Development of a quality assurance system in the stock receipt at Lufthansa Technik Logistik GmbH

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Final thesis, 20 credits

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Preface

This thesis has been accomplished in co-operation with Lufthansa Technik Logistik GmbH and the department of Industrial Management and Logistics at Lund Institute of Technology.

I would like to thank my supervisors Bertil I Nilsson, Associate Assistant Professor at the department of Industrial Management and Logistics at Lund Institute of Technology, and Thomas Wilms, head of Quality Management at Lufthansa Technik Logistik GmbH for the support. I also want to thank Christian Hettrich at Quality Management at Lufthansa Technik Logistik GmbH for the help and information that he has provided.

Hamburg, May 2004

Pär Rosenquist

Abstract

Title Development of a quality assurance system in the stock receipt at Lufthansa Technik Logistik GmbH

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Problem The aviation industry is a branch with extremely high quality requirements on spare parts and belonging documents. These documents, which assure that a part complies with authority requirements, are scanned and electronically saved in the stock receipt at Lufthansa Technik Logistik GmbH in Hamburg. The quality level of scanned documents is to investigate and shall provide useful information for the development of quality improvement actions in this thesis.

Method A combination of a qualitative and a quantitative approach has been chosen for this thesis. This is called triangulation. The working methodology "Six Sigma DMAIC methodology", which contains the five phases define, measure, analyse, improve and control, was used as a roadmap for a structured working procedure. Random test and comparative studies were chosen as techniques for data collection. The random test was performed on scanned documents and the comparative studies in form of benchmarking at an external company and internal at Lufthansa Technik Logistik in Frankfurt. A Failure Mode and Effect Analysis (FMEA) was used to objectively use the result of the random test. This also enabled to take the severity of the effects and the possibility of failure detection before processes or customers are affected in consideration. The most critical failures could thereby be identified.

Conclusions The random test revealed several failure types and also showed that the average quality level is higher at Lufthansa Technik Logistik in Frankfurt than in Hamburg. The FMEA and the random test indicated that the solving of the following failures were to prioritise:

- Black fields on "Airway bill".
- Askewly scanned "Authorised release certificate" where data is missing.
- "Authorized release certificate" is not automatically recognised.

- Black lines along scanned documents.

The following solving suggestions have been developed to solve the most critical quality problems:

- Procure a scanner, which is able to scan “Airway bills”.
- Procure a scanner and software, which can scan and process documents larger than A4.
- Always scan “Certificates” with a solution of 300 dpi.
- Configure the software at all working stations so that the image always appears on the monitor after a document has been scanned.
- Work out co-worker guidelines, which describe how and when to clean the document scanner and how to avoid askew scanning.
- Work out a control document, which verifies performed scanner cleaning and maintenance.
- Inform the co-workers about the importance of OCR-readable ”Authorised release certificates”.
- Perform an additional random test on not automatically recognised ”Authorised release certificates” to identify the main reasons for a non-successful automatic recognition.
- Increase the quality controls on “Airway bills” and certificates until satisfying solutions have been implemented.
- Consider centralising the document scanning and to let expert co-workers perform the document scanning with one or more high performance scanners.

New random test shall be performed in the future to verify the success of implemented actions.

Zusammenfassung

Titel Entwicklung eines Qualitätssicherungssystems für den Wareneingang der Lufthansa Technik Logistik GmbH

Autor Pär Rosenquist

Betreuer Bertil I Nilsson, Technische Universität Lund
Thomas Wilms, Lufthansa Technik Logistik GmbH

Problem Die Qualitätsanforderungen für Ersatzteile und deren Begleitdokumente sind in der Flugindustrie sehr hoch. Die Begleitdokumente der Ersatzteile, die die Übereinstimmung mit gesetzlichen Vorgaben sicherstellen sollen, werden im Wareneingang der Lufthansa Technik Logistik GmbH in Hamburg eingescannt und elektronisch archiviert. Das Qualitätsniveau der eingescannten Dokumente soll in dieser Arbeit untersucht werden und als Vorlage dienen, um Lösungsvorschläge danach ausarbeiten zu können.

Methode Eine Kombination aus qualitativem und quantitativem Ansatz, eine sogenannte Triangulierung, wurde für diese Arbeit gewählt. Die Arbeitsmethodik "Six Sigma DMAIC methodology" wurde als Modell / Wegweiser für ein strukturiertes Vorgehen gewählt. Diese Methodik beinhaltet fünf Phasen: definieren, messen, analysieren, verbessern und kontrollieren. Stichprobe und vergleichende Studien wurden als Methoden der Dateneinsammlung benutzt. Die Stichprobe wurde mit eingescannten Dokumenten durchgeführt. Die vergleichenden Studien wurden als Benchmarking bei einer externen Firma und intern bei Lufthansa Technik Logistik in Frankfurt durchgeführt. Eine Fehlermöglichkeits- und -einflussanalyse (FMEA) wurde benutzt, um das Stichprobenergebnis objektiv anwenden zu können. Dadurch wurden auch die Bedeutung der Fehlerfolgen und die Entdeckungswahrscheinlichkeit der Fehler, bevor Kunden oder weitere Prozesse beeinflusst werden, berücksichtigt. Mit Hilfe der FMEA konnten anschließend die Fehler mit dem höchsten Gesamtrisiko identifiziert werden.

Schluss-folgerung Die Stichprobe hat gezeigt, dass mehrere Fehlertypen an eingescannten Dokumenten existieren und dass das allgemeine Qualitätsniveau bei Lufthansa Technik Logistik in Frankfurt höher ist als in Hamburg.
Die FMEA und die Stichprobe hat vier Fehler, die primär beseitigt werden sollen, aufgezeigt:

- Schwarze Felder auf ”Airway bills”.
- Schräg eingescannte ”Authorised release certificate” auf denen Daten fehlen.
- ”Authorized release certificate” kann nicht automatisch erkannt werden.
- Schwarze Linien auf Dokumenten

Folgende primäre Lösungsvorschläge sind zur Beseitigung der Fehler ausgearbeitet worden:

- Ein Scanner der ”Airway bills” einscannen kann, muss beschafft werden.
- Vorhandene oder wenn notwendig neue Hard- und Software soll sicherstellen, dass es möglich ist, auch außerhalb eines Dokuments (A4-Format) zu scannen.
- ”Certificates” sollen immer mit einer Auflösung von 300 dpi eingescannt werden.
- Die Scannersoftware soll an allen Arbeitsplätzen so konfiguriert werden, dass das eingescannte Bild nach dem Scannen immer am Bildschirm erscheint.
- Verfahrensanweisungen zur inwendigen Scannerreinigung und Vermeidung von schrägem Einscannen sollen ausgearbeitet werden.
- Ein Wartungsprotokoll für jeden Scanner soll erstellt werden, um eine regelmäßige Reinigung sicherzustellen.
- Die Mitarbeiter müssen über die Wichtigkeit eines OCR-lesbaren ”Certificates” informiert werden.
- Eine zusätzliche Stichprobe aus ”Certificates”, die nicht automatisch erkannt wurden, soll durchgeführt werden, um die auffälligsten Ursachen dafür zu identifizieren.
- Bis geeignete Lösungen implementiert sind, sollen die Qualitätskontrollen von ”Certificates” und ”Airway bills” intensiviert werden.
- Langfristig muss sich LTL überlegen, Dokumente zentral von Mitarbeitern mit einer scantechnischen Spezialkompetenz mit Hilfe eines Hochleistungsscanners einscannen zu lassen.

Neue Stichproben sollen zeitnah durchgeführt werden, um den Erfolg der Maßnahmen zu untersuchen.

Sammanfattning

Titel Utveckling av ett kvalitetssäkringssystem i varuingången hos Lufthansa Technik Logistik GmbH

Författare Pär Rosenquist

Handledare Bertil I Nilsson, Lunds Tekniska Högskola
Thomas Wilms, Lufthansa Technik Logistik GmbH

Problem Inom flygindustrin råder mycket höga kvalitetskrav gällande reservdelar till flygplan och dess tillhörande dokument. Dessa dokument, som ska säkerställa att reservdelen uppfyller gällande krav och normer ställda från olika myndigheter och organisationer, scannas och sparas elektroniskt i varuingången hos Lufthansa Technik Logistik GmbH i Hamburg. Kvalitetsnivån med avseende på scannade dokument ska undersökas och resultatet av undersökningen ska ge underlag till att därefter utarbeta lösningsförslag som kan höja kvalitetsnivån.

Metod En kombination av kvalitativ och kvantitativ ansats, så kallad triangulering, valdes i detta arbete. Arbetsmetodiken "Six Sigma DMAIC methodology", som innehåller de fem faserna definiera, mät, analysera, förbättra och kontrollera, användes som modell för ett strukturerat arbetssätt. Som metoder för insamling av data användes stickprov samt jämförande studier. Stickprovet utfördes på scannade dokument och de jämförande studierna utfördes i form av benchmarking på ett externt företag samt internt hos Lufthansa Technik Logistik i Frankfurt. En Failure Mode and Effect Analysis (FMEA) användes för att på ett objektivt sätt kunna använda resultatet av stickprovet. Samtidigt gavs därmed möjligheten att ta hänsyn till hur allvarliga följderna av ett fel är samt hur lätt eller svårt det är att upptäcka och åtgärda ett fel innan det påverkar senare processer eller kunder. Med hjälp av FMEA:n kunde även de allvarligaste felen identifieras.

Slutsatser Stickprovet visade att åtskilliga feltyper existerar på scannade dokument samt att den genomsnittliga kvalietsnivån är högre hos Lufthansa Technik Logistik i Frankfurt än i Hamburg.
FMEA:n och stickprovet indikerade följande fel att primärt åtgärda:

- Svarta fält på "Airway bill"
- Snett inscannade "Certificate" där data saknas
- "Authorized release certificate" känns inte igen automatiskt
- Svarta linjer längs med scannade dokument

Följande primära lösningsförslag har utarbetats för att åtgärda ovanstående fel:

- Införskaffa en scanner som kan scanna ”Airway bills”.
- Införskaffa scanner och mjukvara som kan scanna och elektroniskt bearbeta även utanför ett dokument av A4-format.
- Scanna alltid ”Certificate” med 300 dpi upplösning.
- Konfigurera mjukvaran på alla arbetsplatser så att bilden av ett scannat dokument alltid visas på skärmen direkt efter att det scannats.
- Utarbeta instruktioner för medarbetarna som beskriver hur de ska göra för att undvika sned dokumentinscanning samt hur och när scannern ska rengöras.
- Utarbeta ett kontrolldokument som verifierar utförd scannerrengöring samt –underhåll.
- Informera medarbetarna om hur viktigt det är att ”Certificates” är OCR-läsbara.
- Utför kompletterande stickprov på icke automatiskt igenkända ”Authorized release certificates” för att lokalisera de huvudsakliga orsakerna till misslyckad automatisk igenkänning.
- Öka kontroller på ”Airway bill” och ”Certificate” det att tillfredsställande lösningar implementerats.
- Överväg långsiktigt att låta expertutbildad personal scanna dokument centralt med hjälp av en högpresterande scanner.

Nya stickprov bör utföras i framtiden för att undersöka framgången av implementerade åtgärder.

Table of contents

1 Introduction

The company Lufthansa Technik Logistik GmbH is described in this chapter. Background, task, delimitation's and goal are thereafter defined to give the reader a comprehension of the nature and focus of the project.

1.1. Lufthansa Technik Logistik GmbH

Lufthansa Technik Logistik GmbH (LTL) is a leading logistic provider of the Lufthansa Technik group. The company is responsible for the entire supply chain in the fields of maintenance, repair and overhaul of aviation material.

LTL was founded in 1998 as a joint venture between Lufthansa Technik AG (LHT) and Lufthansa Cargo. The extension of logistics as a specific business segment was made to unify the experiences in material supply from LTL and LCAG, and to give the opportunity to gain additional customers. Since the end of 2003, LHT is the only stakeholder of LTL.

LTL employs more than 850 persons and operates on eight locations in Germany. These are situated in Berlin Tegel (TXL), Berlin Schönefeld (SXF), Düsseldorf (DUS), Frankfurt (FRA), Hamburg (HAM), Cologne (CGN), Munich (MUC) and Stuttgart (STR). LTL accesses four additional locations in the US since the founding of LTL of America. The locations are situated in Dallas, New York, Seattle and Washington. Further permanent and temporary subsidiaries are located in Africa, Asia and South America.

LTL has doubled its revenue to over 100 Million Euros since 1998 and represents a 7% share of the world market. The most important customer of LTL is still LHT, but other important customers are for example Airbus, Alitalia and Rolls-Royce.

LTL is certified by Deutsche Gesellschaft für Qualität (DQS) according to DIN EN ISO 9001 since 1999 but to DIN EN ISO 9001:2000 since 2003.

1.1.1 The services

LTL positions itself as a leading logistic provider and is responsible for the entire supply chain in the fields of maintenance, repair and overhaul of aviation material. The services of LTL fall under the areas of warehouse management, material management and transport management.

Beside the already mentioned locations, LTL accesses approximately 500 "virtual locations" around the world. The large number of partners of Lufthansa and Star Alliance represents the „virtual locations". The virtual distribution centres take over the reliable storage and shipping of LTL at numerous locations. This large distribution network makes it possible to meet the requirements of short transport times and minimal transport stocks.

To face the great variety of parts to deliver to the most different destinations, LTL co-operates with companies as FedEx and DHL. In critical situations an ”On-Board-Courier” is used. An ”On-Board-Courier” is an LTL employee that personally accompanies and delivers a shipment to secure a fast and safe delivery.

The ”Aircraft on ground (AOG) transport service” is a prime example of the integrated logistic solutions of LTL. In case of an unscheduled breakdown of an aircraft, the ”AOG-helpdesk” in Hamburg quickly locates and procures the needed part from the nearest location with help from mechanics, transport and logistic experts. This is possible because of the direct access to suppliers worlwide. The most effective way of transportation is calculated and the part is delivered by for example an ”On-Board-Courier”. [1] [2] [3]

1.1.2 The Hamburg location

The head office of LTL is situated in Hamburg, which is also the largest location with more than 300 employees. The departments of personnel, sales, marketing, quality management, finance, accounting, IT and customs are operating from here. LTL in Hamburg receives approximately 190.000 shipments a year and has about 210.000 warehoused positions to its disposal.

1.1.3 The Frankfurt location

Frankfurt is with its 280 employees the second largest location. LTL Frankfurt receives about 62.000 shipments a year and has 122.000 warehoused positions to its disposal. This is the only LTL location comparable with Hamburg considering size and processes. [3]

1.2. Background

The aviation industry is a branch with extremely high quality requirements. An insufficient quality level can lead to hazardous effects. The level of safety and quality demands is similar to the ones that are to find in for example the nuclear and pharmaceutical industry. Furthermore, many airlines are being confronted with economic difficulties due to intense competition and the travelling recession since September 11th. This results in a great cost pressure.

In the aviation industry, national authorities such as the European Aviation Safety Agency (EASA) and Federal Aviation Administration (FAA) formulate the quality requirements. These organisations have the right to certify suppliers and manufacturers for the aviation industry. Only certified companies are allowed to manufacture and repair aircraft parts (A/C-parts). All A/C-parts must have a valid documentation from a certified manufacturer. Without certified documents which traces the part to the last certified manufacturer or overhaul facility, no A/C-part is allowed to be used. LHT is both a certified manufacturer and a maintenance, repair and overhaul facility. LTL was founded to provide the incoming inspection and shipment services. LTL has thereby committed itself to follow the LHT-

procedures as derived from international legislation. Therefore LTL scans and electronically stores all documents belonging to delivered A/C-parts.

1.3. Task definition

The quality level of scanned and electronically saved documents belonging to A/C-parts in the stock receipt in HAM are to investigate. The measured quality level shall initiate the question which ways there are to improve the documentation quality and to fulfil external documentation requirements.

1.4. Goal

The goal of this thesis is to:

- find and implement methods that objectively measures, illustrates and communicates the documentation quality level, and
- work out solutions, which improve the documentation quality level in the stock receipt.

1.5. Delimitations

The thesis focuses on processes and quality aspects that are possible for LTL to influence. Therefore, only internal processes are investigated. Subprocesses controlled by external forces and interfaces to customers and suppliers are difficult to affect and are not further examined.
The quality aspects of the lead time in the stock receipt shall not be discussed in this thesis.

1.6. Target group

The target group of this thesis is primarily LTL. Other persons with interest in quality management may also acquaint themselves with the contents of this thesis.

1.7. Disposition of the report

LTL and the conditions for the problem and the goal of this thesis were described in chapter one. The disposition of the rest of the report will now be described.

Chapter 2 – Method
This chapter describes the research approach, the working procedure and the different techniques and tools that have been chosen for this thesis. It also describes how the tools are used. The reader shall after reading this chapter have a comprehension of the working methodology and the validity and reliability of it.

Chapter 3 - Theoretical background
Documentation requirements, supplier conditions and different document types are described in this thesis. This theoretical background is important to the understanding and solving of the problem.

Chapter 4 – Analysis of the current situation
This chapter describes the environment and the procedures related to the problem to investigate. The quality level is measured and sever problems are identified. The purpose is to map the current quality level and situation.

Chapter 5 – Comparative studies
Chapter 5 describes observations made during the comparative studies performed at two external locations. The observations shall relate our situation to the situation at these two locations and underlie the solving suggestions and recommendations worked out in chapter 6.

Chapter 6 – Conclusions and recommendations
Solving suggestions for the most critical failures are worked out and recommendations are presented in this chapter. The fulfilment of goal and choice of methods are also discussed.

2 Method

This chapter describes the methods used to fulfil the goal of this thesis. Research approach, data collection techniques and validity and reliability are first discussed. The working procedure and the different tools that have been used are thereafter depicted.

2.1. Research approach

The task definition and purpose of a problem underlie the choice of research approach. To analyse the quality of scanned and electronically saved documents and to work out recommendations, which improve the quality, an adequate approach must be determined. There are principally two forms of research approach: quantitative and qualitative.

A quantitative approach is chosen when information is gained, analysed and presented in the form of numbers. The studies normally deal with quantities, proportions and exact measured values. In the quantitative tradition, the measuring instrument is a predetermined and finely tuned technological tool, which allows little flexibility and imaginative input. An advantage of the quantitative approach is that you gain an objective measure of the probability that the result is accurate. Furthermore, the researcher himself can remain objective and is exchangeable.

A qualitative approach is chosen when data is gained, analysed and presented in the form of words or pictures and often involves subjective elements. In the qualitative tradition, researchers must use themselves as the measuring instrument. The qualitative approach takes the whole situation into consideration in a way, which is usually not possible with a quantitative approach. [4] [5]

The characteristics of the problem in this thesis induce the choice of a combination of a qualitative and a quantitative approach. This is called triangulation and means that different types of data collection techniques are used in order to measure the same variable. [4] The basic idea is that the confidence in the measurement of the quality level grows when multiple indicators are used. [4²] A broader perspective of the quality level and the influencing factors is also likely to be an advantage when working out recommendations for quality improvement. The measurement can be related to further measurements but still remains objective and possible to analyse statistically. A strictly qualitative approach has not been chosen since it would not generate a sufficient objectivity. A strictly quantitative approach would be difficult to implement since there are no technological tools, which can measure all quality features in this case. This means that the researcher will have to use himself as the measuring instrument.

2.2. Data collection techniques

Every researcher uses one or more techniques to collect the needed data. Quantitative data collection techniques are experiments, surveys, content analysis and existing statistics research. Qualitative data collection techniques are observations, case studies and historical-comparative research.

Content analysis and observations have been chosen as data collection techniques in this thesis. They give the possibility to interpret and analyse the quality level from two different perspectives.

Content analysis is a quantitative technique to examine information, or content, in written or symbolic material. In content analysis, a researcher first identifies the material to analyse. The material is constituted of scanned documents in this case. He then creates a system for recording specific aspects of it and finally counts and records how often certain words or characteristics occur. In this thesis, the characteristics to count will be different types of failures on scanned documents. This technique lets a researcher discover features in the content of large amounts of material that might go unnoticed if for example experiments or existing statistics research are performed. That is why this technique was chosen in front of other alternatives.

Observation is a qualitative technique and means that activities are studied on the spot. The researcher watches, listens and asks questions to gain as much information as possible. Locations for document scanning at LTL in HAM and at other places were observed in this thesis. A survey could gain similar information, but the data would risk to be stronger influenced by subjective opinions of the asked persons and was therefore not chosen as a data collection method. [4] [4²]

2.3. Reliability and validity

Reliability and *validity* are central issues in all scientific measurement. Reliability tells us about an indicator's dependability and consistency. If you have a reliable indicator or measure, it gives you the same result each time the same thing is measured. Validity tells us whether an indicator actually measures the characteristics in which we are interested. If indicators have a low degree of reliability and validity, then the final result will be of questionable truthfulness. [4] Research methods have been chosen with the goal to maximise reliability and validity in this thesis. The reliability and validity will be discussed for the used data collection techniques.

2.4. Working procedure

The "Six Sigma DMAIC methodology" have been used as a roadmap in this thesis. It facilitates a structured working procedure and contains five phases:

1. Define
2. Measure
3. Analyse
4. Improve
5. Control

The five phases may appear linear and explicitly defined, but an iterative process is often necessary. The literature describes several different tools, which can be used in each phase. Tools that suit the current situation can therefore be chosen to maximise validity, reliability and available resources. Further advantages are that the methodology gives the possibility to continuous improvements in the future and that it contains quality management tools that have not been used to a great extent at LTL before. [6] [7] [8]

The phases in the working procedure of this thesis are described below and are also illustrated in figure 1.1. The used quality management tools will thereafter be more detailed described.

Define
Goal, quality requirements and process features were defined in this phase. Data to define goal and quality requirements were obtained from approved quality standard documentation describing government regulations and from initiated and competent co-workers at LTL. The processes to investigate were then studied on spot and a **flowchart** was constructed to illustrate and better understand the different process steps and interfaces.

Measure
The documentation quality level at LTL was measured in this phase. Different failure categories were defined and a **random test** on scanned and electronically saved documents was performed. The rates for the different failures were measured for documents scanned in HAM, FRA, CGN, MUC and SXF.

Analyse
The collected data was summarised in a table. **Statistical tools** were thereafter used to analyse the data and to determine the confidence in the measured failure rates. Root causes of detected failures could be located with help from **brainstorming,** observations and discussions with initiated co-workers at LTL. The causes were then structured in a **cause-and-effect diagram.** Failures, causes, effects, failure rates and some further aspects were thereafter implemented in a **failure mode and effect analysis** (FMEA) and the failures with the highest aggregate risk could be identified.

Measure
Good knowledge about the features of the problem was now gained and meaningful comparative studies could be performed. An iteration were therefore made back to the measure phase and comparative studies in form of a

benchmarking were performed at a foreign company. A further benchmarking was decided to be performed at LTL in FRA because of certain observations made in the analysis of the random test. These comparative studies were also considered to provide helpful information for the following improve phase.

Improve
Brainstorming, data gained from comparative studies and literature studies were used to work out ways to eliminate the root causes for the most critical failures. A flowchart was then constructed to illustrate recommended process changes.

Control
A new **random test** implemented in the **FMEA** shall be performed to validate the improvement. If the results are not satisfying, an iteration back to the improvement phase should be made. However, no reliable control calculations could be made since the implementation of recommended actions is not a part of this thesis. Nevertheless, this gives the opportunity for controls and continuous improvements in the future

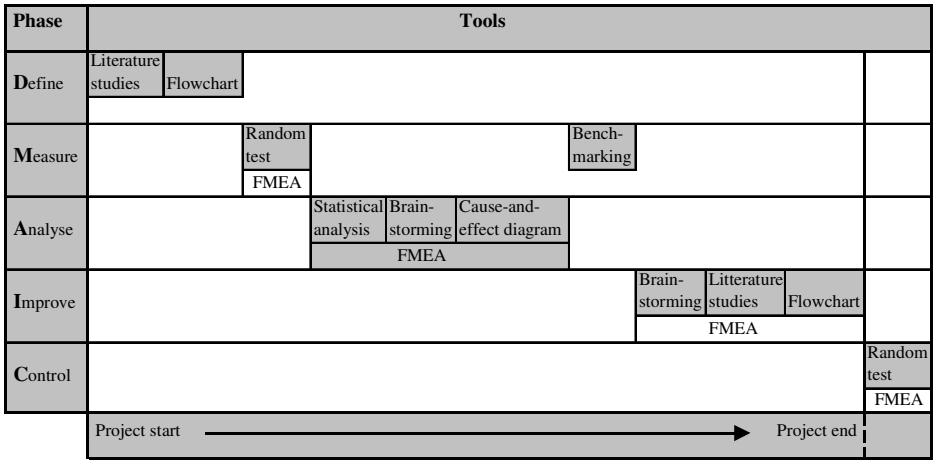


Figure 1.1. The figure shows the working procedure for this thesis. Used tools are illustrated for each phase in chronological order.

2.5. Quality management tools

An understanding of how the quality management tools shall be used is required to form an opinion about the scientific value of the results in this thesis. The tools that are presented in figure 1.1 will therefore be more detailed described.

2.5.1 Literature studies

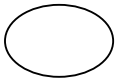
Literature studies have been used to find appropriate quality management methods and to identify quality demands from authorities. Academical literature and approved documents have been used. The search engine of the library at the

Hamburg University of Technology has been used to locate literature for this thesis. Only academical literature from the Hamburg University of Technology has been used and can therefore be considered to be reliable. It has been strived for to use as recently published literature as possible.
The Internet has also been a useful information source. The credibility of used Internet sources have always been critically reviewed. The material has been used with caution and, in case of questionable trustworthiness, the information has not been used at all.

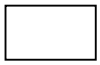
2.5.2 Flowcharts

A flowchart is a diagram that uses graphic symbols to depict the nature and flow of the steps in a process. Flowcharts have been used to describe the document processing in the stock receipt in this thesis. It quickly helps to understand how processes work at an early stage in a project. The symbols that are commonly used in flowcharts have specific meanings and are connected by arrows indicating the flow from one step to another [6].

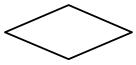
Oval
Ovals indicate both the starting point and the ending point of the process steps.



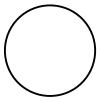
Box
A box represents an individual step or activity in the process.



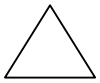
Diamond
A diamond shows a decision point, such as *yes/no* or *go/no-go*. Each path emerging from the diamond must be labelled with one of the possible answers.



Circle
A circle indicates that a particular step is connected to another page or part of the flowchart. A letter placed in the circle clarifies the continuation.



Triangle
A triangle shows where an in-process measurement occurs.



2.5.3 Random tests and statistical analysis

Meaningful discussions about improvement can only begin after that the quality have been quantified. That is why a random test on scanned documents is made in this case. Random tests are a part of the statistical analysis and are made to measure failure rates and determine performances. They give the possibility to statistically analyse and secure the data. [8]

A statistical analysis is executed in four phases; planning, collection of data, analysis of data and presentation. [9]

1. Planning

Define the indicators to measure and if the data are classified as variables or attributes. Variables are those quality characteristics that are measurable, such as weight measured in grams. Attribute data are those characteristics that are classified as either conforming or not conforming to certain specifications.

Also determine the sample size needed to estimate the percentage defective in the population [10]. To calculate the proper size **n** for an attribute random test, three parameters have to be defined:

Z	value for confidence level
p	expected quote of error
E	tolerable error in statement

The sample size **n** can then be calculated according to formula 2.1.

$$n = p(1-p)\left[\frac{Z}{E}\right]^2 \qquad (2.1)$$

2. Collection of data

Ensure that the measurement is:

- Repeatable – the operator shall reach essentially the same outcome if the same test is repeated (reliability)
- Reproducible – different operators shall reach essentially the same outcome when measuring the same outcomes with the same equipment.
- Accurate – the difference between observed measurement and the associated known standard value shall not be to big. It is of great importance to assure that the analysis really measures what it is intended to measure (validity). [6]

Moreover, the sampling lot shall be fully randomised and no external elements are allowed to influence the test. [11]

3. Analysis of data

Identify the distribution type for a correct analysis of data. The confidence interval for desired confidence level could then be calculated. Two distributions, the binomial and the hypergeometric, are relevant in this thesis and will therefore be more detailed described.

Binomial distribution
The binomial is used for the infinite situation. It requires that there will be only two outcomes (a conforming or a non-conforming unit), and that the probability of each outcome does not change. In addition, the use of the binomial distribution requires that the trials are independent. That is, if a non-conforming unit occurs, then the chance of the next one being non-conforming neither increases nor decreases [10].

Hypergeometric distribution
The hypergeometric probability distribution occurs when the population is finite and the random sample is taken without replacement [10].

Approximated Binomial distribution
If the population is large compared to the sample size (the sample is less than 10% of the population), the hypergeometric distribution is usually approximated by the binomial distribution and approximated well [12]. This simplifies the calculations considerably. Since the binomial distribution is for the infinite situation, there is no lot size N in the formula [10].

Confidence interval
The confidence interval for the approximated binomial distribution can then be calculated.

N	population
n	sample size (requirement: **n / N** < 0,1)
x	number of non-conformances
p	failure quote = x/n
σ	standard deviation.

The standard deviation **σ** has to be calculated according to formula 2.2 if unknown.

$$\sigma = \sqrt{p\left(\frac{1-p}{n}\right)} \qquad (2.2)$$

The confidence interval **I** can now be calculated according to formula 2.3.

$$I = p \pm Z\sigma = (p + Z\sigma, p - Z\sigma) \qquad (2.3)$$

4. Presentation of data
Statistical data are usually numerically presented in form of percentage and graphically in form of diagrams, for example histograms.

2.5.4 Cause-and-effect diagram
A cause-and-effect diagram has been used as a picture, which represents relationships between effects and causes regarding the documentation quality in this thesis. It was developed by Dr. Kaoru Ishikawa and is sometimes referred to as

a ”Ishikawa diagram” or a ”Fishbone diagram”. The cause-and-effect diagram is often used in combination with brainstorming. [10] [13].

2.5.5 Benchmarking

Benchmarking has come to be known as a comparative process – comparing performance of one individual or group to another. This tool can provide you with data to show *what* can be achieved and, perhaps more important, it can tell you *how* you can achieve the same type of results [14]. Two different types of benchmarking are described in the literature; internal and external.

Internal benchmarking
An internal benchmarking is made on other locations, areas, factories and branch offices within the organisation. No outside participation is required, which makes this type of benchmarking relatively easy to perform.

External benchmarking
External benchmarking consists of comparing company operations to other organisations in some kind of formal study such as the following:

Competitive benchmarking
The performance of other direct competitors is studied during a competitive benchmarking.

Functional benchmarking
Functional benchmarking means that a comparison of specific activities with similar activities in other organisations and not only with the competitors are made.

Industry benchmarking
Trends, innovations and new ideas within the company’s specific industry are attempted to be identified during an industry benchmarking.

Best-in-Class benchmarking
A comparison with the best of all industries is made in this type of benchmarking.

Benchmarking process steps
The process steps to be considered in benchmark identification include[14] [15]:

1. Define the scope of your efforts
2. Select benchmark approach
3. Identify benchmarking partners
4. Collect data
5. Analyse and interpret the data
6. Implement the best practice

2.5.6 Brainstorming

Brainstorming is a method where the participating members use their knowledge and experience to generate a complete list of subjects related to a specified topic. Keywords are noted and structured into categories. For example, all possible causes for and effects of a specific failure mode are generated through a brainstorming and are structured and illustrated in a cause-and-effect diagram[13].

2.5.7 Failure Mode and Effect Analysis

The ”Failure Mode and Effect Analysis”, usually called FMEA, was innovated by NASA in the 1960´s. This is a tool that in a structured way helps to analyse and document complex problems. The FMEA is normally used at an early stage in the product or process design life, but can also be used as a corrective tool. It is widely used in for example the automotive and the aerospace industry [16]. FMEA is used to:

- identify potential **failure modes**,
- determine their **effect** on a product or process,
- identify possible **causes** for the effect and
- find **solutions** that eliminate the most critical failures.

A **failure mode** is the physical description of a failure. The **effec*t*** describes the impact of a failure and the **cause** refers to the root of the failure.

FMEA types

Four different types of FMEA are described in the literature.

Product FMEA

The Product FMEA (also known as Design FMEA) is used in the construction phase for a product and is designed to assist engineers to prevent problems on new products. Technical drawings and component lists are used to locate failures, effects and causes at an early stage.

Process FMEA

The Process FMEA usually examines manufacturing and assembly processes and is designed to assist engineers to improve existing processes and prevent problems in new processes. When conducting a Process FMEA, it is desirable that the design is already optimised. A Product FMEA is therefore often performed before the Process FMEA.

System FMEA

The System FMEA is constituted of two different types:

- System FMEA Process and
- System FMEA Product

These two types analyse a complete system built up of interacting parts or processes and subprocesses, see figure 2.1 [18]. The system approach to FMEA provides a way to structure an FMEA and enables analysis of large, complex systems.
Three steps are to follow to accomplish this.

1. Break down complex products or processes into manageable parts.
2. Identify problematic interfaces, where many failures occur.
3. Introduce the power of system thinking.

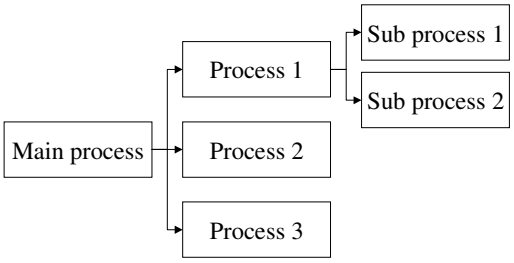


Figure 2.1. Main process broken down into part and sub processes [18].

Service FMEA
The Service FMEA focuses on functions influencing the service level for the customers. Service related processes are examined to reduce customer dissatisfaction. The service is usually subjectively perceived and the result is always related to the customer's feelings.

FMEA procedure
When implementing the FMEA, a systematic procedure has to be followed. Different proceedings are described in the literature. D.H. Stamatis has described the steps for a System FMEA Process in his book "Failure mode and effect analysis – FMEA from theory to execution". This is a widely spread and common used work and the described proceedings have therefore been used as a roadmap for the System FMEA Process in this thesis. The following 20 steps are described in this book:

1. Create an FMEA-team
Create a team with members that represent a broad knowledge spectrum covering all process features. An effective team shall preferably include:

- process engineer
- quality engineer
- production technician
- production operator

2. Define system

Define and delimit the system to analyse and break it down into convenient and logical process steps. Great care has to be taken to define the grade of particularising in the core process and to find meaningful delimitations. The value adding processes should stand in the foreground.

3. Define functions

Define the functions for each process step.

4. Construct an FMEA Worksheet

Construct an FMEA worksheet, see figure 2.2, to document all FMEA data. The worksheet does not have to follow any specific guidelines but shall contain information about the process name, responsible team member and date. The FMEA data will later be filled out in the columns. The columns are normally headlined as follows but can be adjusted to suit the current situation.

1. Process number
2. Process name
3. Potential failure mode
4. Potential effect(s) of failure
5. Potential cause(s) of failure
6. Current control method
7. Severity
8. Occurrence
9. Detection
10. Risk Priority Number
11. Recommended actions
12. Actions taken
13. Severity
14. Occurrence
15. Detection
16. Risk Priority Number

System FMEA Proces Worksheet

Process Name				Prepared by							FMEA date					
		Failure caracteristics			Current situation						Results					
No	Function	Potential failure mode	Potential effect(s) of failure	Potential cause(s) of failure	Current Control Method	SEV	OCC	DET	RPN	Recommended action(s)	Actions taken	SEV	OCC	DET	RPN
1																
	2															
		3														
			4													
				5												
					6											
						7										
							8									
								9								
									10							
										11						
											12					
												13				
													14			
														15		
																16

Figure 2.2. The figure shows an example of a System FMEA Process worksheet.

5. Identify potential failure modes, effects and causes

Conduct a brainstorming to identify all possible failure modes. Use a cause-and–effect diagram to illustrate and analyse the potential effects and causes for each failure mode.

6. Construct severity rating scale

Severity is a rating corresponding to the seriousness of an effect of a potential failure mode. Construct a severity rating scale with a ranking from 1 to 10 where 1 corresponds to ”no effect” and 10 to ”hazardous effect”. Formulate a criteria for each ranking.

7. Construct occurrence rating scale

Occurrence is a rating corresponding to the rate at which a cause and its resultant failure will occur. Construct an occurrence rating scale with a ranking from 1 to 10 where 1 corresponds to ”almost never occurs” and 10 to ”almost certain occurs”. Failure rates are defined for each ranking. Also formulate a criteria for each ranking.

8. Construct detection rating scale

Detection is a rating corresponding to the likelihood that the detection methods or current control methods will detect the potential failure mode before the object is released to an external or internal customer. Construct a detection rating scale with a ranking from 1 to 10 where 1 corresponds to ”almost certain to detect” and 10 to ”almost impossible to detect”. Formulate a criteria for each ranking.

9. Determine severity

Determine the severity (SEV) of the effect(s) for each failure mode. If the ability of the controls to detect the failure is unknown or the detection cannot be estimated, then the detection rating should be 10.

10. Determine occurrence

Determine the occurrence (OCC) for each failure mode. The failure rate is estimated or, preferably, identified through a random test. If the numerical value falls between two numbers always select the higher number.

11. Determine detection

Determine the probability of detection of the failure (DET) before the object reaches an internal or external customer.

12. Calculate the ”Risk Priority Number”

Multiply the values for severity occurrence and detection according to formula 2.4 to receive the Risk Priority Number.

$$RPN = SEV * OCC * DET \qquad (2.4)$$

The maximum value for the RPN is 1000 and the minimum is 1.

13. Rank failure modes

Rank the RPN:s in order of numerical value. The combination with the highest RPN, which indicates the highest aggregate risk, shall be ranked as number one. The combination with the second highest RPN is ranked as number two and so on.

14. Recommend actions

Recommend actions to reduce the severity, occurrence and/or detection primarily for the cases with the highest RPN. Secondary recommend actions for the failures with the highest severity and occurrence. In some situations, only the case with the highest RPN should be corrected. In other situations, it might be necessary to correct the ten highest ranked failures. The number of failure modes to attend to must be suited to the current situation.

15. Implement actions

Implement actions to reduce severity, occurrence and detection.

16. Determine new severity

Determine the severity after the actions have been implemented. An estimated new severity can also be determined if the recommended actions still have not been implemented.

17. Determine new occurrence

Determine the occurrence after the actions have been implemented. An estimated new severity can also be determined if the recommended actions still have not been implemented.

18. Determine new detection

Determine the detection after the actions have been implemented. An estimated new severity can also be determined if the recommended actions still have not been implemented.

19. Re-calculate the ”Risk Priority Number”

Multiply the new values for severity occurrence and detection to receive a new RPN or a new estimated RPN.

20. Calculate %RPN-reduction

Measure the success of the implemented actions through a calculation of the RPN-reduction according to formula 2.5.

$$\%RPN - reduction = \frac{(RPN_{old} - RPN_{new})}{RPN_{old}} \qquad (2.5)$$

An RPN-reduction calculated after the recommendations have been implemented measures the success. An RPN-reduction based on an estimated new RPN before the recommended actions have been implemented measures the potential improvement. [17]

3 Theoretical framework

Theory concerning LTL supplier conditions, documentation requirements and different document types are described in this chapter.

3.1. LTL supplier conditions

The set of suppliers of A/C-parts of LTL is relatively fix. LHT has registered approximately 5000 suppliers as approved sources. All approved sources of LHT, and thereby also of LTL, have been audited and are considered to be serious. Quality parameters for each of these suppliers are registered in SAP R/3.

To register a new approved source, the department of Strategic Purchasing at LTL or LHT has to contact and investigate the reliability of the supplier. If the department of Strategic Purchasing accepts the supplier, the department of Quality Management at LHT thereafter tests the quality level of the source. The supplier is registered in SAP R/3 as an approved source if the department of Quality Management at LHT is satisfied with the investigation. The supplier is then considered to fulfil the quality demands of LTL and LHT, but may later be audited by LHT to secure the quality level. An audit means that representatives from LHT inspect the supplier on spot. An audit might no be needed if the supplier is already certified according to well known standards such as ISO or AECMA. It is consequently rather complicated and expensive to introduce new suppliers

These proceedings are followed to secure that all suppliers deliver high qualitative A/C-parts with a correct and complete documentation, which conforms applicable laws and regulations.

3.2. Documentation requirements

Representatives from aerospace companies in America, Asia and Europe, sponsored by SAE (Society of Automotive Engineers), SJAC (Society of Japanese Aerospace Companies) and AECMA (European Association of Aerospace Industries) have established the International Aerospace Quality Group (IAQG). The purpose is to achieve quality improvements and cost reductions throughout the value stream. IAQG has agreed to take responsibility for the technical contents of the AECMA Standard 9120. This standard is based on ISO 9001:2000 and is technically equivalent to AS 9120. AS 9120 is a standard for stockist distributors in the aircraft industry and is a part of AS 9100. AS 9100 is a standard for design, development, production, installation and servicing in the aircraft industries. In a foreseeable future, no companies are said to be able to supply parts for the aviation industry without an AS 9100 certification [19]. It should therefore be of high priority for LTL to follow the requirements of the AECMA Standard 9120. The following is a quotation from chapter 4.2.4, Control of records, in the AECMA Standard 9120:

"Records shall be established and maintained to provide evidence of conformity to requirements and of the effective operation of the quality management system. Records shall remain legible, readily identifiable and retrievable. A document procedure shall be established to define the controls needed for the identification, storage, protection, retrieval, retention time and disposition of records.

These records shall include where applicable:

- *manufacturer, distributor, repair station, test and inspection reports;*
- *original certificates of conformity (manufacturer, sub-tier distributor). Copies of airworthiness certificates;*
- *non-conformance, concession, and corrective action records;*
- *lot traceability records;*
- *environmental or shelf life condition records.*

Where records are stored in an electronic from, the integrity of the system and the back-up procedures shall be appropriately validated. These records without possibility of change by software, shall be traceable to the original documentation." (AECMA Standard 9120)

Customer feedback's considering the documentation quality level are received from four of the customers of LTL. These customers are Aeroflot, Austrian Airlines, Lufthansa Technik Budapest and Royal Brunei Flight. This information has deliberately not been used in this thesis since the customers who give feedback are not representative for the clientele of LTL. It is assumed that the customers expect LTL to fulfil the demands above.

The documentation requirements can consequently be summarised as follows:

All required documents must be:

- present,
- 100% readable,
- complete and
- traceable.

A further demand is that the scanned documents shall be of an acceptable image quality. However, an acceptable image quality is very subjective and difficult to define explicitly.

3.3. Document types

Several types of documents are used to confirm the compliance and to document the life cycle of parts. Each document type has specific functions and contents, which make them important for different reasons. The most important functions and contents will now be described for each document type.

Airway bill

Function

The airway bill (AWB) is used for customs checks.

Contents

- Shipping company
- Receiving company
- Nature and quantity of shipped goods
- Airport of departure and destination

Certificate

Two types of certificates (Cert) exist, ”Authorized release certificate” and ”Conformity statement”.

Authorised release certificate

Function

The ”Authorized release certificate” affirms the compliance to authority requirements. This means that the A/C-part is produced or repaired by a supplier or manufacturer certified by EASA or FAA and states the airworthiness of the A/C-part. Not all A/C-parts need an ”Authorized release certificate” to be allowed to be used. Exactly which these types of parts are lies outside the scope of this thesis.

Contents

- Approving national aviation authority/country
- Manufacturer
- Part data (description, number etc.)
- Part status (manufactured, repaired etc.)
- Remarks
- Authoriser

Certificate of conformity

Function

The ”Certificate of conformity” (COC), also called ”Conformity statement”, affirms that an A/C-part conforms to specific requirements. For materials, which have been, manufactured according to a defined standard (i.e. DIN), a COC is an appropriate document for the airworthiness. However, this document can not replace an ”Authority release certificate”. The materials for which a COC is sufficient are classified as standard parts and raw materials.

Contents

- Certifying company
- Manufacturer
- Customer
- Part data (description, number etc.)
- Quality assurer

Ident tag

Function

The ”Ident tag” (IT) is a document issued by LHT for repairable A/C-parts and describes activities related to the repair.

Contents

- Part data
- Part status (for example repaired, overhauled)
- Failure description
- Repair task

Delivery note

Function

The delivery note (DN) is a receipt for the shipping of parts.

Contents

- Shipping company
- Receiving company
- Part(s) data

Stock receipt document

Function

The stock receipt document (WEB) is produced by LTL after the goods reception but before the admission into the warehouse. The WEB affirms that the part has been correctly booked and (linked to a corresponding ZID-number.)

Contents

- Shipping company
- Part data
- Warehouse location
- Part quality status

Workshop report

Function

The ”Workshop report” (WR) describes what on an A/C-part that has been repaired and affirms that the it has been repaired in accordance with the guidelines from the manufacturer. The WR has to be retrievable for certain repaired parts to state the airworthiness.

Contents

- Performed repair
- Repairing company
- Part data
- Customer

Repair order

Function

The repair order (RO) describes which part and failure the customer wants the workshop to repair.

Contents

- Failure description
- Customer
- Repairing company
- Part data
- Required condition (for example repaired, recertified)

4 Analysis of the current situation

The layout, equipment and processes in the stock receipt are described in this chapter. Present random test guidelines and the proceedings and the result of a new random test are thereafter presented. Detected failures are then described and the most critical ones are located. The purpose with this chapter is to map the current documentation quality level and situation in the stock receipt.

4.1. Document scanner

The scanners used to scan the documents in the stock receipt are of the model Fujitsu M3093GX, see figure 4.1. It is a black and white scanner with a capacity of 27 documents per minute. The maximal format is A4 and the images are scanned with a resolution of either 200 or 300 dpi depending on the current settings of the scanner. The price for one scanner, including installation and software, is approximately 4600 Euro.

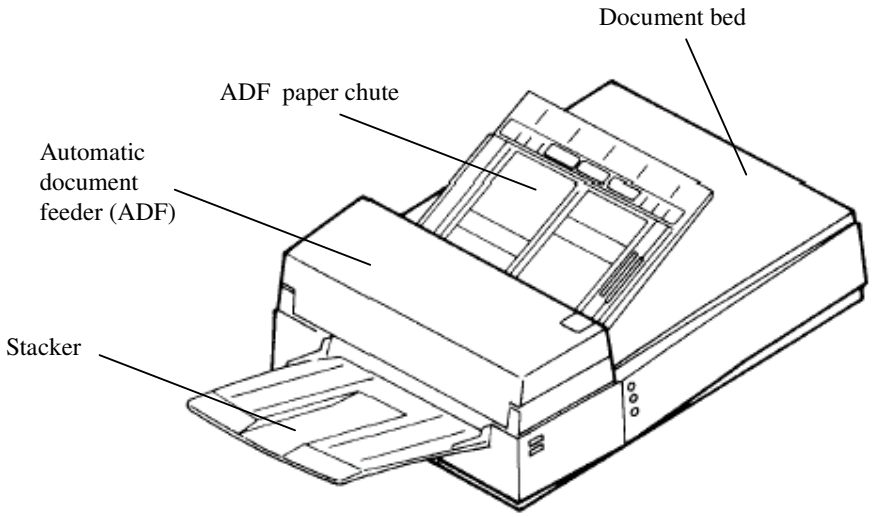


Figure 4.1. The figure shows a Fujitsu M 3093 GX. This scanner type is used for document scanning in the stock receipt.

The following parts of the scanner are of interest in this thesis:

Automatic document feeder (ADF)
The ADF automatically feeds documents to the reading position. The automatic document feeder contains a pick roller and a pad, which help to feed the document straight into the scanner.

ADF paper chute
The paper chute holds the documents to be fed by the ADF.

Stacker
The stacker collects documents read in the ADF.

Document bed
The document bed is used when documents are read in flatbed mode.

4.2. Document scanner maintenance

The automatic document feeder shall be cleaned at least every 5000 pages or if text and images on the document are not read correctly. Pick roller and pad are mechanisms inside the ADF, which are important for the automatic document feeding. The pick roller shall be replaced every 200000 documents or annually and the pad inside the ADF every 100000 documents or annually, or if miss picks occur frequently. The pick roller and pad shall also be cleaned or replaced if miss picks occur frequently. The cleaning and replacement cycles above are recommendations and may vary depending on the types of documents scanned and the cleanliness of the scanner environment [23].

An external firm cleans the scanners at LTL in HAM twice a year. The co-workers in HAM are not allowed to perform any cleaning inside the scanners. A note attached to the scanner prohibits this. The foreman in the stock receipt performs the cleaning occasionally.

4.3. LTL software

LTLT and LHT are using several software programmes for the management of the large amount of parts and documents. The following programmes are of importance for this thesis:

4.3.1 ELO OPAL

”Elektronischer Leitz Ordner Optical Process-integrated Archiving for Logistics”, ELO OPAL, is the document management system of LTL. The system was implemented in the year of 2000 to replace the ”manual” document archive. Scanned documents from HAM, FRA, CGN, MUC and SXF are now digitally saved and sorted into specific folders. This renders the possibility to, through an index or text search, quickly locate a specific document. The customers also have access to this system through a web/client service. ELO OPAL fulfils the requirements of the AECMA Standard 9120 which states that stored records must be traceable to the original documentation and impossible to change.

4.3.2 MAS

MAS is a material requisition system for warehoused parts developed by LHT.

4.3.3 HELAS

HELAS is the warehouse management system of LTL and contains the ZID-numbers for all stored parts. A ZID-number is the identification number for parts and documents. Ordered parts are requisited in MAS which sends the requestions to HELAS. HELAS initiates a warehouse checkout and the ordered part is located and picked up by a co-worker.

4.3.4 OCR software

Optical Character Recognition (OCR) is a software used to read and translate scanned text into a form that the computer can manipulate, for example into ASCII codes.

4.3.5 SAP R/3

SAP R/3 is a standard business system, which manages the data acquisition for all business units at LHT. SAP R/3 can be customised to fit the special requirements of different business units.

4.4. Software Maintenance

The IT-department at LTL services the software on regular basis.

4.5. Personnel

The personnel in the stock receipt work in two shifts from 6.00 to 22.00 Monday to Friday and from 6.00 to 14.15 on Saturdays and Sundays. The salary is not based on performance.

4.6. Documentation processing

The document processing in the stock receipt area will now be described. Figure 4.2 illustrates the layout in a schematic and simplified way. Only objects relevant for the understanding of the documentation processes are described.

A. Stock receipt area.

Shipments of A/C-parts are received in this area. The shipments normally consist of A/C-parts packed in cardboard boxes.

B. Shelves for sorted documents.

Documents belonging to delivered A/C-parts are sorted into shelves numbered 0-9. The sorting is based on the last figure in the customs identification number (ZID-number) on a barcode sticker attached to each box. The co-workers make the sorting.

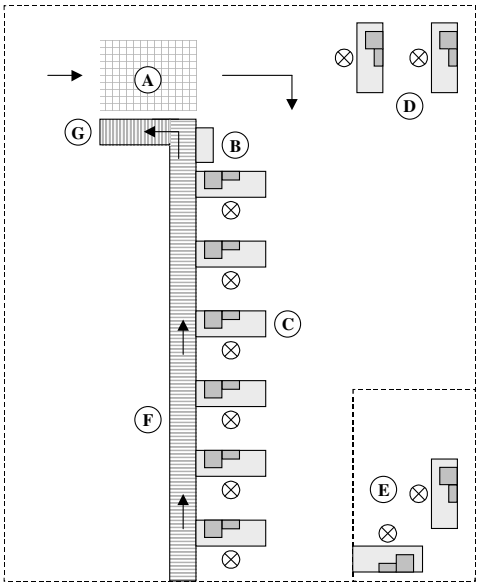


Figure 4.2. The figure shows the layout in the stock receipt at LTL in HAM.

C. Working desks with computer, document scanner and hand scanner.

There are sixteen of these working desks along the conveyor belt. The following equipment is used at each working desk:

- Printer for ZID-barcodes
- Hand scanner for ZID-barcode scanning
- Document scanner

Boxes with A/C-parts are collected in the stock receipt area and brought to and unpacked at the working desks. The co-worker controls if the documents correspond to the part(s) in the box. The ZID-Barcode attached to the box is scanned with a hand scanner and new barcode stickers are printed out and attached to the documents belonging to the part. The ZID-barcode(s) attached to the document(s) is scanned with a hand scanner and a relation between A/C-part, documents and ZID-number is automatically created in ELO OPAL. Index barcodes representing the different document types (except Certificates and Delivery notes) are scanned with the hand scanner to tell the software, which document type that will be scanned next. The software now knows in which directory in ELO OPAL to save the image. The documents are scanned and automatically saved under the already scanned and saved ZID-number in ELO OPAL. An image of the scanned document appears on a monitor and the co-worker can manually control the scan result.

D. Working desk with computer and document scanner.

Stock receipt documents are scanned at this separate location because of administrative reasons, which lay outside the scope of this thesis. The same hardware is used here as at the other working stations.

E. Working desk with computer and document scanner.

Airway bills are also scanned at a separate location because of administrative reasons, which lay outside the scope of this thesis. The same hardware is used here as at the other working stations.

F. Conveyor belt

A/C-parts and belonging documents are placed in a plastic box and automatically shipped to the further processing areas.

G. Further processing areas

Parts and documents are booked into SAP R/3. The correctness of the documentation can be checked here. The part is then stored into the warehouse and the original documents are destroyed. The only A/C-part documentation is now electronically saved. The part is stored in the warehouse until it is requisited from MAS. The correctness of the documentation may be checked again as the part is ordered.

4.6.1 Automatic ZID barcode recognition

After a document has been scanned, the ZID barcode on the document is automatically examined. The ZID barcodes for certificates and delivery notes, see figure 4.3, are automatically recognised and stored in the corresponding folder in ELO OPAL. Index barcodes do therefore not have to be scanned before certificates and delivery notes are scanned.

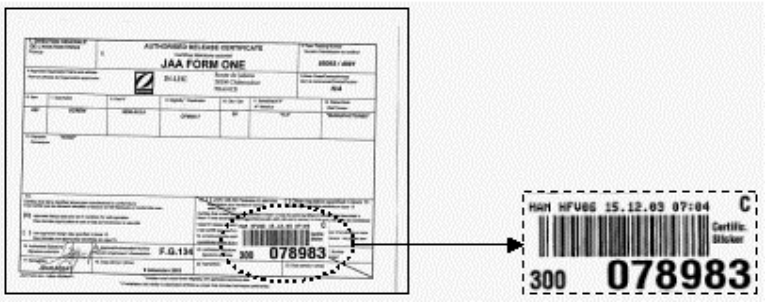


Figure 4.3. The figure shows the ZID barcode, which is automatically recognised on certificates and delivery notes.

4.6.2 Automatic certificate recognition

If the document is recognised and saved as a certificate, the OCR software examines the document to determine if it is an authorised release certificate or not. The script examines:

- The upper quarter of the document.
- The left half of the lower quarter. (see figure 4.4)

A difference is made between unequivocal recognition and recognition based on recognition of one attribute. The document will in both cases be classified as a JAA/FAA certificate.

Unequivocal recognised certificate:
”RELEASE CERTIFICATE” on top and ”JAA FORM ONE” on top and on lower part, or
”FAA FORM” on top and on lower part.

Certificate recognised with at least one attribute:
”JAA FORM ONE” on top or on lower part, or ”FAA FORM ONE” on top or lower part.

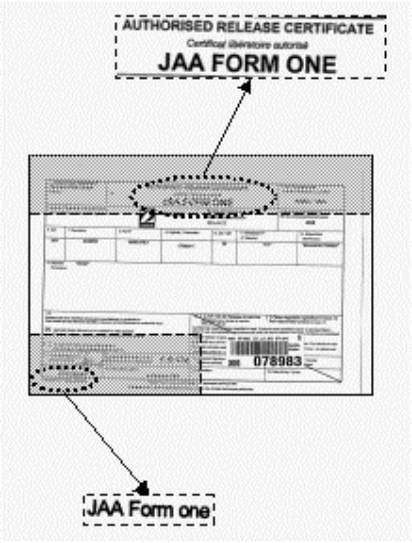


Figure 4.4. The figure shows the areas that are examined by OCR software on certificates.

4.7. Process flowchart

The process flowchart illustrated in figure 4.5 and 4.6 describes the processes related to the document management at LTL.

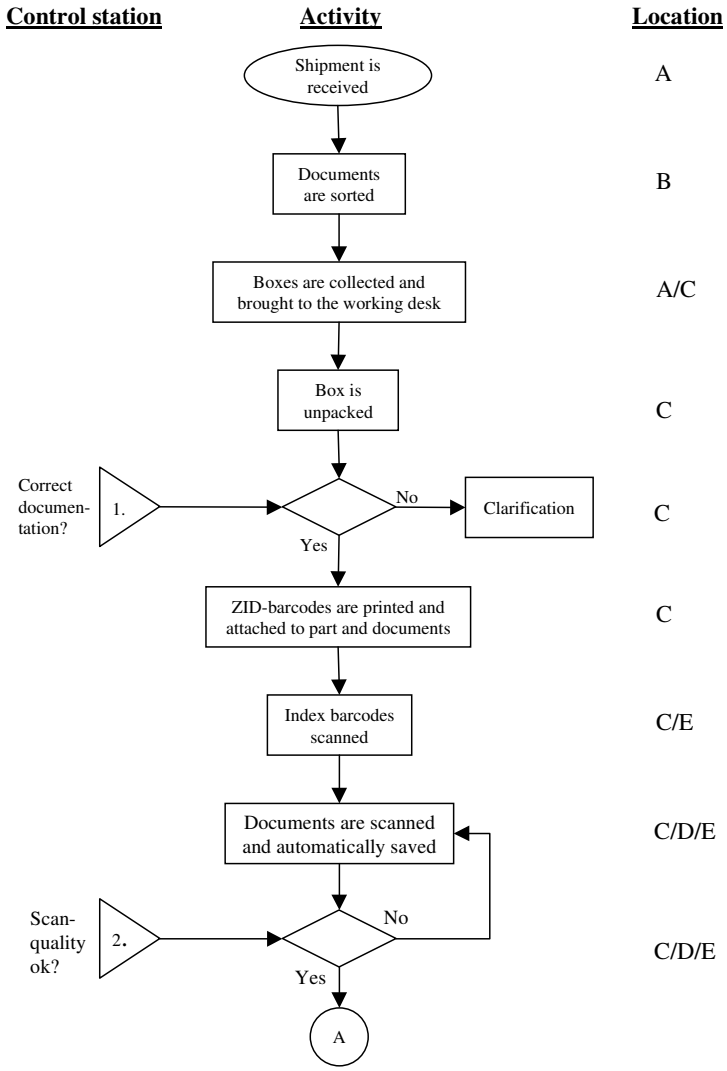


Figure 4.5. The figure shows a flowchart, which illustrates the documentation process steps in the stock receipt. The flowchart continues on the next page.

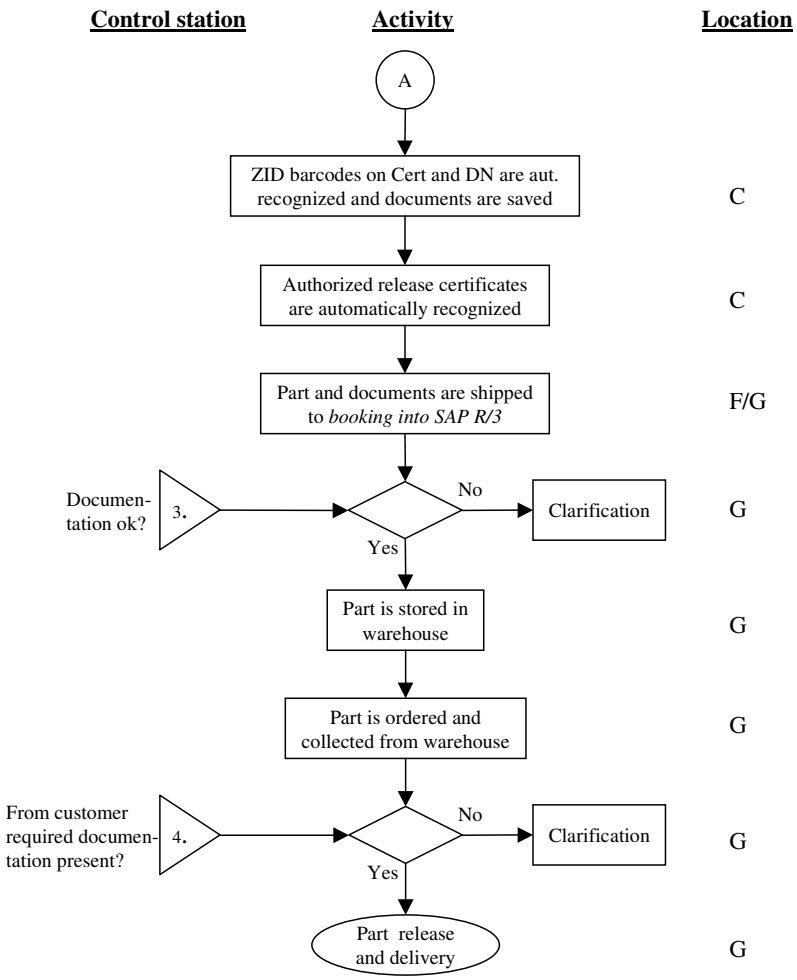


Figure 4.6. The image shows a flowchart, which illustrates the documentation process steps in the stock receipt. The flowchart is a continuation from the previous page.

4.7.1 Control stations

Four control stations are present in the document processing. The stations are represented by the triangles in figure 10. The four control stations are:

Control station 1 - Unpacking

The serial number of the part is compared to the serial number on the documents. The presence of required certificates a normally checked.

Control station 2 – Scanning

The quality of the scanned image can be checked on the monitor. The image is checked occasionally, depending on available time. Different co-workers check the

result differently often. The image does not appear at some working stations and a control was therefore not possible.

Control station 3 – Booking
The documentation is checked when the part and documents are booked into SAP R/3.

Control station 4 – Order
Documents are controlled before a part is delivered if a customer explicitly demand these specific documents.

4.8. LTL random test guidelines

Random tests are currently performed once a month to check the documentation quality in HAM and FRA. The following guidelines for random test proceedings in the stock receipt at LTL were worked out in 2002:

- The tested ZID-number positions must be independent from each other and distributed over time and over several working stations.
- Only ZID-number positions, which require a certificate, are to be tested.
- 125 ZID number positions shall be tested from HAM and from FRA each month.

- Three criteria's must be tested for each position:
  1. Is the scan quality and readability of the certificate ok?
  2. Does the certificate come from an accredited company?
  3. Does the certificate conform to the requirements of the customer? [25]

This is how the quality level is measured today. The results are presented once a month and 0-2 non-conforming certificates are usually detected in the random tests. This is equivalent to a failure rate to 0-1,6%. This represents criteria 1 and criteria 2. Criteria 3 is normally neither measured nor presented.

The validity of the statement of the random test is not *unambiguously* defined by LTL, neither in the guidelines nor anywhere else.

4.9. Random test

A document random test was performed within this project to identify which type of failures that occur on scanned documents and at what rate they occur. All document types were tested. Documents from other LTL locations than HAM were also tested to identify possible differences in quality levels between the different LTL locations.

4.9.1 Random test data

1. Planning

The purpose of the random test was not to give each detected failure a numerical value describing the grade of non-conformance. The random test should rather quantify the rate of different types of nonc-onformances on the tested documents. Before the measurement was performed, two questions had to be answered:

- What is a non-conformance?
- How large must the sample size be?

To gain basis data for decision-making and learning about non-conformances, a preparatory random test was conducted. The test was performed with support from experienced colleagues from the department of Quality Management at LTL, which could inform about criteria's for non-conformances. This preparatory test assures the reliability and validity in form of repeatability and accuracy for later random tests performed by the author.

To determine the proper size of the random test, error quotes, confidence level and tolerable error in the statement now were to be defined.

If the confidence interval from a random test shall have any practical use, a confidence level of 95 or 99% should be used. 95% is considered to be sufficient in this case since the data won't be external communicated [11].

The first random test indicated which preliminary error quotes that were to expect. Error quotes for different types of failures varied between approximately 1,5% and 10%. With varying error quotes, the error in the statements will vary to. A large random test takes up an appreciable period of time. Therefore, a balance between available time and the tolerable error in the statement must be found.

Z = 1,96
p = 1,5-10% and

$$n = p(1-p)\left[\frac{Z}{E}\right]^2$$ gives

E = ± 1,5 percentage points for p = 1,5 % and
E = ± 3,7 percentage points for p = 10.0% at a sample size of

n = 253

This is considered to be a proper sample size when available time, confidence level, tolerable errors and expected quotes of errors have been considered. This sample size renders the possibility to make statements based on ZID-positions with an

acceptable size of largest error. The preparatory random test also showed that every tested ZID number contained approximately four saved documents. A statement based on all tested documents will consequently be even more accurate. 250 ZID numbers corresponding to approximately 1000 documents were decided to be tested to comply with the calculation above.

2. Collection of data

The sample lot was generated from ZID numbers saved in TELOS using the random test function in Microsoft Excel. This assures that the requirement of a fully randomised sampling lot without extern elements influencing the test

TELOS contains ZID numbers for parts with documents scanned in HAM, FRA, CGN, MUC and SXF.

The scanned documents saved under each ZID-number were visually examined in ELO OPAL. Any type of non-conformance was noted for AWB, Cert, IT, DN, WEB, RO and WR.

3-4. Analysis and presentation of data

The 250 tested ZID-numbers contained 1032 scanned documents. The 1032 documents are distributed over the locations as follows:

- HAM 684
- FRA 310
- CGN 20
- SXF 11
- MUC 7

The collected data are presented for all failures and document types in appendix A.

The test was found to contain to few documents from CGN, SXF and MUC to make any reliable statements about these locations.

The distributions of the failure rates were approximated with a binomial distribution. Confidence intervals were calculated for the locations in HAM and FRA for statements based on the total number of documents and the total number of ZID-number positions. Table 4.1 shows the 95%-confidence intervals for failure rates of 1% and 10% on documents in HAM and FRA. Table 4.2 shows the same thing but for failure rates based on ZID-number positions.

Failure quote:	**HAM, 684 documents**	**FRA, 310 documents**
1%	(1.754, 0.254)	(2.108, 0.0)
10%	(12.248, 7.752)	(13.340, 6.660)

Table 4.1. 95% confidence intervals for failure rates based on the total number of documents.

Failure quote:	**HAM, 127 ZID-numbers**	**FRA, 98 ZID-positions**
1%	(2.731, 0.0)	(2.970, 0.0)
10%	(15.218, 4.782)	(15,940, 4.060)

Table 3. 95% confidence intervals for failure rates based on the total number of ZID-number positions.

Two diagrams were constructed to render the possibility to quickly read off the largest error in statement, E, for different failure rates, which represent an approximated binomial distribution. E for a 95% confidence interval for failure rates based on documents can be read off in figure 4.7 and E for failure rates based ZID-numbers can be read off in figure 4.8.

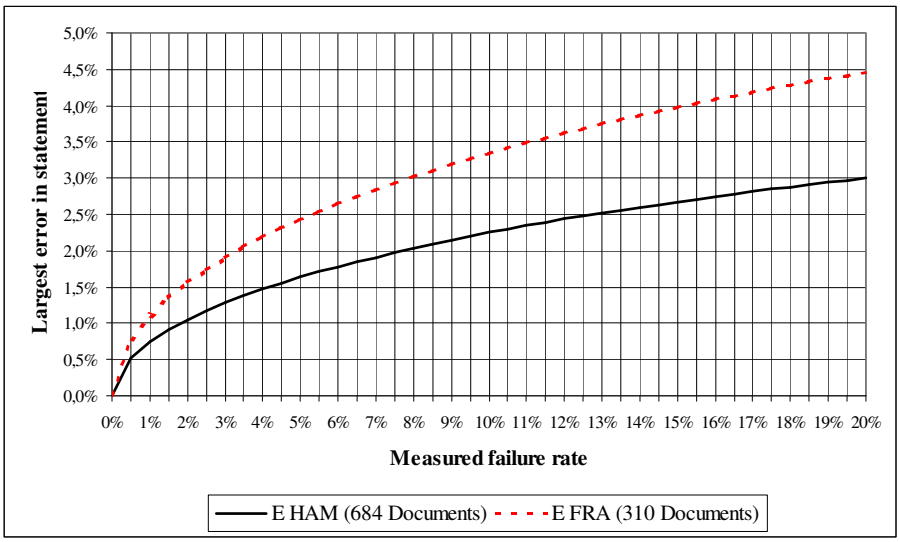


Figure 4.7. Largest error in statement (E) for 95% confidence interval for approximated binomial distribution based on failure rates for documents.

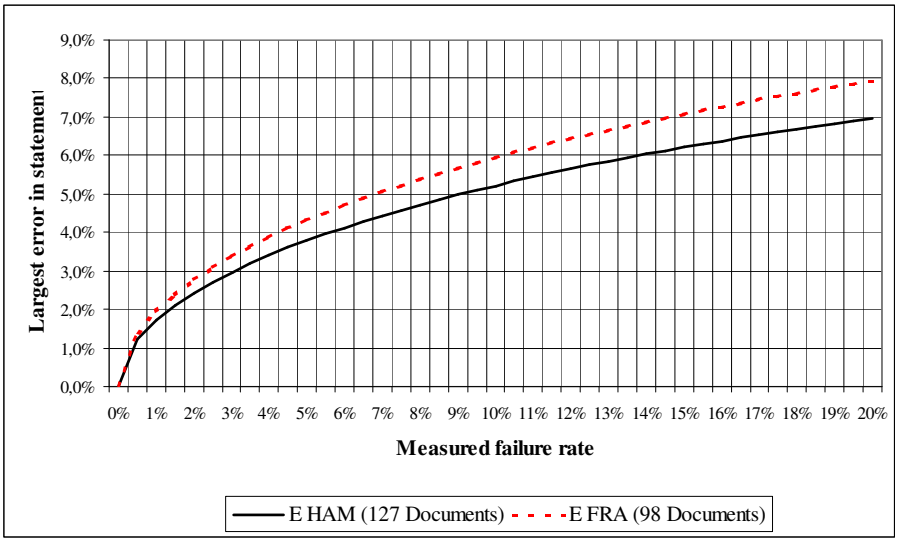


Figure 4.8. Largest error in statement (E) for 95% confidence interval for approximated binomial distribution based on failure rates for ZID-numbers

The largest errors in the statements are considered to be within an acceptable range. The difference in the span of the confidence intervals between HAM and FRA, which depends on the difference in the size of the random tests, are small. The failure rates for the two locations can therefore be compared to each other. An even larger random test would of course provide a more exact statement. However, the chosen lot size has been found to be an adequate compromise between the requirements of a valid statement and available time. This in combination with the preparatory random test assures the validity and reliability of the measurement in this random test.

4.9.2 Detected failures

The non-conformances were interpreted by the author and it is possible that other testers might not make the exact same judgement for each and every document and non-conformance. All detected failure types have therefore been exemplified with images in appendix B and defined with words in this chapter. This was made to facilitate the possibility for other persons to reproduce the test and for readers to understand the different failure characteristics. Rates for the failures below are presented for all documents together and for the different document types separately in appendix A. Rates for HAM, FRA, CGN, MUC and SXF are presented.

No entry found

The message ”No entry found” („Kein Eintrag gefunden“ in German) occurs on the screen when a ZID-number is searched in ELO OPAL and no scanned documents can be tested.

Black fields
Black fields occur on parts of or over the whole image. The text is not possible to read where black fields are present. See appendix B, image 1 and image 2.

Dark image
The scanned image is completely or partly dark but still possible to read. See appendix B, image 3 and image 4.

Dirty/Dusty image
Points, small lines etc. are present on the scanned image. See appendix B image 5.

Low quality in general
This category represents the types of failures that can not be assigned to any explicit failure category. It could be a combination of several ”harmless” or light failures, which creates a low quality altogether. For example, if a document is a bit askew, slightly dirty and a little bit dark, the overall picture might not look to good despite that maybe none of the failures alone were remarkable enough to be considered as a failure in the random test. See appendix B image 6.

Black or grey lines along the document
One or more black or grey lines are to see along the document. See appendix B, image 7 and image 8.

Low text quality
The text is vague and therefore difficult to read. See appendix B image 9.

Askew, whole document scanned
The document is askew, but no part of the document lays outside the scanned area. See appendix B image 10.

Askew and/or misplaced, part of document not scanned
The document is askew and/or misplaced and a part of the document lies outside the scanned area. No data exist on the area that was not scanned. See appendix B image 11.

Askew and/or misplaced, part of documents not scanned, data missing
The document is askew and/or misplaced and a part of the document, where data is present, lies outside the scanned area. See appendix B image 12.

Incorrectly saved
The document is saved in the wrong folder in ELO OPAL. For example, a Certificate is saved an AWB.

Incorrectly + correctly saved
The document is saved in the wrong and in the correct folder in ELO OPAL. For example, the same Certificate is saved as a Certificate and as an AWB.

No ZID-barcode
None of the documents saved in a folder in ELO OPAL have a ZID-barcode. This is not always to consider as a failure.

Document ripped
The scanned document is partly ripped, but no piece is missing. See appendix B, image 13.

Document knicked
The scanned document is knicked. This is seen as a dark line or thin shadow along the document. See appendix B image 14.

Document wrinkled
The scanned document is wrinkled. See appendix B image 15.

Not readable handwriting
Handwriting on the document is so indistinct that it is difficult to read. See appendix B image 16. This failure is similar to the failure ”Low text quality”.

Paper background
A background pattern is to see on the scanned document. See appendix B image 17.

Certificate not automatically recognised
The authorised release certificate can not be automatically recognised by the OCR software. This is automatically registered in ELO OPAL. ”Typ 1” means that the automatic recognition was successful and ”Typ 2” means that it failed.

Document missing, document not saved
Only the presence/absence of certificates were investigated in the random test. The tester does not possess adequate knowledge about documentation requirements for A/C-parts. Persons with very good knowledge about documentation requirements helped the author to determine which of the tested ZID-number positions that missed a required certificate. No time was available to test the presence of other required document types.

4.10. Causes and effects

In this phase, a brainstorming was conducted to come up with possible causes and effects for the different failure modes. The causes were structured in a cause-and-effect diagram, see figure 4.9, and the root causes were identified for each failure. The produced cause-and-effect diagram illustrates all root causes summarised and not for each and every effect since this was not considered to be meaningful. The effects are illustrated in figure 4.10 instead.

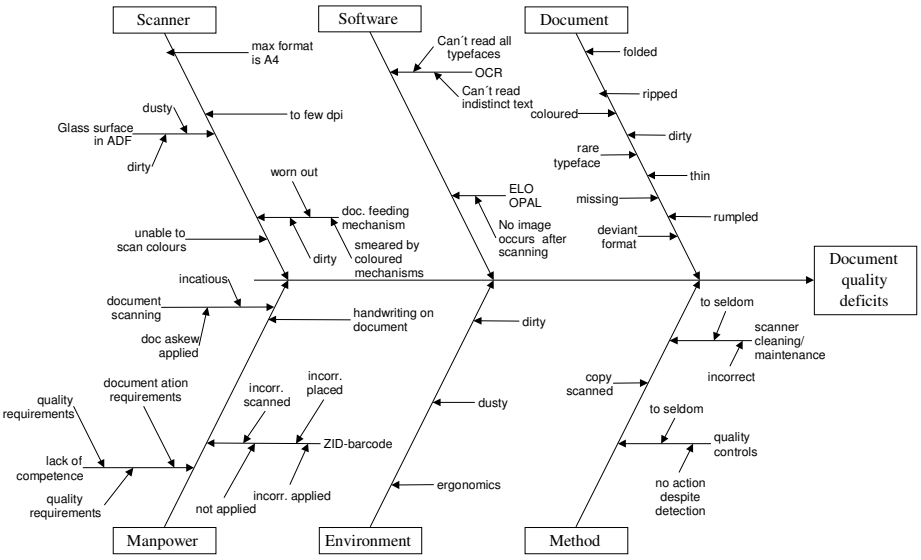


Figure 4.9. The figure shows a cause-and-effect diagram, which illustrates possible root causes for different failure modes.

4.10.1 Effect descriptions

The causes illustrated all may lead to different types of effects. The effects have been located through observations and discussions within the FMEA-team. These effects are described below and illustrated in figure 4.10.

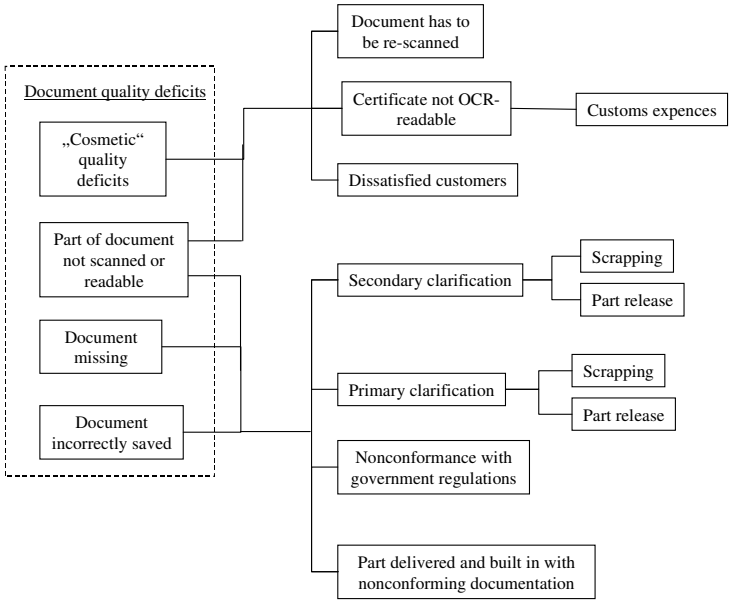


Figure 4.10. The figure illustrates the possible end effects caused by document quality deficits.

Authorized release certificate can not be automatically recognised
LHT and LTL has an agreement with the customs authorities which gives the right to put a part into free circulation if the belonging authorized release certificate is automatically recognised. The part must be put in a customs bonded warehouse and duties have to be paid if the authorized release certificate could not be automatically recognised.

Document has to be re-scanned
A re-scan of a document takes up time and costs arise thereby.

Dissatisfied customers
An image quality that differs from the quality of an original document normally causes dissatisfied customers. What customer regard as an unsatisfying quality is subjective and can not be concretely defined. But image quality deficits are not the only reason for customer dissatisfaction. Missing documents or data will off course cause a great dissatisfaction among the customers.

Clarification
A clarification follows if it is discovered that the required documentation for an A/C-part is missing. It is distinguished between a *primary* and a *secondary* clarification. A primary clarification follows if the non-conforming documentation is discovered at LTL before the part is delivered. A secondary clarification follows it is detected first at the customer. A secondary clarification is more sever than a primary.
Three actions are possible in case of a clarification caused by a non-conforming documentation:

1. The correct documentation can be provided from the supplier.
2. The A/C-part can be recertified by LTL and new documents can be produced with that.
3. The manufacturer can recertify the A/C-part and new documents can be produced with that.

A *part release* follows if the documentation is possible to reproduce. If none of the three actions are successful, the part has to be scrapped.
A clarification is very costly and a scrapping is always the worst consequence.

Non-conformance with government regulations
A non-conformance with government regulations means that the documentation for an A/C-part does not fulfil the legal requirements stated by international authorities.

Part delivered and used without correct documentation
A/C-parts without a conforming documentation may circulate in the LHT material currency if the documentation deficits are not discovered. An A/C-part with an incomplete or missing Cert, WR or IT is said to be unapproved. A complete

documentation for built in A/C-parts must be retrievable in case of for example an aircraft accident. Otherwise, grave juridical consequences risk to follow.

4.11. System FMEA Process

The failure rates and the different types of failures that may occur had now been identified. But instead of just making a statement about the quality level based on the random test, the gained data were implemented in a System FMEA Process with the goal to be able to analyse the quality level in a more precise way.

1. The FMEA-team

The causes and effects have been identified in co-operation with three representatives from LTL. These persons together with the author can be said to constitute the ”FMEA-team”. In other words, the FMEA-team is represented by:

- the author,
- the head of Quality management,
- a co worker at Quality management with great technical and theoretical experience from the aviation industry and
- a quality assurance engineer.

A team member that may seem to be missing is a production operator. However, great experience with respect to the production is available within the team and the absence of a production operator should therefore not weaken the team.

2. FMEA system definition

The system to investigate, ”Document processing”, was now broken into manageable process parts. The system shall begin where LTL takes over the responsibility for the documents and end where the documents are no longer changed or processed. This agrees to the made delimitations and is illustrated in figure 4.11.

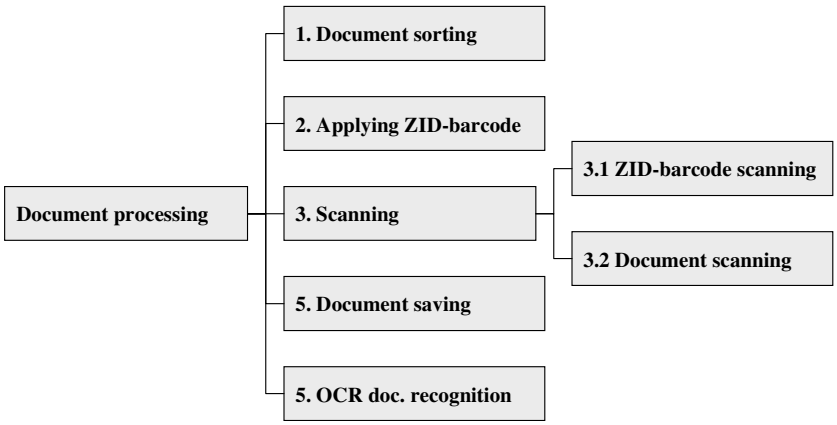


Figure 4.11. The figure illustrates the part- and subprocess for the document processing.

3. Construction of FMEA worksheet

A FMEA worksheet was constructed and all possible failure modes, effects and causes for each process step were thereafter inscribed in the FMEA worksheet, see appendix D.

4. Construction of severity rating scale

A severity rating scale with criteria's for the current situation was now created. The criteria's for each level have been discussed and very carefully considered within the FMEA-team. These considerations are described for rank 1-10 and have been placed in appendix C. The formed criteria's have resulted in a severity rating scale, see table 4.3.

Severity Rating Scale		
Rank	**Severity**	**Criteria**
10	Hazardous	• Part has to be scrapped • Suspected unapproved parts in LHT material currency • Noncompliance with government regulation
9	Very high	• Secondary Clarification, document not present (Cert, AWB, IT, WR) • Part delivered and used with document(s) missing
8	High	• Secondary clarification, document present (Cert, AWB, IT, WR) • Primary clarification, document missing (Cert, AWB, IT, WR) • Part delivered and used with <100% readable documents, • Incorrectly saved • Certificate can not be automatically recognized
7	Moderately high	• Primary clarification, document present (Cert, AWB, IT, WR) • Secondary clarification, document missing (DN, WEB, RO) • Customers very dissatisfied
6	Moderate	• Secondary clarification, document present (DN, WEB, RO) • Primary clarification, document missing (DN, WEB, RO) • Customers dissatisfied
5	Low	• Primary clarification, document present (DN, WEB, RO) • Customers moderately dissatisfied
4	Very low	• Customers slightly dissatisfied • Document is re-scanned
3	Minor	• Light effect on performance.
2	Very minor	• Customer not annoyed. • Very slight effect on performance.
1	None	• No effect.

Table 4.3. The table shows the severity rating scale. [17] [21] [22].

5. Construction of occurrence rating scale

An occurrence rating scale with criteria's and failure rates was now created. It is not self evident how to relate the measured failure rate to the different ranking levels. Several different approaches are described in the literature. The most common used rating system and criteria's for this type of situations was chosen to be used. This resulted in the occurrence rating scale below, see table 4.4.
Each ranking (1-10) in the occurrence rating scale corresponds to a failure rate interval. For example, rank 8 corresponds to failure rates =2% and <10%.

Occurence Rating Scale			
Rank	**Detection**	**Criteria**	**Possible failure rates**
10	Almost certain	• Failure almost certain. • History of failures exists from previous or similar design.	50%
9	Very high	• Very high number of failures likely.	10%
8	High	• High number of failures likely.	2%
7	Moderately high	• Moderately high number of failures likely	1%
6	Medium	• Medium number of failures likely. Occassional failures, but not in major proportions.	0,5%
5	Low	• Occassional number of failures likely.	0,2%
4	Slight	• Few failures likely	0,1%
3	Very slight	• Very few failures likely	0,05%
2	Remote	• Rare number of failures likely. Isolated failures exist.	0,005%
1	Almost never	• Failure unlikely. History shows no failures.	0%

Table 4.4. The table shows the occurrence rating scale. [17] [21] [22]

6. Construction of detection rating scale

Normally the detection rating corresponds to the likelihood that a potential failure mode is detected before it reaches the customer or the next process step. However, if a failure is detected but not corrected before the item is released, the damage is just as sever as if it would not have been detected at all. A second criteria is therefore added in this thesis; namely the probability that a detected failure will be corrected. The detection rating scale is shown below, see table 4.5.

Detection Rating Scale		
Rank	**Detection**	**Criteria**
10	Almost impossible	• No control. • Failure will never be corrected if detected • Very high likelihood that the part will be delivered with the defect.
9	Very remote	• Control very likely will not detect the existence of a defect. • Control is achieved with indirect checks only
8	Remote	• Controls more likely will not detect the existence of a defect. • Control is achieved with indirect or random checks only • High likelihood that the part would be delivered with the defect
7	Very low	• Controls may detect the existence of a defect • Occasional controls
6	Low	• Moderate likelihood that the part would be delivered with the defect • Failure might be corrected if detected
5	Moderate	• Controls have a good chance of detecting the existence of a failure • Regulary conrols
4	Moderately high	• Low likelyhood that the part would be delivered with the defect • Error easy to detect
3	High	• Remote likelihood that the part would be delivered with the defect • High frequency of controls
2	Very high	• Automatical error detection
1	Almost certain	• Controls almost certainly will detect the existence of a defect. • Very remote likelihood that the part would be delivered with the defect • 100% control

Table 4.5. The table shows the detection rating scale. [17] [21] [22]

7. Determine severity

The severity of all possible effects for all failure modes was explicitly defined when constructing the severity rating scale. The ratings were now to enter for each effect in the SEV-column in the FMEA worksheet in appendix D.

8. Determine occurrence

The failure rates from the random test were compared to the failure rates in the occurrence rating scale. The corresponding ranking was then entered in the OCC-column in the FMEA worksheet for each case. The failure rates were often

different for different document types and this off course lead to different rankings for different document types. The rates were entered in the OCC-column in the FMEA worksheet in appendix D.

9. Determine detection

Not only the most critical effects but also failures less critical are considered in this FMEA. This results in different detection ratings for the different types of effects that a failure mode might have.

If a customer set specific requirements of which documents that must be delivered with the part, these documents will be controlled at the third and fourth control stations described in the flowchart (see figure 4.5 and 4.6). If the customer expresses no specific documentation demands, no scanned documents will be controlled specifically at these stations.

Different document types also have different probabilities of failure detection. The probability depends on how often the customers demand a certain document type to be delivered with the part. A difference was made between two document groups.

1. Cert, AWB, DN and IT are more often required from the customers and therefore more often controlled when a part is ordered.
2. WEB, WR and RO are on the other hand not very often asked for and are therefore less often controlled.

Failures may also be detected on other places in the processes, for example in the workshop. Still, the probability of failure detection at these places is quite occasional and is therefore not included in the FMEA rating.

The detection rating is mainly based on experience and estimations since there is no efficient way to measure the exact probability of detection. The different detection ratings have been compared to each other to secure a logical and correct classification. The criteria's and considerations are documented in appendix C. The ratings were entered in the DET-column in the FMEA worksheet in appendix D.

10. Calculate the "Risk Priority Number"

As the ratings for severity, occurrence and detection had been entered in the FMEA worksheet, the "Risk Priority Number" were to calculate for all combinations. RPN:s between 630 and 42 were received.

11. Rank failure modes

The ranking for all failure modes can be seen in the Rank-column in the FMEA worksheet in appendix D. Three failure modes for specific document types received significantly higher RPN:s than all other failure modes. The RPN for the highest ranked case is 648 and 630 for the other two. The third highest RPN is 560. Nine failure modes for different documents received this value and it was therefore a natural decision to focus on the three highest ranked failures with RPN 648 and

630. The number of cases would have been too large regarding to the available time for this thesis if the combinations with RPN 560 and higher would have been investigated. The three failure modes with the severity, occurrence and detection ranking which caused the highest RPN are illustrated in an excerpt from the FMEA worksheet, see table 4.6.

Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN
OCR	**Certificate is not automatically recognised**	Part can not be duty free delivered	Low image quality	Certificate	1, 2	8	9	9	**648**
Scanning	**Black fields on document**	Noncompliance with government regulations	Document paper quality Scanner features	AWB	2, 3, 4	10	9	7	**630**
Scanning	**Document is askew, data missing**	Part is delivered and used with data missing, suspected unapproved parts in LHT material currency	Document features Scanner features Co-worker Scanning method	Certificate	2, 3, 4	10	9	7	**630**
		Nonconformance with government regulations	Document features Scanner features Co-worker Scanning method	Certificate	2, 3, 4	10	9	7	**630**

Table 4.6. The three failure modes with the highest RPN.

In addition to the three cases above, a fourth failure mode will be closer investigated because of its very high occurrence. The failure mode ”Black lines along document” occur on 13,9% of all documents and this is considered far to high to not be corrected.
Actions to reduce the RPN for the following four failure modes:

- Certificate is not automatically recognised,
- Black fields on documents (AWB),
- Document is askew, data missing (Certificate) and
- Black lines along document (all document types)

will consequently be discussed in the next chapter.

Step 12 – 20 of the FMEA are either parts of the following chapter or lay in the future.

5 Comparative studies

Chapter 5 describes observations made during the comparative studies performed at GbD and at LTL in FRA. The observations shall make it possible to relate and compare the situation at LTL in HAM to the situation at these two locations and underlie the solving suggestions and recommendations worked out in chapter 6.

5.1. Benchmarking

A random test gives a numerical value of the quality level. To be able to relate a measured quality level to something, a comparison with data from an external source is meaningful. To gain this data, a benchmarking was decided to be performed. In addition to the comparison of quality levels, the benchmarking ought to answer some further questions:

- Do other companies have the same quality problems as LTL have?
- Which quality parameters are used?
- What kind of quality assurance systems and methods are used?
- What is the technological level of the used equipment?
- Are there any significant processing and handling differences?
- What is a possible quality level?

A desirable benchmarking, producing valuable and useful data, would be an external competitive benchmarking. However, it is not realistic to believe that LTL would get the required access to collect useful data from any of our direct competitors in the aviation logistics industry.

A second appropriate alternative is an external functional benchmarking. The company GbD - Gesellschaft für beleglose Datenverarbeitung mbH - was identified as a suitable object for a benchmarking.

5.1.1 External functional benchmarking at ”Gesellschaft für beleglose Datenbearbeitung mbH”

Gesellschaft für beleglose Datenbearbeitung mbH (*Company for Processing of Voucherless Documents*) is Europe's biggest provider of outsourcing solutions in electronic voucher collection, processing and archiving and is a 100% daughter of Lufthansa Systems. In the past 3 years, GbD have produced around 250 million colour images for Deutsche Lufthansa AG, Deutsche Bahn AG and Swiss International Airlines.

It is plausible to assume that GbD possess expert knowledge in processes and activities interesting for LTL. GbD is no competitor of LTL and even expressed a belief on mutual benefit from a benchmarking. These are reasons to why GbD was considered to be a suitable company for a benchmarking.

The benchmarking was performed at a meeting with Mr. Volker Schuldt, Manager of Quality Assurance and Customer Relations at GbD. Scanning procedures and

related activities were observed and described during a guided tour through the facilities. Thereafter, additional questions and reflections were discussed with Mr. Schuldt.

Scanners and scan operators

GbD uses high-speed scanners with a capacity of 100 documents per minute. One scan generates four images; two black and white and two colour images in .tif and .jpg file format. One high-speed scanner costs approximately 250 000 Euro. GbD uses OCR-software to automatically translate images into text. The goal is to reach a 100% automatic scanning and OCR-reading.

The scanner operators are low or uneducated. Every co-worker shall master only one part of the process and perform it perfectly without being influenced by other things. Goal is to have a specialist for each specific process step and therefore no job rotation is made. The task for each operator is documented and very specific describe what the co-workers are to do and not. No further internal education is made.

The scan operator's salary is based on performance. More scanned documents mean more money. A quality based bonus system is being discussed, but the problem is that it is more difficult to measure the quality level than the amount of scanned objects.

The co-workers have a 5-minute break every 60 minutes. The goal is to have a sickness quote at a maximum of 3%.

The premises gave an impression of being very clean and well structured. The working stations have a good illumination and ergonomic chairs.

Quality aspects
GbD defines documentation quality through three criteria's:

1. Image quality
2. Completeness quality
3. Validity

GbD hard cost pressure because of the multitude of competitors on the market. Therefore, costs are always strongly considered also when talking about quality aspects. Depending on the demands from the customers, different quality levels are offered at different price levels. For example, a 100% quality control can be performed as long as the customer is ready to pay the corresponding price. If the customer does not specify the desired quality level, GbD sets the level and acts only if the customer reports an insufficient quality. However, GbD always recommends their customers to choose colour scanning because of the higher quality level. The highest scan quality the GbD can produce is equal to the quality of the original documents. GbD can not tell the average quality level in the branch.

Quality problems and levels
GbD is aware that errors are running through the system. These are what they call ”normal errors” which you simply can not avoid. Systematic errors do not exist in the processes according to Mr. Schuldt.

The large quantities of different documents with different features and the multiple process steps are sources of many errors, for example are some documents scanned twice and some not at all. The customers expect a completeness quality of 100%.

Another problem at GbD is the indexing error. An indexing error is for example when the OCR-software translates a 7 into a 1. This effects the validity and occurs approximately 4 times per 10 000 scanned documents (0,04%). GbD usually have a deal with the customer complying with this indexing quality level.

A further problem is the unreadable data. 11-12% of the scanned aeroplane tickets are not fully OCR-readable. This depends on the different formats and structures of the documents and is no software problem.
A reading quote of 99% is considered possible.

Quality assurance systems
GbD adjusts the quality controls to the individual customer demands and the importance of the scanned documents.

Both manual and automatic methods are used in the quality control. Random tests are always manually executed through controls of scanned images on a monitor, either in the processes or from the archive. GbD does not follow any norms or standards when implementing random tests and can not tell what an optimal test rate is. The average random test at GbD corresponds to approximately 5% of the lot. Images are regularly compared to prior scannings to secure a constant quality level.

Airway bills are automatically scanned and translated with OCR-software. When a document can’t be successfully translated or if all fields are not filled in, the system automatically alarms and a manual control follows. If the document still can not be interpreted it is forwarded to a co-worker with more experience and a better overall view.

In case of missing documents, the software is able to discover this and alarm. If a document is misplaced or has an unexpected format, the scanning process is automatically interrupted.

To assure that the whole document has been scanned and archived, GbD scans around the documents. This creates a black frame. If the black frame is broken the whole document has not been scanned and data might be missing. This is the only way to secure a perfect completeness. If the customers won’t accept this black frame, GbD can not guarantee that everything has been scanned.

Reliability and validity.
The observations made in this benchmarking will be useful when developing quality improvement suggestions in this thesis. However, there is a risk that the information provided from GbD is of questionable validity. It is possible that Mr. Schuldt did not always know or want to communicate the exact data.
Furthermore, it is difficult to tell in what grade it is possible to compare and transfer the situation at GbD to the situation at LTL.

5.1.2 Internal benchmarking at LTL in FRA

Since the random test indicated significant differences between the locations in HAM and FRA, an internal benchmarking was made at the LTL location in FRA. It is known that process differences exist and the goal was to identify possible reasons for the higher quality level in Frankfurt.

The documentation processing in the stock receipt area will now be described. The illustrations in figure 5.1 describe the layout in a schematic and simplified way. Only objects relevant for the benchmarking and the understanding of the documentation processes are present in the illustrations.

A. Stock receipt area.

Shipments are received. The shipments normally consist of A/C-parts packed in cardboard boxes.

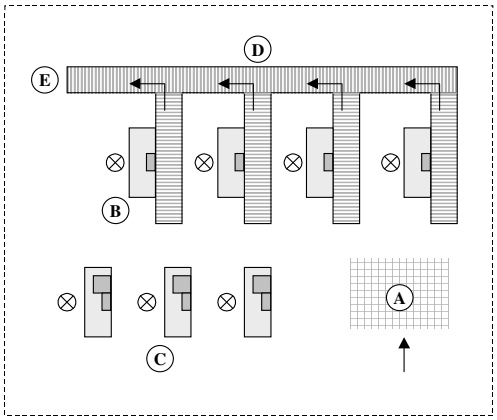


Figure 5.1. The figure shows the layout of the stock receipt at LTL in FRA

B. Working desk with computer and hand scanner

Cardboard box is opened.
Content of the box is controlled. The documents have to agree with the received A/C-parts considering amount, part number etc.
New barcode stickers are printed out and attached to the documents belonging to the part.
A/C-parts placed in a plastic box and automatically shipped to the next processing area (E).
Documents are brought to one of the three working desks for scanning (D)

C. Working desk with computer and document scanner

No documents are scanned at the working desks by the conveyor belt. The document scanning is executed at three separate working desks by co-workers performing only this task.

The ZID-Barcodes attached to the documents and the consignment is scanned with a hand scanner at the working desks by the conveyor belt. A relation between A/C-part, documents and ZID-numbers is automatically created and saved. Since this process is separated from the document scanning, the scanned images are not automatically saved under its own ZID-number in ELO OPAL. The scanner operator must therefore save the documents manually. This is done through a re-scan of the ZID-barcode on the document or through a manual editing on the keyboard. The manual keyboard editing might be a source of failures.
Documents are scanned with a flatbed scanner and automatically saved under the already saved ZID-number in ELO OPAL.
The image of scanned the document appears on a monitor and the scan result is manually controlled by the co-worker. If black or dark shadows occur on the image, the original document is usually copied on a normal photocopier to avoid the problems.
After scanning a document, the image automatically appears on the monitor. To continue scanning, a *confirmation-verification-button* has to be mouse-clicked on the monitor. This takes extra time but gives an opportunity to check the scan quality.

D. Conveyor belt
The conveyor belt transports parts to further processing areas.

E. Further processing areas
Parts and documents are booked into SAP R/3 and. the part is stored into the warehouse.

Scanners and scan operators
Exactly the same hard- and software are used in FRA and HAM. An external company cleans the scanners twice a year. In case of low scan quality caused by a dirty scanner, the scanner operators in FRA wipe off the glass surface inside the scanner. This takes no more than one minute and is an uncomplicated procedure according to one of the scanner operators in Frankfurt. The cleaning is performed on the scanner operator's own initiative since no present documentation neither describes the cleaning proceedings nor forbid it.
The scanner operators gave an impression of being scan-technical competent in FRAU. The reason is probably that the scanning competence is concentrated to few working stations
Furthermore, the working load for the scan operators seemed to be at a level that rendered it, in terms of time, possible to control the scan quality in a large.

Reliability and validity
Fewer parts are received in Frankfurt than in Hamburg and the random test indicated that approximately half as many documents are scanned in Frankfurt as in Hamburg per month. Therefore, it is possible that all processes might not be fully comparable and transferable to the Hamburg location.

Differences, reflections and interesting observations during the external and internal benchmarking will be presented in the next chapter.

6 Conclusions and recommendations

Solving suggestions for the most critical failures are worked out in this chapter. Further long-term solutions are also discussed and a new process flowchart is produced. Recommended actions are thereafter presented. The fulfilment of goal and choice of methods are finally discussed.

6.1. Solving suggestions

The collected data shows that the documentation quality level at LTL in Hamburg does not fulfil authority and customer demands. However, the benchmarking showed that there are ways to reach a higher quality level. Made observations, literature studies and brainstorming have been used as a support when problem-solving suggestions for reduction of the most critical failures have been worked out.

There are three ways to reduce the RPN in the FMEA and consequently the total risk of a failure; a reduction of the failure occurrence, an increase of the failure detection or a reduction of the severity of the effect. Since it is impossible, or at least very difficult, for LTL to influence the effects of the failure, two alternatives remain. An increased failure detection can be reached through increased controls. Increased controls result in higher costs and are therefore usually not considered as a primary solution. Preventive actions such as higher demands on the suppliers are often recommended instead. However, the very high quality demands, the strict regulations and the limited possibility of exchange of suppliers limit the possibilities for LTL to decrease the inspections in general and the receiving inspection in particular. Nevertheless, one alternative remains; namely the reduction of the failure occurrence. The recommendations in this thesis have therefore been worked out to primarily reduce the rates of failure occurrences.

6.1.1 Solving suggestions for critical failures

Solving suggestions for the most critical failures identified in the FMEA and the failure mode with the highest rate for all documents have primarily been worked out to reach a satisfying documentation quality. Suggestions for the following failure modes have been worked out:

- Black fields on AWB,
- Askew and/or misplaced certificate, data missing,
- Authorized release certificate not automatically recognised
- Black lines along document

Actions considering hardware, software, environment and method and co-worker guidelines have been worked out and will be discussed for the failure modes above. Some of the actions will influence and reduce more than one failure mode. These actions will only be described in detail for one failure mode to avoid redundancy.

Actions considering the layout in the stock receipt influence all failure modes and actions and will therefore be discussed at last.

Black fields on AWB

Cause

The black fields (see appendix B image 1 and 2) occur on documents because of coloured document paper. A further aggravating factor is most likely thin document paper. Thin paper is hard to scan as the light from the scanner can go through the paper. It has been noticed that the black fields very often occur direct after the ZID-barcode stickers on the document. Owing to this observation, there is reason to believe that an inconstant paper thickness, big material or colour differences complicate the scanning of documents. AWB:s very often consist of a thin, pink-coloured paper and are therefore more often error prone than other document types.

Effect

17,6 % of all AWB:s are completely or partly impossible to read because of the black fields. This does in no way conform to the requirements of a readily identifiable and readable documentation in the AECMA Standard 9120. AWB:s are also of great importance because of customs legislation. The AWB functions as legal evidence in case of queries from customs or customers. Information about the shipped goods, receiving and shipping company, airport of departure and destination then *have* to be fully readable. A less than 100% readable AWB risk to cause juridical consequences.

Solving suggestions

Hardware

The scanners, which are used today, are obviously not able to scan the AWB:s with a satisfying outcome. The AWB:s are currently scanned at a separate location (see figure 4.2, position G) because of administrative reasons. LTL needs to procure this location with hardware capable of producing high quality images from documents with thin and coloured paper. The following alternatives should to be tested in this order:

1. Possibly modifications on present scanners

Black fields do not occur on all images of scanned AWB:s with thin and coloured paper. The scanners at LTL are obviously able to scan these documents correctly under certain circumstances. Alternative scanning proceedings and scanner settings should be investigated to determine if it is possible to scan AWB:s in a better way with the present scanners. If there is an alternative way to scan the AWB:s with a good result using the present scanners, this would off course be to prefer because of the low investments needed. If no modifications in the use of the current scanners can solve this problem, the next alternative shall be tried out.

2. Photocopier

Photocopiers are already used as an alternative to the scanners at LTL in FRA and HAM. If black fields are detected on the scanned image, the original document is sometimes photocopied. Black fields do not occur as often on the copy as on a scanned image according to the co-workers. The produced copy is then scanned with a better result. However, this is a lengthy procedure, which does not always produce high qualitative images and is therefore not an optimal solution. It is rather to consider as a short-term alternative, which can be implemented until a new and more efficient solution is found.

3. Colour scanner

It is likely that colour scanner scans coloured paper with a higher quality than a black and white scanner. GbD always recommends colour scanners to be used because of the higher scan quality. Disadvantages are the higher price of a colour scanner and that colour image files are larger and therefore more costly to save than black and white images. The purchase of a colour scanner might however be a good long term alternative.

Software

The random test showed a failure rate of 2,9% in FRA for this failure mode. Since exactly the same document scanners are used in HAM and FRA, the reason for this big difference most likely originates from other differences. One difference that was observed during the benchmarking in FRA can explain the lower rate of black fields in FRA. The image always appears on the screen after a document has been scanned in FRA. A mouse click on the monitor is then required for further scanning. This is not the case in HAM. The effect is a more frequent control of the scan result in FRA. If black fields are detected on the image, the scanner operator tries to solve this problem through scanning a photocopy of the AWB. It is consequently possible to improve the quality of AWB:s with increased controls and the use of a photocopier in case of detected black fields. This software difference can explain several of the differences in failure rates between HAM and FRA. A change of the software in HAM so that it functions in the same way as in FRA would most likely improve the quality level for all of the failure modes treated in this chapter. However, an increased quality control is not a desirable long-term solution. More frequent controls take time and cost money. The earlier in the value adding process a failure can be detected, or preferably avoided, the better. A short-term alternative is to programme the software in HAM so that the image always appears on the screen when an AWB has been scanned. A mouse click on the screen shall then be required before further scanning can continue. This function shall be implemented until a satisfying solution has been found.

Corrective software for this type of problems exist but is, according to initiated co-workers at LTL, very expensive and is therefore not considered as an alternative to prioritise.

Method and co-worker guidelines
As said, the quality control on scanned AWB:s ought to be increased until a satisfying solution has been found. The document shall then be photocopied in case of non-conformance. An alternative is to use black construction paper as a background eliminate the problems with light shining through the thin document paper by scanning and photocopying. This is an alternative, which may be tested if photocopying does not work satisfying.

Askew and/or misplaced certificate, data missing
Cause
The cause of an askew or misplaced image is that the ADF function on the scanner can not feed the document straight into the scanner. An improper document feeding can be caused by various reasons [23]:

- Document is unprecise or askew applied
- Document is rumpled or folded
- Deviant document formats
- Feeding mechanisms are dirty or worn out

In some cases, multiple physical copies of a certificate are needed and scanned for several A/C-parts. If a certificate is askew photocopied and then straight scanned, the image will off course be askew.

Data more often misses on askew certificates than on other askew documents. The reason to this is that certificates usually have text in the lower corners. This text easily falls outside the scanned area if the document is askew.

Effect
Not every information on the document is electronically archived. This does not conform to the requirements of a readable documentation in the AECMA Standard 9120.
If information on an authorized release certificate is missing, the corresponding part might be unapproved. Unapproved A/C-parts are never allowed to be used and are to regard as scrap. If they are delivered or used, sever juridical and economical consequences risk to follow.

Solving suggestions

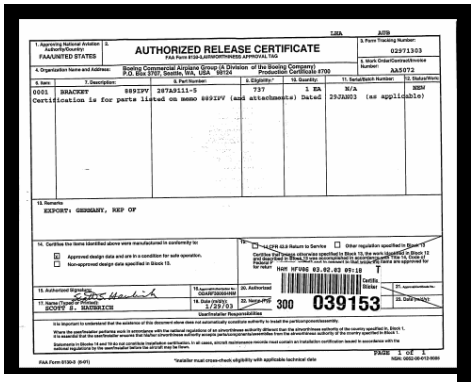

AUTHORIZED RELEASE CERTIFICATE

Figure 6.1. The figure shows an authorized release certificate with a black frame as a completeness assurance

Hardware

A completeness assurance method observed during the benchmarking at Gbd can be implemented to solve this problem. GbD scans outside the document. This creates a black frame around the image, see figure 6.1. An unbroken black frame is the only way that GbD can guarantee their customers that the whole document has been scanned.

Available, or if necessary new hardware, shall secure that it is possible to scan outside the document. The alternative with a black frame as a completeness assurance method shall be discussed with the customers to assure their comprehension and approval.

Software

The scanner software and ELO OPAL must be able to process documents which have been scanned outside the size of an A4 format. A possibility to digitally erase the black frame is also desirable.

A short-term alternative is to programme the software in HAM so that the image always appears on the screen when a certificate has been scanned. A mouse click and a quality control on the screen shall then be required before further scanning can continue. This function also works as a preventive quality control system for the failure mode ”authorized release certificate not automatically recognised” and shall be implemented until satisfying solutions have been found.

It is possible to subsequently straighten up an askew image with data processing [24]. This is, according to initiated co-workers at LTL, technically demanding and is therefore not considered as a primary alternative.

Method and co-worker guidelines

The goal should be to minimise the occurrence of askew or misplaced documents even if it is scanned outside the document and a black frame is used as a completeness assurance system. The random test showed that the failure rate for askew certificates in FRA is significantly lower than in HAM; 1,4% compared to 17,5%. It was also observed that co-workers in FRA were more careful in general when placing the document in the ADF paper chute. This hints that the handling influences the result greatly. New scanning instructions shall therefore be worked out for HAM and the co-workers shall be given required training. These instructions should exhort the co-workers to always:

- apply the document straight and carefully into the scanner.
- flatten and straighten out a rumpled or folded document so that it fits the conditions illustrated in figure 6.2.

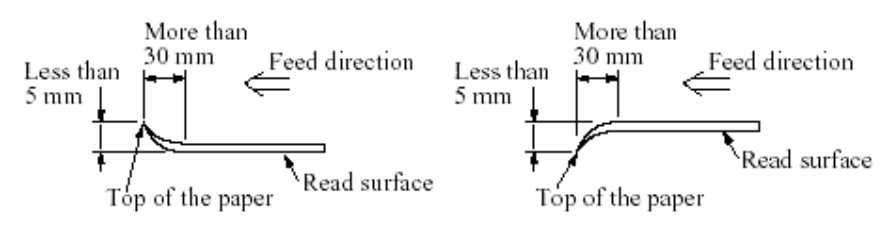


Figure 6.2. Document requirements for the ADF function [23].

A difference between the scanner maintenance instructions in HAM and FRA was discovered during the internal benchmarking. The co-workers in HAM are not allowed to clean the scanners inside. Instructions on the scanner prohibit this and only the foreman is allowed to perform the cleaning. The co-workers in FRA clean the scanners themselves. This could be a further explanation to the much lower rate of askew scanned certificates in FRA since dirty feed and pick rollers in the ADF affect the ability of automatic feeding negative.
New guidelines for scanner cleaning performed by the co-workers should therefore be worked out for HAM and the co-workers shall be given required training. The guidelines shall describe when and how to clean the scanner:

- The feeding mechanisms are to clean as soon as it is noticed that the automatic feeding performs less good than normally.
- The cleaning instructions that are available in the scanner operator's guide shall be described in the guidelines.

The production of these guidelines and related co-worker training can be made internal at LTL. The training is estimated to last no more than a few hours. The costs are therefore considered to be reasonable.

The maintenance performed by the external firm should be intensified if the cleaning performed by the co-workers does not effect the feeding performance. It is possible that the feeding mechanisms wear out faster than normally because of the dirty and dusty environment at LTL in HAM and consequently should be replaced more often.

Random tests should be made over a longer time to identify if there is a relation between executed external service and the ADF performance if other implemented actions did not have the desired effect.

Authorized release certificate is not automatically recognised

Cause
Three reasons can make the automatic recognition of an authorized release certificate impossible:

- Low scan quality, which makes it difficult for the OCR software to translate the image into text. In this case a low scan quality means a blurry, dark, vague, partly black or dirty image.
- Askew and/or misplaced, data missing.
- Rare typeface. The typeface is unknown or difficult to interpret for the OCR software.

Effect
The part can not be put into free circulation without paying duties if the authorized release certificate have not been recognised automatically.

Solving suggestions
Hardware
Certificates shall always be scanned with a resolution of 300 dpi to create as sharp images as possible. 200 dpi might be insufficient if the text on the original document is very small or indistinct.

Software
The OCR software should be upgraded so that rare typefaces can be translated to text.

Methods and co-worker guidelines
It is important to inform the co-workers about the importance of a high scan quality on certificates. All co-workers do not know that the certificates will be read by OCR and what effects and costs an unsuccessful automatic recognition has. This is to motivate them to be extra careful when scanning certificates. The co-workers must also be instructed to never scan the certificates in high format if they do not have to.
A higher scan quality in general will probably increase the rate of automatic recognition. This can most likely be reached through the new guidelines for scanner cleaning that have been described earlier in this chapter.

The most common reason for this failure should be identified with a random test on and an analyse of authorised release certificates that have not been automatically recognised. This test shall be performed before other major actions are taken. The random test made in this thesis contained 17 not automatically recognised authorized release certificates. This quantity is not large enough to make a statement about the most common cause. A random test on approximately 100 certificates spread over time would provide representative basic data for identification of the most common failure causes. GbD has a failure rate of 11-12% for automatic document recognition. It is plausible to assume that LTL can reduce

the measured rate of 22,1% to the level at GbD if the most common root causes are identified. Solutions have been worked out based on the current knowledge of causes.

The quality control on certificates shall be increased until sufficient solutions have been worked out and implemented.

Black lines

Cause
Particles such as dust, dirt, staples etc. on the glass surface in the ADF on the glass surface in the scanner have been identified as a root cause for the black lines. The lines very often occur in the feed direction on the documents scanned in Hamburg. The cardboard boxes that are opened at the working desks probably produce a lot of the particles. The operators guide from Fujitsu states that scanners shall not be used at dusty places at all [23].

Effect
Black lines along many of the documents cause customer dissatisfaction.

Solving suggestions
Hardware
A solution is to procure scanners designed for dusty environments. This most certainly means high investment costs and is therefore not the best alternative.

Environment
The scanners should either be placed on a cleaner location or the current location should be cleaner. It would bring a lot if the scanners were separated from the dust-producing opening of cardboard boxes. This suggestion will be more detailed discussed later in this chapter.

Methods and co-worker guidelines
The difference in failure rates in HAM (13,9%) and FRA (5,8%) can again be explained by the differences in maintenance instructions. Co-workers in FRA wipe off the glass surface inside the ADF if black lines are detected on the image. New guidelines for scanner cleaning performed by the co-workers should therefore be worked out for HAM. Relevant training shall also be given to the co-workers. The guidelines shall describe when and how the cleaning is to perform:

- The glass surface is to clean as soon as black or grey lines occur on the image.
- The cleaning instructions in the scanner operator's guide shall be described and followed.

These guidelines and the training shall be integrated with the guidelines and the training concerning straight document scanning.

A verification document shall be established to secure a regular scanner cleaning and maintenance. The document shall describe the cleaning and maintenance intervals for the different parts of the scanner. The contents of this documentation shall be strictly followed and the co-worker that has performed the service shall confirm this with his signature. A service and maintenance verification document shall be present for each and every scanner in the stock receipt.

6.1.2 Centralisation of the document scanning

Observations made in the random test, at LTL in FRA and at GbD give the reason to believe that a centralisation of the document scanning would increase the scan quality. Reasons for this statement are presented below.

Observations made at LTL in FRA

The random test indicated significant differences in the failure rates between the LTL locations in HAM and FRA. 50,0% of the documents scanned in HAM contained at least one error. The rate in FRA was 33,2%. The most obvious difference identified in the internal benchmarking was that the document scanning was performed at a separate working station, by co-workers with this as their only task. It is plausible to assume that the co-workers thereby gain a higher overall scan technical competence than the co-workers in Hamburg.

Observations made at GbD

A similar observation was made during the external benchmarking at GbD. Each co-worker performed only one task. The goal was to have an expert for each process step. The fewer tasks a co-worker had to perform, the more he could concentrate on his specific process step. This leads to a higher quality according to Mr. Schuldt at GbD.

GbD sees the variety of document types and formats as a problem, which makes it more difficult to scan with a consistently high quality. They therefore aspire to scan similar documents at the same occasion. Documents are therefore collected and sorted according to their features and thereafter scanned at a central high performance scanner.

Observations made in the random test

The random test showed that the failure rates for WEB:s are very low. An example of a scanned WEB of high quality is illustrated in appendix B, image 18. The rate for documents with at least one failure is 4,0% for WEB:s and 50,0% for all documents. The rates for the failures described earlier in this chapter are very low for WEB:s:

- Black fields 0,0%
- Askew and/or misplaced, data missing 1,3%
- Black lines 0,0%

WEB:s are always scanned at a separate location at LTL in HAM. No cardboard boxes are opened at this place and the scanners here are probably cleaner because of this. Few different co-workers scan the WEB:s. The format and the document paper quality is always uniform. This implies that it is that a higher quality level can be reached if similar scanning conditions are created for other documents to. AWB:s are also scanned at a separate location, but the failure rates are still high. The problems on AWB:s are caused by the special document paper features and are therefore not as representative as the WEB:s.

Advantages with a centralisation of the document scanning

A centralisation of the document scanning is more of a long-term solution than the already described solutions. However, the scanner centralisation would certainly make the suggestions more easy to implement, thus it is not a prerequisite for the implementation of the specific solving suggestions.

The result of a scanner centralisation would be that a lower number of scanners have to be used. The scanners do not use their full capacity today since they stand still as the co-workers perform other tasks. A centralisation where co-workers have document scanning as a separate task would render the possibility to use the capacity better.

A lower number of needed scanners means lower investment costs if new scanners have to be procured. Improvements of scanner performance would consequently be easier to implement.

Co-worker guidelines and new methods are not that costly to implement if fewer co-workers than today perform the document scanning. These co-workers should be specially educated to improve their knowledge about documents, quality demands and scanning technology and maintenance.

In addition to the possibility to improve hardware and co-worker competence, a centralisation of the scanning would render the possibility to increase the cleanliness in the scanner environment. The scanners shall be placed in a closed room to avoid dust and dirt from other activities to come in contact with the scanners. This would improve the scan quality and the lifetime of the scanners.

Furthermore, different document types shall be collected and sorted before they are scanned. Similar documents shall then be scanned together to avoid a large divergence in document formats. The scanning would then resemble the scanning of WEB:s.

Layout and process changes

A suggestion of a changed layout is illustrated in figure 6.3.

The different processing areas are labelled A-F.

A. Stock receipt area.
B. Shelves for sorted documents.
C. Working desks with computer and hand scanner.
D. Closed room for document scanning with computer, document scanner and hand scanner.
E. Conveyor belt
F. Further processing areas

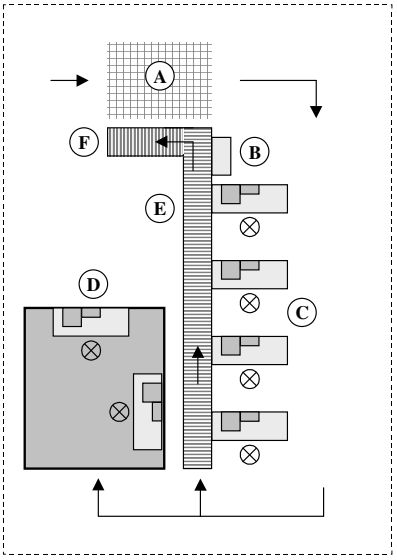


Figure 6.3. The figure shows an alternative layout in the stock receipt at LTL in HAM.

The scanners should be removed from the working desks C and placed in a closed room D.

The co-workers at the working desks perform the same task as today except of the document scanning. All documents shall be brought to the room for document scanning D after the boxes have been unpacked. The room shall remain closed to keep the scanners separated from a dirty and dusty environment. The documents are then to be sorted into piles, which shall consist of documents of uniform type and shape. Each pile is thereafter scanned separately by a skilled co-worker. This does not only generate a higher scan quality but also a higher efficiency with less dead time for the scanners. This means that fewer scanners need to be used which makes scanner purchase and maintenance cheaper. The co-workers that scan the documents shall also master a further task, which they can perform as soon as no documents to scan are present.

A risk with letting some co-workers perform only the document scanning is that the job will be more monotonous. This is probably not a big problem since the tasks still would be more varying than the tasks at GbD. GbD has had no problems with monotonous tasks according to Mr. Schuldt.

This alternative should be further investigated by LTL since the available time and the delimitations in this thesis do not allow this.

6.1.3 New process flowchart

The centralisation of the document scanning induces some changes of the process flowchart, see figure 4.5 and 4.6, presented in chapter 4.The new process flowchart is illustrated in figure 6.4 and 6.5. The locations A-F are the same as the ones described in the layout in figure 4.2.

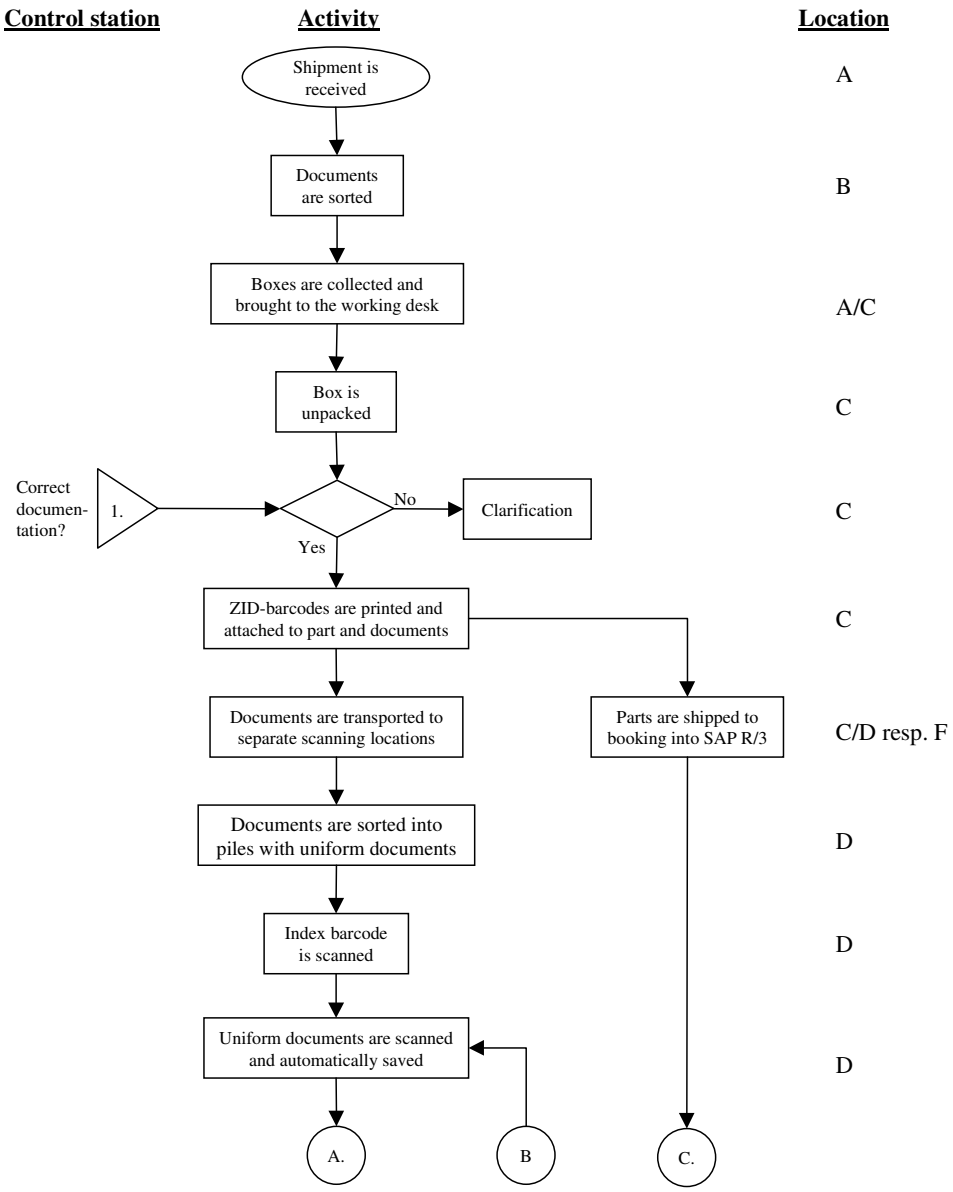


Figure 6.4. The figure illustrates the process flowchart after a centralisation of the document scanning. The flowchart continues on the next page.

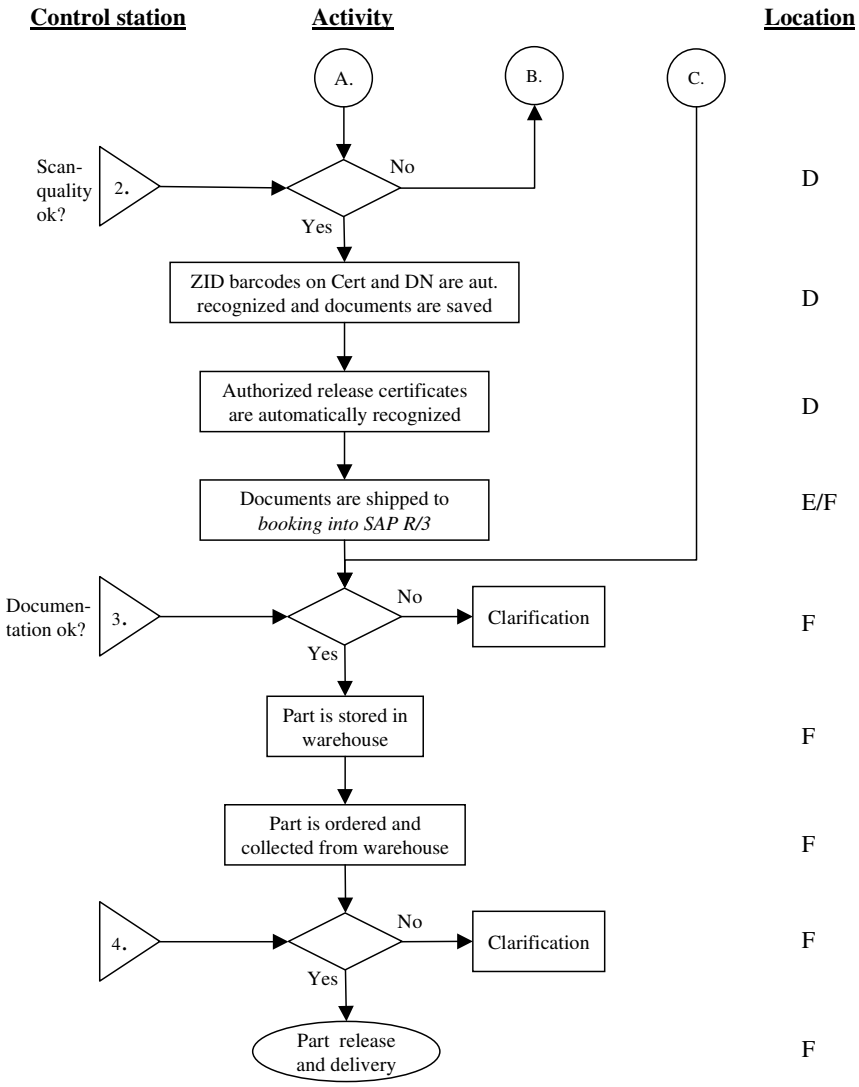


Figure 6.5. The figure illustrates the process flowchart after a centralisation of the document scanning. The flowchart is a continuation from the previous page.

6.2. Recommended actions

The actions for reduction of the most critical failures, which are recommended to be implemented primarily, are summarised below. The recommendations mainly aim for the reduction of failure occurrences, but increased controls may in some cases be a short-term alternative as well. However, this is only an alternative as long as other successful solutions have not been implemented.

Hardware

- Procure hardware, which is able to scan AWB:s.
- Procure hardware, which is able to scan outside a document of A4 format to secure completeness.
- Always scan certificates with 300dpi.

Software

- Procure software, which is able to process documents of A4 format which have been scanned outside the original document size.
- Configure the scanner software so that the image always appears on the screen after a document has been scanned at *all working* stations.

Method and co-worker guidelines

- Work out new co-worker guidelines to avoid an askew and misplaced scanning
- Work out scanner cleaning instructions for the co-workers.
- Carry out co-worker training to avoid an askew and misplaced scanning. Also educate the co-workers to perform scanner cleaning and maintenance.
- Establish a cleaning and maintenance verification record for every scanner.
- Inform the co-workers about the importance of an OCR readable certificate.
- Increase quality controls on AWB:s and Certificates until satisfying solutions have been implemented.
- Perform a random test on approximately 100 not automatically recognised authorized release certificates to identify the root causes.

Centralisation of document scanning

- A centralisation of the document scanning shall be investigated as a long-term change for a higher documentation quality.

Future controls

It is difficult to estimate what effects the implementation of recommended actions would have. No recalculation of the RPN has been made since it would be too speculative. A random test similar to the one described in this thesis shall be performed *after* the implementation of the recommended actions. The result can thereafter be used in the FMEA to measure the success.

6.3. Fulfilment of goal

A control of the fulfilment of the goal of this thesis can now be made. The goal was defined in chapter 1:

F*ind and implement methods that objectively measure, illustrate and communicate the documentation quality level.*

The random test objectively measured the failure rates, which were integrated in the FMEA. The FMEA illustrates and communicates the documentation quality level in a satisfying way and gives a good overall picture. The comparative studies made the communicated quality level at LTL even more predicative and the goal is considered to be fulfilled.

W*ork out solutions, which improve the documentation quality level in the stock receipt.*

The goal has been fulfilled tin chapter X, Conclusions and recommendations. The performed benchmarking and related measurements confirm that the recommended actions would increase the quality level at LTL.

The result of this thesis should be of great interest for LTL and other companies in a similar situation. The result is probably of less value for students and universities.

6.4. Choice of methods

The chosen methods and tools have fulfilled the purpose of the thesis. However, the choice of FMEA as tool can be questioned. The conduction of an FMEA appeared to be very time-consuming and it is uncertain if it would be profitable for LTL to perform a new FMEA on other problematic topics. It is possible that a person with very good knowledge about the investigated processes could have reached essentially the same conclusions about the quality level using only a random test. Nevertheless, the FMEA makes the understanding of the problematic situation easier for a person without prior knowledge about LTL. It also takes aspects such as the severity of different effects and the probability of detection into consideration. This would not have been that easy without the use of an FMEA and the choice of this tool is considered to be correct.

The random test was a self evident and successful choice of method. The only objection may be that the test only included documents from one month, but the available time did not allow an extended test. The result can still be considered to be representative since neither suppliers and documents nor processes and equipment have changed to any large extent during the last time.

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Glossary

A/C-part	Aircraft part
ADF	Automatic document feeder
AOG	Aircraft On Ground
AWB	Airway bill
Cert	Certificate
DIN	Deutsche Industrie Norm
DN	Delivery note
EASA	European Aviation Space Agency
FAA	Federal Aviation Administration
FMEA	Failure Mode and Effect Analysis
FRA	Frankfurt
HAM	Hamburg
IT	Ident tag
LHT	Lufthansa Technik AG
LTL	Lufthansa Technik Logistik GmbH
MUC	Munich
RO	Repair order
SXF	Berlin Schönefeld
TXL	Berlin Tegel
WEB	Stock receipt document
WR	Workshop report

Appendices

Appendix A – Failure rates

	HAM	FRA	MUC	CGN	SXF	Total
All documents						
ZID-numbers tested	127	98	11	9	5	250
% share of all ZID´s	50,8%	39,2%	4,4%	3,6%	2,0%	100,0%
Number of documents tested	684	310	13	20	11	1.038
% share of total	65,9%	29,9%	1,3%	1,9%	1,1%	100,0%
Nbr of tested documents with at least one error	342	103	10	9	3	467
	50,0%	33,2%	76,9%	45,0%	27,3%	45,0%
No entry found	3	19	1	2		25
% share	2,4%	19,4%	9,1%	22,2%	0,0%	10,0%
ZID´s without certificate	41	66	9	8	4	128
% share of ZID´s without certificate	32,3%	67,3%	81,8%	88,9%	80,0%	51,2%
Black fields (or completely black)	48	4		2		54
% share	7,0%	1,3%		10,0%		5,2%
Dark	46	18		1		65
% share	6,7%	5,8%		5,0%		6,3%
Dirty/dusty	26	16	5	3		50
% share	3,8%	5,2%		15,0%		4,8%
Black/grey lines along the document	95	18		2		115

	HAM	FRA	MUC	CGN	SXF	Total
% share	13,9%	5,8%		10,0%		11,1%
Low/moderate quality in general	51	17				68
% share	7,5%	5,5%				6,6%
Low text quality	15	16	1	-	2	34
% share	2,2%	5,2%	7,7%	0,0%	18,2%	3,3%
Askew, whole document scanned	57	14	2			73
% share	8,3%	4,5%				7,0%
Askew, part of document not scanned	15	3			1	19
% share	2,2%	1,0%	0,0%	0,0%	9,1%	1,8%
Askew, part not scanned, data missing	38	6	2			46
% share	5,6%	1,9%	15,4%			4,4%
Misplaced, part not scanned	4					4
% share	0,6%					0,4%
Misplaced, part not scanned, data missing	7					7
% share	1,0%					0,7%
Askew and misplaced, part not scanned	9	1		1		11
% share	1,3%	0,3%		5,0%		1,1%
Askew and misplaced, part not scanned, data missing	7	1				8
% share	1,0%	0,3%				0,8%

	HAM	FRA	MUC	CGN	SXF	Total
Incorrectly saved	8	14		1		23
% share	1,2%	4,5%		5,0%		2,2%
Incorrectly + correctly saved	4	3				7
% share	0,6%	1,0%				0,7%
No ZID-barcode	6	2		2		10
% share	0,9%	0,6%		10,0%		1,0%
Document ripped	2	1				3
% share	0,3%	0,3%				0,3%
Document knicked	6	4	2	1		13
% share	0,9%	1,3%	15,4%	5,0%		1,3%
Document wrinkled	1					1
% share	0,1%					0,1%
Not readable handwriting	3					3
% share	0,4%					0,3%
Paper background (Copy, copy, copy...)	6					6
% share	0,9%					0,6%
Certificate missing	1					1
% share of ZID numbers which require a certificate	1,1%					0,8%

	HAM	FRA	MUC	CGN	SXF	Total
Airway Bill (AWB)						
Nbr of ZID´s with at least one AWB	117	47	0	3	0	167
% of ZID´s with AWB for each location	92,1%	48,0%	0,0%	33,3%	0,0%	
Nbr of tested AWB:s	233	102		4		339
Nbr of tested documents with at least one error	121	36		4		161
	51,9%	35,3%		100,0%		47,5%
Black fields (or completely black)	41	3		1		45
	17,6%	2,9%		25,0%		13,3%
Dark	23	13		1		37
	9,9%	12,7%		25,0%		10,9%
Dirty/dusty	8	4		1		13
	3,4%	3,9%		25,0%		3,8%
Black/grey lines along the document	23	3				26
	9,4%	2,9%				7,7%
Low/moderate quality in general	18	5				23
	7,7%	4,9%				6,8%
Low text quality	2	8				10
	0,4%	5,9%				2,9%
Askew, whole document scanned	16	4				20
	6,9%	3,9%				5,9%
Askew, part not scanned	2					2
	0,9%					0,6%
Askew, part not scanned, data missing	2	1				3
	0,9%	1,0%				0,9%
Misplaced, part not scanned	2					2
	0,9%					0,6%

	HAM	FRA	MUC	CGN	SXF	Total
Misplaced, part scanned, data missing	1					1
	0,4%					0,3%
Askew and misplaced, part not scanned, data missing		1				1
		1,0%				0,3%
Incorrectly saved		2		1		3
		2,0%		25,0%		0,9%
Incorrectly + correctly saved		2				2
		1,0%				0,6%
No ZID-barcode	1	1		2		4
	0,4%	1,0%		50,0%		1,2%
Document ripped		1				1
		1,0%				0,3%
Document knicked	1					1
	0,4%					0,3%
Document wrinkled	1					1
	0,4%					0,3%
Not readable handwriting	3					3
	1,3%					0,9%
Ident-Tag (IT)						
Nbr of ZID´s with at least one Ident-Tag	20	24	7	0	1	52
% of ZID´s with Ident-Tag for each location	15,7%	24,5%	63,6%	0,0%	20,0%	
Nbr of tested Ident-Tags	20	24	7	0	1	52
Nbr of tested documents with at least one error	16	17	6		1	40
	80,0%	70,8%	85,7%		100,0%	76,9%
Black fields (or completely black)	1	1				2
	5,0%	4,2%				3,8%

	HAM	FRA	MUC	CGN	SXF	Total
Dark	5	1				6
	25,0%	4,2%				11,5%
Dirty/dusty	6		5			11
	30,0%		71,4%			21,2%
Black/grey lines along the document	3	4				7
	15,0%	16,7%				13,5%
Low/moderate quality in general	7	7				14
	35,0%	29,2%				26,9%
Low text quality	3	1			1	5
	15,0%	4,2%			100,0%	9,6%
Askew, whole document scanned	1	4	2			7
	5,0%	16,7%	0			13,5%
Askew, part not scanned	3	2				5
	15,0%	8,3%				9,6%
Askew, part not scanned, data missing	1	2				3
	5,0%	8,3%				5,8%
Askew and misplaced, part not scanned	1					1
	5,0%					1,9%
Document knicked	2	4	1			7
	10,0%	16,7%	14,3%			13,5%
Delivery Note (DN)						
Nbr of ZID´s with at least one Delivery Note	116	54	2	4	5	181
% of ZID´s with Delivery Note for each location	91,3%	55,1%	18,2%	44,4%	100,0%	
Nbr of tested Delivery Notes	185	68	4	13	5	275
Nbr of tested documents with at least one error	107	18	2	4	1	132
	57,8%	26,5%	50,0%	30,8%	20,0%	48,0%

	HAM	FRA	MUC	CGN	SXF	Total
Black fields (or completely black)	5			1		6
	2,7%			7,7%		2,2%
Dark	12	1				13
	6,5%	1,5%				4,7%
Dirty/dusty	5	6		1		12
	2,7%	8,8%		7,7%		4,4%
Black/grey lines along the document	30	5		2		37
	16,2%	7,4%		15,4%		13,5%
Low/moderate quality in general	20					20
	10,8%					7,3%
Low text quality	4	6	1			11
	2,2%	8,8%	25,0%			4,0%
Askew, whole document scanned	24	4				28
	13,0%	5,9%				10,2%
Askew, part of document not scanned	6				1	7
	3,2%				20,0%	2,5%
Askew, part not scanned, data missing	13		2			15
	7,0%		50,0%			5,5%
Misplaced, part not scanned, data missing	2					2
	1,1%					0,7%
Askew and misplaced, part not scanned	8			1		9
	4,3%			7,7%		3,3%
Askew and misplaced, part not scanned, data missing	4					4
	2,2%					1,5%
Incorrectly saved	4	5				9
	2,2%	7,4%				3,3%
Incorrectly + correctly saved	3	1				4
	1,6%	1,5%				1,5%

	HAM	FRA	MUC	CGN	SXF	Total
No ZID-barcode	2					2
	1,1%					0,7%
Document ripped	1					1
	0,5%					0,4%
Certificate (Cert)						
Nbr of ZID´s with at least one Certificate	86	32	2	1	1	122
% of ZID´s with Certificate for each location	67,7%	32,7%	18,2%	11,1%	20,0%	
Nbr of tested Certificates	148	69	2	1	1	221
Nbr of tested documents with at least one error	77	17	2	1	-	97
	52,0%	24,6%	100,0%	100,0%	0,0%	43,9%
Automatically recognised certificates	60	15	2	0	0	77
	69,8%	46,9%	100,0%	0,0%	0,0%	63,1%
Not automatically recognised certificates	26	17	0	1	1	45
	30,2%	53,1%	0,0%	100,0%	100,0%	36,9%
ZID´s with Conformity Statement	9	8	0	0	0	17
	10,5%	25,0%	0,0%	0,0%	0,0%	13,9%
ZID´s with authorised certificate	77	24	2	1	1	105
	89,5%	75,0%	100,0%	100,0%	100,0%	86,1%
ZID´s without certificate	41	66	9	8	4	128
	32,3%	67,3%	81,8%	88,9%	80,0%	51,2%
Black fields (or completely black)	1					1
	0,7%					0,5%
Dark	3	3				6
	2,0%	4,3%				2,7%
Dirty/dusty	2	6		1		9
	1,4%	8,7%		100,0%		4,1%

	HAM	FRA	MUC	CGN	SXF	Total
Black/grey lines along the document	27	2				29
	18,2%	2,9%				13,1%
Low/moderate quality in general	6	4				10
	4,1%	5,8%				4,5%
Low text quality	4	1				5
	2,7%	1,4%				2,3%
Askew, whole document scanned	13					13
	8,8%					5,9%
Askew, part of document not scanned	1					1
	0,7%					0,5%
Askew, part not scanned, data missing	19	1				20
	12,8%	1,4%				9,0%
Misplaced, part not scanned	1					1
	0,7%					0,5%
Misplaced, part not scanned, data missing	4					4
	2,7%					1,8%
Askew and misplaced, part not scanned						
Askew and misplaced, part not scanned, data missing	3					3
	2,0%					1,4%
Incorrectly saved	1	1				2
	0,7%	1,4%				0,9%
Incorrectly + correctly saved	1					1
	0,7%					0,5%
No ZID-barcode		1				1
		1,4%				0,5%
Wrong ZID-barcode		1				1
		1,4%				0,5%

	HAM	FRA	MUC	CGN	SXF	Total
ZID incorrectly positioned	3		2	1		6
	2,0%		100,0%	100,0%		2,7%
Document ripped	1					1
	0,7%					0,5%
Document knicked	3		1	1		5
	2,0%		50,0%	100,0%		2,3%
Paper background (Copy, copy, copy...)	6					6
	4,1%					2,7%
Certificate missing	1					1
% share of ZID numbers	0,8%					0,4%
Stock receipt document (WEB)						
Nbr of ZID´s with at least one WE-Beleg	73	30	0	0	2	105
% of ZID´s with WE-Belege for each location	57,5%	30,6%	0,0%	0,0%	40,0%	
Nbr of tested Stock receipt documents	75	31			2	108
Nbr of tested documents with at least one error	3	8			1	12
	4,0%	25,8%			50,0%	11,1%
Dark	1					1
	1,3%					0,9%
Dirty/dusty	1					1
	1,3%					
Black/grey lines along the document		1				1
		3,2%				0,9%
Low/moderate quality in general		1				1
		3,2%				0,9%
Low text quality					1	1
					1	0,9%

	HAM	FRA	MUC	CGN	SXF	Total
Askew, whole document scanned		2				2
		6,5%				1,9%
Askew, part not scanned	1					1
	1,3%					0,9%
Askew, part not scanned, data missing	1					1
	1,3%					0,9%
Askew and misplaced, part not scanned		1				1
		3,2%				0,9%
Incorrectly saved		3				3
		9,7%				2,8%
Workshop Report (WR)						
Nbr of ZID´s with at least one Workshop-Report	4	6				10
% of ZID´s with Workshop-Report for each location	0	0				
Nbr of tested Workshop reports	6	9				15
Nbr of tested documents with at least one error	6	3				9
	100,0%	33,3%				60,0%
Black/grey lines along the document	3					3
	50,0%					20,0%
Low text quality	2					2
	33,3%					13,3%
Askew, part not scanned	2					2
	33,3%					13,3%
Askew, part not scanned, data missing	1					1
	16,7%					6,7%
Incorrectly saved	1	3				4
	0	0				0

	HAM	FRA	MUC	CGN	SXF	Total
No ZID-barcode	3					3
	50,0%					20,0%
Repair Order (RO)						
Nbr of ZID´s with at least one Repair-Order	10	4	0	2	2	18
% of ZID´s with Repair-Order for each location	7,9%	4,1%	0,0%	22,2%	40,0%	
Nbr of tested Repair orders	17	7	0	2	2	28
Nbr of tested documents with at least one error	12	4				16
	70,6%	57,1%				57,1%
Black fields (or completely black)	1					1
	5,9%					3,6%
Dark	3					3
	17,6%					10,7%
Dirty/dusty	4					4
	23,5%					14,3%
Black/grey lines along the document	9	3				12
	52,9%	42,9%				42,9%
Askew, whole document scanned	3					3
	17,6%					10,7%
Askew, part not scanned		1				1
		14,3%				
Askew, part not scanned, data missing	1	2				3
	5,9%	28,6%				10,7%
Incorrectly saved	2					2
	11,8%					7,1%

Appendix B – Failure images

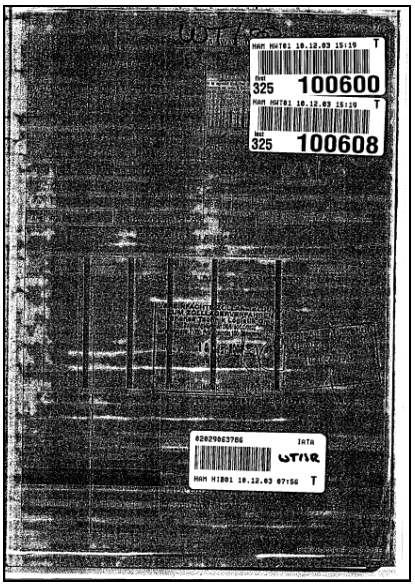

Image 1. Completely black AWB.

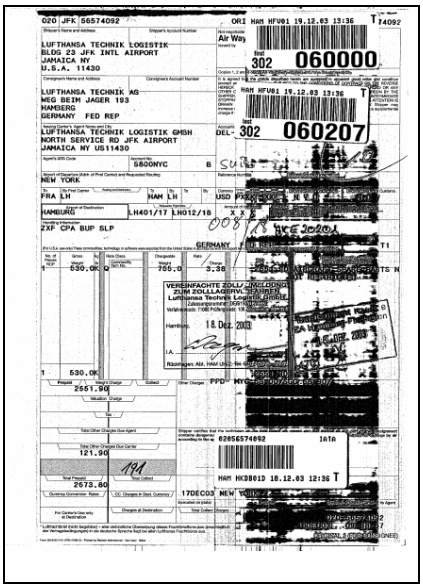

Image 2. Black fields on AWB.

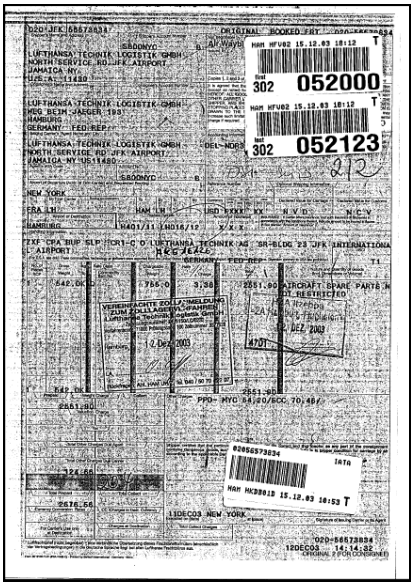

Image 3. Dark AWB

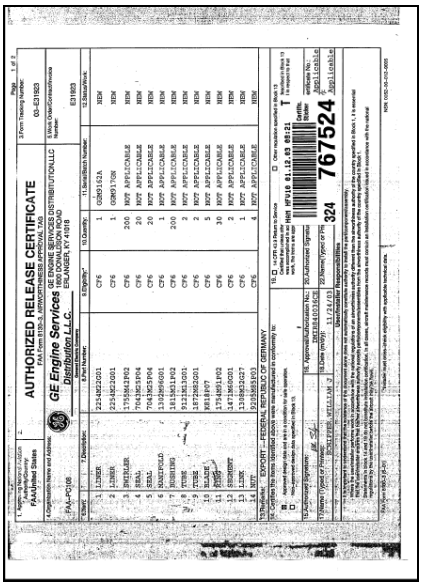

Image 4. Dark authorized release certificate

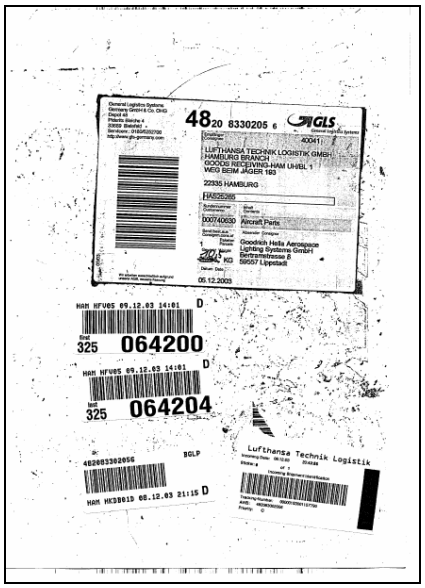

Image 5. Dirty AWB

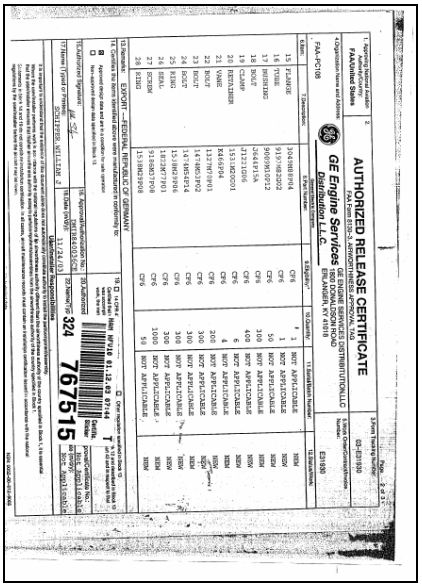

Image 6. Authorized release certificate with low quality in general.

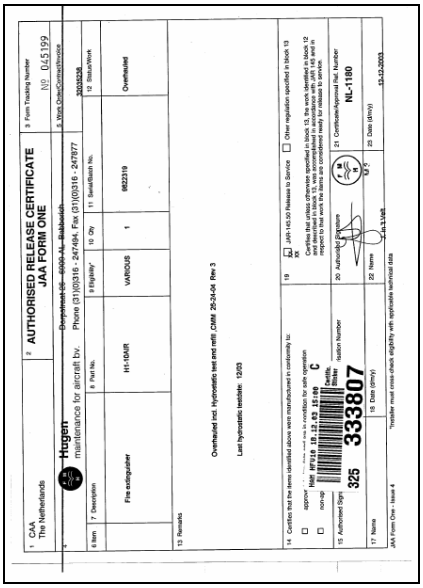

Image 7. Black line along authorized release certificate.

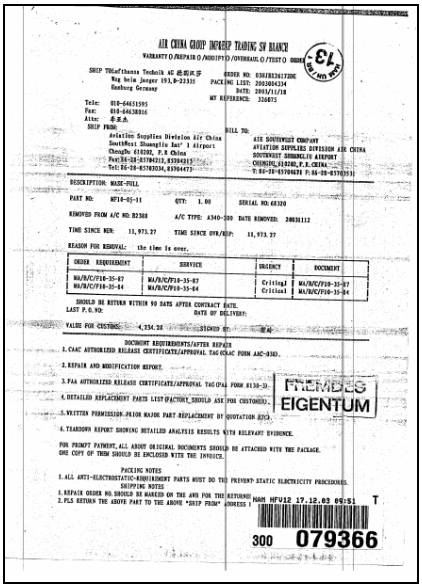

Image 8. Grey lines along repair order.

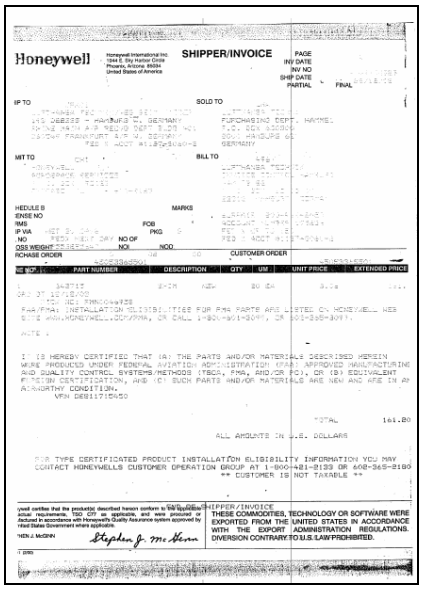

Image 9. Low text quality on delivery note.

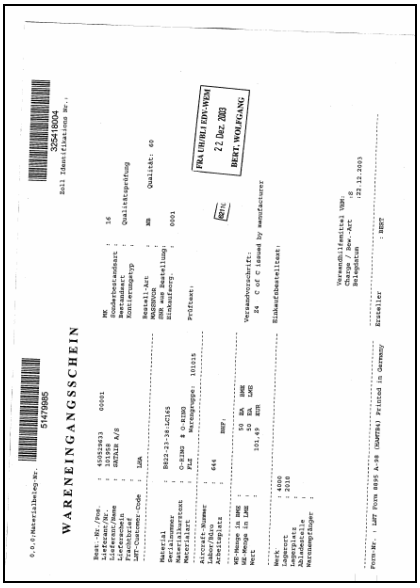

Image 10. Askew stock receipt document, whole document scanned.

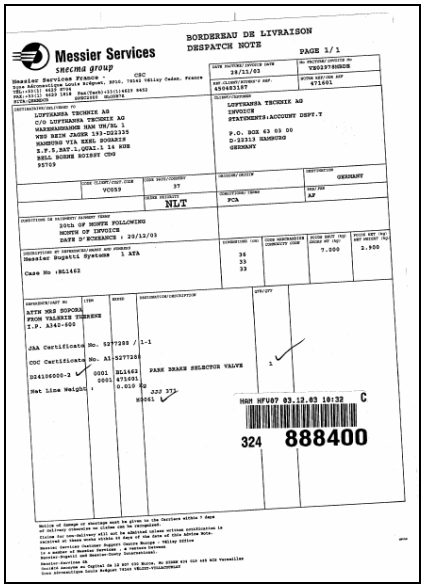

Image 11. Askew delivery note, part of document not scanned.

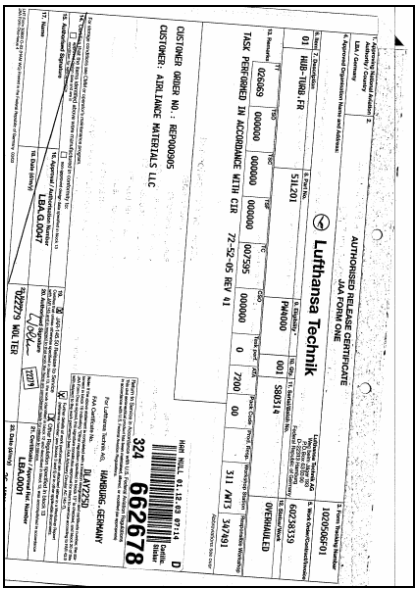

Image 12. Askew and misplaced certificate, data missing.

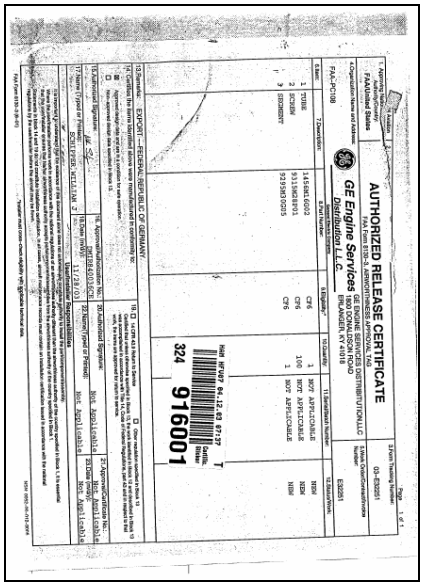

Image 13. Ripped authorized release certificate

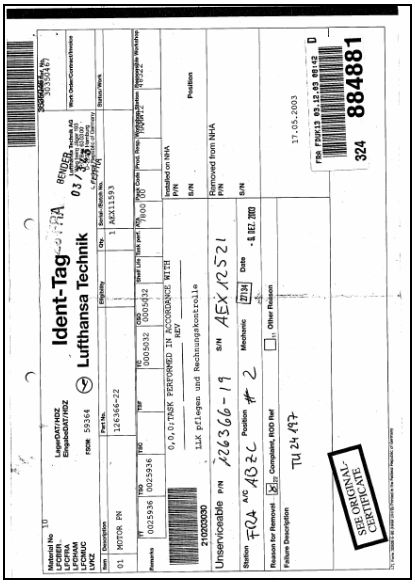

Image 14. Knicked ident tag

Image 15. Wrinkled AWB.

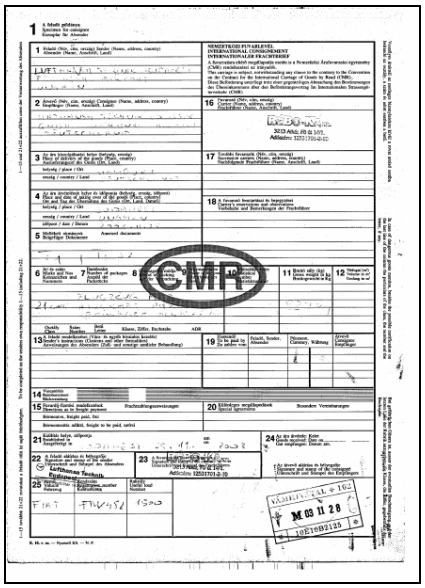

Image 16. Handwriting, difficult to read on AWB

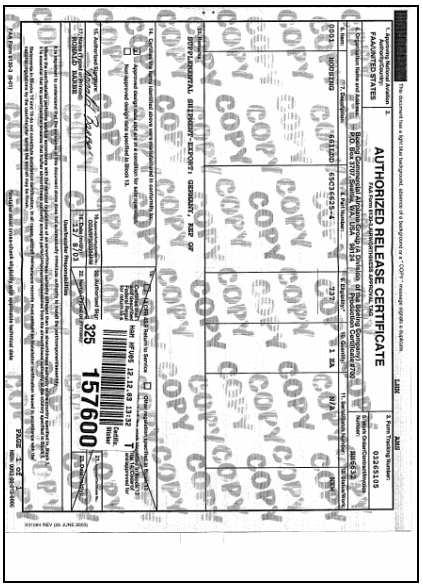

Image 17. Background pattern on certificate.

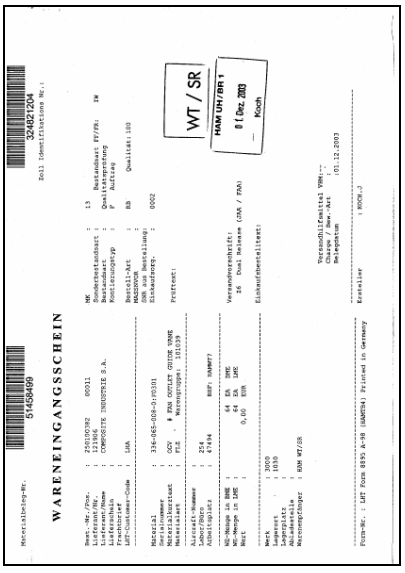

Image 18. Stock receipt document scanned with a high quality.

Appendix C – FMEA rating criterias

Criterias and considerations regarding the construction of the severity rating scale.

Rank: 10
Severity: Hazardous
Criterias: The effect of a failure mode will always be rated with a 10 if:

- a part, no matter if it is considered ”cheap” or ”expensive”, risks to be scrapped because of a nonconforming documentation.
- a part risks to be delivered without a required or with a less than 100% readable Cert, WR or IT. The beklonging part then risk to be considered as unapproved.
- it might cause a noncompliance with government regulations. This could later result in fines or commercial restrictions.

Rank: 9
Severity: Very high
Criterias: The effect of a failure mode will always be rated with a 9 if:

- a secondary clarification risks to follow because of a missing Cert, AWB, IT or WR. These four document types are considered more important and more difficult to reproduce than DN, Cert, AWB, IT and WR. A clarification caused by these important documents are therefore consistently ranked two steps higher than a clarification caused by the documents considered less important. A secondary clarification is consistantly ranked higher than a primary clarification. This is because a secondary clarification automatically includes customer dissatisfaction.
- a part risks to be delivered without its DN, WEB, or AWB.

Rank: 8
Severity: High
Criterias: The effect of a failure mode will always be rated with an 8 if:

- a secondary clarification risks to follow because of an error prone Cert, AWB, IT or WR.
- a primary clarification risks to follow because of a missing Cert, AWB, IT or WR.
- a Cert can not be automatically recognised.
- a part risks to be delivered with incorrectly saved documents.

Rank: 7
Severity: Moderately high
Criterias: The effect of a failure mode will always be rated with a 7 if:

- a primary clarification risks to follow because of an error-prone Cert, AWB, IT or WR.

- a sencondary clarification risks to follow because of a missing DN, Cert, AWB, IT or WR.
- customers risk to be very dissatisfied. Missing documents and unreadable data are failures that may cause great dissatisfaction.

Rank: 6
Severity: Moderate
Criterias: The effect of a failure mode will always be rated with a 6 if:

- a secondary clarification risks to follow because of an error-prone Cert, AWB, IT or WR.
- a primary clarification risks to follow because of a missing DN, WEB or RO.
- customers risk to be dissatisfied because of serious quality deficits. However, the text must still be readable for this rating. Otherwise the customer dissatisfaction shall be rated with a 7.

Rank: 5
Severity: Low
Criterias: The effect of a failure mode will always be rated with a 5 if:

- a primary clarification risks to follow because of an error-prone DN, WEB or RO.
- customers risk to be moderately dissatisfied. Less sever “cosmetical” errors belong to this category.

Rank: 4
Severity: Very low
Criterias: The effect of a failure mode will always be rated with a 4 if:

- customers risk to be slightly dissatisfied. No sever quality defects are present. A slightly askew or misplaced image may cause a slight dissatisfaction.
- a document has to be re-scanned.

Rank: 3
Severity: Minor
Criterias: The effect of a failure mode will always be rated with a 3 if:

- it has a light effect on the performance.

Rank: 2
Severity: Very minor
Criterias: The effect of a failure mode will always be rated with a 2 if:

- the effect will not annoy the customers at all.
- it has a very slight effect on the performance.

Rank: 1
Severity: None
Criterias: The effect of a failure mode will always be rated with a 2 if:

- it has no effect at all on the performance.

Considerations regarding the determining of detection

Rating: 10
No failures were considered to be this difficult to detect and correct.

Rating: 9
Failures which risk to make an automatical certificate recognition impossible are difficult to detect. The only chance to detect and correct such failures is direct in the scan process. Certificates with slight quality deficits that are difficult to detect may be impossible for the OCR-software to read.
It is also very difficult to foresee that a document will have to be rescanned and failures which risk to cause this effect are therefore rated with a 9.

Rating: 8
Failures that are usually only detected and corrected when they are scanned are always ranked with an 8. WEB, WR and RO are seldom controlled when a part is ordered and delivered. Failures on these documents which risk:

- that a document is delivered with a <100% readable document
- that a part is delivered with a document missing
- to cause a noncompliancee with government regulations
- to cause customer dissatisfaction

are therefore rated at this level.
Failures which may cause a primary clarification also receive a detection ranking of 8. If these failures shall be corrected *before* they may cause a primary clarification, they preferably should be detected direct as the document is scanned. All document types receive the same ranking since no difference in the probability of detection could be observed between the different document types in this case.

Rating: 7
Failures on Cert, DN, AWB and IT´s which risk:

- that a document is delivered with a <100% readable document
- that a part is delivered with a document missing
- to cause a noncompliancee with government regulations
- to cause customer dissatisfaction

are rated with a 7 since they are more often controlled than the document types rated with an 8 for the same failures and effects.

Rating: 6
The probability to detect a failure before it causes a secondary clarification is a higher than the probabily to detect it before it causes a primary clarification. The customer normally informs LTL if there are any specific documentation requirements. The documents are then controlled before the part is delivered. A detected deficit would then cause a primary clarification. If the defect runs through the control at LTL, a secondary clarification may follow if the customer detects the defect. WR, WEB and RO with failures which may cause a secondary clarification are less often controlled at LTL than other documents.

Rating: 5
Failures on Cert, AWB, DN or IT which risk to cause a secondary clarification are more often detected than than failures on the documents described for rating 6 because of a more frequent control.

Rating: 4, 3, 2 and 1
No failures where found to be detected and corrected this often.

Appendix D – FMEA worksheet

System FMEA Process worksheet

Process Name: Document processing **Prepared by**: Pär Rosenquist, Thomas Wilms, Christian Hettrich, Jürgen Lumpe **FMEA date**: 2003.11 - 2004.04

	Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
1.	**Document sorting**	Sorted in wrong pile	Primary clarification, part release	Co-worker related causes	Cert, AWB, IT, WR	1, 2, 3, 4	7	8	8	**448**	8
					DN, SRD, RO	1, 2, 3, 4	5	8	8	**320**	20
			Secondary clarification, part release	Co-worker related causes	Cert, AWB, IT	1, 2, 3, 4	8	8	5	**320**	20
					WR	1, 2, 3, 4	8	8	6	**384**	13
					DN	1, 2, 3, 4	6	8	5	**240**	27
					SRD, RO	1, 2, 3, 4	6	8	6	**288**	23
			Dissatisfied customers	Co-worker related causes	Cert, DN, AWB, IT	1, 2, 3, 4	6	8	7	**336**	18
					SRD, WR, RO	1, 2, 3, 4	6	8	8	**384**	13
			Part delivered and used with incorrectly saved documents	Co-worker related causes	Cert, DN, AWB, IT	1, 2, 3, 4	8	8	7	**448**	8
					SRD, WR, RO	1, 2, 3, 4	8	8	8	**512**	4
		Document is missing	Primary clarification, part release	Document was never delivered from supplier	Cert	1, 2, 3, 4	8	7	8	**448**	8
				Document is lost somewhere at LTL							
			Primary clarification, scrapping	Document was never delivered from supplier	Cert	1, 2, 3, 4	10	7	8	**560**	3
				Document is lost somewhere at LTL							
			Secondary clarification, part release	Document was never delivered from supplier	Cert	1, 2, 3, 4	9	7	5	**315**	21

	Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
				Document is lost somewhere at LTL							
			Secondary clarification, scrapping	Document was never delivered from supplier	Cert	1, 2, 3, 4	10	7	5	**350**	16
				Document is lost somewhere at LTL							
			Noncompliance with government regulation	Document was never delivered from supplier	Cert	1, 2, 3, 4	10	7	7	**490**	6
				Document is lost somewhere at LTL							
			Dissatisfied customers	Document was never delivered from supplier	Cert	1, 2, 3, 4	7	7	7	**343**	17
				Document is lost somewhere at LTL							
			Part delivered and used with document(s) missing. Suspected unapproved parts in LHT material currency	Document was never delivered from supplier	Cert	1, 2, 3, 4	10	7	7	**490**	6
				Document is lost somewhere at LTL							
2	**Applying ZID-barcode**	No ZID-barcode applied (and incorrectly saved)	Primary clarification, part release	Co-worker related causes	Cert, AWB, IT, WR	2, 3, 4	7	6	8	**336**	18
					DN, SRD, RO	2, 3, 4	5	6	8	**240**	27
			Secondary clarification, part release	Co-worker related causes	Cert, AWB, IT	2, 3, 4	8	6	5	**240**	27
					WR	2, 3, 4	8	6	6	**288**	23
					DN	2, 3, 4	6	6	5	**180**	33
					SRD, RO	2, 3, 4	6	6	6	**216**	29
			Dissatisfied customers	Co-worker related causes	Cert, DN, AWB, IT	2, 3, 4	4	6	7	**168**	35

Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
				SRD, WR, RO	2, 3, 4	4	6	8	**192**	32
		Part delivered and used with incorrectly saved documents	Co-worker related causes	Cert, DN, AWB, IT	2, 3, 4	8	6	7	**336**	18
				SRD, WR, RO	2, 3, 4	8	6	8	**384**	13
	Wrong ZID-barcode applied	Primary clarification, part release	Co-worker related causes	Cert, AWB, IT, WR	2, 3, 4	7	2	8	**112**	40
				DN, SRD, RO	2, 3, 4	5	2	8	**80**	45
		release	Co-worker related causes	Cert, AWB, IT	2, 3, 4	8	2	5	**80**	45
				WR	2, 3, 4	8	2	6	**96**	43
				DN	2, 3, 4	6	2	5	**60**	49
				SRD, RO	2, 3, 4	6	2	6	**72**	46
		Dissatisfied customers	Co-worker related causes	Cert, DN, AWB, IT	2, 3, 4	4	2	7	**56**	50
				SRD, WR, RO	2, 3, 4	4	2	8	**64**	48
		Part delivered and used with incorrectly saved documents	Co-worker related causes	Cert, DN, AWB, IT	2, 3, 4	8	2	7	**112**	40
				SRD, WR, RO	2, 3, 4	8	2	8	**128**	38
	ZID-barcode incorrectly placed, covering important data	Primary clarification, part release	Co-worker related causes	Cert, AWB, IT, WR	2, 3, 4	7	2	8	**112**	40
				DN, SRD, RO	2, 3, 4	5	2	8	**80**	45
		Secondary clarification, part release	Co-worker related causes	Cert, AWB, IT	2, 3, 4	8	2	5	**80**	45
				WR	2, 3, 4	8	2	6	**96**	43
				DN	2, 3, 4	6	2	5	**60**	49
				SRD, RO	2, 3, 4	6	2	6	**72**	46
		Dissatisfied customers		Cert, DN, AWB, IT	2, 3, 4	7	2	7	**98**	42
				SRD, WR, RO	2, 3, 4	7	2	8	**112**	40

	Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
			Part delivered and used with important data not archived	Co-worker related causes	AWB, DN	2, 3, 4	8	2	7	**112**	40
					SRD, WR, RO	2, 3, 4	8	2	8	**128**	38
			Part delivered and used with important data not archived, suspected unapproved parts in LHT material currency	Co-worker related causes	Cert, IT	2, 3, 4	10	2	7	**140**	37
					WR	2, 3, 4	10	2	8	**160**	36
3.1	**ZID-barcode scanning**	Wrong index barcode scanned	Primary clarification, part release	Co-worker related causes	Cert, AWB, IT, WR	2, 3, 4	7	8	8	**448**	8
					DN, SRD, RO	2, 3, 4	5	8	8	**320**	20
			Secondary clarification, part release	Co-worker related causes	Cert, AWB, IT	2, 3, 4	8	8	5	**320**	20
					WR	2, 3, 4	8	8	6	**384**	13
					DN	2, 3, 4	6	8	5	**240**	27
					SRD, RO	2, 3, 4	6	8	6	**288**	23
			Dissatisfied customers	Co-worker related causes	Cert, DN, AWB, IT	2, 3, 4	6	8	7	**336**	18
					SRD, WR, RO	2, 3, 4	6	8	8	**384**	13
			Part delivered and used with incorrectly saved documents	Co-worker related causes	Cert, DN, AWB, IT	2, 3, 4	8	8	7	**448**	8
					SRD, WR, RO	2, 3, 4	8	8	8	**512**	4
3.2	**Document scanning**	Black fields/shadows on image	Primary clarification, part release	Document paper quality	AWB	2, 3, 4	7	9	8	**504**	5
				Scanner features	IT	2, 3, 4	7	8	8	**448**	8
					Cert, WR	2, 3, 4	7	6	8	**336**	18
					DN	2, 3, 4	5	7	8	**280**	24
					SRD, RO	2, 3, 4	5	6	8	**240**	27

Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
		Secondary clarification, part release	Document paper quality	AWB	2, 3, 4	8	9	5	**360**	15
			Scanner features	IT	2, 3, 4	8	8	5	**320**	20
				Cert	2, 3, 4	8	6	5	**240**	27
				DN	2, 3, 4	6	7	5	**210**	30
				WR	2, 3, 4	8	6	6	**288**	23
				SRD, RO	2, 3, 4	6	6	6	**216**	29
		Dissatisfied customers	Document paper quality	AWB	2, 3, 4	7	9	7	**441**	9
			Scanner features	IT	2, 3, 4	7	8	7	**392**	12
				Cert	2, 3, 4	7	6	7	**294**	22
				DN	2, 3, 4	7	7	7	**343**	17
				SRD, WR, RO	2, 3, 4	7	6	8	**336**	18
		Part is delivered and used with a <100% readable document	Document paper quality	AWB	2, 3, 4	8	9	7	**504**	5
			Scanner features	DN	2, 3, 4	8	7	7	**392**	12
				SRD, RO	2, 3, 4	8	6	8	**384**	13
		Part is delivered and used with a <100% readable document, suspected unapproved parts in LHT material currency	Document paper quality	WR	2, 3, 4	10	6	8	**480**	7
			Scanner features	Cert	2, 3, 4	10	7	7	**490**	6
				IT	2, 3, 4	10	8	7	**560**	3
		Noncompliance with government regulations	Document paper quality	Cert	2, 3, 4	10	7	7	**490**	6
			Scanner features	WR	2, 3, 4	10	7	8	**560**	3
				IT	2, 3, 4	10	8	7	**560**	3
				AWB	2, 3, 4	10	9	7	**630**	**2**
		Document is re-scanned	Document paper quality	AWB	1	4	9	9	**324**	19

Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
			Scanner features	IT	1	4	8	9	**288**	23
				Cert, DN, WR, SRD, RO	1	4	7	9	**252**	25
	Image is dark	Dissatisfied customers	Document paper quality	AWB, IT	2, 3, 4	6	9	7	**378**	14
			Scanner features	DN, Cert	2, 3, 4	6	8	7	**336**	18
				SRD, WR, RO	2, 3, 4	6	5	8	**240**	27
		Document is re-scanned	Document paper quality	AWB, IT	1	4	9	9	**324**	19
			Scanner features	DN, Cert	1	4	8	9	**288**	23
			Original doc is dirty	SRD, WR, RO	1	4	5	9	**180**	33
	Black lines along document	Dissatisfied customers	Document features	IT, AWB, DN, Cert	2, 3, 4	5	9	7	**315**	21
			Scanner features	SRD, WR, RO	2, 3, 4	5	9	8	**360**	15
		Document is re-scanned	Document features?	IT, AWB, DN, Cert, SRD, WR, RO	1	4	9	9	**324**	19
	Image is of low quality in general	Dissatisfied customers	Document paper quality	IT	2, 3, 4	5	9	7	**315**	21
			Scanner features	AWB, DN, Cert.	2, 3, 4	5	8	7	**280**	24
				SRD, WR, RO	2, 3, 4	5	3	8	**120**	39
		Document is re-scanned	Document paper quality	IT	1	4	9	9	**324**	19
			Scanner features	AWB, DN, Cert.	1	4	8	9	**288**	23
				SRD, WR, RO	1	4	3	9	**108**	41
	Low text quality	Dissatisfied customers	Original document with low text quality	AWB, DN, Cert	2, 3, 4	5	6	7	**210**	30
			Document paper quality	IT	2, 3, 4	5	8	7	**280**	24
			Scanner features	SRD, WR, RO	2, 3, 4	5	6	8	**240**	27
		Document is re-scanned	Original document with low text quality	AWB, DN, Cert, SRD, WR, RO	1	4	6	9	**216**	29
			Document paper quality	IT	1	4	8	9	**288**	23

Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
			Scanner features		1					
	Askew, whole doc scanned	Dissatisfied customers	Scanner features	AWB, Cert, IT	2, 3, 4	4	8	7	**224**	28
			Document format	DN	2, 3, 4	4	9	7	**252**	25
			Co-worker related	SRD, WR, RO	2, 3, 4	4	5	8	**160**	36
			Scanning method							
		Document is re-scanned	Scanner features	AWB, Cert, IT	1	4	8	9	**288**	23
			Document format	DN	1	4	9	9	**324**	19
			Co-worker related	SRD, WR, RO	1	4	5	9	**180**	33
			Scanning method							
	Askew, part of doc not scanned	Dissatisfied customers	Scanner features	Cert	2, 3, 4	6	6	7	**252**	25
			Document format	IT	2, 3, 4	6	9	7	**378**	14
			Co-worker related	DN	2, 3, 4	6	8	7	**336**	18
			Scanning method	AWB	2, 3, 4	6	6	7	**252**	25
				SRD, WR, RO	2, 3, 4	6	6	8	**288**	23
		Document is re-scanned	Scanner features	Cert	1	4	6	9	**216**	29
			Document format	IT	1	4	9	9	**324**	19
			Co-worker related	DN	1	4	8	9	**288**	23
			Scanning method	AWB, SRD, WR, RO	1	4	6	9	**216**	29
	Askew, part of doc not scanned, data missing	Dissatisfied customers	Scanner features	Cert	2, 3, 4	7	9	7	**441**	9
			Document format	IT, DN	2, 3, 4	7	8	7	**392**	12
			Co-worker related	AWB	2, 3, 4	7	6	7	**294**	22
			Scanning method	SRD, WR, RO	2, 3, 4	7	7	8	**392**	12
		Document is re-scanned	Scanner features	Cert, IT, DN	1	4	9	9	**324**	19
			Document format	AWB	1	4	6	9	**216**	29

Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
			Co-worker related	SRD, WR, RO	1	4	7	9	**252**	25
			Scanning method		1					
		Primary clarification, part release	Scanner features	Cert	2, 3, 4	7	9	8	**504**	5
			Document format	IT	2, 3, 4	7	8	8	**448**	8
			Co-worker related	DN	2, 3, 4	5	8	8	**320**	20
			Scanning method	WR	2, 3, 4	7	7	8	**392**	12
				AWB	2, 3, 4	7	6	8	**336**	18
				SRD, RO	2, 3, 4	5	7	8	**280**	24
		Secondary clarification, part release	Scanner features	Cert	2, 3, 4	8	9	5	**360**	15
			Document format	IT	2, 3, 4	8	8	5	**320**	20
			Co-worker related	DN	2, 3, 4	6	8	5	**240**	27
			Scanning method	WR	2, 3, 4	8	7	6	**336**	18
				AWB	2, 3, 4	8	6	5	**240**	27
				SRD, RO	2, 3, 4	6	7	6	**252**	25
		Part is delivered and used with missing data	Scanner features	DN	2, 3, 4	8	8	7	**448**	8
			Document format	AWB	2, 3, 4	8	6	7	**336**	18
			Co-worker related	SRD, RO	2, 3, 4	8	7	8	**448**	8
			Scanning method							
		Part is delivered and used with missing data, suspected unapproved parts in LHT material currency	Scanner features	Cert	2, 3, 4	10	9	7	**630**	**2**
			Document format	IT	2, 3, 4	10	8	7	**560**	3
			Co-worker related	WR	2, 3, 4	10	7	8	**560**	3
			Scanning method							

Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
		Nonconformance with government regulations	Scanner features	Cert	2, 3, 4	10	9	7	**630**	**2**
			Document format	IT	2, 3, 4	10	8	7	**560**	3
			Co-worker related	WR	2, 3, 4	10	7	8	**560**	3
			Scanning method	AWB	2, 3, 4	10	6	7	**420**	11
	Misplaced, part of document not scanned	Dissatisfied customers	Scanner features	IT	2, 3, 4	6	2	7	**84**	44
			Document format	AWB	2, 3, 4	6	5	7	**210**	30
			Co-worker related	DN	2, 3, 4	6	7	7	**294**	22
			Scanning method	Cert	2, 3, 4	6	8	7	**336**	18
				SRD, WR, RO	2, 3, 4	6	2	8	**96**	43
		Document is re-scanned	Scanner features	IT	1	4	2	9	**72**	46
			Document format	AWB	1	4	5	9	**180**	33
			Co-worker related	DN	1	4	7	9	**252**	25
			Scanning method	Cert	1	4	8	9	**288**	23
				SRD, WR, RO	1	4	2	9	**72**	46
	Misplaced, part of document not scanned, data missing	Dissatisfied customers	Scanner features	Cert	2, 3, 4	7	8	7	**392**	12
			Document format	IT	2, 3, 4	7	2	7	**98**	42
			Co-worker related	DN	2, 3, 4	7	7	7	**343**	17
			Scanning method	AWB	2, 3, 4	7	5	7	**245**	26
				SRD, WR, RO	2, 3, 4	7	2	8	**112**	40
		Document is re-scanned	Scanner features	Cert	1	4	8	9	**288**	23
			Document format	DN	1	4	7	9	**252**	25
			Co-worker related	AWB	1	4	5	9	**180**	33

Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
			Scanning method	IT, SRD, WR, RO	1	4	2	9	**72**	46
		Primary clarification, part release	Scanner features	Cert	2, 3, 4	7	8	8	**448**	8
			Document format	IT, WR	2, 3, 4	7	2	8	**112**	40
			Co-worker related	AWB, DN	2, 3, 4	5	7	8	**280**	24
			Scanning method	SRD, RO	2, 3, 4	5	2	8	**80**	45
		Secondary clarification, part release	Scanner features	Cert	2, 3, 4	8	8	5	**320**	20
			Document format	IT	2, 3, 4	8	2	5	**80**	45
			Co-worker related	DN	2, 3, 4	6	7	5	**210**	30
			Scanning method	WR	2, 3, 4	8	2	6	**96**	43
				AWB	2, 3, 4	8	5	5	**200**	31
				SRD, RO	2, 3, 4	6	2	6	**72**	46
		Part is delivered and used with missing data	Scanner features	DN	2, 3, 4	8	7	7	**392**	12
			Document format	AWB	2, 3, 4	8	5	7	**280**	24
			Co-worker related	SRD, RO	2, 3, 4	8	2	8	**128**	38
			Scanning method							
		Part is delivered and used with missing data, suspected unapproved parts in LHT material currency	Scanner features	Cert	2, 3, 4	10	8	7	**560**	3
			Document format	IT	2, 3, 4	10	2	7	**140**	37
			Co-worker related	WR	2, 3, 4	10	2	8	**160**	36
			Scanning method							
		regulations	Scanner features	Cert	2, 3, 4	10	8	7	**560**	3
			Document format	IT	2, 3, 4	10	2	7	**140**	37
			Co-worker related	WR	2, 3, 4	10	2	8	**160**	36

Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
			Scanning method	AWB	2, 3, 4	10	5	7	**350**	16
	Askew and misplaced, part of doc not scanned	Dissatisfied customers	Scanner features	AWB, Cert	2, 3, 4	6	2	7	**84**	44
			Document format	DN, IT	2, 3, 4	6	8	7	**336**	18
			Co-worker related	SRD, WR, RO	2, 3, 4	6	2	8	**96**	43
			Scanning method							
		Document is re-scanned	Scanner features	AWB, Cert, SRD, WR, RO	1	4	2	9	**72**	46
			Document format	DN, IT	1	4	8	9	**288**	23
			Co-worker related							
			Scanning method							
	Askew and misplaced, part of doc not scanned, data missing	Dissatisfied customers	Scanner features	IT, AWB	2, 3, 4	7	2	7	**98**	42
			Document format	Cert, DN	2, 3, 4	7	8	7	**392**	12
			Co-worker related	SRD, WR, RO	2, 3, 4	7	2	8	**112**	40
			Scanning method							
		Document is re-scanned	Scanner features	IT, AWB, SRD, WR, RO	1	4	2	9	**72**	46
			Document format	Cert, DN	1	4	8	9	**288**	23
			Co-worker related							
			Scanning method							
		Primary clarification, part release	Scanner features	IT, AWB, WR	2, 3, 4	7	2	8	**112**	40
			Document format	DN	2, 3, 4	5	8	8	**320**	20
			Co-worker related	Cert	2, 3, 4	7	8	8	**448**	8
			Scanning method	SRD, RO	2, 3, 4	5	2	8	**80**	45

Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
		Secondary clarification, part release	Scanner features	IT, AWB	2, 3, 4	8	2	5	**80**	45
			Document format	DN	2, 3, 4	6	8	5	**240**	27
			Co-worker related	Cert	2, 3, 4	8	8	5	**320**	20
			Scanning method	WR	2, 3, 4	8	2	6	**96**	43
				SRD, RO	2, 3, 4	6	2	6	**72**	46
		Part is delivered and used with missing data	Scanner features	DN	2, 3, 4	8	8	7	**448**	8
			Document format	AWB	2, 3, 4	8	2	7	**112**	40
			Co-worker related	SRD, RO	2, 3, 4	8	2	8	**128**	38
			Scanning method							
		missing data, suspected	Scanner features	Cert	2, 3, 4	10	8	7	**560**	3
			Document format	IT	2, 3, 4	10	2	7	**140**	37
			Co-worker related	WR	2, 3, 4	10	2	8	**160**	36
			Scanning method							
		Nonconformance with government regulations	Scanner features	AWB, IT	2, 3, 4	10	2	7	**140**	37
			Document format	Cert	2, 3, 4	10	8	7	**560**	3
			Co-worker related	WR	2, 3, 4	10	2	8	**160**	36
			Scanning method							
	Not readable handwriting	Dissatisfied customers	Not readable handwriting on original document	AWB	1, 2, 3, 4	5	7	7	**245**	26
			Scanner features	IT, DN, Cert	1, 2, 3, 4	5	2	7	**70**	47
				SRD, WR, RO	1, 2, 3, 4	5	2	8	**80**	
	Paper background (Copy, copy...)	Dissatisfied customers	Original document paper features	Cert	1, 2, 3, 4	6	8	7	**336**	18

Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
			Scanner features	IT, AWB, DN, Cert	1, 2, 3, 4	6	1	7	**42**	53
				SRD, WR, RO	1, 2, 3, 4	6	1	8	**48**	52
	Document ripped	Dissatisfied customers	Original document ripped	IT, AWB, DN, Cert	1, 2, 3, 4	6	5	7	**210**	30
				SRD, WR, RO	1, 2, 3, 4	6	5	8	**240**	27
	Document knicked	Dissatisfied customers	Original document knicked	IT	1, 2, 3, 4	5	9	7	**315**	21
				Cert	1, 2, 3, 4	5	8	7	**280**	24
				AWB	1, 2, 3, 4	5	5	7	**175**	34
				DN	1, 2, 3, 4	5	2	7	**70**	47
				SRD, WR, RO	1, 2, 3, 4	5	2	8	**80**	45
	Document wrinkled	Dissatisfied customers	Original document wrinkled	IT, DN, Cert	1, 2, 3, 4	6	2	7	**84**	44
				AWB	1, 2, 3, 4	6	7	7	**294**	22
				SRD, WR, RO	1, 2, 3, 4	6	2	8	**96**	43
	Document is not being scanned	Primary clarification, part release	Co-worker related causes	Cert	3, 4	7	7	8	**392**	12
		Secondary clarification, part release	Co-worker related causes	Cert	3, 4	8	7	5	**280**	24
		Dissatisfied customers	Co-worker related causes	Cert	3, 4	7	7	7	**343**	17
					3, 4	6	7	8	**336**	18
		Part is delivered and used without scanned document(s), suspected unapproved parts in LHT material currency	Co-worker related causes	Cert	3, 4	10	7	7	**490**	6
		Nonconformance with government regulations	Co-worker related causes	Cert	3, 4	10	7	7	**490**	6
	Part(s) of document have not been scanned	Primary clarification, part release	Original document features	Cert, AWB, IT, WR	1, 2, 3, 4	7	1	8	**56**	50

	Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
		(other causes than askew/misplaced)			DN, SRD, RO	1, 2, 3, 4	5	1	8	**40**	54
			Secondary clarification, part release	Original document features	Cert, AWB, IT	1, 2, 3, 4	8	1	5	**40**	54
					WR	1, 2, 3, 4	8	1	6	**48**	52
					DN, SRD, RO	1, 2, 3, 4	6	1	5	**30**	55
			Dissatisfied customers	Original document features	Cert, DN, AWB, IT	1, 2, 3, 4	7	1	7	**49**	51
					SRD, WR, RO	1, 2, 3, 4	7	1	8	**56**	50
			Part is delivered and used with partly not scanned document(s)	Original document features	Cert, DN, AWB, IT	1, 2, 3, 4	8	1	7	**56**	50
					SRD, WR, RO	1, 2, 3, 4	8	1	8	**64**	48
			Nonconformance with government regulations	Original document features	Cert, AWB, IT	1, 2, 3, 4	10	1	7	**70**	47
					WR	1, 2, 3, 4	10	1	8	**80**	45
4	**Saving document**	Document saved in wrong folder in ELO OPAL	Primary clarification, part release	Manually incorrectly saved	AWB, IT, WR	3, 4	7	8	8	**448**	8
					SRD, RO	3, 4	5	8	8	**320**	20
				Wrong ZID-Barcode	Cert	3, 4	7	8	8	**448**	8
				Manually incorrectly saved	DN	3, 4	5	8	8	**320**	20
			Secondary clarification, part release	Manually incorrectly saved	AWB, IT	3, 4	8	8	5	**320**	20
					WR	3, 4	8	8	6	**384**	13
					SRD, RO	3, 4	6	8	6	**288**	23
				Wrong ZID-Barcode	Cert	3, 4	6	8	5	**240**	27
				Manually incorrectly saved	DN	3, 4	8	8	5	**320**	20
			Dissatisfied customers	Manually incorrectly saved	AWB, IT	3, 4	6	8	7	**336**	18
					SRD, WR, RO	3, 4	6	8	8	**384**	13

	Process	Possible Mode	Possible Effect	Possible Cause	Document	Control system	SEV	OCC	DET	RPN	Rank
				Wrong ZID-Barcode	Cert, DN	3, 4	6	8	7	**336**	18
				Manually incorrectly saved		3, 4					
			Part delivered and used with incorrectly saved documents	Co-worker related causes	AWB, IT	3, 4	8	8	7	**448**	8
					SRD, WR, RO	3, 4	8	8	8	**512**	4
				Wrong ZID-Barcode	Cert, DN	3, 4	8	8	7	**448**	8
				Manually incorrectly saved		3, 4					
		Document not saved in ELO OPAL	Primary clarification, part release	Co-worker related causes	Cert	3, 4	7	7	8	**392**	12
			Secondary clarification, part release	Co-worker related causes	Cert, AWB, IT	3, 4	8	7	5	**280**	24
			Dissatisfied customers	Co-worker related causes	Cert, DN, AWB, IT	3, 4	7	7	7	**343**	17
			Suspected unapproved parts in LHT material currency	Co-worker related causes	Cert, IT	3, 4	10	7	7	**490**	6
5	**OCR**	Authorized release certificate is not automatically recognised	Document has to be manually recognised	Low image quality	Cert	1, 2	8	9	9	**648**	**1**
				Rare typeface							
				Data missing							
				Software problems							