

# FAILURE PREVENTION IN MAINTENANCE SERVICES AND LOGISTICS

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The authors within the scientific contribution present the Preventive and non-routine maintenance activities on aircraft demand for varying priorities, service provider have to ensure a maximum of flexibility. Key competences for Maintenance, repair and overhaul (MRO) operators are permanent availability, a short respond time, continuous access to current information and real-time process monitoring for customers. Company specific material logistics analyzes the transfer operations of consuming goods to the place of in-house processing (spatial, temporal and quantitative). In the age of globalization a variety of partners work together in logistic chains.

## KEYWORDS

logistics chains, quantitative, maintenance, quality, real time, quality interfaces, flexibility management

## 1 INTRODUCTION

Within the framework of reliability already introduced some fundamentals of quality management systems according to ISO 9000 family. This is, essentially, a set of static rules to constitute the basic requirements of quality. But a complete quality management system cannot be reduced to a simple set of rules; it is rather the implementation of thinking quality. Only a certification according to valid norms does not guarantee a positive quality development. The key aspect of improvement is to integrate all quality actors – the system must be lived and experienced. In a first step quality will be defined and the classical quality management systems will be introduced. Based on this fundamental knowledge a new comprehensive quality management system for aircraft maintenance organizations will be presented. Company specific material logistics analyzes the transfer operations of consuming goods to the place of in-house processing (spatial, temporal and quantitative). In the age of globalization a variety of partners work together in logistic chains. An integrated analysis of the goods flow from creation of spare parts to the place of maintenance is summarized as supply chain management; regarding the aerospace business the spare part logistics requires a detailed examination of all sub-processes. Pervaded by customers' needs, processes must be organized so that staff and equipment are always available at the right time, in sufficient quantity and quality at the agreed location. The use of modern measures helps to counteract organizational uncertainties:

The use of modern measures helps to counteract organizational uncertainties:

- An inventory management monitors the inventory (real-time) across all parts of the supply chain,
- A tour planning system which is supplemented by a tracking system (barcode, Radio frequency Identification (RFID), etc.) helps to organize spare part distribution,
- A packaging system Returnable transport packaging (RTP) keeps the supply chain in motion and meets environmental goals.
- A flexibility management needs to be implemented for recognizing the customer requirements; the service process will be influenced by special care instruments already starting with the production of spare parts [Stiller 2002], [Tempelmeier 2006].

## 2 QUALITY

A general definition of quality is given by EN ISO 9000:2005 as a "degree to which a set of inherent characteristics fulfills requirements". The degree to which these requirements are fulfilled is transferable to products and processes; so quality must be distinguished into process quality and product/service quality. Broader definitions of quality consider five aspects: transcendent, customer-related, value-related, production-related and product-related. The transcendent aspect will not be considered here; it is more a philosophic approach which takes individual experiences during the whole life of product into account [DIN EN 2005], [Garvin 1984].

Figure 1. Processes, products and main quality interfaces of airline business, gives an overview of product flows and processes in airline business; the most important interface is given by airport, airline and passenger (1). Regarding to aircraft maintenance organization procedures the quality interfaces between aircraft manufacturer/Original equipment manufacturer (OEM) and maintenance services (2) as well as between airline and maintenance services (3) are of particular importance. The processes of interface (1) can be summarized to a service for passengers; the service product is a pleasant and safe flight as scheduled. Processes of interface (2) are reducible to the products: serviceable and safe aircraft anytime and anywhere. Products generated at interface (3) are serviceable spare parts, documentations and support on request and as soon as possible. As presented in figure 1 the smallest units of interest which create consumable service products are processes and product flows (processes with a material flow). According to EN ISO 9000:2005 products resulting from processes and efforts for improving the general service quality should focus these units particularly.

### 2.1 PROCESS QUALITY

Process quality definitions reflect a value- and production-related approach with explicitly measurable elements and properties. The result of this measurement provides a degree of meeting the requirements for the considered elements and properties of products and processes. Each negative deviation is equivalent to a quality reduction [Heinemann 2012].

The definition of a process is given by EN ISO 9000:2005 as a "set of interrelated or interacting activities which transforms inputs into outputs" in order to add a value. Process orientation has a high relevance for industrial practice; quality monitoring for processes is the basis of reliability [DIN EN 2005].

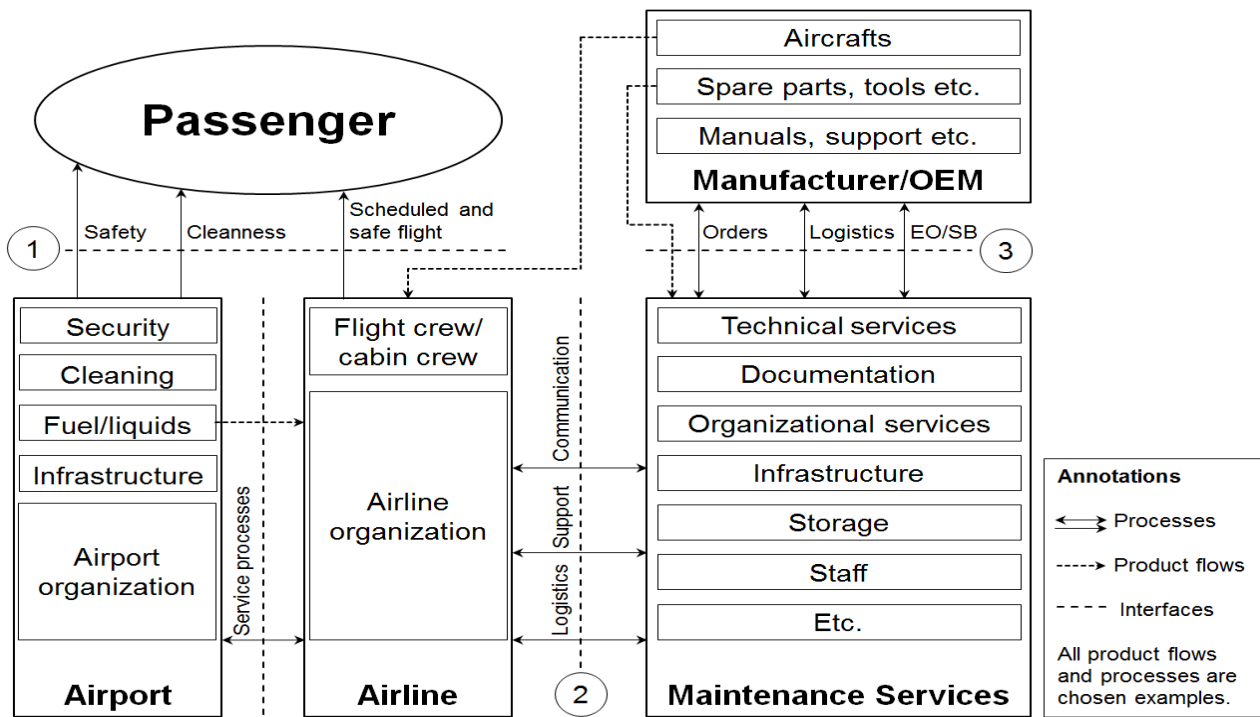


Figure 1: Processes, products and main quality interfaces of airline business

Improving the quality of processes is synonymous to improve product/service quality and means to focus on customer needs. As an additional benefit economic efficiency and profits usually increase. As a result of processes there is a product with an added value; in case of Fig. 1 the products of the interfaces are services. Each service is a customer-oriented product and the priority of implementing quality improvements measures depends on the connected value. Service/product quality always has a (quasi-)transcendent aspect; next to safety and reliability sustainability also influences the level of customer satisfaction. From customers point of view the number of incidents as a consequence of the service/product has a high impact on service product quality. Fig. 2. Service/product quality spells profits, illustrates influencing aspects of service product quality and their impact on profits. Especially for new customers and customer acquisition the benefits result from service and product quality [Heinemann 2012], [Kossmann 2006].

All presented aspects and Fig. 2. Service/product quality spells profits, refer to internal as well as to external service/product quality.

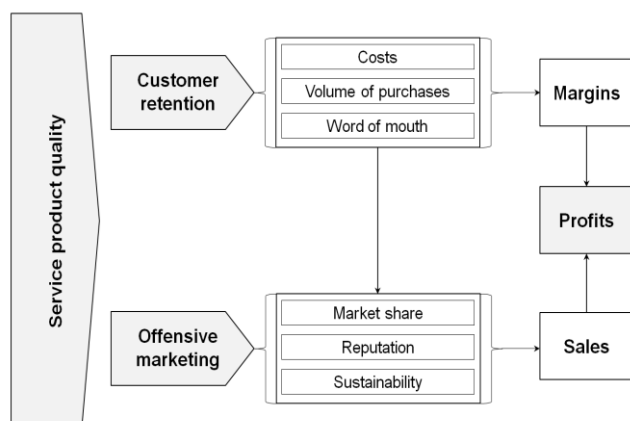


Figure 2: Service/product quality spells profits [Kossmann 2006]

In case of exclusive internal services marketing offensives do not relate to the whole market; they are adapted for internal use. Aspects of customer retention need to be considered anyway to improve quality.

### 3 MANAGEMENT SYSTEMS

Quality needs rules; without a strict set of standards quality in aircraft maintenance and logistics is not possible. These standards define requirements which are absolutely necessary to enable quality. Furthermore, these standards must be able to evaluate and to improve themselves. The aim is to provide a comprehensive quality management system for all products and services in aircraft maintenance environment. Following, the properties of the two most important quality approaches EN ISO 9000 family and EFQM (European Foundation of Quality Management) are introduced.

The ISO 9000 family is a set of standards designed for any type of organization. It helps to manage, control and improve the quality. A static system of rules is given to establish an organization which is enabled to provide quality.

Thereby the regulatory framework covers the following eight areas:

- Customer focus,
- Responsibility of leadership,
- Involvement of people,
- Process-oriented approach,
- System approach to management,
- Continuous improvement,
- Factual approach to decision-making,
- Mutual beneficial supplier relations [Lang 2009], [Seear 2012].

A general concept for each type of organization is provided; the family has industry-specific interpretations of the guidelines:

- ISO/TS 16949 –Quality management system requirements for automotive-related product suppliers,
- TL 9000–Quality excellence for suppliers of telecommunications,

- ISO EN 9100, AS 9100 –Aerospace industry implementation of ISO 9001,  
 - ISO EN 134485–Medical industry implementation of ISO 9001.  
 The ISO 9000 family standards are provided as a process-based

TQM (Total Quality Management) system a complete quality management with a continual improvement. Fig. 3. Model of a process-based quality management system, displays the functioning of an ISO 9000 quality management [DIN EN 2005].

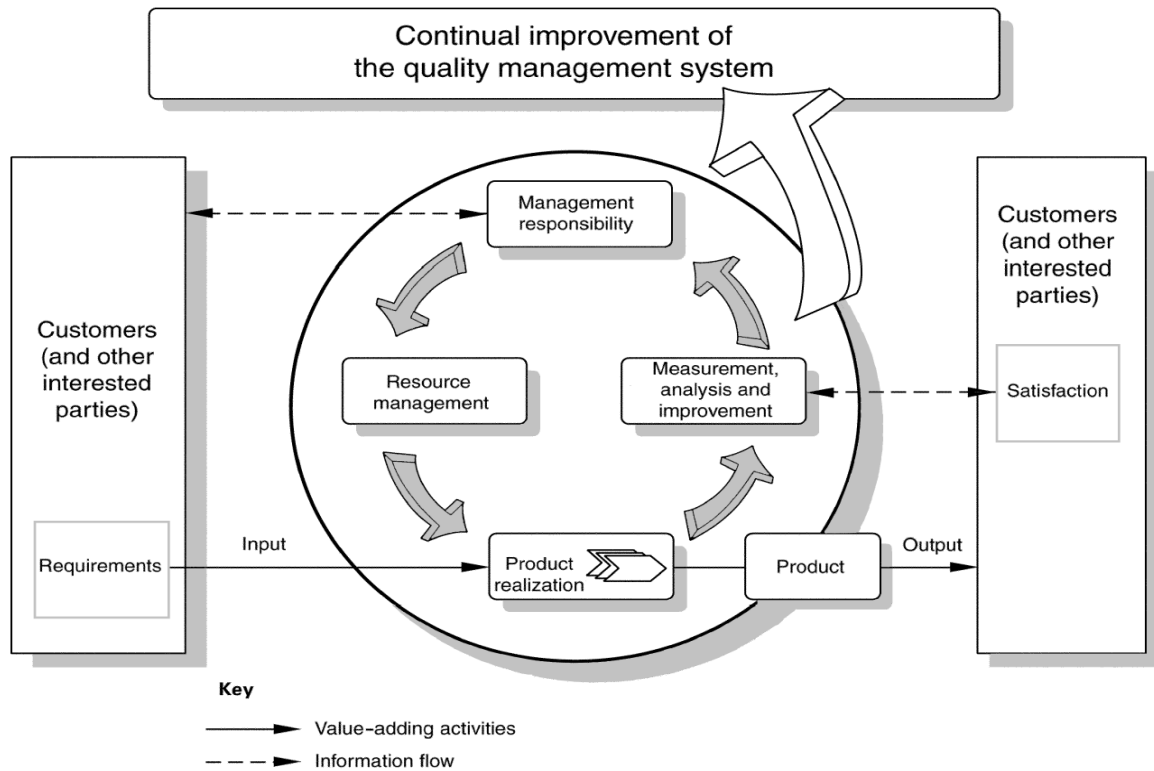


Figure 3: Model of a process-based quality management system [DIN EN 2005]

An ISO 9000 certification provides a harmonized concept of common certification standards which is a key factor for international business. If all related business partners and suppliers in national, international and global markets have a common certification standard, an essential precondition of cross-industry quality is fulfilled.

The regulatory framework of the ISO 9000 family is binding for all certified participants. Although there is implemented a continuous improvement the set of rules is static; the certification process bases on standardized checklists. A Benchmarking system with much more flexibility and a much higher level of up-to-dateness is not provided.

### 3.1 EFQM SYSTEMS

European Foundation of Quality Management (EFQM) is a structured concept that provides an opportunity to any kind of business for evaluation of the own quality management system. This concept supports the development of such systems and serves as a progress monitoring system. It bases on clear management responsibility as well as on an employee and a resource responsibility. All requirements of ISO 9000 family standards are fulfilled; they are fundamental for establishing EFQM systems and in result for a TQM system. Self-evaluation in combination with Benchmarking aspects facilitates continuous improvement.

A complex view on the business organization becomes possible through implementation of an EFQM model. Therefore, the system is distinguished in nine criteria (see Fig. 4) with five enablers (leadership, partnerships and resources, strategy, people and processes) and four results (people results, customer results, society results and key results). Each criterion of the EFQM systems is weighted with a level of importance;

customer results have the most impact with about twenty percent [Amelung 2013], [Weigert 2004].

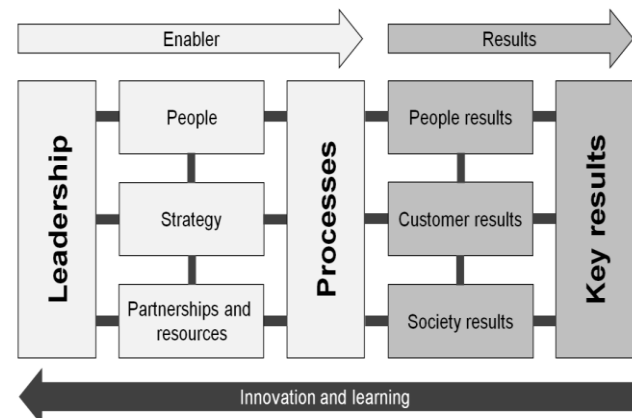


Figure 4: EFQM model (quality management)

Continuous improvement is a key aspect of EFQM and has significantly more importance in contrast to the ISO 9000 family; customer results have a much higher impact. The system fulfills all general ISO 9000 requirements and it is applicable for nearly every business. However, aircraft maintenance business is subjected to a much more complex regulatory framework. And yet, the level of continuous improvement and the consideration of customer needs are trendsetters for new quality management systems in aircraft maintenance business.

#### 4 QUALITY MEASUREMENT AND MANAGEMENT APPROACH

Quality is not just available – quality must be created and improved; a key pre-condition is the measurement of the present quality level. So the status quo is attested and a systematic use of identified potentials is certified. Therefore, it is necessary to provide standard quality data and information

as reference for reviewing measured data. As a basis for a subsequent analysis the measurement provides data which have to meet defined requirements. According to Fig. 5. Quality—a target-performance comparison, each quality concept is reducible to a target-performance comparison [Masing 2007], [Rieck 2011] [Zollondz 2012].



Figure 5: Quality – a target-performance comparison [Masing 2007]

The degree of compliance is determined through reviewing conformity. Dimensional characteristics of quality are measurable objectively; non-dimensional quality criteria allow only a subjective measurement (especially in case of evaluating sensual impressions). Thus, a measurement is carried out fundamentally for an objective review and a quality determination [Rieck 2011].

In general, transparency and traceability of inspection results are prerequisite for decision-making and implementing improvements. Fig. 6. Measurement and review of quality, illustrates a measurement of criteria and the determination of the degree of compliance to the target conditions. Without a measurement (a review and an analysis of the results) there is no support for planning, management or improvement of quality [Weckenmann 2007].

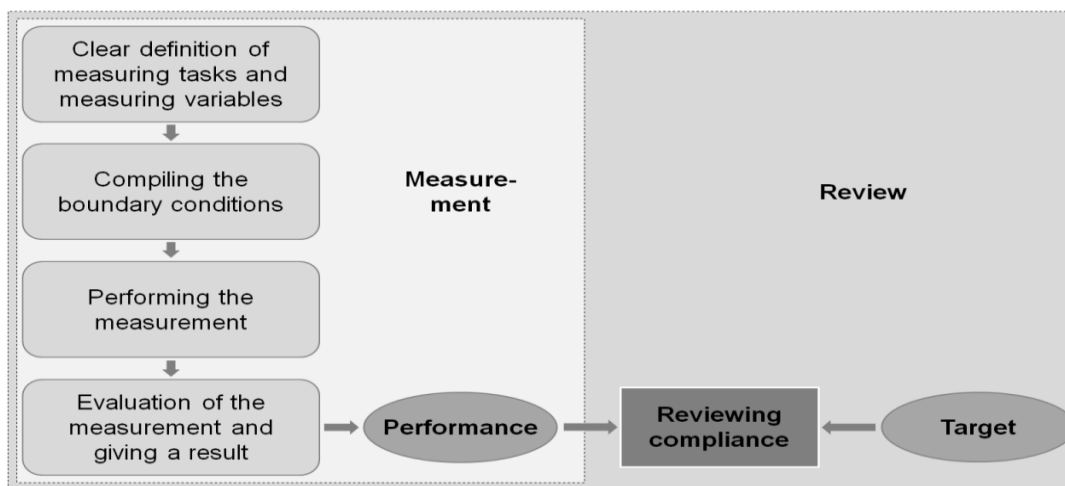


Figure 6: Measurement and review of quality [Weckenmann 2007]

Safety, reliability and customer satisfaction summarized by the concept of quality are the reason for implementing quality management systems. Designing them is a balancing act between a strict regulatory framework and a flexible construction which is adaptable to each type of business. It should be found an optimum of necessary regulations which considers all requirements of aircraft maintenance business and the provisioning of capabilities for continuous improvement of processes as well as the organization itself.

##### 4.1 REQUIREMENTS OF A COMPREHENSIVE QUALITY MANAGEMENT SYSTEM

Requirements of a quality management system often are derived from quality expectations of the stakeholders. Tab. 1. Quality expectations of some stakeholders, gives an overview of involved stakeholders selected and their expectations.

Customer	Public	Provider
Function and equipment	Safety	Failure reduction
Trust	Environmental protection	Flexibility (set-up times)
Safety	Sustainability	Production capabilities
Service life	Trust	Product conformity
Reliability		Economic efficiency
Finishing quality		

Table 1: Quality expectations of some stakeholders

As introduced before, conformity to the ISO 9000 family of standards provides a good basis for managing quality; but the requirements need to be extended to provide a more self-evaluating quality management system with a broader focus on improvement. Identified demands are distinguishable into

general and aircraft maintenance-specific requirements [Daneshjo 2012].

The most common quality standard used in Europe is the EN ISO 9000 family with their general standard “EN ISO 9001: Quality Management Systems”. Tab. 2. General requirements of quality management systems, introduces requirements and compares them to the standard EN ISO 9001.

Requirement	Comparison to EN ISO 9001
<b>Process oriented approach</b>	Fulfilled
<b>Type of quality management</b> Open-loop system with self-reference and the ability of comprehensive improvement.	Closed-loop-system with defined input interfaces.
<b>Quality management design</b> General requirements, documentation, quality manual, control of documents and records.	Mentioned
<b>Management responsibility</b> Commitment, customer focus, quality policy and objectives, planning, responsibility, authority, review, communication.	Mentioned
<b>Resource management</b> Provisioning of resources and human resources, infrastructure, work environment.	Mentioned
<b>Product realization</b> Planning (projects, risks, configurations), customer relationship, design and development, purchasing, product and service provision, control of monitoring and measuring equipment.	Mentioned
<b>Measurement, analysis and improvement</b> General, monitoring and measurement (audits, customer satisfaction etc.), control of nonconforming products, data analysis, improvement, corrective and preventive actions.	Mentioned
<b>Conformity to applicable legislation</b>	Applicable legislation is not touched.
<b>Motivational aspects</b> Chyba! Nenalezen zdroj odkazů. Job enrichment, company governance and personal satisfaction of staff, internal communication, feedback rules, time approaches etc.	Not considered
<b>Types of improvement</b> Benchmarking, comprehensive improvement	Considered only for slight/continuous improvement.
<b>Change management for improvements</b> Planning, staff involvement, operational business etc.	Not considered

Table 2: General requirements of quality management systems

If aspects are mentioned by norms, it is just a general consideration. A norm provides facets to take into account; there is no implementation information.

#### 4.2 AIRCRAFT MAINTENANCE-SPECIFIC REQUIREMENTS

Aircraft maintenance-specific quality management systems are recognized in EN ISO 9000 family through “EN ISO 9110; Quality Management Systems – Requirements for Aircraft Maintenance Organizations”.

All facets of EN ISO 9001 are considered; special aspects for aircraft maintenance organizations are added. Table 3. Aircraft maintenance - specific requirements of quality management systems, introduces specific requirements and compares them to the standard EN ISO 9110.

Requirement	Comparison to EN ISO 9110
<b>Harmonization with applicable European and national law</b>	Applicable law is not touched although it is very close to it; there is no harmonization.
<b>Failure reporting system</b> An independent and anonymous failure reporting system is required by Regulation (EC) 2042/2003.	Not considered
<b>Human factors</b> Human factors are of high importance in aircraft maintenance; it is recognized by continuous qualification of personnel.	It is only considered by aspects of internal communication; less importance.
<b>Audits of the NAAs</b> Scheduled and spontaneous audits of the responsible NAA should supplement quality management audits.	NAA audits are just mentioned; they are not part of audit plans.
<b>Checklist procedures</b> As an effective instrument to avoid recurrent errors.	Not considered

Table 3: Aircraft maintenance-specific requirements of quality management systems

The ISO 9000 family of standards provides an organizational framework with absolutely necessary fundamentals of quality. Enhancements are required for a higher level of meeting the demands and for establishing an open loop quality management system. Quality management systems can be viewed as a black box with an input and an output value [Brunner 2010]. The input value consists of customer needs and the requirements of a quality management system as defined previously; the output is the final product or service. All organizational fundamentals of EN ISO 9110 are also fulfilled for the comprehensive quality management approach in aircraft maintenance (see Fig. 7).

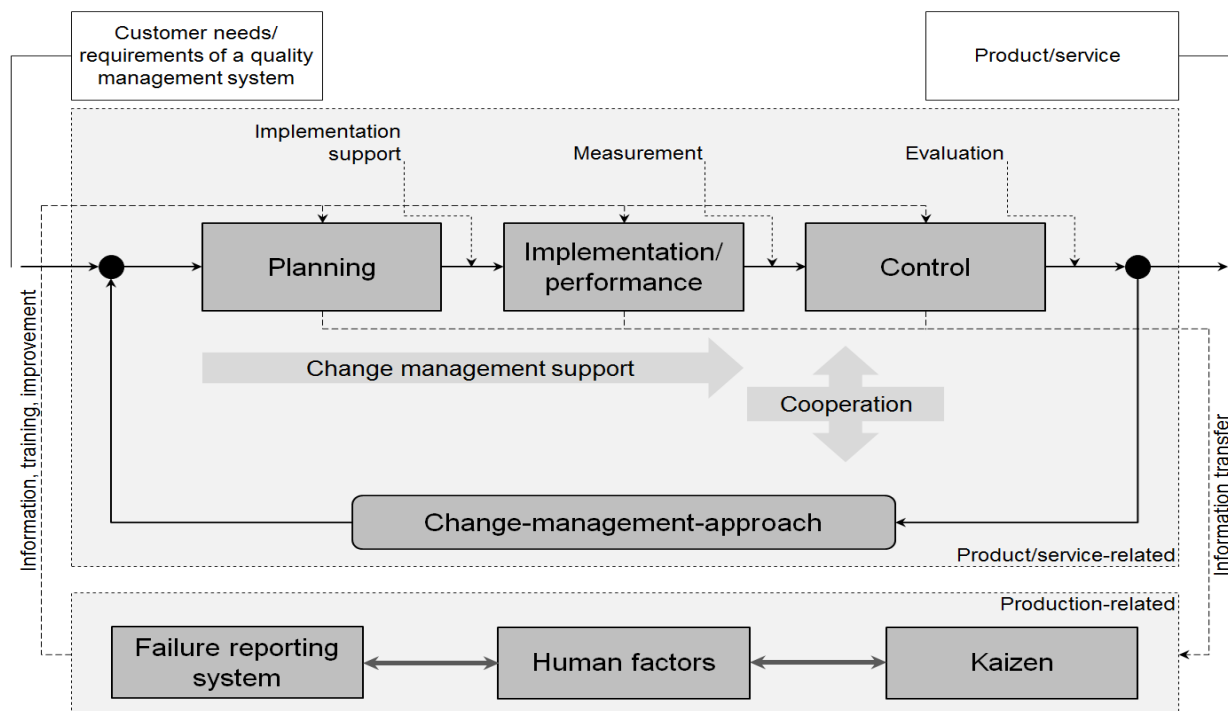


Figure 7: A comprehensive quality management approach – design and functioning

The present thesis is a practical-oriented research paper that derives recommendations for a better structuring of aircraft maintenance organization procedures; based on in-depth academic research. Beside the practical implementation this thesis gives impulses for further research especially in cybernetic and stochastic theories as well as statistic reliability. Criteria for maintenance decision making are of particular interest for further research. The speed of technical evolution is steadily increasing; so forecasting methods and decision criteria premising on large extents of maintenance and inventory data are not appropriate. Thus, there is a special need for modern and scientifically validated stochastic decision-making systems.

## 5 CONCLUSIONS

A good planning is the basis of customer satisfaction, safety and finally of quality. In result product/service blueprints, checklists, etc. are developed and provided for the next step implementation/performance. There is no clear dividing line between planning and implementation/performance; the planning process continues up to performance and provides support for implementation. This way, unforeseeable problems can be corrected during implementation. Performance measurements proceed in the background of regular performance; data for the control step is generated. The control step evaluates the accordance of the final product/service with the input variables as well as with Benchmarking data (product-related). If there is no gap between input variables and Benchmarking data towards the final product/service a high quality standard is provided. The introduced quality management system is designed for all activities referring to aircraft maintenance. It considers the legal requirements and fulfills any other conditions. Quality of the company with the aspects corporate culture, structural organization, infrastructure, leadership, and employees as well as processes quality with the aspects materials, information, energy, work and flow are of essential importance for the performance quality (products (soft- and hardware) and

services/interactions) and the whole system. A basic requirement is the accordance with EN ISO 9001/EN ISO 9110 which defines organizational fundamentals. The new quality management approach completes the quality-based safety and reliability to fulfill all demands of products and services related to aircraft maintenance. Preventive maintenance activities should proceed before a failure occurs. Pressure is built up through enormous aircraft on ground (AOG) costs but due to economic reasons, preventive maintenance may not be performed sufficient long before an expected failure.

A good quality management system necessitates a review scheme. Audits are defined as detailed and independent checks to evaluate activities and processes with regard to the requirements; they are a substantial element of each quality management system and also an important management tool. Particularly for aircraft maintenance this thesis provides several criteria for decisions concerning servicing and maintenance organization.

The main aspect is to keep up reliability-based safety and quality with the following main decisions:

- Location of business,
- Extent of provided services and depth of service (criteria for new purchases in maintenance and repairshops and transparency of activities).
- Places of demand (centralized or decentralized organization and development of supply chains),
- Amount of the real demand,
- National or international cooperation with regard to support, services or strategic alliances,
- Aspects and level of harmonization,
- Type of quality management

Aircraft maintenance is an interdisciplinary business; different fields of scientific research get joined together. A definition of the degree of safety is given by the harmonization level of different fields with conflicting interests. The approach of the present thesis to increase the safety of aircraft maintenance organization unifies the following fields of scientific research:

- Engineering sciences: Mechanical, aeronautical, quality engineering and others,
- Economic sciences: Logistics, change management, improvement, cost reduction and others
- Law: Certification processes, legal harmonization, standard frameworks and others,
- Social sciences: Human factors, teamwork, public networks and others.

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