the increasing amount of information generates also challeges and obstacles to the enterprice because enomious amounts of data comes from several different sources. The income data needs to be structured and organized to a

understandable and usable form. (Oliveira, et al. 2013, p. 385) The increasing amount of information might be challenge if the technological know-how in the enterprice is not on adequate level. As the eMaintenance heavy need of the ICT causes challenges to maintenance staff due that the staff is not used to the technologies and rather uses the traditional ways of act. (Jantunen, et al. 2010a, p. 5) One stated challenge according to Jantunen et. al. (2010b) is that paper is not lost from the companies. Lot of information is in paper format and the culture change in the companyt in not an easy task. The data format standard is required for supporting the companys processes. Also the communication protocol needs to be defined. The data management is one of the key issues due the complexity of the data. The data should be managed in coordination to communicate the between the different systems. (Jantunen, et al. 2010b, p. 205)

Maintenance work requires information and experience. Therefore effective implementation of eMaintenance requires efficient information management. (Guo, et al. 2013, p. 1847) eMaintenance responds to the strategic decision requirements in integrity to the strategic decision of the enterprise. They define maintenance trends and other objectives integrated to maintenance processes within the enterprice. (Borissova & Mustakerov 2013)

According to Campos (2014, p. 244) eMaintenance will use cloud services in the future. The use of eMaintenance tools are expected to grow as an everyday practice in the industry if the provided solutions will be affordable and cost effective to investment (Jantunen, et al. 2010a, p. 204).

2.3 Product Lifecycle Management Information Flows

Industries with high safety and control requirements like aviation, medicine and hospitals, nuclear power plants first implemented the PLM concepts. The evolution of PLM within these industries have began from configuration management (CM) from where it developed to electronic data management systems (EDMS) which is the further developed to product data management (PDM). (PLM 2015) Christian (2015, p. 1) rise classical benefits of PLM as follows:

- the system integration enables more effective information flow and management of the product development will be easier,
- defined information flow in the network and integrated ICT systems for the product lifecycle,
- Boost and optimize the project portfolio

- collecting and implementing the regulations easily

The result of PLM benefits are better quality of the product, the products are brought to market more rapidly, the product is supported better during its lifecycle. (Christian 2015, p. 1).

PLM is considered as an information processing system that provides the necessary conditions to connect different data systems, processes and gives more transparency to the actions. PLM enables broad range of actions and assets to support the various processes involving in products design, planning, documentation, circulating, distribution and revising of information (Sääksvuori & Immonen 2008 p. 15). Figure 3 point out that PLM is a common and central databank.

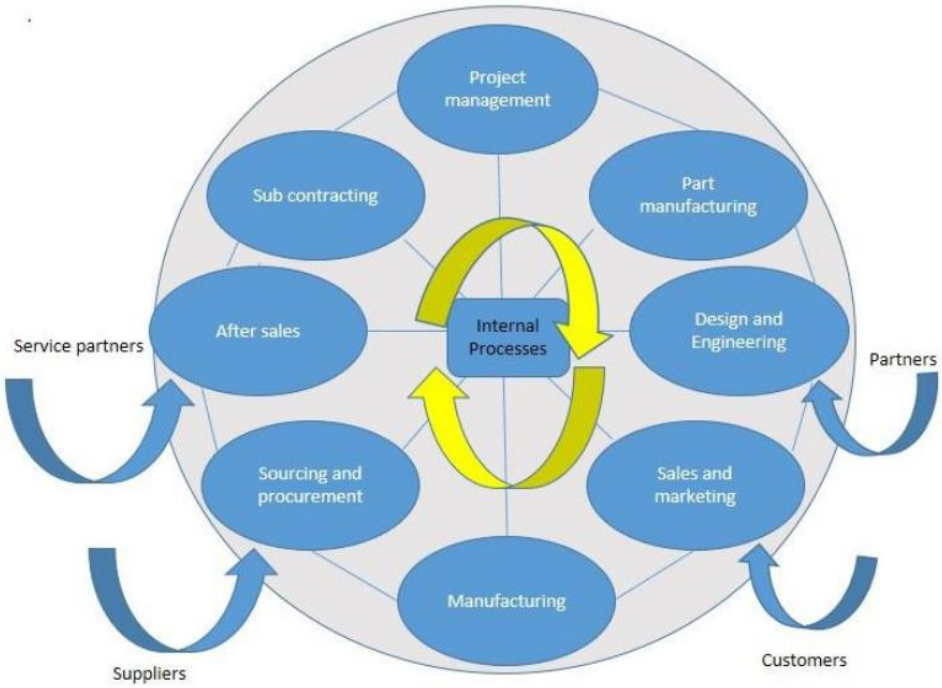

Figure 3. PLM - a common and central databank according to Sääksvuori & Immonen (2008, p. 15)

Grieves (2008, p. 1) described PLM as follows. PLM integrative information-driven business concept comprised of staff, practices, processes and technology to entire products lifecycle taking also into consideration of environmental issues from the products design and development to its manufacturing and finally to products removal from service. PLM guides the lean thinking to next generation by trading the product information across the all over the company's network and into supply chain.

A huge amount of lifecycle information is generated during the whole product lifecycle and the different phases generate plenty of information flows. The key of PLM is to identify the availability of information in phases involved and how the information can be used in order to enhance the processes. Product lifecycle information shall be achievable all the time regardless of place. The product lifecycle information shall be also stored in proper format for the information users. The concept closed-loop PLM has been introduced for observing, monitoring and use the information of lifecycle uniformly the whole product lifecycle. The information flow ends generally after the customer gets the product. So in closed-loop system the information flows during the throughout the product lifecycle and the flow is horizontally and vertically closed. (Hong-Bae & Kiritsis 2012, p.14-18.)

Information have normally a certain sequence to process or generate in a certain sequence. This is referred to as the information flow. The figure 4 presents the characteristics of PLM information.

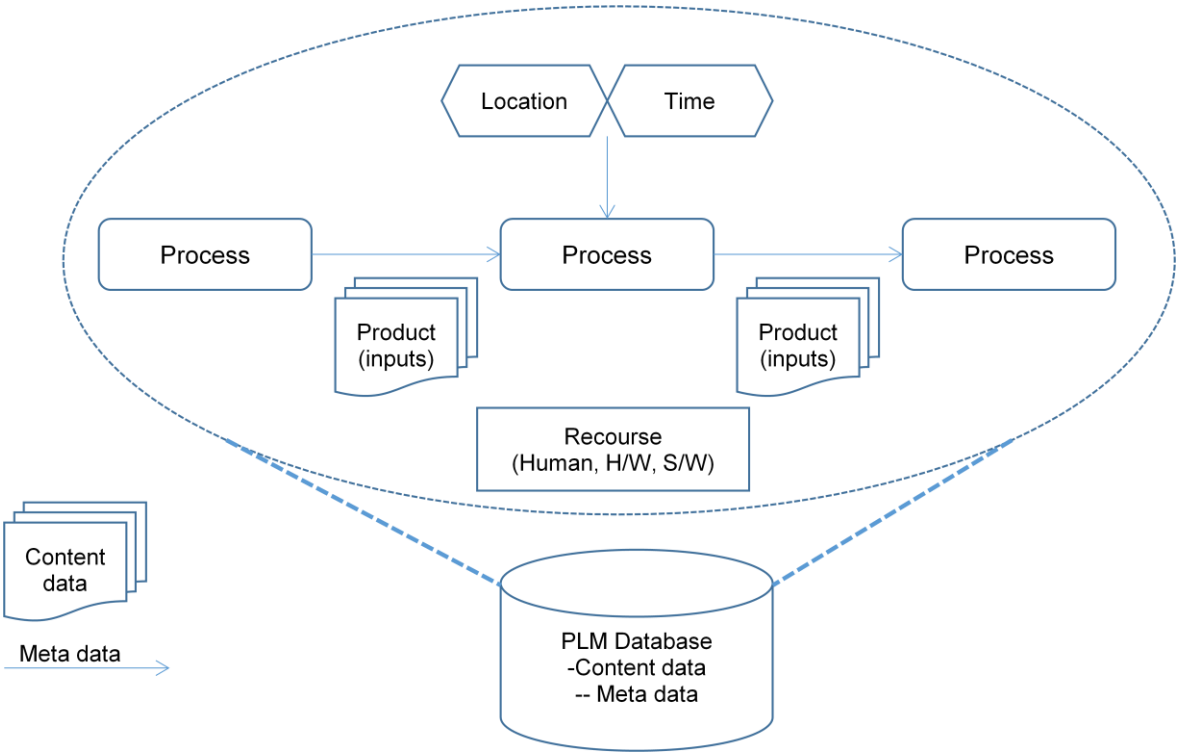

Figure 4. Characteristics of PLM information. (Hong-Bae & Kiritsis 2012, p. 17)

PLM circles the business functions like information, staff involved, support systems and processes. Golovatchev & Budde (2007, p. 1.) argues that “process supporting technologies/solutions like Workflow Management Systems (WFMS), PDM-System etc. exist today for the creation of a seamless environment for accessing, manipulating and reasoning

about product information that is being produced in fragmented and distributed environment." PLM consist of following elements:

- management of documents like design and process,
- create and management of bill of material (product structure) documents,
- electronic document storage,
- contains metadata of custom and built-in parts,
- identify the material content aligning to environmental requirements,
- allow task assignments focused per item,
- change management for workflow and processes,
- user control and electronic signature,
- data export. (PLM, 2015)

While the information and focus to environmental issues arise, PLM emerges an important matter in fulfilling a sustainable demand. It's very important to assign the role of maintenance as a vital approach for lifecycle management. Every business reaches a common goal: to boost the production at the minimum costs, while keeping the high quality. Lifecycle management for closed loop manufacturing has had impacts to companies' business models. They have been forced to transform from product providers to service providers. With this point of view the maintenance is one big service identified with PLM. Maintenance intention is to keep the products condition on the required level throughout its lifecycle. Maintenance is a significant factor in lifecycle management, when leading ambition is to augment the eco-efficiency of the product throughout its lifecycle. (Takata et al. 2004, p. 2.)

The lifecycle costs and environmental impacts are reached with maintenance centered lifecycle due to the product functions are carried out longer period with maintenance. There is also rising interest to the lifecycle management due to its economic and environmental aspect. One major item in lifecycle maintenance management is to give an information platform in order to distribute product and maintenance data throughout the lifecycle. This enables customer support and maintenance to optimize processes, achieve more effective activities, and improved part and equipments inventory management. (Stark 2015, p. 181; Takata et al. 2004, p. 7.)

The challenge in aviation is relatively long life span of services with complex equipments and parts of the product. The lifespan on an A/C is considered 30 or more. Maintaining the A/C with proper maintenance gives added value for the operator. The profitability is not

generated from the sale of the A/C but maintaining it on shape. So the aircraft maintenance organizations need to concentrate heavily on maintenance performance. The benefits of PLM applications in aircraft maintenance are lower the turnaround times and time for maintenance, control and lower the maintenance costs, and extending the intervals of maintenance. (Lee, et al. 2008, p. 298)

Lee, et al (2008, p. 299) listed the objectives of PLM in aircraft maintenance as follows:

1. to verify and return when needed the A/C safety and reliability,
2. to access the necessary information to meet the safety and reliability standards,
3. to get the needed information for components and tools,
4. to manage time limits and costs.

The feedback is a vital element of PLM in entire enterprise. The PLM collaborative management function is particularly useful for quality checks. (Lee, et al. 2008, p. 299)

With closed loop feedback feature of PLM it enables trustworthy and precise information within the network in a broad company and in the different stages of lifecycle; it will enhance the efficiency of maintenance by taking out the non-value added tasks and optimize inventory levels. (Lee, et al. 2008, p. 302; Romero & Vieira 2014, p. 163)

Aircraft is made of thousands of parts and components and is sophisticated product. The lifespan is normally decades as described earlier. Maintenance has to verify the compliance of the approved procedures with the references issued by OEM manufacturers, and air operators. Maintenance organization needs extensive expertise on continually developing and changing every now and then. With effective PLM solution the maintenance organization have entry with integrated systems and could spread the information effectively within the network in case of i.e. technical defects To ensure that the A/C is free from sources that could lead to accident the demand of maintenance are concentrated on safety and quality. PLM system could be used in A/C maintenance for information spreading during the maintenance action. Also different lean strategies are introduced for minimizing the downtime and costs. (Romero & Vieira 2014, p. 165)

The possibilities of current technology give also obstacles to A/C maintenance. Even the technology is considered to give opportunities to improve maintenance services, the increasing complexity of the technology challenge the maintenance services. Technology enables to focus more time to maintenance actions. To decrease the times spend to maintenance an integrated PLM solution with the A/C manufactures and its suppliers

could be a possibility. With this kind of system also the knowledge would improve. Expanding PLM between OEM and maintenance organization the tasks and other maintenance related publication that is produced in 3D during the manufacturing process can be shared. Maintenance staff could communicate with the model to quickly and thoroughly understand the exact issue and solution. Also other data like history records and original designs could be compared. (Romero & Vieira 2014, pp. 165-166)

2.4 Aircraft maintenance process

The proper maintenance of aircraft is extremely important in airline operations due to the effect on safety, reliability, reputation, and economy. In general maintenance activities are approximately 20 per cent of an operator's direct costs. Improper aircraft maintenance could result in safety hazards and costly repairs. (Arnaiz, et al. 2010, p. 137; Zhao, et al. 2006, p. 1) According to Civil Aviarion Requirements the air operator is responsible to keep the aircraft on Airworhiness condition based on the regulations and Aircraft manufacturers maintenance program. Maintenance can be carried out by an organisation maintaining the continuation airwothiness. The airoperator must ensure the transfer of aircraft continuing airworhiness records to maintenance organisation. The current records should be available for use when required. The maintenance organisation should establish a work card or work sheet system to be used and shall be traceable accurately. Maintenance organisation uses the flight report book as a primary source of information to take on maintenance. Maintenance planning is one of the key functions to ensure that all maintenance are carried out according to aviation requirements and operators requirements. Maintenance planning document describes the type and frequency of various tasks. Maintenance planning document is approved by CAA. (EASA, 2014, pp. 14-16)

The aircraft maintenance covers tasks and actions necessitated to return or keep an A/C's systems, components, and structures in good shape for safety operation shortly in airworthy condition. Airworthiness determines whether an aircraft, system or new part is fit for entry into service. According to Ackert (2010, p. 12) there are three main resons for A/C maintenance:

1. ***"Operational*:** To keep the aircraft in a serviceable and reliable condition so as to generate revenue,"
2. ***"Value Retention*:** To maintain the current and future value of the aircraft by minimizing the physical deterioration of the aircraft throughout its life,"

3. ***"Regulatory Requirements*:** The condition and the maintenance of aircraft are regulated by the aviation authorities of the jurisdiction in which the aircraft is registered. Such requirements establish standards for repair, periodic overhauls, and alteration by requiring that the owner or operator establish an airworthiness maintenance and inspection program to be carried out by certified individuals qualified to issue an airworthiness certificate."

Aircraft maintenance is vital in many aspects and it is also mandatory and regulated. But the nature of the business is that there is no revenue while the aircraft is on ground. For air operators it is valuable to take care of the maintenance effectively. Due to the mandatory nature of maintenance the image is not positive and maintenance suffers lack of respect and understanding. It is usually recognized as a cost, a necessary evil, not as a value adding partner (Levrat, et al. 2008, p. 409). According to Ackert (2010, p. 14) maintenance program for the aircraft fleet can be selected between basic and customized. Where basic program is more generic reflecting every applicable maintenance tasks for the fleet concerned based on newest maintenance planning document (MPD) revision. The customized maintenance program takes into account the actual aircraft usage (Ackert, 2010, p. 14). The benefits of basic maintenance program are quickly implemented and it simplifies planning and work scheduling. The customized maintenance program reduces A/C's ground time and is cost effective if managed well but it increases planning and scheduling (Ackert, 2010, p. 14).

The maintenance action binds many roles and actors together. The roles are management, support planning, preparation, execution, assessment and improvement. The figure 5 shows the maintenance process phases in general. The maintenance process phases involves of different kinds of activities, which are interrelated and tied to fulfill demands of different stakeholders. The objective of the aircraft operator and maintenance organization is to ensure safe operation at lowest possible costs. There might be also other values like environmental or domestic. The network related to the maintenance process uses and creates information when performing maintenance related actions (Candell, et al. 2009, p. 941; Lee, et al. 2008, p. 298)

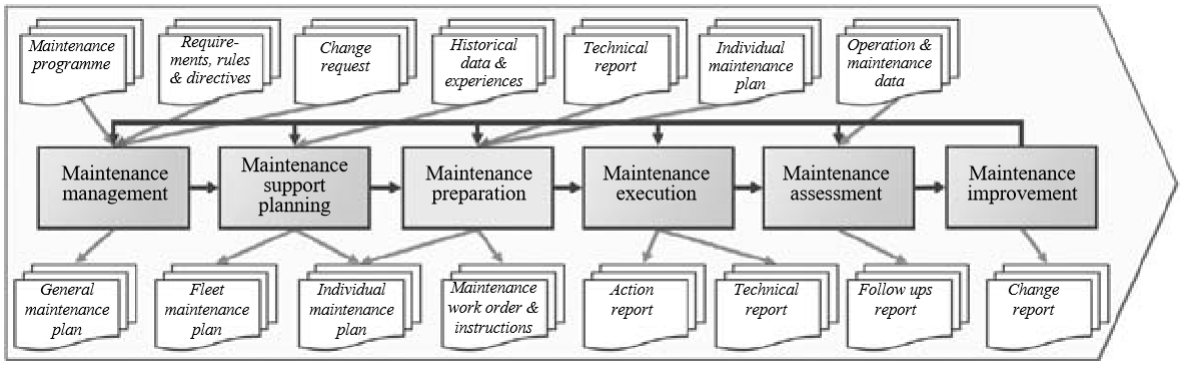

Figure 5. Maintenance process phases according to Candell, et al. (2009, p. 132)

Mertins et al. (2012, p. 166) defined the current planning and control process (AS-IS) and how it could be (TO-BE). Currently (AS-IS) the planning and control processes are executed in order including redundant loops. These loops and interfaces using different media and other forms from the maintenance demand until the A/C is serviceable. The complexity will be even higher due to the mixture of the planned and unforeseen MRO work. The maintenance execution phase needs different loops and paper documents by the technician for the maintenance actions. Mertins et al. (2012, p. 172) defines TO-BE process which should be paperless and should happen with electronic devices. The tasks, instructions and all necessary information including history details could be available on mobile.

Maintenance is deviated in to two types. The types are scheduled maintenance and unscheduled maintenance. The purpose of the maintenance is to allow and operate the aircraft safety, efficiently and respecting aviation regulations. Maintenance is still classified as on- or off-aircraft. The maintenance performed on or in the aircraft it self is considered on-aircraft maintenance. On-aircraft maintenance may be executed without taking the aircraft out of service and can happen on apron. On-aircraft maintenance is commonly called line maintenance and the off-aircraft maintenance is called hangar maintenance. Maintenance providers offer different type of check services. Usually these are based on flight hours or time elapsed since the last maintenance action. Complex and sophisticated aircraft systems have on condition based fleet management systems. Examples of such checks and inspections includes checking oil levels, wheels and brakes, the condition of hatch and the surfaces of the fucelage for damage or liquid leakage. Hangar maintenance induce scheduled checks, required modifications by OEM, authorities, engineering department or by the operator. The A/C is out of service during the scheduled maintenance. (Lee, et al. 2008, p. 299; Romero & Vieira 2014, p. 161)

The tasks for the forthcoming maintenance are allocated and scheduled into works packages and work orders. The checks and maintenance actions to items with similar intervals are grouped into a number of maintenance packages. The intervals are defined normally by the OEM. The intervals vary from daily walk around checks to checks performed on apron or bigger maintenance events done in hangar during the off-aircraft maintenance. The “A” check is executed usually after 500-800 flight hours. A-check is normally executed in hangar and is considered off-aircraft maintenance. The interval of the service varies and depends on the used aircraft type. There are different kinds of interval types; cycle based where one cycle is one takeoff and landing, or the calendar based since last maintenance. A “B” check is conducted usually between 3 or 6 months. It normally takes 1 to 3 days and is scheduled off-aircraft maintenance. The interval of “B” check is defined similarly than A-check intervals. A “C” check occurs usually between15 to 21 months or a certain number of flying hours. C check is wider than B check. During the C check the entire A/C is inspected and it will be out of operation until the check is performed by the maintenance organization. (Ackert 2010, p. 12; Romero & Vieira 2014, p. 161)

Defined maintenance checks can be done either block check or phase check method. In block check focused on the principle of grouping tasks according to defined intervals. This method produces a limited amount of comparatively huge work packages having the disadvantage of a considerable long maintenance when the A/C is out of operation. In phase check tasks are grouped into minor work packages that can be able to execute more frequently than huge work packages introduced in block check. The aim of the phase check is to shorten the downtime of an A/C and even the work load. Phase check increases the maintenance planning and scheduling efforts but on the other hand it reduces downtime and manpower and increases the A/C availability. The handicap is the limitation to do major modification during shorten downtimes and react to unscheduled maintenance actions. (Ackert 2010, p. 14)

“Maintenance planning is a matter of sharing data with MROs so the overall value chain can be better optimized. It can be internal within an airline, so engineering, maintenance, procurement and logistics are all working according the same procedures. It can be also sharing plans and information between an airline and its maintenance provider.” (Trebilock 2014, p. 1) For some aircraft maintenance action is planned so, that A/C has to go through certain maintenance despite of the situation. The maintenance slot is then fixed to the A/C for certain maintenance actions and has to be taken account planning the A/C’s operation. For the intention the A/C is then forced to follow a certain routes until the maintenance slot occurs or limited to arrive to the airport the booked and planned mainte-

nance takes place. In normal situation it is expected that the planned maintenance action takes place within booked timeframe. The maintenance slot can be also allocated as rolling basis. This is easier to do when the maintenance is within the airline. (Basdere & Bilge 2014, pp. 325-326)

An airline, the airoperator is regulated to provide maintenance data to the maintenance organization at least when the maintenance action is in progress. The approved maintenance organization has to keep a hardcopy of the maintenance documents and any other maintenance data at least three years from the date the maintenance action done. The maintenance documents under this point have to be retained in a manner of ensuring protection from theft, alteration, damage and loss. Computer software and hardware used for the documentation have to have backup in a different location from that containing the operational data in an environment that verifies the documentation stays in condition. In case when a maintenance organization ends its operation, the maintenance documentation from the last three years have to be given to the owner of the A/C or have to be given to competent authority. (EASA, 2014, pp. 21-22)

The aviation regulations allow that the maintenance record can be done data based or on papers. Also combination of these are allowed. The data based system shall:

- pledge riskless access for authorized personnel,
- quarantee incorruption and exactness of the certified data,
- not allow personnel to sign blank form,
- maintain a high degree of assurance that the data has not been changed after having signed the form,
- ensure own signature to each authorized staff member and identify the signature. The signature shall be achieved only when the signatory is present.

If paper system is used the material shall be strong enough to cope with handling and filing. The record shall persist readable during retention period. Computer programs can be used to supervise maintenance and record details of already completed maintenance performances. Computer programs used for maintenance shall have minimum one backup system which shall be updated certain intervals. Every device must have program safeguads to avoid access of unauthorized personnel. Electronic signature and release an aircraft to service have few requirements set by EASA. (EASA, 2015, p. 46; van Lieshout, 2015, p. 23)

The section has dealed the maintenance management in aviation. As we have seen the maintenance management is bunch of actions of different actors in network. The goal for the actions should be the same. The information management of the network is one player in the field and will pave the way to smoother operation and situational awareness.

3 INFORMATION MANAGEMENT IN AVIATION

Business processes have been considered as series of accomplished actions done on the basis of definite and presume information flows. Those information flows accumulate operators with relevant facilities to perform different tasks. There is need of seeping through and complying to make connections between tasks and actions appear in more flexible complex networks. (Pareschi & Fontana 2015, p. 9)

Before going further with information management the meanings and differences between the terms of data and information have to be shortly clarified for the study. Data by itself has little relevance or purpose and provides no judgement. Data is usually stored in technology systems. Record keeping and effecive data management is a vital for success of the firm. Information is described as a message with sender and reciever. Hard and soft networks make information move around the organisation. A hard network is visible and on defined base like information channels and computer sofware. A soft network is more informal and more invisible for example in ad hoc-situations. Information has the importance and pertinence. To become information data needs its creator to add meaning to it. (Davenport & Prusac 2000, p. 1-2)

3.1 Information management in Aircraft Maintenance Process

It is undeniable that communication improves effectiveness, wellbeing and motivation of employees. (Zwijze-Koning & de Jong 2005, p. 429). Symon (2000, p. 394) pointed out five assumptions for links between communication technologies and new ways of working.

1. all necessary information shall be able to be sent electronically,
2. most employees use electronic forms of communication,
3. developing electronic communication links makes communication and participation easier,
4. electronic networking makes working more independent and flexible,
5. work using communication technologies is adjusted to administrative goals.

ICT enables communication across boundaries and will provide knowledge in workers wider variety of data sources. The necessary information by these employees must be able to be transmitted electronically by involved employees. Supported by electronic distribution list and departmental intranet more information can be transmitted more efficiently. It is also noted that electronic devices help in adding these values and transforming

data into information. Computers seldom can help with context and employees usually have to make categorization, calculation and condensing. Information can be transmitted easily and there is a possibility to transmit too much information “just in case” in the firm and its network. The requirements and rules should be established for managing the information, otherwise the greater access to electronic provided information could be a two-edged sword. It should be remember that new IT is only the pipeline and storage system for information exchange. (Davenport & Prusac 2000 p. 3, 10; Symon 2000, p. 395)

In aviation activities and commercial operations the transparency of monitoring all activities during maintenance and the flight preparation stage is to deliver the true picture to the Operation Control Center (OCC). Aircraft maintenance is strict in many ways and a lot of actors are involved. The process monitors system’s ability to launch services, reports troubles for analysis and takes corrective, adjusting, revised or precautionary actions. The process shall be efficient and effective and shall be coordinated with the operation and modification processes and relate with the demands of network and customers. The maintenance actions are confirmed and restored by authorized personnel. (Karim, et al. 2009, p. 128; Makhloof, et al. 2014, p. 23; Söderholm, et al. 2007, p. 22)

In maintenance process the right information provision should be handed also to maintenance support functions. Maintenance support consists of following resources: documentation, staff, support supplies, materials, service parts, facilities, information and information systems. The support functions needs right information with right quality on right time. The desirable situation needs optimization of the information supply process. The maintenance data should be transformed into information by adding value in several ways and methods like as follows:

- **contextualized:** the involved personnel shall know why the data have been chosen,
- **categorized:** we know the analysis system or key elements of the data,
- **calculated:** the data may have been evaluated statistically or mathematically,
- **corrected:** mistakes have been deleted from the data,
- **condensed:** the data may have been condensed to shorter form.

Four aspects for the information supply process have been identified in the literature:

1. time management, “when to deliver”,
2. content management, “what to deliver”,

3. communication management, “how to deliver”,
4. context management, “where and why to deliver”. (Davenport & Prusac 2000, pp. 2-3; Karim, et al. 2009, p. 128; Meissen, et al. 2005, p. 335)

As earlier stated the monitoring of the activities allows OCC automatically do actions and decisions about how to face any difficulties in operation punctuality, define responsibilities and access achievements regarding all activities. The management and accessing activities used to be performed manually and by telephone caused inaccurate and false data and delays. Because of human factor the data was more unclear. (Makhloof, et al. 2014, p. 23)

The aircraft maintenance process phases have different information needs. The maintenance process has been described earlier in this study and it consisted of various function from management, preparation, maintenance action, evaluation of the action and improvement. The needs for management are to offer better information guidance in terms of time management, implementation, observing and change management, as well as functionality of information transfer from external resources and tools for analysis and processing. The information needs for support planning are from several sources: information managed in former phases, logistics information with respect to aircraft fleet, line replaceable units (LRU), and shop replaceable units (SRU). In addition, past information about the operation and maintenance and clear definitions of the maintenance actors and their competencies shall be available. The preparation state of information focus is on the arrangement of information services maximizing the effectiveness and role competence. This can be completed by a minimizing time-consuming access to non-electronic connections, actors within the network, and manual interference. The execution phase produces reports like accomplished tasks, replaced LRU’s and report’s findings and obstacles during the maintenance action. Due to the nature of maintenance actions there is a need for entry to operational information, work orders, the maintenance manuals, logistic flows, and staff qualification. ICT should easy the access to the needed information sources i.e. a digital service platform that supplies many different assisting actions via one unified convenient interface. Maintenance evaluation needs most of the information about the maintenance action that has been produced during the earlier stages. Maintenance improvement requires the equal information as the maintenance evaluation stage (Candell, et al. 2009, p. 941; Karim, et al. 2009, pp. 133-135; Lee, et al. 2008, p. 298)

MRO activities have to take in to account the aviation requirements, authorities requirements, other aviation directives and bulletins providing operation of fleet and aircraft

types. Ucler & Gok (2015, p 1507) have drawn the information flow and responsibilities of these activities see figure 6.

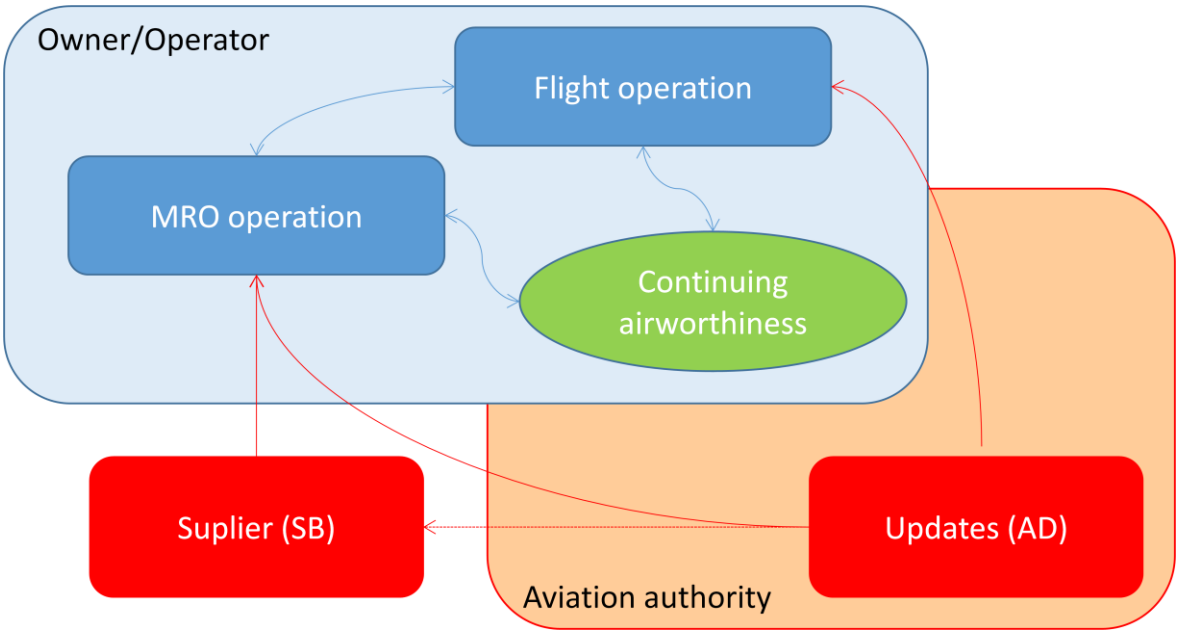

Figure 6. Information flow and responsibilities by Ucler & Gok (2015, p 1507)

For better and smooth information flow between the different tasks and application the need of paper based documentation should be eliminated. This would also reduce the costs. Aircraft maintenance actors need information for performance of activities in their work role within the maintenance process. They also need to have an access to the information in a multi-application environment. The applications between information supplier have minimal or no integration between each other, like fault localization support tools, modification services, condition monitoring and feedback of operational data, and maintenance publications. (Candell, et al. 2009, p. 136)

3.2 Challenges in Information Management Aircraft Maintenance Process

Different kinds of challenges are identified in research and literature. The security and telecommunication safety is not handled in this study even those are identified challenges. The large and networked companies are usually organized according to functions like planning, engineering, marketing, manufacturing, maintenance and overhaul. These departments are designated as some of the organizations actions. The personnel are designated to a department. Engineering personnel are doing their best to achieve engineering objectives. The IS applications would then try to optimize for the department and for its benefits. When thinking this concept there are remarkable organizational challenges in crossfunctional teams and cooperation networks. The challenge is related to information.

Collecting information is done from many sources. Collection information involves elements like as localizing the right information origin, entry to the information source, delivery of the needed data, collection of data to the needed level, verification and staff qualification and makes the information visual for the concerning information user. Common understanding, descriptions, software and digital platforms and information flows are required on management level in order to be able to reuse the information. Construction of shared commonly agreed information flows and tools are part of challenges in reusing information within the cooperation networks. The challenge is related also to the numbers of interfaces between the applications in use for the information. (Karim, et al. 2009, p. 136; Silventoinen, et al. 2014, p. 727; Stark 2015, pp. 183-184)

As described earlier by Davenport & Prusac, (2000, p. 3, 10) and Symon, (2000, p. 395) the computers adds value and easy the way of transforming data into information, but this might lead to situation where we are transmitting too much information in the network. The lack of rules and requirements for information management and spreading is a challenge in information management. The challenge will be also when the organization do not know for what purposes the data and information is collected, do not know the key components of the data, the data is not analyzed and the errors in the data is not removed. Situational awareness may be disturbed if there is too much data and no access to the right information (Davenport & Prusac 2000, pp. 2-3; Karim, et al. 2009, p. 128; Meissen, et al. 2005, p. 335). Silventoinen et al. (2015, p 195) stated also that one additional challenge in network where the information should be available is the ownership of the information. (Silventoinen, et al. 2014, p. 723)

Stark (2015, p. 195) listed cases where the workflow was disturbed by of lack of clarity:

- unclear or not defined roles for access and rights at each phase,
- unclear how information flows in the workflow,
- not known phases of the workflow and not known to where the information in the workflow is being used for,
- not known what happens at each stage and not known what kind of conditions to be met before going further to the next phase.

According to Makhloof et al. (2014, p. 23) activities used to be performed manually and by telephone caused inaccurate and false data and delays. Because of human factor the data was more unclear. Paper based documentation should be eliminated for avoiding challenges in information management in aviation due that in the air operation network

there are so many information consumers for the smooth flight and passenger operation. (Candell, et al. 2009, p. 136)

The lack of integrated information solutions or monitoring systems with challenge linked to human factors, like the motivation and skills might lead to situation where the information gaps could occur. The excessive amount of information can encourage information users to regret the information. Or it might lead to a greater susceptibility to strategic information misinterpretation. (Crespo-Marquez & Iung 2008, p. 64; Silventoinen, et al. 2014, p. 727)

3.3 Information Network Analysis in Maintenance Process

Generally networks and networking are considered actions and co-operation between two different companies or organizations. These networks are based on trust and voluntary and the aim is to benefiting all parties to co-operate. In this section the network is considered as information flows between the co-operation departments working towards smooth air operation for customers. The information Network Analysis will be described in this section combining with two different theories; information management described above and Value Network Analysis.

According to Allee (2008, p. 6) the purpose of networks within the organizations, consists of various kind of roles and value interactions oriented towards the outcome or agreed objective. People are the participants in the network by playing the different roles. Also Zhang & Yang (2002, p. 235) highligts the importance of the roles, privileges and interrelationship of the duties and how to violate any constraint of the roles. Bovet & Martha (2000, p. 22) instead alleges that a value network of the organization is a dynamic information flows of customer and supplier partnerships. A value network adds value for all of its actors and because these participants operate within a collaborative, electronically linked network.

Bovet & Martha (2000, p. 23) allege also that digital technology is vital for value of networks. Digital technology enables real-time information distribution among the network. Exact and correct timing of information creates value to the network. The global business is feasible and the overall situational awareness reduces the stocks. (Bovet & Martha 2000, p. 23) Value network analysis gives tools to, analyze, access, and enhance the capability of a business to convert tangible and intangible assets into other forms of negotiable value, and to realize greater value for itself. The ability to convert the gathered value into another defines the firm's success. "An example of value conversion occurs when an intangible asset such as professional expertise is converted into a more negotiable form of

value, perhaps in the form of consulting services. The conversion dynamic also applies to value realization. An example is when a tangible value input, such as purchased market intelligence reports, is converted into a non-financial asset of increased levels of marketing competency." (Allee 2008, pp. 5-6)

Network analysis helps to reveal the unofficial communication forums and information sources but for the analysis it is necessary to map the relationships within the organisation. The results are the be compared to the established communication structures. (Zwijze-Koning & de Jong 2005, p. 431) Zwijze-Koning & de Jong (2005, p. 431) alleges that literature have two limitations for network analysis. First limitation is that usually the focus is emphasessed to the analysing of network data i.e. attention is given to the calculations rather than connectedness, density and degree of centrality. Second limitation based on literature is that the focus is set on wide context which are not comparable to the communication and information.

Allee (2008, p. 14) developed the value network analysis-method. The full value network analysis is possible to do while important roles, value transforms and operations have been mapped and known. There are three simple questions for the analyzing the network. The questions are adressed to assess the value dynamics, health and vitality, and value conversion capability of the system as a whole and concentrate on each specific role as it relates to value conversion. Allees (2008, p. 14) basic questions for value network analysis are:

1. exchange analysis – What is the overall pattern of exchanges and value creation in the system as a whole? How healthy is the network and how well is it converting value?
2. impact analysis – What impact does each value input have on the roles involved in terms of value realization?
3. value creation analysis – What is the best way to create, extend, and leverage value, either through adding value, extending value to other roles, or converting one type of value to another?

In short the value network analysis will be answered to question what roles and interactions are needed (Allee 2008, p. 22). Figure 7 shows an example of the Value Network Analysis.

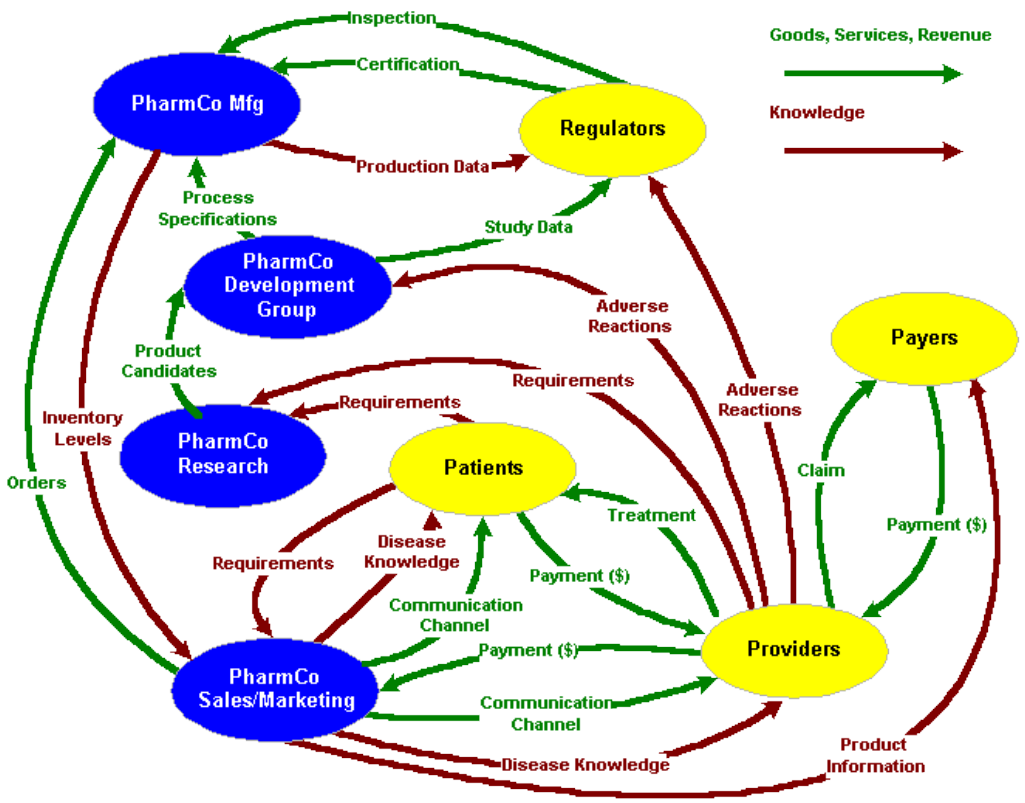

Figure 7. Value Network Analysis Diagram according to Allee (2000, p. 38)

The Allees (2000, p. 38) example in the figure 7 reveales tangible the financial relationship with medical providers and the intangible, communication loop about vital information flow to smooth the way for providers.

The Information Network Analysis is new idea for the thesis. The Information Network Analysis is derived from the theories of Information management, value Network Analysis and PLM. With the information network analysis is thought to tackle of any process information flows with correct data and timing. Information Network Analyis answers the questions: what to deliver, contacts to deliver and where to deliver. Shortly it will gives the sight of the networks actors connections to each other in point of view of proper information flow. The basic questions are:

1. what to deliver: basic information are location, time and task,
2. contacts to deliver: basic information are location, time and task,
3. where to deliver: basic information are where to report the information of accomplished task i.e. data base and supervisor/next information user in the network.

For the Information Network Analysis it is needed to identify the actors, the roles and the timing for spreading the information in the workflow. It have to be clear to all parties and stakeholders to know how the information and the process will proceed when the nessessary information is needed by the actors. The figures 8 and 9 describes the general idea of the information network analysis. In the figure 8 are defined the roles in the network. The figure 9 is a picture of supervisors and tecnicians slots of the analysis. The analysis could be also draw on to organization chart, process chart, or add to value network analysis as one dimension.

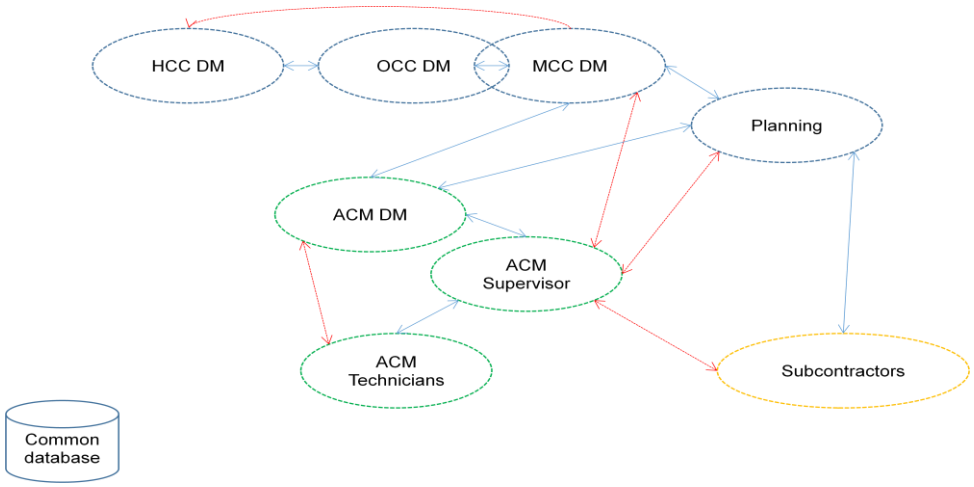

Figure 8. Information Network Analysis derived from Information management and Value Network Analysis; The roles in the network: ACM – aircraft maintenance, MCC – maintenance control center, OCC – operation control center, HCC – hub control center

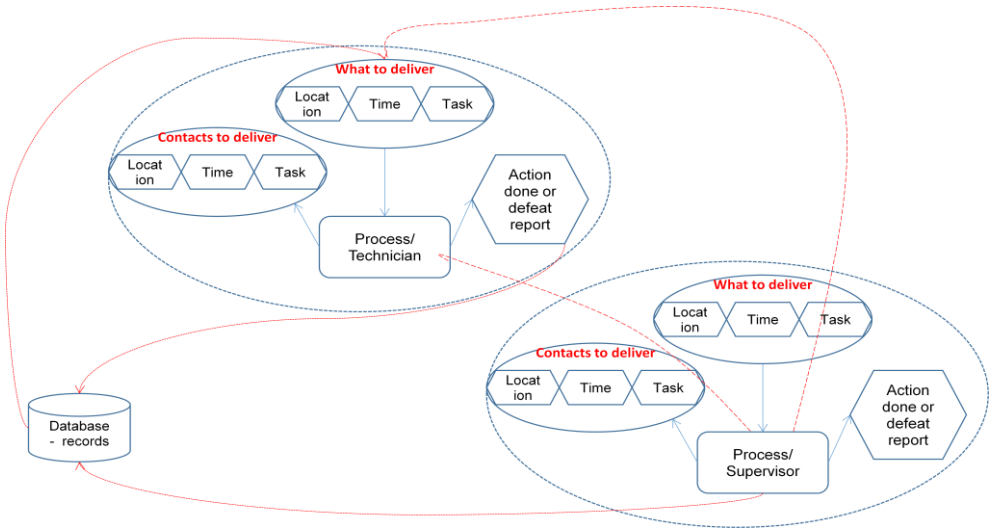

Figure 9. Detailed picture of supervisors and technicians Information Network Analysis

4 METHODOLOGY

This section describes the case organization, research process, the collected data and material and the used methods. This is a qualitative study with inductive approach. The qualitative data is analyzed with a systematic procedure in the inductive approach and is derived by specific evaluation objectives. The inductive approach provides research findings to emerge without any restrictions. The raw data leads the findings by structured methodologies (Thomas 2006, p. 237). The subject of the study is a traditional aviation maintenance organization which procedures, actions and the scope of work have been in change for last few years. During the study there were several ongoing projects for improving and digitalizing processes and the organization.

4.1 Case description

The case organization in this study is an aircraft maintenance organization which is a part of an airline. The study is limited to concentrate to the maintenance activities and the maintenance organization network it serves. In an airline the revenue comes from the travelling passengers and cargo. The customers, passenger and cargo will buy service and the service for an airline is carry passenger or cargo from place A to place B. The planning for air operation takes account the need of scheduled maintenance.

The development process during the last years in the case origination has been challenging. The competition and common regulations have been shaping the aviation industry a lot and the company has been forced to adapt to the situation with massive re-organizing and process changing. The main business is the air operation. The case organization has been reducing its capability from nose-to-tail service provider to service which enables the airlines operation according to its route schedule. In other words the maintenance organization has been concentrating its effort totally to support the airlines operation. In shortly this means that the case maintenance organization deals mainly line maintenance up to C-checks. The heavier maintenance tasks are done with third party maintenance provider.

Aircraft Maintenance department is responsible to produce high quality aircraft maintenance production cost-effectively for air operators Airbus fleet. Main focus is on effective line maintenance support in Europe. Supportive role is on structural repairs, parts and Component repairs, modifications and simple base maintenance tasks and checks. Ad-hoc technical support is provided on out-stations as necessary on availability basis. Aircraft Maintenance department is responsible for the following activities:

- produce high quality aircraft maintenance production cost-s Airbus fleet,
- provides line maintenance support in Europe,
- supports structural repairs, parts and Component repairs, modifications and simple base maintenance tasks and checks,
- provides Ad-hoc technical support is on out-stations as necessary on availability basis,
- EASA Part 21G Production Organization activities as described on POE.

Line maintenance end-to-end process is described as in the figure 10 shows. In this study is concentrated to the maintenance execution and maintenance closing.

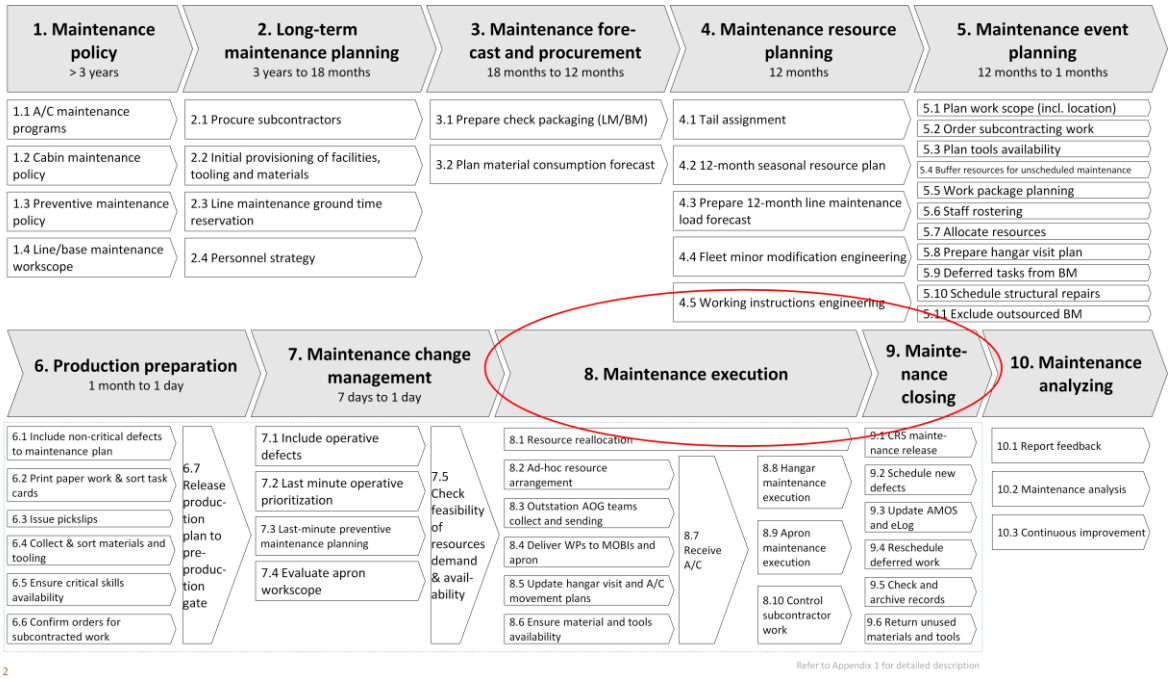

Figure 10. Line maintenance end-to-end process

4.1.1 The actors and responsibilities in aircraft maintenance

Aircraft Maintenance department executes the scheduled and unscheduled maintenance. The controlling responsibility of the maintenance activities is on Maintenance Control (MC). MC is to control the scheduled and unscheduled line and base maintenance based on operational and airworthiness requirements. Department is responsible for decisions on irregularity situations (information of maintenance and technical issues). MC provides status of fleet usability within the organization, ensures contracts for maintenance services at line stations. Analyzes recurring defects and incidents and proposes/generates corrective action campaigns. The following tasks and responsibilities are set for MC:

- responsible for decisions on maintenance 24/7,
- control of scheduled and unscheduled line and base maintenance actions based on operational and airworthiness requirements,
- update the short term maintenance plan Support line and base maintenance providers with instructions,
- defect management,
- provide with information of maintenance and technical status of the fleet potentially impacting flight operations,
- contracting and support for line stations,
- aircraft on ground (AOG) control.

MC is a part of Operation Control Centers (OCC) functions. The main function OCC in short is to keep the planned flight schedule so that flight departures occur at the planned timing. OCCs have also other aims like as reducing the occurrence of delays and facing any internal or external challenges to the operation. So is important to follow-up the activities that the correct situational snapshot is automatically delivered to OCCs. The snapshot helps the OCC to make rapid and right decisions. The data might be unreliable due to rapid obstacles are communicated with telephone and other manual methods. Also due to the methods delays might cause and human factor issues could occur. The following functions are included in the OCC:

- Operations Control,
- Slot Coordination,
- Flight Planning, and Flight Planning Support functions,
- Crew Control,
- Maintenance Control,
- Disruption Management and Operational System Control Support.

While the OCC is in charge of all operational issues for the air operation the HCC is responsible for the passenger and cargo flows. HCC manages the real time monitoring of sub processes of the air operations. The paths are divided into two main lines: Customer path and Ground handling path. Hub Control-application shows how all sub processes are performed in real time. The real time information of the sub processes are handled in most cases with RFID. For the customer experience and smooth operation HCC needs to know all the tasks for the aircraft during its ground stop. HCC executes the company's strategic traffic plan, Monitoring fleets, crews, ATC restrictions and passenger flows, iden-

tifying the critical path in the network, Proactive approach in disruption management. HCC is key player in the operation. The figure 11 shows the stakeholders of HCC.

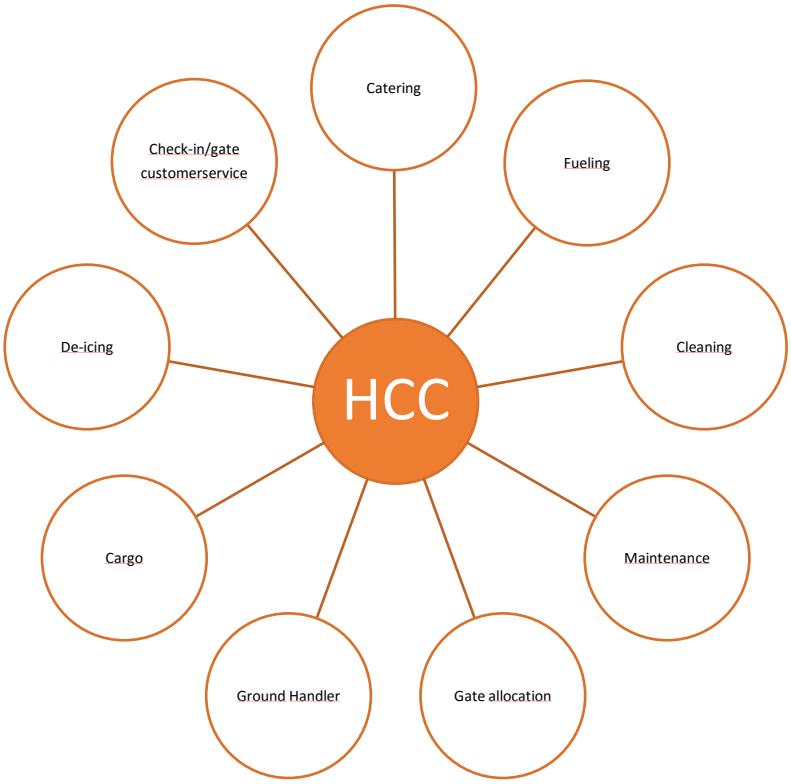

Figure 11. HCC Stakeholders

The case organizations network is basically internal network where the functions vary depending on the department. The above mentioned descriptions are highlighted for this study due that those are the information consumers for the aircraft maintenance process. The company's operational division is shown in traditional organizational chart in figure 12. In the figure 12 is highlighted with colors the functions described earlier. The blue boxes are considered maintenance related issues and the green boxes are HCC related issues It can be seen also that the organization will work in matrix.

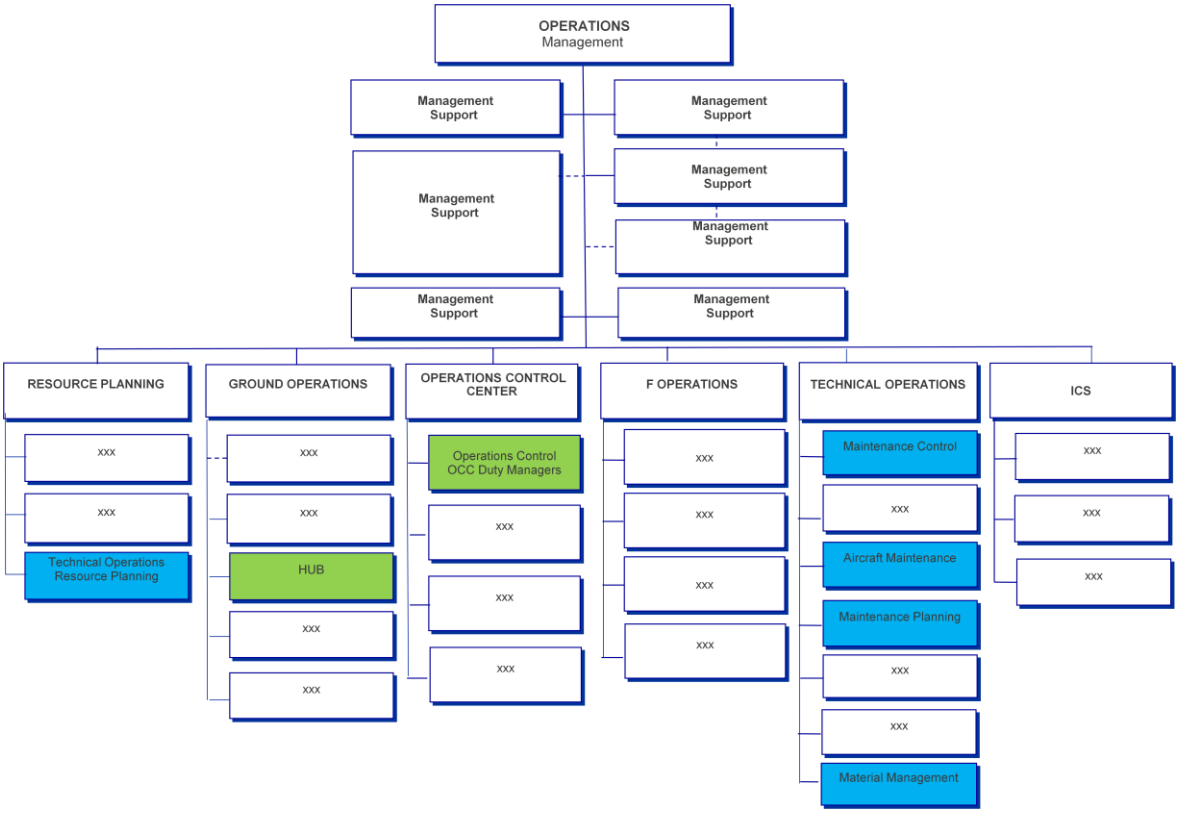

Figure 12. The organization chart of the case company.

4.1.2 Tasks and resources usage in aircraft maintenance

Maintenance preparation concerns of scheduled maintenance. Scheduled maintenance work packages are updated assigning open defects to planned work scope. Also maintenance events with short interval will be added. Work due lists will be checked for recently added items. Finalized work packages are prepared to production by:

- printing task cards and necessary maintenance data,
- ordering spare parts and materials needed from stock,
- ordering special tools from stock,
- communicating with stakeholders about ordered external services,
- comparing shift total workload and labor capacity.

Service Check due times are controlled and next executions are scheduled. Hangar utilization is planned and A/C tows to and from hangar are ordered accordingly. Maintenance resources are allocated based on production plan. Scheduled maintenance will be performed and raised defects will be prepared and in case all needed resources are available raised defects will be rectified. Maintenance will be closed and reported back for issuing CRS for aircraft. The staff usage (technicians) is divided with the ACM and MCC. Technically the staff is allocated to ACM. The MCC needs resources for apron maintenance for

dealing the daily operations according to the flight plans. The figure 13 shows generally the activities and the responsibilities for maintenance actions from planning to execution.

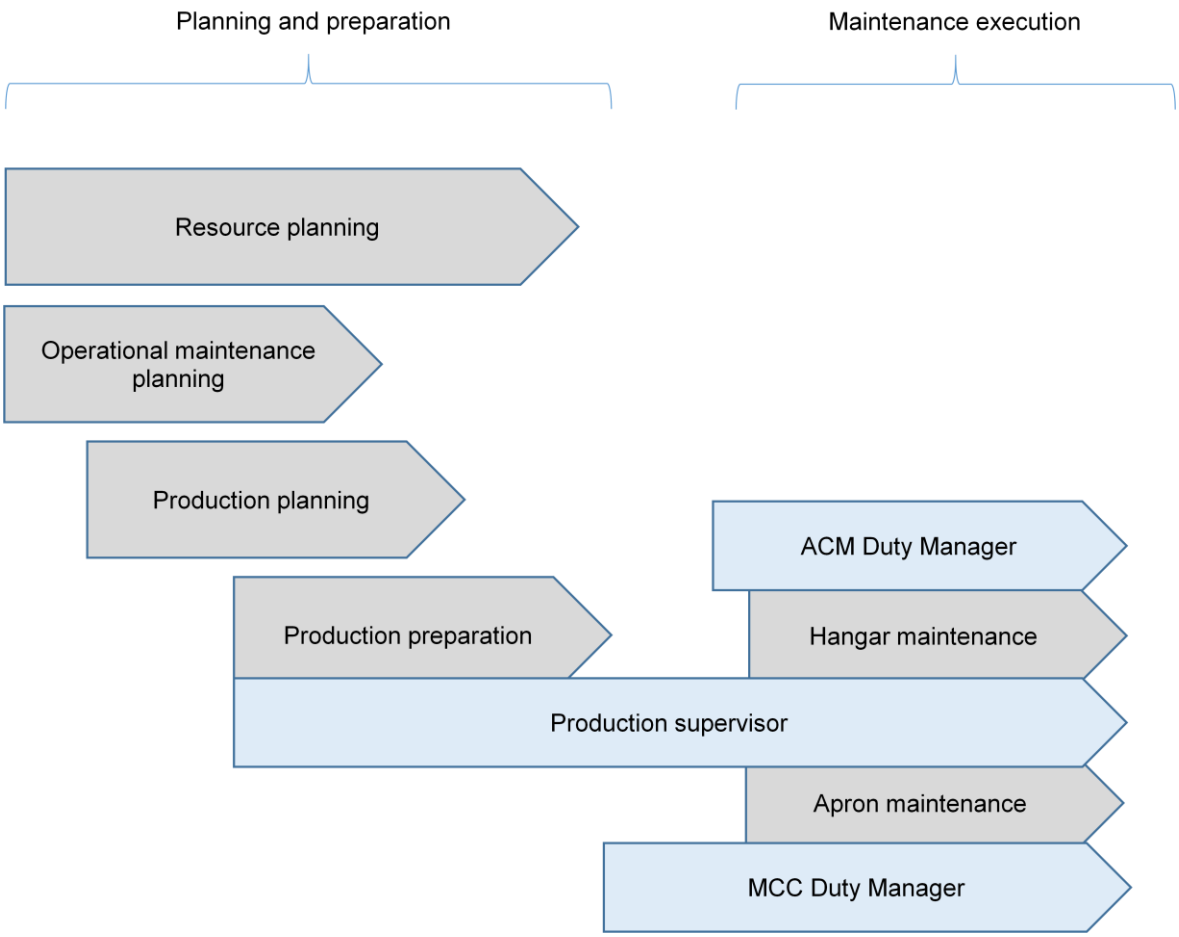

Figure 13. Maintenance planning, preparation and execution

Several different information resources are used for spreading the information in ACM and among the network users. The AMOS is the main Aircraft Maintenance and Repair Management Software. AMOS is used by several functions for maintaining the aircraft i.e. work planning and resource planning. Digi DM is a tool for duty managers (DM) in ACM and MCC. Digi DM holds A/C's turn around lists, man power reports and the most important maintenance tasks. Primavera shows maintenance load against the capacity and it uses AMOS data. Primavera is mainly for short term planning for guiding. Electronic logbook (eLog) is electronic system for collecting technical data and aircraft maintenance log data which enables both maintenance staff and flight crew to record logbook events and allow this information to be transmitted immediately within the network involved. Verbal and paper information spreading happens mainly between the supervisors and technicians during the shift hand over and task closings. The last minute changes in work packages and tasks may be transferred to next maintenance will be handled by phone with

ACM DM and MCC DM. The changes may be also planned and agreed by chat. E-mail is used for maintenance situational reports to all network parties. The content of the e-mail is produced by ACM DM three times a daily. Scope provides routing information to all aircrafts. Scope is used widely all over the organization because it is the main routing software for the airline. Scope is also used by ACM, MCC, OCC and HCC. OPS Metrix was a new software which was in use only in HCC during the study. It is meant to be gathering software for the company for “heads up” actions. SRT Matrix and Maint OPS are used for ordering subcontractors and LRU’s. The table 1 shows the used Information Tools and the users by functions:

Table 1. Information resources for aircraft maintenance

System	**ACM**	**MCC**	**OCC**	**HCC**
AMOS	X	X		
Chat	X	X	X	X
Digi DM	X	X		
eLog	X	X	X	
e-mail	X	X	X	X
Excel	X	X		
Maint. OPS	X	X		
OPS Metrix	X	X	X	X
Verbal	X	X		
Paper	X			
Phone	X	X	X	
Primavera	X	X		
Scope	X	X	X	X
SRT Matrix	X	X		

* There might be some other resources which did not came out in this study

4.2 Empirical data collection

In qualitative research the data will be collected as much as it is necessary for the subject and set research target. In practice until the saturation is reached. (Eskola & Suoranta 1998). The empirical evidence in this study is collected with observation processes, interviews and questionnaires. The processes were observed six times during the study. Four of the times concentrated to ACM processes, one to the MCC/OCC process and one to HCC process. The table 1 shows the in chronological order the observed processes. During the visits the discussions paved the way to understand to wholeness. These discussions were not documented. Two questionnaires were sent to selected roles concerning the information flows and information sources. The questionnaires were done in Finnish

and later translated by the thesis writer. The questionnaires appendix 1 and 2 were carried out with Google forms-platform and distributed by e-mail.

Table 2. List of observed processes:

Date	**Observed process**
14.9.2015	Maintenance action: A-check process
1.10.2015	ACM maintenance process (supervisor – technician, planning)
2.10.2015	OCC/MCC process
14.10.2015	HCC Process
20.10.2015	An interview together with Aalto University
29.10.2015	Duty Manager process

The first questionnaire concentrated on the specific observed A-check process and the personnel involved to the maintenance process. The purpose of the questionnaire was to map the information paths from different roles in the maintenance action. The questionnaire included 16 questions from where 13 were open questions and three were multiple choice questions. The questionnaire was sent to 13 persons via e-mail. The response time was from 17th of September to 25th of September. The distribution list was selected together with the management of ACM. The roles for the selected questionnaire receiver were ACM management, customer (MCC), planning, duty manager (ACM), supervisor, technicians. The response rate for the first questionnaire was approximately 46%.

The second questionnaire concentrated on maintenance process information management. The purpose of the second questionnaire was to map maintenance actions information flows and situational awareness between the involved networks. The questionnaire included 18 questions from where the 15 questions were multiple choice questions and three open questions. The questionnaire was sent to 13 persons. The response time was from 4th of October to 12th of October. The distribution list was selected together with the

management of ACM. The roles for the selected questionnaire receiver were management of ACM and MCC, customer duty manager (MCC), planning management, duty manager (ACM), supervisor and technicians. The response rate for the second questionnaire was approximately 70%.

The researchers of Aalto University were conducting research of interface and usability for mobile signing the tasks during the fall 2015. The researcher of Aalto started their research at the same time while this study started. The researcher of Aalto had their own plan for collecting data. One Aalto arranged interview was anticipated together and we observed together the HCC process. With Aalto researchers we shared information and the results of interviews, questionnaires and process observation results because it was found out that there were synergies with the study and the research.

4.2.1 The raw data of the first questionnaire

In the figure 14 is shown the number and roles of the respondents. The low response rate may be explained the fact that the questions were mainly open questions rather than multiple choice questions. Other reason could be also that the productions staff does not have own computers at work or the ICT skills are limited.

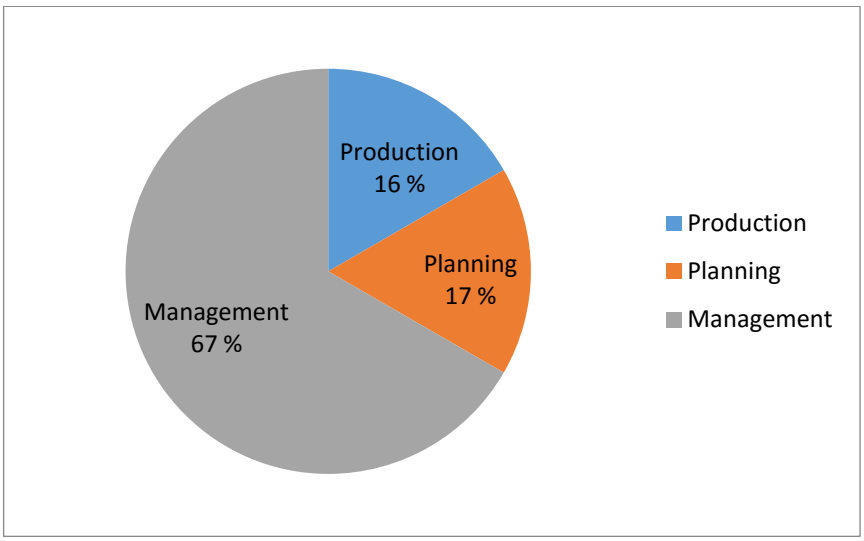

Figure 14. Number and respondents roles in the first questionnaire

The questionnaire concentrates to a specific maintenance event which happened on 14.-15. of September 2015. Even this is directed to the certain maintenance event the raw data can be generalized. The questions were concentrating to the need, sources and reporting of information for the maintenance event.

The information needs prior the maintenance action were asked with open question. The answers did not vary much depending on the work roles. The maintenance organization needs certain information before the planned maintenance action.

- “the tasks that have to be done before the A/C enter to the hangar (fueling etc.)”,
- “long lasting maintenance actions or defect repair and tasks that have to be started right in the beginning of the maintenance action”,
- “tasks that needs special skills”,
- “the schedule of subcontractors”,
- “the situation of the materials needed for the maintenance event”,
- “the information of transferred tasks that could be if needed transfer to other maintenance slot”,
- “the allocated resources”,
- “the target for the run-up test”.

The information sources and how and when the information will reach the actors in different roles were asked with few open questions. There were some deviations between the roles i.e. the production staff will get mainly the information from the superior at the beginning of the work shift instead of planning or management will have regular meetings scheduled for the maintenance event. It is seen that the other roles than production knows widely the context of the planning. There are several functions from where the information will come. This might give some obstacles for the smooth flow of the information if it have to be mined from different sources.

- “planning and resource planning”,
- “Tech OPS planning, MCC planning, MCC DM, Engineering, ACM DM, tool group, procurement IT systems: SRT matrix, Maint OPS, primavera, scope (routing information), AMOS”,
- “nowadays, hardly nowhere. A planner collects the work package but for me it becomes clear just when I come to work. If there is "ear marked" tasks for me in advance those can be find from Amos but that information can still change before I come to work. The information has to be found out from the system by myself”.

Then it was asked how the above information reaches the actors. Here is seen the differences by the roles. The production staff gets the information at the beginning of the shift from superior and from the AMOS while the planning and management sees the situation

overview in few days window. It is heavily depending on the role how the information reaches the actors. Some of the information is only in verbal format if it comes via phone. Then the information is generated by the actors together from the current situation based on their tacit knowledge. Spreading this information lays then on the individual's expertise and will be forwarded by chat and verbal.

- "at the beginning of the work shift and searching from Amos. Superior might have some last minutes hits also",
- "amos and phone",
- weekly report general overview +8 days window Planning meeting few days before the extra noticed tasks like engine change, Big A-check or some modification. Primavera real time-information from the wall ACM DM current situation report (three times a day) daily report by e-mail.

The information can be found also from the various systems and sources:

- the tasks that have to be done before the a/c enters to the hangar (fueling etc.): task card and sometimes work package summary (front sheet),
- long lasting maintenance actions or defect repair and tasks that have to be started right in the beginning of the maintenance action: AMOS, calling to MCC,
- tasks that needs special skills: Man Power report and sometimes work package summary,
- A/C's maintenance status related tasks like (fuel tank, jacking, body washing): Task card and sometimes work package summary,
- the schedule of subcontractors: asking from AMC DM, WP Summary or looking from Maint Ops-system,
- the situation of the materials needed for the maintenance event: AMOS and calling to AOG desk,
- the information of transferred tasks that could be if needed transfer to other maintenance slot: Calling to MCC DM,
- the allocated resources: Man Power report and having a conversation with ACM DM,
- the target for the run-up test: departure time and maintenance progress.

The timing of the information reaches the actors in different roles were asked with one question. And when the above information has become?

- in all the above mentioned information will come when supervisor have sorted it out unless the issue is not written to WP Summary by planners/planning,
- weekly report before hand - power point which will not up-date Primavera-system - real-time view from work load vs. resources one week ahead divided into shifts (the view have faced an inflation) Planning meeting few days before the maintenance action.

As it can be seen there is lots of information before the maintenance action. It was also asked is the prior information for the maintenance action (A-Check) been adequate (whether there has been too much or too little)? In the figure 15 shows the opinion of the respondents to the question. There is lots of deviation due that two respondents have thought that there are enough and sufficient information before the maintenance action but rest of the respondents think that there are too little information prior the maintenance execution.

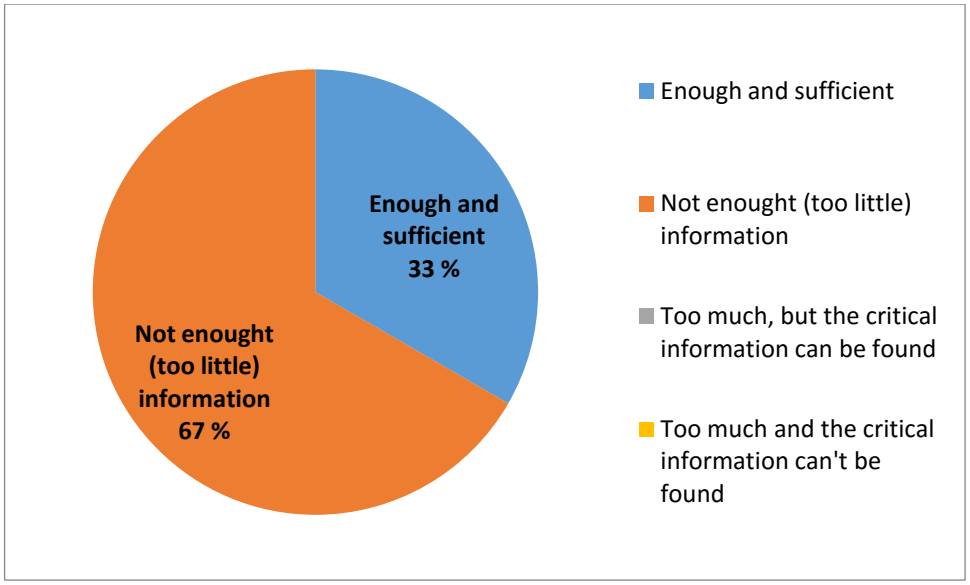

Figure 15. Is the prior information for the maintenance action been adequate

The reporting of maintenance data were asked with two questions for mapping the information to report as a wholeness and how the maintenance data is reported. To these questions were also linked a question to map the general knowledge that who will need the reported data. During the maintenance execution the reported information are as follows:

- defect notes and other remarks. Completed task cards after the guys returns those,

- the finding during the maintenance action which could cause delay to the departure,
- returning of task cards (finished tasks) will give also the feedback of the progress of the maintenance action,
- defect findings.

These are reported forward again differently depending on the roles. The production staffs will reports both verbally to supervisor and making the AMOS reports. The management will report the information with e-mail and phone. The planning uses multiple channels.

- closing the Amos Work orders and if some defects found, opening the defect work orders. Verbally to the supervisor what have happened during the maintenance,
- to status reports via e-mail and Consulting with MCC about the status of the maintenance and bottle necks. Possible transferred tasks via phone,
- Amos - ACM DM - MCC DM - MCC Planner - AOG Desk - Technicians - Planning - Subcontractors - Transfer coordinator - Phone - Face to Face - e-mail.

Who will need the reported maintenance data is an interesting question and the deviation between the answers can be seen below.

- the management board of the ACM will follow the maintenance actions and the schedules,
- supervisor, DM and MCC,
- the operator,
- especially the operator (MCC) and the distribution list for the status reports.

4.2.2 The raw data of the second questionnaire

The second questionnaire was focused more on general level to the maintenance process information flow and the situational awareness in different functions in the organization. There were 18 questions from where the 15 questions were multiple choice questions and three open questions. The questionnaire was sent to 13 persons. The response rate for the second questionnaire was approximately 70%.

In the figure 16 is shown the number and roles of the respondents. The response rate was much better than the first questionnaire. The reason for the better rate might be due that

most of the questions were multiple choice questions. It is remarkable that there are zero customer responses.

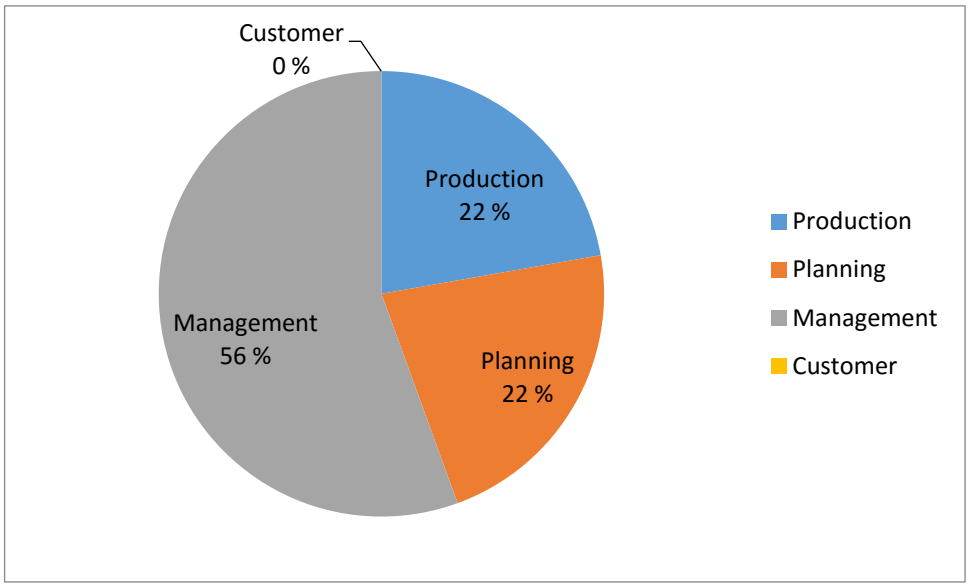

Figure 16. Number and respondents roles in the second questionnaire

By grouping the questions there can be find some interesting outcomes from the data. It was asked if the organization uses all the available data for smooth maintenance production, is the organization able to utilize the data for turning it into information for maintenance execution and the third, I know and pass the essential information for improving the maintenance execution. In the figures 17, 18 and 19 are presented the answers to these questions. It is interesting to see that staff at least tends to know the essential information but still it is not seen to be turned for the organization use.

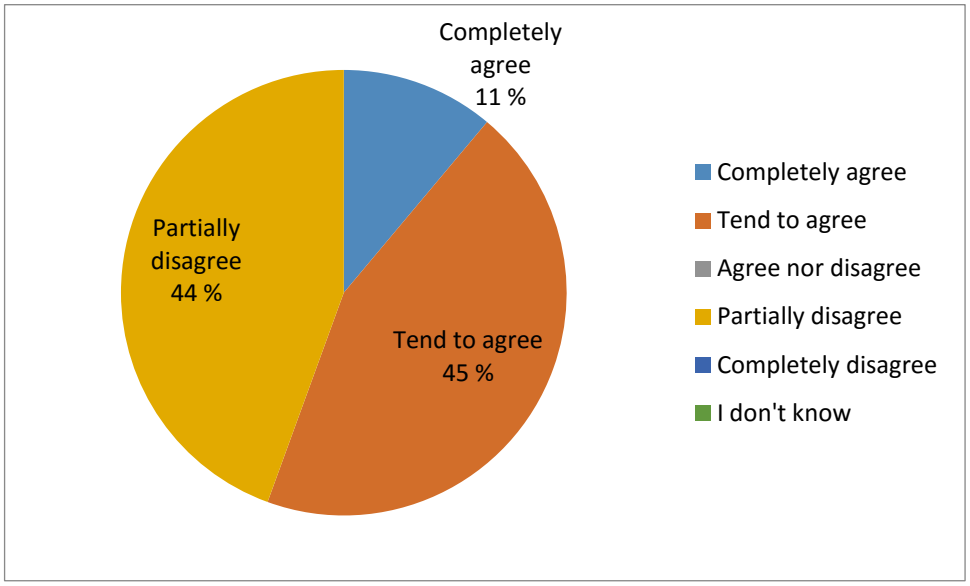

Figure 17. Organization uses all the available data for smooth maintenance production

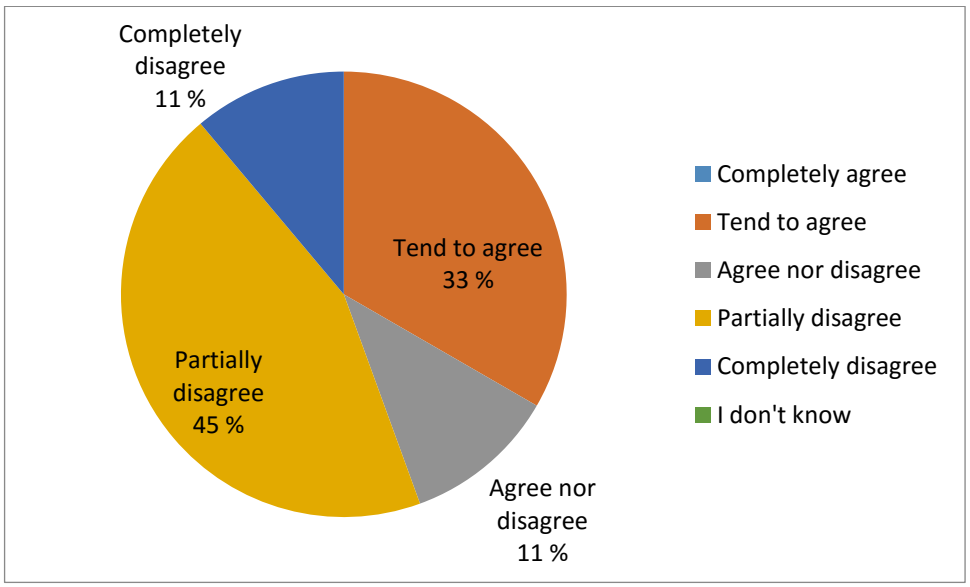

Figure 18. The organization is able to utilize the data for turning it into information for smooth maintenance execution

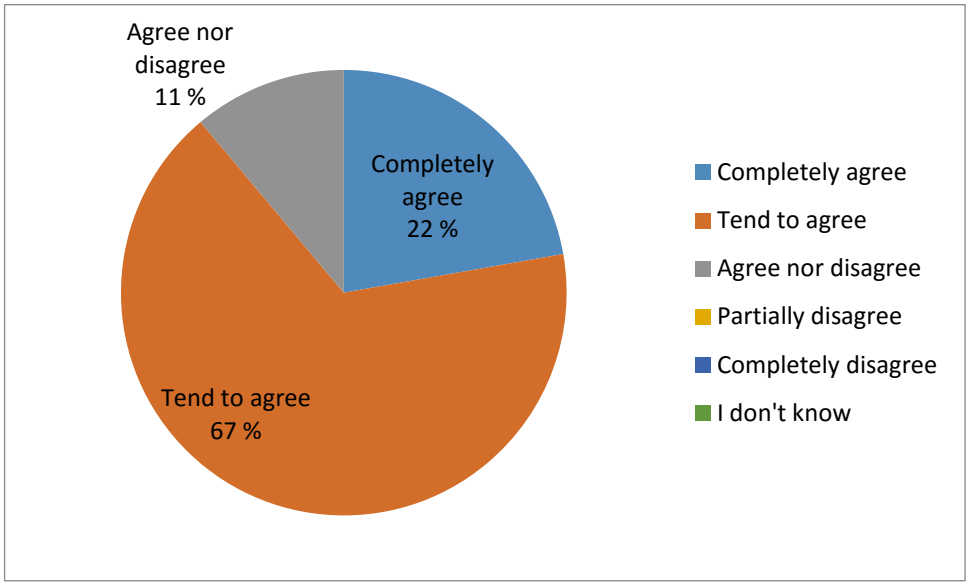

Figure 19. I know the essential information to pass in the organization for giving a smooth possibilities for maintenance execution

In the figures 20 and 21 based on the answers, there are some pointless information spreading in the organizations related to maintenance process and the information flow between the departments and functions might have some obstacles.

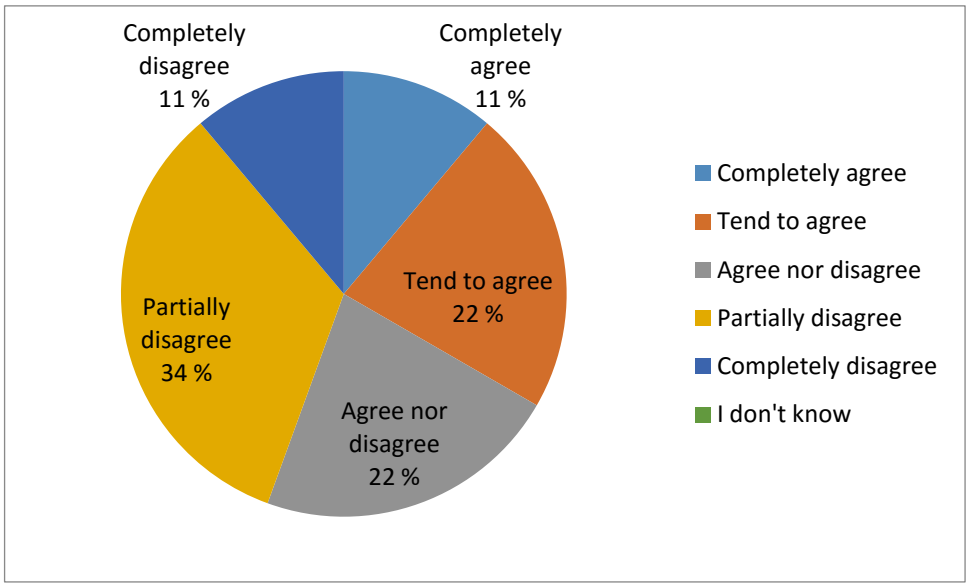

Figure 20. Only the essential information is spread in the organization for smooth maintenance execution

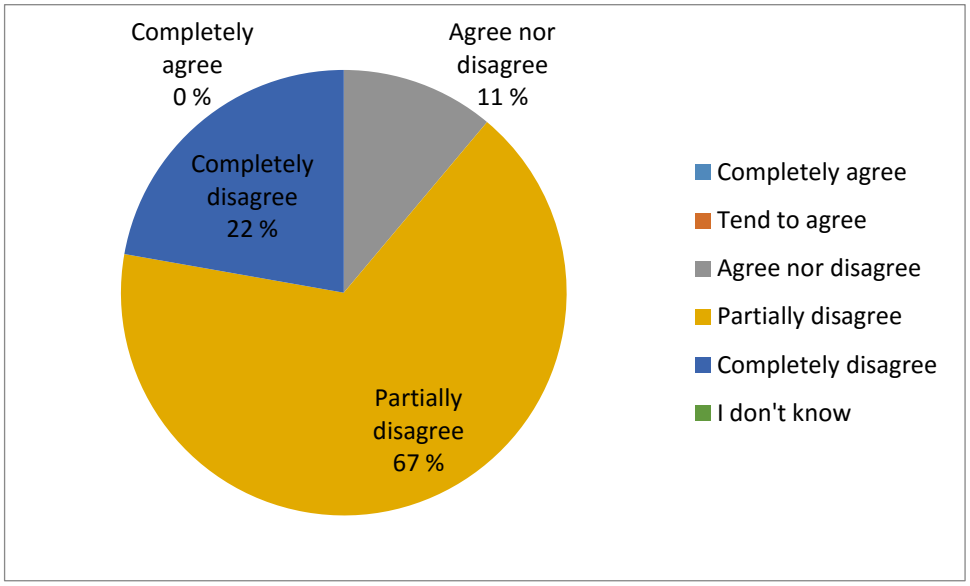

Figure 21. The information flow between the departments and functions is on sufficient level

What comes to the information for maintenance execution there are thoughts that the given information is necessary but there could be bit more information. The good point is that the staff will know where to find the missing relevant information. The figures 22 and 23 will show the distribution of the answers to these questions.

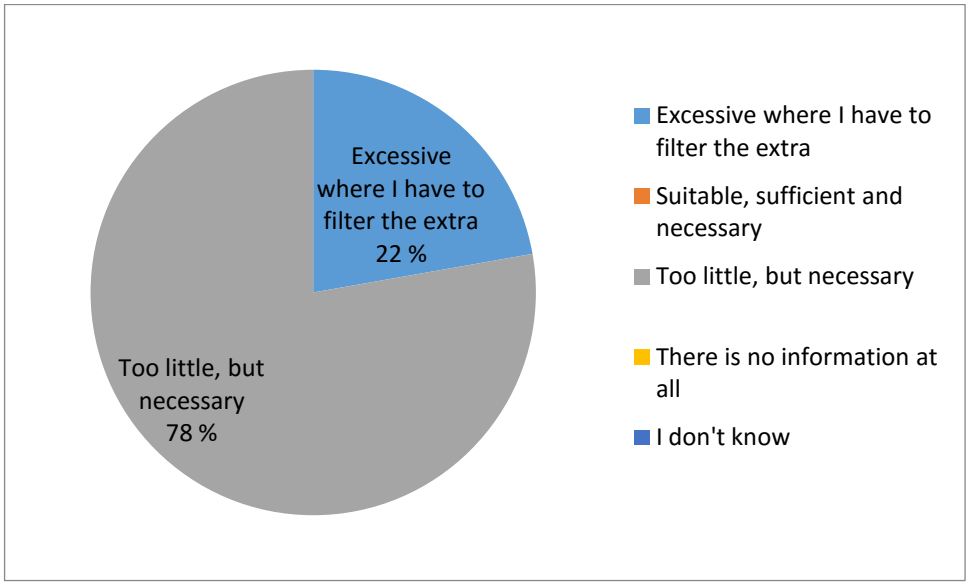

Figure 22. The information needed in my role in maintenance execution

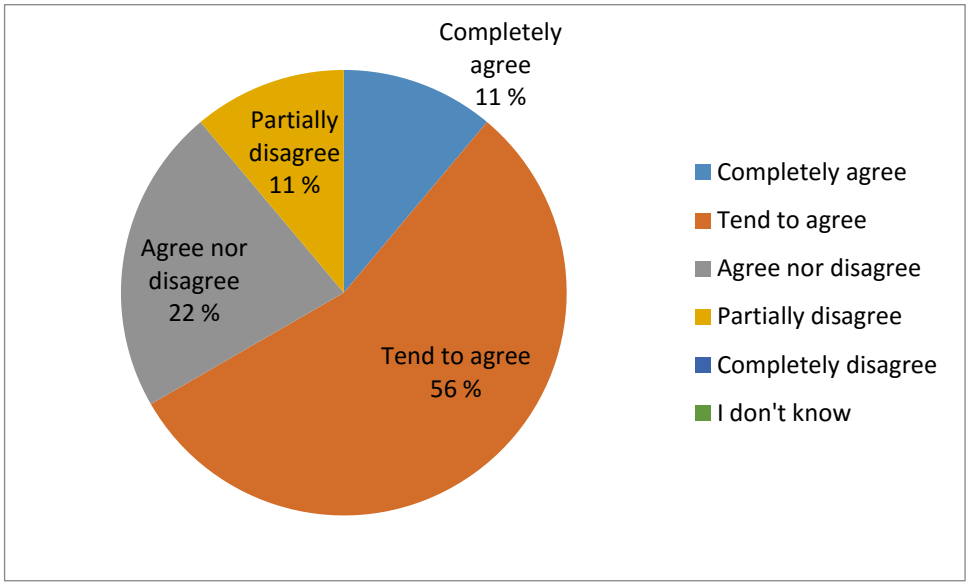

Figure 23. I know where I can find the needed information for completing my task

The organization has several ongoing digitalization projects for improving the effectiveness and real time situational awareness. There were four questions concerning to the digitalization, interfaces, real time situational awareness and the systems compatibility. The figures 24, 25, 26 and 27 shows that in the field of digitalization could be found much for improve.

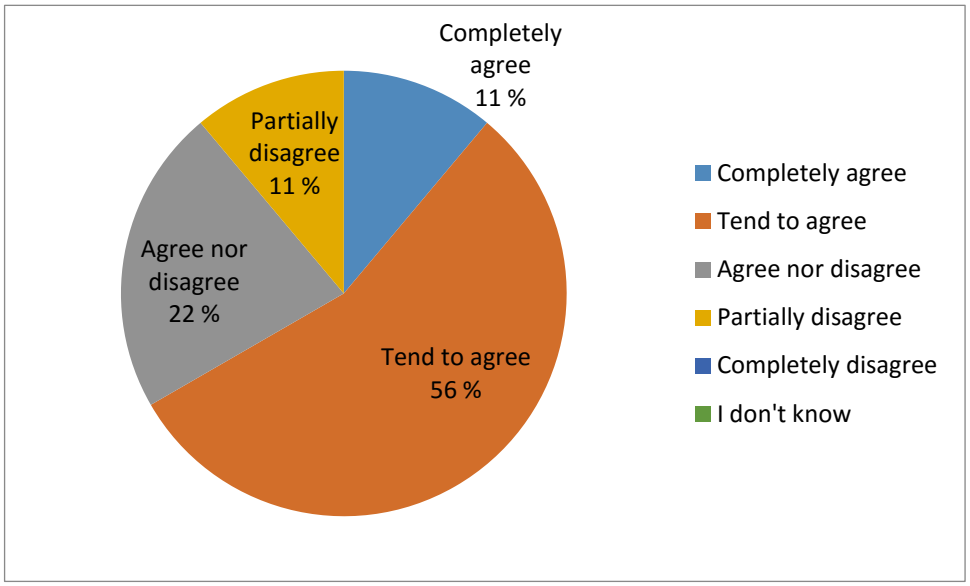

Figure 24. The data of maintenance production is entered to the systems via digital interface

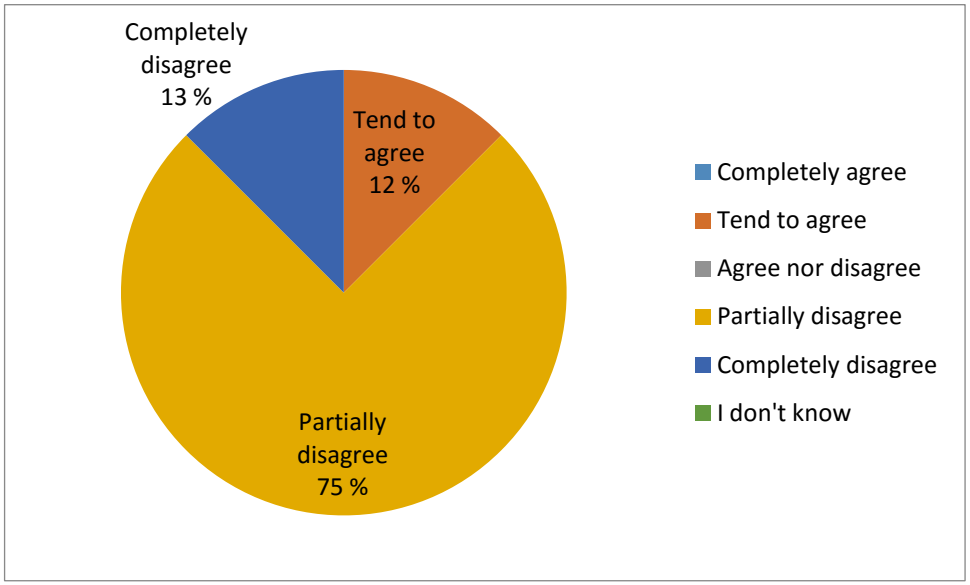

Figure 25. The progress of maintenance execution can be followed in real time

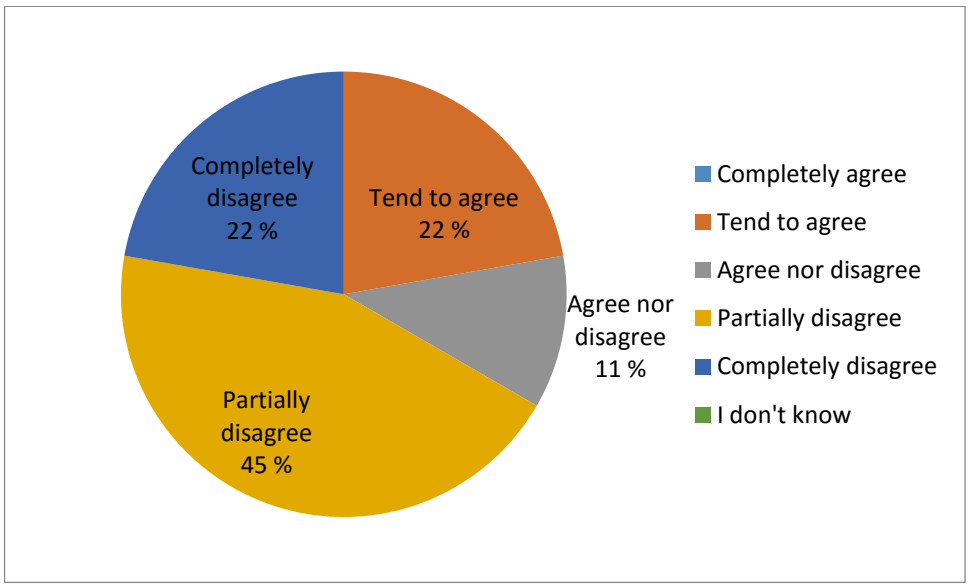

Figure 26. The information systems I use are compatible with each other

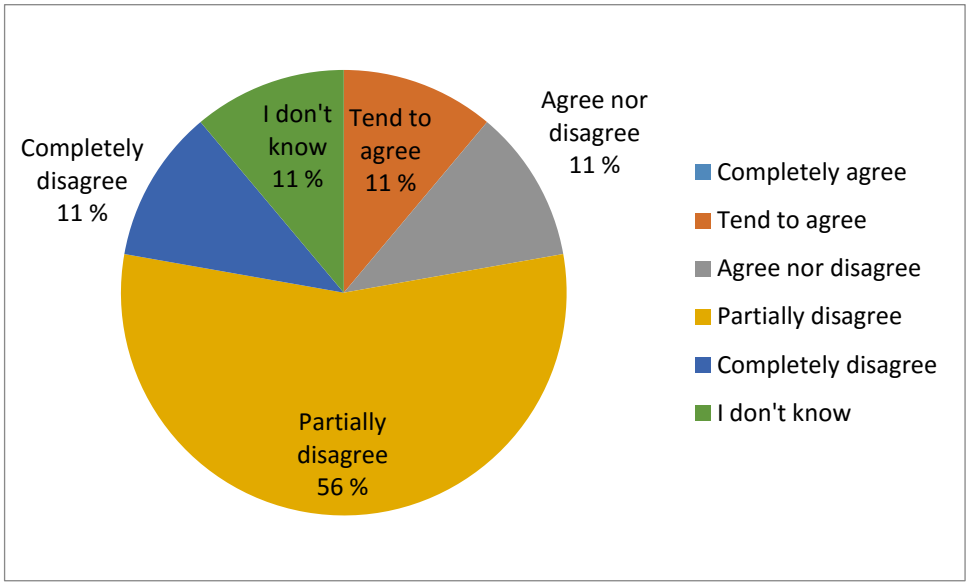

Figure 27. The maintenance production data management process is entirely electronic

The roles and the information flows were asked with one dedicated question to find out if there have been give deeper analyzed thoughts for the information flows. The figure 28 shows the distribution of the answers to the question.

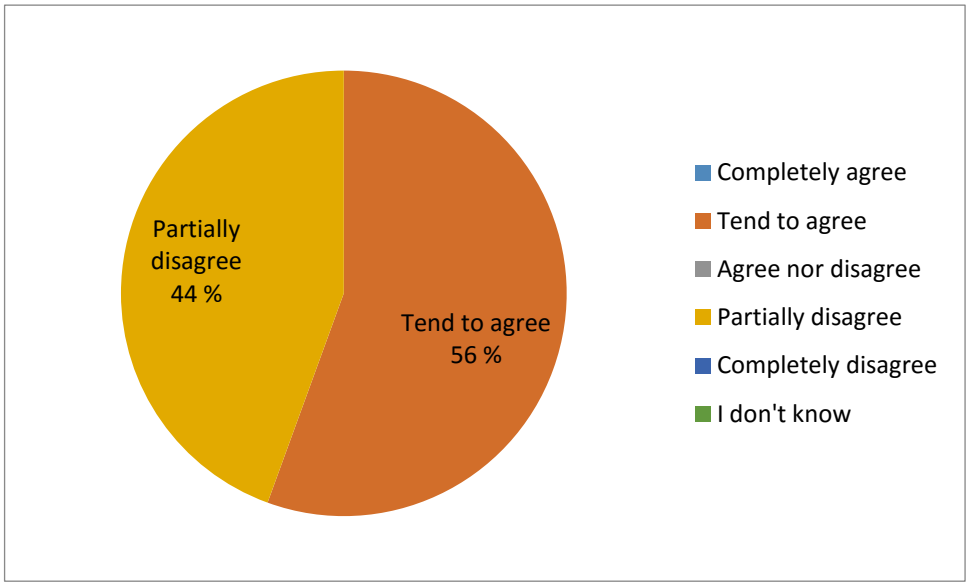

Figure 28. The dissemination of information in maintenance execution is thought out in advance by roles and groups

To the open question were generated some development ideas and wishes for improving the information management in maintenance process were pointed out to the questionnaire. An easy follow up for improving the situational awareness is needed:

- an easy and clear visible of up-coming maintenance events. Now the big picture of the up-coming events is difficult to see -> difficulties to find out the critical tasks,
- I would collect all the maintenance information to one visualized screen which would serve all the stakeholders from planning to MCC. Currently the information is spread to many IT systems and in many places in the matrices organization,
- the obstacles and bottlenecks in the undergoing maintenance process. I.e. the real time situational awareness from single maintenance event and its status and progress to report forward to stakeholders,
- mechanics and technicians tasks signing should be in electronic format so the real time situational awareness would improve.

Also some ideas for the roles were highlighted:

- clear the roles in the maintenance process,
- the priorities in the maintenance packages should be clearer -> from where to start,
- the main idea in the aircraft maintenance organization is to do the maintenance tasks rather than IT tasks.

To the in-use software's were given also some improvement ideas:

- the information systems should better work together,
- all the reports should have same data and information but those should be tailored for the target groups or functions. These reports could be shown on info screen all over the organization and in addition to that those could be seen also from your own computer.

5 RESULTS

This chapter presents the results according to reversed research questions. First the current situation of the information flow between the functions. Second the maintenance information snapshot deviation in the organization. Then in the third sub-chapter is tried to find out the essential information in aircraft maintenance production and finally the real time situational awareness in aircraft maintenance process.

5.1 Information flow between the functions

The information management has been mapped with observing the processes and with targeted questionnaires. Also the unofficial conversations during the observations gave lots of information about the current situation of the information flows in the maintenance process to the operations. In general the actors know what information has to be reported even there are plenty of tools and software to use for reporting, storing the maintenance data and spreading the information for the stakeholder and also in ACM. The information delivery for the stakeholders could be distributed by the systems and software but still in the current situation the critical ad hoc information is spread in most cases manually.

Figure 29 is drawn based on the collected information. Production support (PS) and maintenance planning (MP) are general terms in the figure representing the activities in general. PS is for example for the spare parts and special tools, MP is for the planning. Aircraft maintenance duty manager (ACM DM) and maintenance control center duty manager (MCC DM) are using same manpower resources. Digi DM is planning software for the DM for i.e. manpower resources. The arrows in the figure show the information flows. Blue arrows are defined information, defined channel and tools for spreading the information. The green dotted arrows are defined or not yet defined information i.e. from the supervisors the information will be entered to the AMOS database but there are delays depending on several issues. The OPS Metrix is new software which was not yet fully implemented in the organization. The red arrows are unspecified information channels or tools and are dependent on experts. Subcontractors get the task information from the data system and will enter to the A/C when allocated. After the subcontractor’s task is finished it will be signed in the data system. Scope-software provides the details of each A/C’s flight and maintenance plans. MP uses the data from Scope. eLog is an electronic flight logbook where the flight crew reports the founded defects. The defined information in the figure is considered such information which is founded from data base and is available for the value network. The red arrows represent the information which is not available for the

value network at least immediately after event. For example technician reports the defeat to supervisor or ACM DM and MCC DM swaps resources from hangar maintenance to apron maintenance.

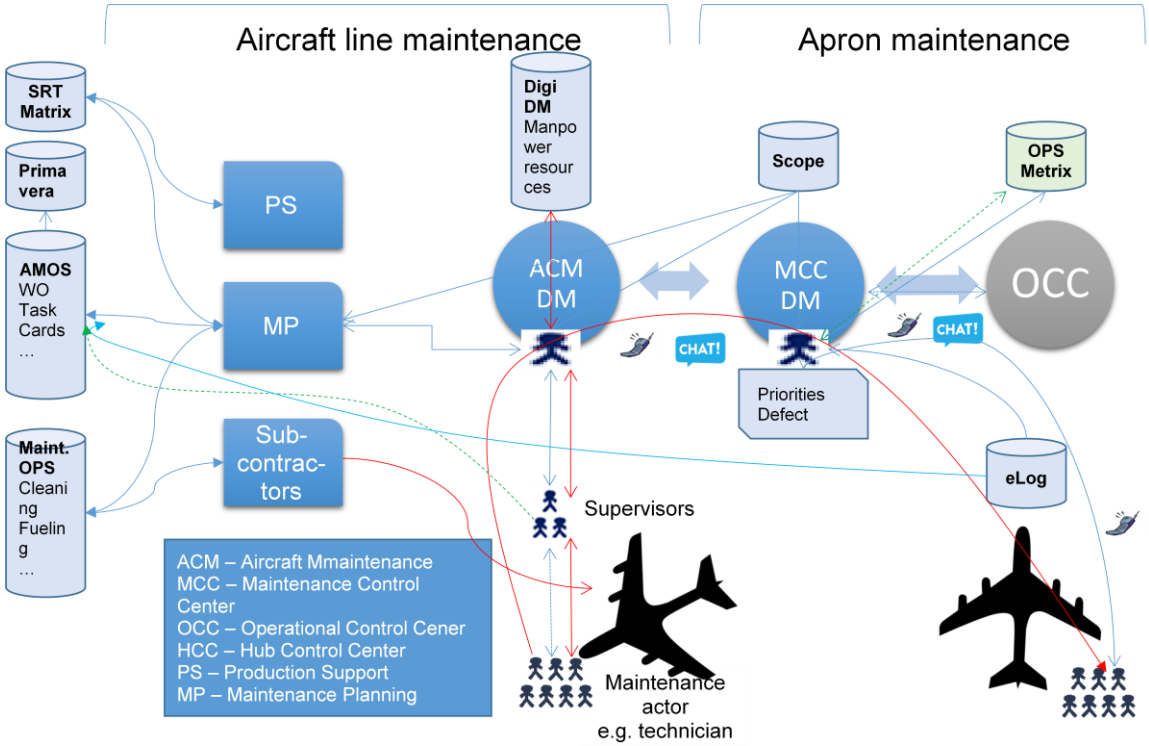

Figure 29. A snapshot of the current information flow in aircraft maintenance industry

5.2 Maintenance information snapshot deviation between in the organization

The maintenance action is done generally in two “silos”. The aircraft line maintenance takes place mainly in hangar and the apron maintenance takes care of the daily air operation. The resources are mainly the same but the management of the recourses is divided. MCC DM will be in charge of the resource usage in the end. The resources are allocated during the maintenance planning phases prior the planned action. The plan could still change in short notice in case of AOG. The roles of the DM’s are defined and seem to be implemented.

The obstacle occurs while there will be the AOG situation. In ACM the supervisor have planned the works according to the information in his earlier shift and when the shift starts there are taken technicians to other tasks with higher priority. In the AOG situations the information is mainly spread with phone and chat. These situations will generate the pressures to the ACM actions due that the schedule for the A/C in check is more or less fixed.

Apron maintenance belongs to MCC. MCC nerve center is located physically next to OCC. The main system is AMOS for recording the maintenance data and the completed tasks. Defects may be also indicated in eLog by the pilots or cabin staff. The defects opened to eLog are signed off also in eLog. In these cases the radiophone will be used for spreading the information from the apron to the MCC/OCC office for keeping them on aware of the situation. Also in trouble shooting cases radiophone or phone is used for getting the needed information for repairing the defect. In these operational cases the maintenance data will be set to the maintenance systems (AMOS) afterwards. In general the radiophone is the reporting tool between the technician and MCC. When the technician enters the A/C he will report it to MCC, during the maintenance action he will report to MCC and also if he need support for the task the radiophone is used. Finally, when the task is done he will report it with radiophone. There are fixed frequencies for the radiophones. The frequencies are divided to wide body and narrow body fleet. The conversation will be heard in AMC, MCC, OCC and in HCC. So there are possibilities to get the information from the operational level. The obstacle is that the information will be not recorded during the action but only afterwards to the systems. This leads to the situation where the network gets the information later.

The situational awareness and information of aircraft maintenance to the stakeholders relies on the information in AMOS and the verbal feedback by the supervisors and technicians. In the beginning of the shift the tasks are handled on paper to the technicians assigned to the maintenance action by the supervisor. One technician could get bunch of tasks for the shift. He will do the tasks mainly according to his mind and in the worst case scenario in the end of the shift he will bring half of the tasks not made during his shift. This will possible give an eight hour gap for not knowing the progress situation of the maintenance event. After the technician has returned the tasks he did during his shift the supervisor usually puts the records to the AMOS-system. Then it is considered to follow up by the other actors and stakeholders.

ACM DM will generate three times a day a daily report with wide distribution list. The report will be distributed via e-mail and the DM will collect the situational data by hand from different sources i.e. AMOS, visiting an A/C to ask the situation. The report is considered to be very important information channel for the stakeholders and for the top management of the ACM capability.

HCC needs to know all the tasks for the aircraft during the ground stop. As earlier told the information from maintenance actions depends on several aspects and there might be

some delays of the information and it might come only on phone/radiophones once. This will cause obstacles for the HCC while its function is to control all the sub-processes on A/C during its stop. The verbal information might be lost in the information overflow. When the technicians report his activities on the A/C on verbal, the airport officer report his actions with RFID which can be traced afterwards and will stay on memory.

The roles are defined and the roles are known by the actors. There are still some deviations in the information between the network in the organization due that the spread information is not always coming from the same database and in many cases the information will come from an individual person. There are some delays to put the information to the defined databases as previous described. There are also some gaps of information or in defining the roles i.e. in OPS Metrix-system is new or not totally implemented in the organization. For the system it is important to know what data should be put in, when to put and who will do it.

5.3 The essential information in aircraft maintenance production

There are many information levels to takes account of aircraft maintenance production. Derived from this the essential information depends on the phase of the production. In this study the aircraft maintenance production includes the planning as well as preparation and maintenance execution.

Planning and preparation involves resource planning, operational maintenance planning, production planning and production preparation functions. Tech ops's planning makes long term planning for A/C maintenance. MCC planning window is from 0 days to 3 days. This short term planning ensures that all the maintenance tasks are prepared also the last minutes defects. The resource planning is done according to the labor legislation by the technical operations resource planning. Production preparation prepares the service packages on a practical level, resources, tools, spare parts, hangar area, and work order papers. Production preparation works in close relation between the ACM and the MCC. When the maintenance packages are "locked" and handed out to production MCC is responsible for the change management of the work package.

Prior the maintenance action starts there are certain information needs to know for the smooth maintenance operation and staying in the turnaround time. There might be some tasks that need to be done before the A/C enter the hangar i.e. fueling or defueling which are not allowed to do in hangar. Long lasting maintenance tasks and defect repairs have to be started right in the beginning of the maintenance action. The need of special skills is

essential information for the maintenance action. The special skilled staff has to be called for the maintenance. The need and availability of materials for the maintenance have to be checked and ensured. In point of view of maintenance production it is necessary to know the schedule of the subcontractors. Due to the lack of resources or short turnaround time the information of tasks that may be transferred to the next maintenance action should be known. For the maintenance department it is vital information to know the target time for run-up test and when the A/C has to be on line again. For the stakeholders the progress follow-up of the maintenance event is essential information.

The above mentioned essential information uses following tools and software:

- the tasks before the A/C enters to the hangar: Task card, Work Package Summary (front sheet),
- long lasting maintenance actions or defect: AMOS, Phone ACM - MCC,
- needs of special skills: Man Power report and WP Summary,
- A/C's maintenance status related tasks like (fuel tank, jacking, body washing): Task card and WP Summary,
- the schedule of subcontractors: Maint Ops, AMC DM or WP Summary,
- material needs: AMOS and AOG desk,
- the information of transferred tasks: Phone ACM DM - MCC DM,
- the allocated resources: Man Power report and conversation with ACM DM,
- the target for the run-up test: Scope (departure time).

When the A/C enters to hangar for maintenance actions the essential information for the stakeholders MCC and HCC is the estimated time for the A/C entering to the line again.

5.4 Real time situational awareness in aircraft maintenance process

The situational awareness is major advantage in aviation business. Efficient processes and compatible information systems, as well as software, enable the the accurate situational awareness of the organisation and its network. In this study the network is limited to the airline’s departments involving the maintenance process and airoperation.

The situational awareness in aircraft maintenance process is needed in different departments. The operational chain in need of information from the maintenance perspective is: ACM and the subcontractors, MCC, OCC and in the end of the chain HCC.

The maintenance slot is planned and agreed in advance between the airoperator and the maintenance organisation. The length of the maintenance slot depends on the level of the check. ACM needs to follow the progress of the maintenance event for ensuring that the event will be done in the schedule. Currently the progress of the maintenance is not able to follow in real time even the business environment could give the possibility. Still the whole production data is not completely electronic. The accomplished maintenance tasks will be closed in the AMOS system afterwards usually by the supervisor. The information systems are not totally compaltible with each other and so the information have to be collected by hand and verbally from different sources. The supervisors should know the situation of their aircrafts. They collect the progress of the tasks from the technicians verbally by radiophone or going personnally by foot to the A/C. The data for the daily reports is collected also from different sources and at the latest verbally by ACM DM. The daily reports are distributed by e-mail for all over the organisation and written by hand.

ACM reports to MCC about the maintenance progress situation and MCC may follow the actions also from AMOS system. When the maintenance slot is defined the need of information or the progress is on level on time/not on time or “lack of resources”. ACM and MCC use same man power resources and because that MCC is operating closer to the airoperation it has higher priority of using man power resources on daily basis. When the maintenance slot is coming to an end the need of the completion of the maintenance on time is needed – when the A/C is back on line. Apron maintenance is more or less defect actions and those are reported by pilot or cabin staff on eLog. The repairs will be signed out also to eLog. During apron maintenance the communication happens mainly with radiophone and phone. These conversation could stay only between two individuals unless one of them put the information to chat discussion when it is seen in the network.

The passenger and cargo operations are managed by the HCC. HCC follows nearly 200 processes during the A/C turn around. The processes are well organized and mainly can be followed on time. For example the gate officer’s tasks are phased in minor actions and after every action the gate officer reports the tasks with RFID. The aircraft maintenance actions are not seen in HCC systems with RFID. It is considered that the maintenance actions can be made during the A/C turn around time unless a more extensive fault is found. The information of maintenace actions are based on radiophone announcements on apron maintenance. In case of defect found which will affect delay or cancellation should be announced to HCC. In this kind of situations the estimated completion of the defect repair should be given for the HCC purposes. Currently the estimation is not accurate or there is no estimation at all. Hangar maintenance is more predictable and in

the situation where the A/C is not going to be ready for the given slot the situation is communicated normally between ACM and MCC in advance so the information for HCC comes normally earlier. In these kind of situations OCC prepares for the divergence in the plan and re-routes and changes the A/C. The new system, OPS Metrix was not totally in use for spreading the information but it may give relief to the information spreading in the network.

The obstacle is that the actors in network use many systems and databases which are not using sama data or even same parameters for the data. The situational awareness in the network relies much on the individuals whose responsibility it is to spread information to the network. The process is working smoothly despite the mentioned obstacles due to organisational experience, but it gives extra load for the actors. And the actors in the process have different kinds of backgrounds which will give the process different kind of situational awareness. For the managerial point of view it is not easy to follow the process in real time.

6 CONCLUSIONS

The goal of the study was to identify and map the internal information flows and used information recourses by functions and roles in aircraft maintenance process. The research was based on theories of maintenance management and information management in aviation and empirical evidence collected from the case company.

The time frame of this study was short and may be considered as a snapshot picture of the situation during the study. However the results show that identifying and mapping was important to present in one document even though the company might know the gaps in general. This may help the company in its on-going development projects for taking the maintenance production to the world class level. Also the increased understanding of the information management in aircraft maintenance process increases the efficiency of management and development. In addition to this the suggestions and the visio for 2020 in the end of the study give initiatives for the company for the future.

6.1 Answering the research questions

How does the information flow between the functions?

Within aviation there are many information consumers for the air operation. The lack of integrated IT solutions with challenge of risk with human factors could lead to a situation where information gaps might occur. IT systems add value for information transmitting but rules for the information should be put in place to avoid transmitting too much information in the network. The data overload might blur the situational awareness.

On the basis of collected material the channels and tools for the information flows between the functions vary and are also depending on aircraft maintenance actions. There are many IT systems for running the daily basis operations. The systems do not totally compatible with each other and do not necessary use same database for generating the information. It seems that the systems are focused mainly on tasks of one department task and might not take into account other department’s needs.

AMOS system is used for the maintenance actions and maintenance related functions. It was also seen that during hangar maintenance the accomplished tasks are reported to the system in many cases many hours later than the actual event happened.

The information change between the ACM and MCC were on tolerable level because of the same IT systems and shared resources. One reason can be also that the personnel of

both functions have mainly same kind of working background and they have common language. There might still be some unrecorded actions and unreliable data and delays while some maintenance action is moved to next maintenance slot by ACM and MCC DM's via phone.

HCC needs the accurate information of the availability of the A/C's. HCC manages hundreds of sub processes around an A/C. The interfaces of maintenance actions are inadequate or the information is not accurate enough for HCC. HCC needs more precise information about managing the operational processes. For the passenger and cargo operations the estimated time should be given to be able to plan the daily basis operation.

Despite the incompatibility of IT solutions the information flows between the functions to keep the operation on time. The information flow is still clear for the staff. This shows that the staff of the networks is professional but it also makes lots of extra tasks for the staff in the organization.

How does the maintenance information snapshot differ between the networks and units?

Within network organization the situational awareness should be similar even if the functions are different. The spreading of information or used information can be adjusted for the needs of the functions and roles but it should use same database to avoid the deviation of the situational awareness.

As described the information systems have little or no integration between each other and the information channels vary. This leads to situations where information gaps appear. This can be found also from the empirical evidence. The information flow between the departments and functions were assessed on non-sufficient level. The roles are not defined exactly and in some cases there is too much information from where the essential information should be found out.

From the maintenance's point of view there is enough information available and in some cases even overflow occurs. The snapshot between the ACM and MCC differs only little due the same data systems. The differences can be found for example in the maintenance situational report where tasks that have been done not yet put in to the data system are not known in the network. The differences can also be seen also in the interpretations of situational awareness. This might due personal priorities even the goals are the same. The deviation between the maintenance action (hangar and apron) might be found while the A/C is on apron. MCC needs the manpower recourses from ACM and the hangar

maintenance may fall out of resources. In this kind of situation the same target and planning is vital to arrange the maintenance actions so that the air operation will go as planned even with the change of A/C.

HCC needs basically the information if the A/C is available or not. Currently the information flow is not always in structured form. The HCC will get the information via various routes but it seems that they still are uncertain. The snapshot perhaps does not differ from HCC, OCC and MCC but the available information might be pending of HCC.

In maintenance process the right information should also be handed to the network and support functions. Optimizations of the information supply process are needed for optimal situation.

What is essential information in aircraft maintenance in perspective of production?

Aircraft maintenance involves a wide range of actors for the production. Maintenance process also monitors the technical systems. The needed information within maintenance production can be divided in few phases: the information before the maintenance action, the information during the maintenance action and the information after the maintenance action. The needed information depends on the networks and units.

For the information before the maintenance action, the planning's essential information is:

- A/C's maintenance status,
- need of special skills,
- material need,
- the allocated resources.

During the maintenance action the essential information is:

- the allocated resources,
- the tasks before the A/C enters to the hangar,
- long lasting maintenance actions or defects,
- the schedule of subcontractors,
- the information tasks that may be transferred,
- the progress of the maintenance (individual tasks)
    - deviations during the execution the tasks,
    - shortage of material,
- the target for the run-up test.

After the maintenance action the essential information is:

- the new airworthiness document for the A/C,
- the reasons for delays and bottlenecks for improving the maintenance execution.

OCC and HCC need the estimated time information to be able to plan their own operations. If the maintenance action will be delayed it has to be reported with new estimated ready-time to OCC and HCC. The aircraft maintenance action is a matter of sharing data within MRO and its network so the overall value chain can be better optimized.

In what ways information management in maintenance process can be developed to get better real time situational awareness in aircraft maintenance process?

Communication is important for the effectiveness of the organization. The communication is linked to information management and to the situational awareness with the communication technologies. These technologies are oriented to managerial goals. Nowadays all required information can be transmitted electronically and most employees are willing to use electronic forms of communication.

Employees are participants in the network by playing different roles. The individual role's information needs and information usage should be clarified for right information access at each work step and the information should be available at the right time and at the right location. In addition to that the information flow in the workflow what happens at next step should be known and by the employees to prevent unclear conditions for moving to the next work step. The information network analysis introduced in the thesis could be one useful tool for mapping the roles, information flows, work flows and timing. The introduced basic questions were:

- what to deliver: location, time and task,
- contacts to deliver: location, time and task,
- where to deliver: supervisor, next information consumer.

The aircraft maintenance process should be written out from the operator and the usage of the A/C to the individual technician in the hangar doing a single maintenance action to check. Table 3 shows the idea of information network analysis in worksheet format. But as mentioned earlier the analysis could also be drawn on to organization chart, process chart, or add to value network analysis as one dimension.

Table 3. Information Network Analysis, general example

Actor	What to deliver			Contacts to deliver			Where to deliver		
	Location	Time	Task	Location	Time	Task			
HCC	x	xx.yy.zzzz hh	Maintenance	x	xx.yy.zzzz hh	Maintenance	OCC		
OCC	x	xx.yy.zzzz hh	Maintenance	x	xx.yy.zzzz hh	Maintenance	Subcontractor and ACM DM		
Subcontractor, A/C towing	x	xx.yy.zzzz hh	Towing	y	xx.yy.zzzz hh				
MCC DM	x	xx.yy.zzzz hh	A/C Reg, Check	y	xx.yy.zzzz hh	A/C Reg, Check	ACM DM		
ACM DM	y	xx.yy.zzzz hh	A/C, Check, Resources	y	xx.yy.zzzz hh	A/C, Check, Resources	ACM Supervisor		
ACM Supervisor	y	xx.yy.zzzz hh	Check,						
ACM Technician	y	xx.yy.zzzz hh	Tasks to be done	y	xx.yy.zzzz hh	Completed tasks	ACM Supervisor		
ACM Supervisor	y	xx.yy.zzzz hh	Check, maintenance tasks, target time	y	xx.yy.zzzz hh	A/C Check ready	ACM DM, MCC, Subcontractor		
ACM DM	y	xx.yy.zzzz hh	A/C, Check, Resources	y	xx.yy.zzzz hh	A/C, Check, Resources	ACM Supervisor		
Subcontractor, A/C towing	y	xx.yy.zzzz hh	Towing	z	xx.yy.zzzz hh	Towing	OCC, HCC		

The communication technologies and the data systems should be used more efficiently and paper based documentation should be eliminated. To improve the communication and to avoid the deviation of situational awareness in all functions the separate systems should use same database to generate information to the stakeholders. With the current technology the information spreading and usage can be adjusted for the need of the functions and roles. The situational awareness would also be improved with an easy and clearly visible maintenance screen where the up-coming and on-going maintenance actions with completed tasks and not completed tasks with real time visibly could be seen. The information of the screen could also be shown to the customer, in this case OCC and HCC so that they see if processes are progressing on-schedule or if there are problems and obstacles.

The major leap for getting to better situational awareness in the aircraft maintenance process is electronic signing, eSignature. After the technician has done the task it will be signed electronically and the information will immediately be available for other users. Supervisor has then better chances to follow the process in real time and will give possibilities to find out process bottlenecks.

6.2 Recommendations

This research is an overview of a cross-section of activities that are linked to information management in aircraft maintenance process. The information and its flow with the processes are in a big role in smooth operation and could give success and competitive advantage.

The vision how the information could process in the case organization in 2020:

- information needs for the decision-making by roles are clear,
- employees know their roles and their importance in the work process and in smooth information flows,
- the information management is totally in electronic format including the signings,
- the network uses same database for all information,
- the stakeholders are able to follow the maintenance process in real time.

Based on the material it is recommended that the information needs for the work roles is defined. Also the information spreading within the network should be defined because the needs heavily differ and should avoid transmitting too much information in the network. The data overload might blur the overall situational awareness. The role-exercise would also be good for the whole network to understand the big picture and each stakeholder need in different work phases.

It is also recommended to use same data in the information management systems to avoid information deviation. To improve the real time situational awareness the signature should be put in place and avoid paper based documentation in network organization.

The alternative wild vision for information management in aircraft maintenance process is as follows. When the technician enters to an A/C it will be automatically recorded to the maintenance management system like AMOS with a microchip mounted to the technician. After arriving to the A/C the technician enters the task or defect he is going to do to the maintenance system with his mobile phone. On the apron maintenance the needed spare parts and material for the task or defect is delivered to the A/C by an unmanned aerial vehicle (UAV), commonly known as a drone. Simultaneously the drone will observe the work safety aspects and report forward if accidents occur. The occupational wellbeing of the staff will be monitored with heartbeat-system that records the technician’s physical condition and gives alert if stress level gains over the normal level. All the systems are connected to each other and the progress of the maintenance will be able to be followed in real time by any functions. This alternative vision does not base on the questionnaires nor the interviews of the study. Innovative ideas were developed during the discussions with the case company representatives while processing the research.

7 SUMMARY

There is information everywhere. Well managed information can be used to streamline processes, to give real time alternative information to the networks and stake holders, to make things better, faster, select the best one(s) and to promote competitive advantage and economic value. The challenge is to use information effectively in complex networks.

This research is set up of searching the possibilities to find out and suggest improvements for the information management in aircraft maintenance. The focus was on aircraft maintenance point of view. To scoop the big picture of information flows and channels the whole operational network was examined.

To cover the research gap the literature was selected from the fields of maintenance management and information management in aviation. These titles were divided in subtitles to deepen the theoretical background for the research. The study was started from aircraft maintenance management, general information about the maintenance, repair and overhaul going from eMaintenance via PLM to aircraft maintenance process. Aircraft maintenance is highly regulated and includes lots of activities before, during and after the maintenance action. Aircraft maintenance is network co-operation. The information spreading in network is extremely important. The information management within aviation starts from maintenance process going to challenges and then to information network analysis. The literature points out the potential of nowadays technology which helps to gather the operation, processes, information flows and life cycles together. Maintenance management, operations, tools and information become available to be utilize anytime and anywhere. It supports decision making and business process integration across the company. The study was conducted with qualitative research method with inductive approach. The empirical evidence was collected with questionnaires and observing processes.

The case organization has an overall goal to gain the aircraft maintenance production to world-class level. There are several on-going projects towards the goal. The objective of the study was to map and identify the development gaps to the situational awareness in aircraft maintenance process and its information management within the network.

Based on the literature and empirical evidences from the case organization some development areas within the information management in aircraft maintenance process were found: the information needs according to the work roles should be defined, the communication technologies and the data systems should be used more efficiently and paper

based documentation should be eliminated. Also a vision for year 2020 was given to the organization. During the literature research the term information network analysis was generally not known. The term was introduced in this study and some ideas to use it as a tool to improve organization information management were created.

The selected literature and research method together with the empirical evidence were suitable for the study. The research questions were answered based on the theory and empiric evidence, and the objectives of the study were reached.

REFERENCES

Aboelmaged, M. G., 2014. Predicting e-readiness at firm-level: An analysis of technological, organizational and environmental (TOE) effects on e-maintenance readiness in manufacturing firms. *International Journal of Information Management*, Vol. 34, Issue 5, pp. 639-651.

Ackert, S. P., 2010. *Basics of Aircraft Maintenance for Financiers.* [Online] Available at: http://www.wikiprogress.org/images/Paper_sheremetyevo.docx [Accessed 1 10 2015].

Ackoff, R. L., 1989. From data to wisdom. *Journal of Applied Systems Analysis 16*, pp. 3-9.

Allee, V., 2000. Reconfiguring the value network. *The Journal of Business Strategy*, Vol. 21, Issue 4, pp. 36-39.

Allee, V., 2008. Value network analysis and value conversion of tangible and intangible assets. *Journal of Intellectual Capital*, Vol. 9, Issue 1, pp. 5-24.

Arnaiz, A., Ferreiro, S. & Buderath, M., 2010. New decision support system based on operational risk assessment to improve aircraft operability. *Proceedings of the Institution of Mechanical Engineers*, Vol. 224, Issue O3, pp. 137-147.

Basdere, M. & Bilge, Ü., 2014. Operational aircraft maintenance routing problem with remaining time consideration. *European Journal of Operational Research*, Vol. 235, Issue 1, pp. 315-328.

Borissova, S. & Mustakerov, I., 2013. *A Concept of Intelligent e-Maintenance Decision Making System.* s.l., IEEE International Symposium on Innovations in Intelligent Systems and Applications.

Bovet, D. & Martha, J., 2000. Value nets: reinventing the rusty supply chain for competitive advantage. *Strategy & Leadership*, Vol. 28, Issue 4, pp. 21-26.

Campos, J., 2014. Current and prospective information and communication technologies for the emaintenance applications. *Journal of Quality in Maintenance Engineering*, Vol. 20, Issue 3, pp. 233-248 .

Canaday, H., 2014. *Airlines Investing In MRO IT, But Carefully.* [Online] Available at: http://aviationweek.com/mro/airlines-investing-mro-it-carefully [Accessed 26 9 2015].

Candell, O., Karimb, R. & Söderholmc, P., 2009. eMaintenance—Information logistics for maintenance support. *Robotics and Computer-Integrated Manufacturing*, December, p. 937–944.

Christian, T., 2015. *cambashi.* [Online] Available at: http://www.cambashi.com/plm-chemicals-process-manufacturing [Accessed 12 Nov 2015].

Crespo-Marquez, A. & Iung, B., 2008. A review of e-maintenance capabilities and challenges.. *Systemics, cybernetics and informatics*, Vol. 6, Issue 1, pp. 62-66.

Davenport, T. H. & Prusac, L., 2000. Working Knowledge: How Organizations Manage What They Know. *Ubiquity*, August.

EASA, E. A. S. A., 2014. Commission Regulation (EU) No 1321/2014. *Official Journal of the European Union*, 26 Nov., pp. 1-194.

EASA, E. A. S. A., 2015. Annex II to ED Decision 2015/029/R. *Acceptable Means of Compliance (AMC) and Guidance Material (GM) to Regulation (EU) No 1321/2014*, 17 12, pp. 1-82.

Galar, G., Thaduri, A., Gatelani, M. & Ciani, L., 2015. Context awareness for maintenance decision making: A diagnosis and prognosis approach. *Measurement*, 29 Jan., pp. 137-150.

Giachetti, R. E., 2004. A framework to review the information integration of the enterprise. *International Journal of Production Research*, 15 March, Vol. 42, Issue 6, p. 1147–1166.

Golovatchev, J. D. & Budde, O., 2007. *Next Generation PLM - an integrated approach for the Product Lifecycle Management.* Beijing, International Conference on Comprehensive Product Realization 2007.

Grieves, M., 2008. *Product Specification Management (PSM): Enabling Manufacturing Quality,* s.l.: Florida Institue of Technology.

Guo, F., Zou, J. & Chen, H., 2013. Development of Knowledge Integration Model for EMaintenance. *Research Journal of Applied Sciences, Engineering and Technology*, Vol. 5, Issue 5, pp. 1841-1847.

Hong-Bae, J. & Kiritsis, D., 2012. Several aspects of information flows in PLM. In: *Product Lifecycle Management. Towards Knowledge-Rich Enterprises.* Springer Berlin Heidelberg, pp. 14-24.

Iung, B., Levrat, E., Crespo Marquez, A. & Erbe, H., 2009. Conceptual framework for eMaintenance: Illustration by e-Maintenance technologies and platforms. *Annual reviews in control*, Vol 33, Issue 2, pp. 220-229.

Jantunen, E., Adgar, A., Emmanouilidis, C. & Arnaiz, A., 2010b. *Next generation maintenance through the adoption of e-maintenance.* Verona, Euromaintenance 2010 Conference.

Jantunen, E., Emmanouilidis, C., Arnaiz, A. & Gilabert, E., 2010a. Economical and technological prospects for e-maintenence. *International Journal of System Assurance Engineering and Management*, Vol 1, Issue 3, pp. 201-209.

Jiang, D. et al., 2015. epiC: an extensible and scalable system for processing Big Data. *Special Issue Paper The VLDB Journal*, 23 July, pp. 1-24.

Karim, R., Söderholm, P. & Candell, O., 2009. Development of ICT-based maintenance support services. *Journal of Quality in Maintenance Engineering*, Vol. 15, Issue 2, pp. 127-150.

Lee, S. G., Ma, Y. S., Thimm, G. L. & Verstraeten, J., 2008. Product lifecycle management in aviation maintenance, repair and overhaul. *Computers in Industry*, March, Issue 2–3, p. 296–303.

Levrat, E., Iung, B. & Crespo Marquez, A., 2008. E-maintenance: review and conceptual framework. *Production Planning and Control*, Vol. 19, Issue 19, pp. 408-429.

Makhloof, M. A., Waheed, M. E. & Badawi, E.-R., 2014. Real-time aircraft turnaround operations manager. *Production Planning & Control*, Vol. 24, Issue 1, pp. 2-25.

Meissen, U., Pfennigschmidt, S., Voisard, A. & Wahnfried, T., 2005. Context- and Situation-Awareness in Information Logistics. In: *Current Trends in Database Technology - EDBT 2004 Workshops.* Heraklion: EDBT 2004 Workshops PhD, DataX, PIM, P2P&DB, and ClustWeb, pp. 335-344.

Mertins, K., Knothe, T. & Gocev, P., 2012. Towards CPS Based Aircraft MRO. In: *Collaborative Networks in the Internet of services.* Bournemouth: s.n., pp. 166-173.

Muller, A., Crespo Marquez, A. & Iung, B., 2008. On the concept of e-maintenance: Review and current research. *Reliability Engineering and System Safety*, Vol. 93, pp. 1165-1187.

Ni, J. & Jin, X., 2012. Decision support systems for effective maintenance operations. *CIRP Annals - Manufacturing Technology*, Vol. 61, Issue 1, pp. 411-414.

Oliveira, A. C., Araujo, R. B. & Jardine, A. K., 2013. A Human Centered View on E-Maintenance. *Chemical Engineering Transactions*, Vol. 33, pp. 385-390.

OPH, 2016. *Mitä on kunnossapito.* [Online] Available at: http://www03.edu.fi/oppimateriaalit/kunnossapito/perusteet_1-1_mita_on_kunnossapito.html
[Accessed 24 January 2016].

Pareschi, R. & Fontana, F. A., 2015. Information-driven network analysis: evolving the "complex networks" paradigm. *Mind & Society*, 11 July, pp. 1-13.

Parida, A., Kumar, U., Galar, D. & Stenström, C., 2015. Performance measurement and management for maintenance: a literature review. *Journal of Quality in Maintenance Engineering,* Vol. 21, Issue 1, pp. 2-33.

Pintelon, L. & Parodi-Herz, A., 2008. Maintenance: An Evolutionary Perspective. In: *Complex System Maintenance Handbook.* s.l.:s.n., pp. 21-48.

PLM, 2014. *Product Lifecycle Management.* [Online] Available at: http://www.product-lifecycle-management.com/
[Accessed 25 Oct. 2015].

PLM, 2015. *Product Lifecycle Management (PLM).* [Online] Available at: http://www.product-lifecycle-management.com/
[Accessed 12 Nov. 2015].

Romero, A. & Vieira, D. R., 2014. Using the Product Lifecycle Management Systems to Improve Maintenance, Repair and Overhaul Practices: The Case of Aeronautical Industry. In: *Product Lifecycle Management for a Global Market.* Yokohama: s.n., pp. 159-168.

Silventoinen, A., Denger, A., Lampela, H. & Papinniemi, J., 2014. Challenges of information reuse in customer-oriented engineering networks. *International Journal of Information Management,* Dec., Vol. 34(6), pp. 720-732.

Stark, J., 2015. Information Systems in the PLM Environment. In: *Decision Engineering.* s.l.:s.n., pp. 173-233.

Symon, G., 2000. Information and communication technologies and the network organization; A critical analysis. *Joumal of Occupational and Organitiational Psychology* , 73, pp. 389-414.

Sääksvuori, A. & Immonen, A., 2008. *Product Lifecycle Management,* s.l.: Springer eBook,

Söderholm, P., Holmgren, M. & Klefsjö, B., 2007. A process view of maintenance and its stakeholders. *Journal of Quality in Maintenance Engineering*, Vol. 13, Issue 1, pp. 19-32.

Takata, S. et al., 2004. Maintenance: Changing Role in Life Cycle Management. *CIRP Annals - Manufacturing Technology*, Vol. 53, Issue 2, p. 643–655.

Thomas, D. R., 2006. A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation*, June, Vol. 27(no. 2), pp. 237-246.

Trebilock, B., 2014. Get smart about planning. *Aviation Week&Space Technology*, Vol. 176, Issue 31.

Uclera, C. & Gokb, O., 2015. Innovating General Aviation MRO's through IT: The Sky Aircraft Management System - SAMS. *Procedia - Social and Behavioral Sciences*, July 2015, Volume 195, pp. 1503-1513.

Ucler, C. & Gok, O., 2015. Innovating General Aviation MRO's through IT: The Sky Aircraft Management System -SAMS. Volume 195, pp. 1503-1513.

van Lieshout, C., 2015. *The use of EFB andElectronic ATL in Commercial Air Transport.* s.l., EASA, pp. 1-30.

Xu, Z. & Zhao, N., 2016. Information fusion for intuitionistic fuzzy decision making: An overview. *Information Fusion*, Vol. 28, pp. 10-23.

Zhang, C. N. & Yang, C., 2002. Information flow analysis on role-based access controll model. *Information Management & Computer Security*, 10, Issue 5, pp. 225-236.

Zhao, W., Mavris, D., Lu, J.-C. & Yao, Y., 2006. *Feature Exploration for Aircraft Maintenance Knowledge Discovery.* s.l., IIE Annual Conference. Proceedings, pp. 1-6.

Zwijze-Koning, K. H. & de Jong, M. D., 2005. Auditing Information Structures in Organzations: A Review of Data Collection Techniques for Network Analysis. *Organizational Research Methods*, 8, Issue 4, pp. 429-453.

A-Check questionnaire (YY-REQ), 14.-15.9.2015

Hi,

I'm studying in Lappeenranta University of Technology of Industrial Engineering and Management. During the winter 2015-16 I am finalizing the studies with master's thesis. The thesis is commissioned by Airline X. The subject of the work is an "Information management in Maintenance process - Case "An Airline" Technical Operations".

During the thesis work I'm going to observe the maintenance workflows and processes in production. In addition to the observations I'm going interview personnel with theme interviews, as well as electronic feedback gathering.

Whit this questionnaire is meant to identify the information flows and situational awareness in maintenance production linked to the A-check 14.-15.9.2015.

Please kindly reply to the questionnaire with best of your knowledge and your role.

Best regards,

Samu Linnimaa
tel. 044-xxx xxx

Work role
The question is for mapping the role of the defendants during the maintenance action

- ○ Production
- ○ Planning
- ○ Management (supervisor, Duty Manager, Production Manager)
- ○ Customer (MC)

What information you need prior the maintenance action
With the question is tried to clarify the information needs by different roles, which is essential information on the service in preparation for the event. Reply according to your role.

From where the above information come from?
The question focuses on how and what ways the information flows to production

How the above information come from?
The question maps the information routes according to different roles (telephone, supervisor, system, etc.

Continues

When the above information has become?
The question explains the information timeliness, right time information

Is the prior information for the maintenance action (A-Check) been adequate (whether there has been too much or too little)?
The question is for explaining the amount of information received as compared to the required amount

- ☐ Enough and sufficient
- ☐ Too much, but the critical information can be found
- ☐ Too much and the critical information can't be found
- ☐ Too little information

Additional details to the previous question:

What kind of information you should report during maintenance action
The information flow during the maintenance action according to your role

How did you were working on the reported data during the maintenance action
What is the system you entered the information, to whom you informed and by what means.

Who need the the information of maintenance action process during the maintenance
According to your role, who needs the information you report

What information you report after the maintenance action
This question tries to find out the information flows after the maintenance actions

Continues

How the post-maintenance information is handled
What is the system you entered the information, to whom you informed of and by what means.

Who will need and use the above mentioned information
According to your role, who needs the information you report

During the maintenance action did you were forced to rely on tacit knowledge

Did the A-Check went according to the preliminary plans

- ☐ Maintenance action worked out and succeed
- ☐ It remained room for improvement
- ☐ It would be more successful if the information would have been more
- ☐ It would be more successful if the information would have been less

What would you do differently in perspective of data/information flow for improving maintenance actions information flow and what would be the tools for improving?
In ACM, together with customer

Information management in maintenance process questionnaire

Work role

The question is for mapping the role of the defendants during the maintenance action

- ○ Production (mechanic, technician, etc.)
- ○ Planning
- ○ Management (supervisor, Duty Manager, Production Manager)
- ○ Customer (MCC, OCC)

Organization uses all the available data for smooth maintenance production?

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

The organization is able to utilize the data for turning it into information for smooth maintenance execution

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

Continues

I know the essential information to pass in the organization for giving a smooth possibilities for maintenance execution?

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

Only the essential information is spread in the organization for smooth maintenance execution

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

The information flow between the departments and functions is on sufficient level (in perspective of maintenance production)

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree

- ○ I don't know

The information needed in my role in maintenance execution is

- ○ excessive where I have to to filter the extra
- ○ suitable, sufficient and necessary
- ○ too little, but necessary
- ○ there is no information at all
- ○ I don't know

I know where I can find the needed information for completing my task

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

The dissemination of information in maintenance execution is thought out in advance by roles and groups

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

busy, lack of time or human error is often hampered by the correct communication of essential information to target groups

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

The data of maintenance production is entered to the systems via digital interface

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

The progress of maintenance execution can be followed in real time

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

The information systems I use are compatible with each other

- ○ Completely agree

- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

The maintenance production data management process is entirely electronic

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

I often need to rely on tacit knowledge on my position

- ○ Completely agree
- ○ Tend to agree
- ○ Agree nor disagree
- ○ Partially disagree
- ○ Completely disagree
- ○ I don't know

What is the essential information related to your role in own words

How could you improve or what you would do differently in point of view of information flow so that the maintenance production related information would improve and how you would do this?