University of Bremen

Knowledge Management for Failure Analysis

Implementation of knowledge management within the process of Failure Analysis

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Declaration

I certify that I have prepared the Bachelor Report without outside help. I have not used any sources and aids other than those indicated. All passages that are taken verbatim or in spirit from publications are marked as such.

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Felix Ziegler

With special thanks to

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Contents

Chapter 1

Introduction

Aircrafts are generally considered to be one of the safest forms of transport. The chance of an aircraft having a bad accident was 1 in 2 million in 2019 (Eiselin, 2019). If failures or unusual events do occur, specialists from the manufacturer look for the causes in the Failure Analysis (sometimes abbreviated as FA in the course of the work). Among other things, the work of Failure Analysis has led to a two-thirds reduction in aviation casualties over the last 20 years (Eiselin, 2019). Besides a lot of technical knowledge (explicit knowledge), the experts in Failure Analysis also need experience in the practical implementation of test and analysis methods (tacit knowledge). In the process, they constantly generate new knowledge. Therefore, the process of Failure Analysis can be considered knowledge-intensive (Barton et al., 2017). In order to distribute the large amount of existing knowledge, new knowledge and experience widely among the Failure Analysis staff, a functioning and efficient Knowledge Management (sometimes abbreviated as KM in the course of the work) is required. Knowledge Management does not only mean the technical equipment to share information faster. It also implies organizational conditions that continuously promote the sharing of knowledge (Mescheder and Sallach, 2012; Probst et al., 2012).

In the manufacturing industry, Failure Analysis plays an important role. It is not only concerned with the search for causes of damage. The results also have a great influence on future product development (Tawancy et al., 2004). Furthermore, the quality and safety of all products produced also depends on this process. On the other hand, existing resources, such as knowledge, may not be properly used in large companies to optimise this process (Saulais and Ermine, 2020). In view of this importance for manufacturing companies, a closer look at the process of Failure Analysis is needed. Since knowledge and experience play a major role in this process, the focus should be on generating and managing them, which requires aspects of Knowledge Management. Therefore, this thesis deals with the question:

Which aspects of Knowledge Management could be implemented in a highly specialized working environment within the process of Failure Analysis?

This thesis aims to analyze the process of Failure Analysis. Based on this, concrete suggestions will be discussed as to which aspects of Knowledge Management could actually be implemented. These will then finally be evaluated for their costs and feasibility.

To achieve these goals, the process of Failure Analysis must first be analyzed to gain an overview. The process of Failure Analysis is analyzed using a case study at Airbus Operations GmbH. Besides literature research, the analysis mainly includes expert interviews. This method was chosen because the experts are the stakeholders of the process and can provide the most important information (Gläser and Laudel, 2010; Kaiser, 2014). The results of the interviews are then evaluated in a Qualitative Content Analysis according to Mayring. Case studies are ideally suited as a field of application for information retrieval using Qualitative Content Analysis (Mayring, 2015). The results of the Qualitative Content Analysis are then used to develop a process model in BPMN (Business Process Modeling Notation). BPMN is the tool of choice, because it pursues the goal of correctly depicting business processes both from the perspective of the business unit and from the perspective of IT. The process model will then be used to make suggestions for the implementation of aspects of knowledge management that have already been obtained in the literature review.

The work begins with a theoretical introduction to the topic. There, the topics of Knowledge Management and Failure Analysis are discussed and related to each other. In addition, the aspects of Knowledge Management are presented on the basis of literature. This is followed by the methods section. Here, the methods used are described in more detail and their use is justified. It makes sense to explain the methods in detail, as the resulting findings are relevant for the next chapter. In the results section, the results from the interviews are discussed with regard to Failure Analysis and Knowledge management. This also includes a description of how process models were developed from the results. These are also part of the results section. The results should be thoroughly evaluated and discussed in the following. So the next chapter deals with the discussion of concrete aspects of Knowledge Management, which are also based on ideas from the interviewees. These discussed aspects are evaluated in the conclusion. The conclusion also contains an outlook on possible further research approaches.

Chapter 2

Theoretical basics

2.1 Failure Analysis

Precise calculation and construction of components, careful selection of materials, appropriate manufacturing and proper operation of machines and systems should ensure that damages do not occur. The emergence of damages is thereby usually exceptional, but still not uncommon. Besides the immediate property damages, it often results in production downtimes and sometimes personal injuries. Not least for this reason, avoiding damages is one of the most important tasks of an engineer (Bargel and Schulze, 2018).

The failures discussed here often refer to the failure of materials, for example a fracture in the material triggered by corrosion. However, there are also other causes of failure that occur in production, in-service or already during development. The Failure Analysis examines these causes of failure (Tawancy et al., 2004).

Failure Analysis describes the process from the appearence of a failure via the cause of damage investigation to the final report. The final report should not only include the investigation results which lead to the cause of damage, but also a proposal to correct the failure acutely and preventively (VDI-Fachbereich-Werkstofftechnik, 2011).

Failure Analysis is not only the investigation of the failure cause. It is also necessary to prevent failures in the future. The prevention of failures in general is the knowledge about weak spots and possible error sources. The course of technical development shows the impact of Failure Analysis to the general improvement (Schmitt-Thomas, 2009).

The results of a Failure Analysis are useful for designers of the same or a comparable

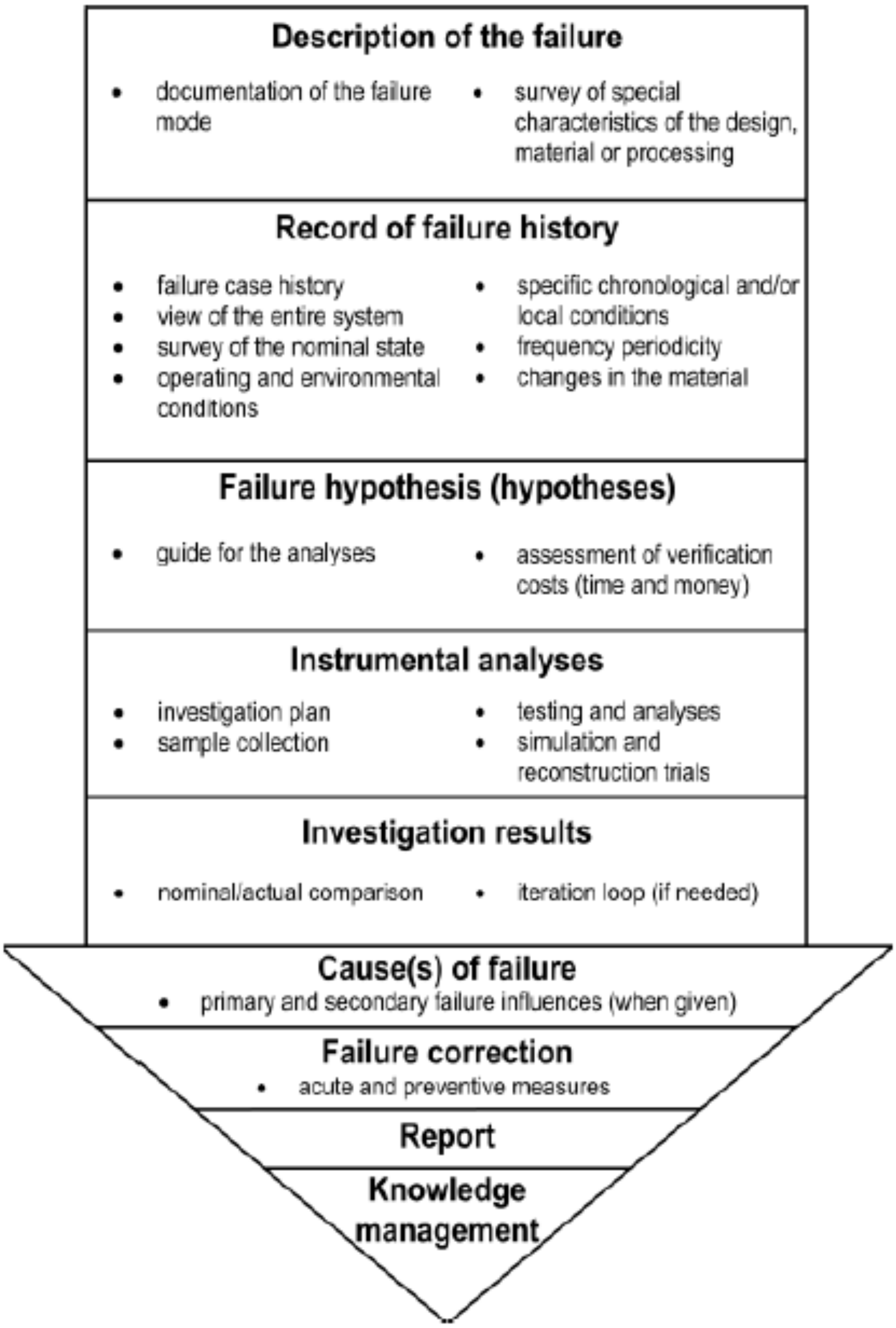

Figure 2.1: Performance of a Failure Analysis (VDI-Fachbereich-Werkstofftechnik, 2011)

product. With knowledge about former incidents, the development and quality of new and existing products improves. Also, results of failure analyses could be subject of legal proceedings as well (Tawancy et al., 2004).

Figure 2.1 is a process diagramm presented by the German association of engineers (VDI) and displays the different steps. Obviously, Knowledge Management is the last step in this figure. An explanation of Knowledge Management and its possible importance to Failure Analysis follows. This thesis shall give a closer look to the other steps later.

2.2 Explicit and Tacit Knowledge

According to Probst et al. (2012) knowledge describes the totality of knowledge and skills that individuals use to solve problems. This includes theoretical knowledge as well as practical daily rules and instructions. Although knowledge is based on data and information, it is always related to people. It is constructed by individuals and represents their expectations about cause and effect relationships (Probst et al., 2012).

Explicit Knowledge describes the universal, writable and transferable knowledge. It is displayed in sentences, drawings and writings. Explicit knowledge is saved in databases, libraries or archives (Nonaka, 1994; Nonaka and von Krogh, 2009). For companies, Explicit Knowledge is the key knowledge to produce or sell their products. It is easy to explain and to share with others. Examples for Explicit Knowledge are patents or specifications (Dubey and Kalwale, 2010).

Tacit Knowledge is described as personal knowledge based on intuition. It is hard to describe and therefore not easy to transfer to others. For example, employees are doing tasks experience-based. It is difficult for them to explain their actions to others (Mescheder and Sallach, 2012; Nonaka, 1994; Nonaka and von Krogh, 2009).
Tacit Knowledge could be divided into two components. There is the technical component which is composed of the elusive and poor documented "Know-How". Whereas the cognitive component is about values, ideals, attitudes and beliefs. It influences the way in which people perceive, judge and experience the world (Mescheder and Sallach, 2012). The differences between Explicit and Tacit Knowledge are displayed in Table 2.1.

Table 2.1: Tacit and Explicit Knowledge (Mescheder and Sallach, 2012)

	Explicit Knowledge	**Tacit Knowledge**
Character	knowing what, rules and facts, problem solving through systematic, logical formal derivation	knowing how, intuition and cognitive patterns, problem solving through analogies and heuristics
Acquisition	book learning, acquired context independent	experience-based, acquired contextually
Presentability	descriptive and easy to formalize	hard to describe
Knowledge carrier	traceable in documents and programs	linked personally
Transferability	easy to transfer	hard to transfer
Strengths	low error risk, easy to check	reflexive and quick usability, flexibel with uncertainty and inconsistencies
Weaknesses	huge time exposure at systematical application of knowledge, less flexibel with inconsistencies	higher error risk, hard to change and expand, hard to transfer to organizational knowledge, blockages of progress in the event of strong discrepancies between the context of development and the context of use

Although explicit knowledge and tacit knowledge can be distinguished from each other, both are needed. The knowledge spiral describes precisely this process of how one is transformed into the other. This process goes on continuously (Nonaka, 1994; Nonaka and von Krogh, 2009). The differentiation is nevertheless necessary to determine what kind of knowledge is being dealt with in the process of Failure Analysis. As described at the beginning, Failure Analysis is not only about explicit, technical knowledge, but also about the know-how of the test and analysis procedures (tacit knowledge) (Barton et al., 2017; Tawancy et al., 2004).

2.3 Knowledge Management

The purpose of Knowledge Management is to create an environment supporting thriving and propagation of knowledge (Mescheder and Sallach, 2012). This definition is based on the statement, that knowledge is a resource that propagates, not shrinks, while sharing it (Keller and Kastrup, 2009). Frequently, knowledge is shared and transferred via social interactions. Nonaka and Takeuchi researched on the transition between explicit and tacit knowledge inside social interaction processes. To visualize their approach, they used the SECI-Model (Socialization, Externalization, Combination, Internalization). The model is shown in Figure 2.2. The SECI-Model deals with four different types of knowledge and therefore with four processes to transfer knowledge to other types. The process starts with the so called socialization. Socialization describes sharing tacit knowledge via observation or imitation. In this step, mainly experiences, values and ideas are shared with others. The second knowledge transformation is called the externalization. In this step, tacit knowledge is transferred to explicit knowledge. Therefore, knowledge has to be changed into a representable, communicable and, especially, storable form. When this explicit knowledge is generalized into concepts, new explicit knowledge is generated. This process is called combination. Employees internalize explicit knowledge in regular use and generate new tacit knowledge. This transformation of knowledge is called internalization which corresponds to the typical way of learning (Mescheder and Sallach, 2012; Nonaka, 1994).

Nonaka describes these processes as knowledge creation, which is an important outcome of Knowledge Management (Nonaka and von Krogh, 2009). Nonakas approach is not only the outcome of Knowledge Management, but also the description of the individual and organizational knowledge base. Probst names the processes changing the individual and organizational knowledge base Organizational Learning. Controlling and organizing Organizational Learning is subject of Knowledge Management.
Probst identified six key processes of Knowledge Management:

- Knowledge identification
- Knowledge acquisition
- Knowledge development
- Knowledge sharing
- Knowledge exploitation
- Knowledge retention

One goal is to find aspects, or sub-processes, of Knowledge Management that integrate these six processes into Failure Analysis. If knowledge objectives are defined and knowledge assessment is performed, it is possible to implement a management cycle to receive starting points for knowledge managers. How this cycle is built up is shown in Figure 2.3 (Probst et al., 2012).
To put it in a nutshell, Knowledge Management should provide the right technical and infrastructural possibilities to share and save knowledge. These platforms should be easy to handle for every shareholder. Additionally, Knowledge Management should provide the best environment for employees to improve their individual knowledge resulting in an increasing organizational knowledge. The combination of both, the technical and the individual component, is important for an efficient Knowledge Management.
This thesis shall discuss the three identified main aspects of Knowledge Management: organizational infrastructure, technical infrastructure and encouraging knowledge sharing (Probst et al., 2012). These main aspects include sub-aspects, which will be discussed in chapter 5.

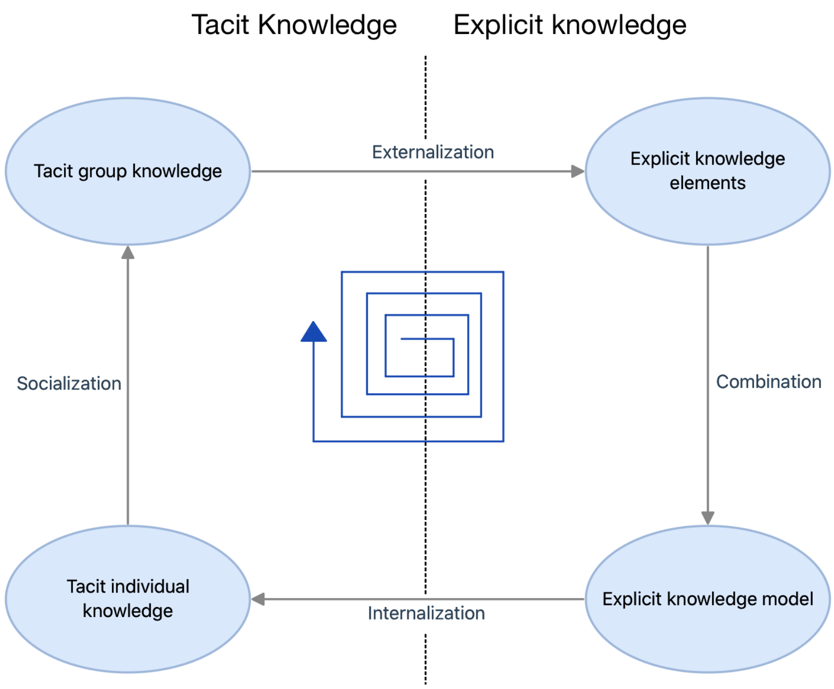

Figure 2.2: SECI-Model (Mescheder and Sallach, 2012)

2.4 Business Process

Failure Analysis is an important business process. Therefore, it is worth taking a look at the definition of a business process. It should also be clarified what makes the business

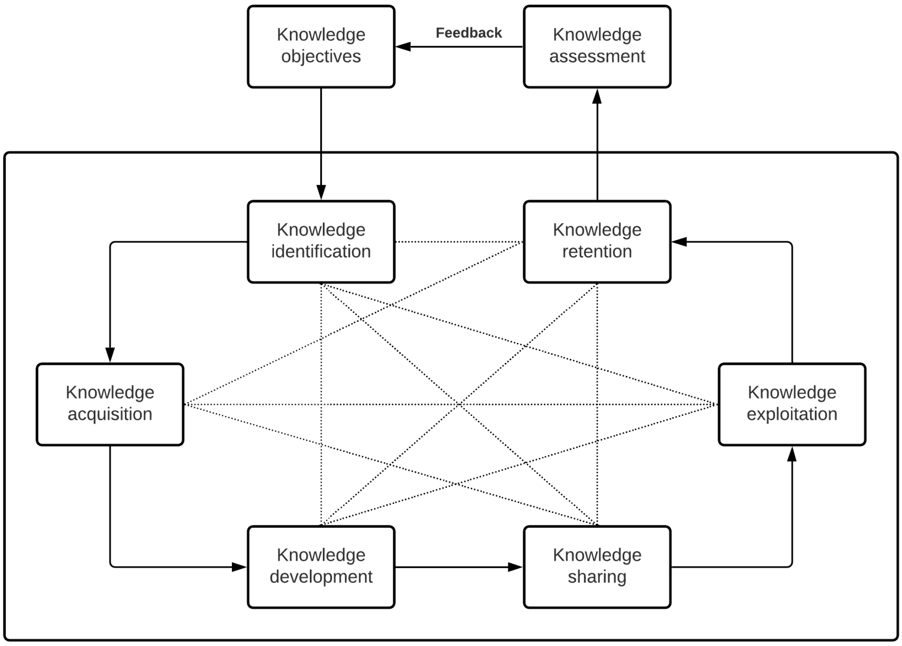

Figure 2.3: Components of Knowledge Management (Probst et al., 2012)

process of Failure Analysis interesting in terms of Knowledge Management.

A business process gives an inside view of the organization as well as on the functions and services (Jarke, 2019). Generally, a business process consists of a coherent, complete sequence of activities to fulfill operational tasks (Rosenkranz, 2005). Section 2.1 deals with the necessary operational tasks to perform the Failure Analysis process. This thesis defines the Failure Analysis process as a knowledge-intensive process according to Barton et al. (2017). Barton et al. (2017) give six characteristics for knowledge-intensive processes:

1. target-orientated
2. weak structure
3. dynamic and data-driven
4. unique in detailed implementation
5. collaborative
6. complex

A knowledge-intensive process should be target-orientated (Barton et al., 2017; Saulais and Ermine, 2020). Failure Analysis is target-orientated, because it has the objective to determine the cause(s) of failure resulting in the prevention of failures in the future. Additionally, it should propose a concept to correct the failure acutely and preventively (Tawancy et al., 2004; VDI-Fachbereich-Werkstofftechnik, 2011).

The second characteristic is the weak structure of the process. There is a structure given by the association of German engineers (see Figure 2.1), but it is not possible to structure the sub-processes exactly. The beginning and the objective of Failure Analysis is usually identical. The journey to reach the objective variates each time (Tawancy et al., 2004).
So the sub-process are more weakly structured and fulfill this characteristic. According to Tawancy et al. (2004) and the association of German engineers (2011), the shareholder of Failure Analysis decide further actions, during the process, dynamically and data-driven. This is another characteristic given by Barton et al. (2017). The next characteristic results from the previous aspects. The application of the Failure Analysis process should be unique, meaning that a typical (sub-)process is not identical to the ones before. This results from the aspect of a weak structure and dynamically and data-driven process. The last two characteristics could be connected. Due to the high collaborative work between, for example, labor staff, engineers and project leader, the process gets more complex. Also the amount of different sub-processes gives an evidence for the complexity of Failure Analysis (Bargel and Schulze, 2018; Tawancy et al., 2004; VDI-Fachbereich-Werkstofftechnik, 2011).

The result is that Failure Analysis could be characterized as a knowledge-intensive process (Barton et al., 2017). It follows that the knowledge available and used here should be managed sensibly. Furthermore, it should be ensured that the process of knowledge creation is supported and promoted. These aspects are part of Knowledge Management.

Chapter 3

Research Design

3.1 Case Study

This thesis deals with the question, how Knowledge Management (partly abbreviated by KM) could be a helpful part of continuous improvement in a highly specialized working environment within the process of Failure Analysis. To approach this question, this thesis develops a process model displaying the real application of a Failure Analysis process according to a case study.

Usually, case study research is allocated to the qualitative research (Ridder, 2020). In contrast to this allocation is the statement from Schögel and Tomczak (2009) that the case study method collects both qualitative and quantitative data. Case study research is more like a process focussing on capturing and describing a concrete practical challenge (Schögel and Tomczak, 2009).

Oates (2005) deals with three types of of case studies: exploratory, descriptive and explanatory. The combination of a descriptive and explorative case study on short-term bases is the type of choice. This thesis will examine the process of Failure Analysis based on semi-structured interviews (see section 3.2) with stakeholders of the process. Additionally, published company data will be considered and a literature review is given in section 2.1. Therefore this case study has descriptive as well as explorative aspects. This combination of types is chosen, because it fits well to the process analysis (Oates, 2005; Pankow, 2008).

As described in section 2.1, Failure Analysis is a complex process. The process could differ between companies and also between company documents and the daily performed process. The case study gives the opportunity to show the complexity and the differences between official documents and daily work. Also the researcher is able to propose improvements based on the case study (Oates, 2005).

The subject for this thesis is the process of Failure Analysis at Airbus Commercial. This thesis will be prepared in cooperation with the Airbus Operations GmbH at site Bremen. Airbus employs more than 130.000 people all over the world and approx. 2.500 people in Bremen (Airbus S.A.S., 2020). The business process of Failure Analysis (partly abbreviated by FA) is embedded in the department of engineering. As many departments and processes at Airbus Failure Analysis are organized in a trans-national way, meaning that stakeholders of the process are located at different sites all over the world.

Because this thesis is prepared in collaboration with the Airbus Operations GmbH and its employees, sensible personal and organizational data is collected. Personal data of employees and sensitive data of the company will be anonymized, changed or not used in this thesis, e.g. names or department abbreviations. The interview partners will be anonymized as well, but their role in the process and in the company will be treated the real way. The list of people that were interviewed is not exhaustive, but limited on the key and main stakeholders necessary to run the FA process. This is done as their role is a supporting function that is needed randomly and not always, so their consideration will exceed the scope of this thesis.

3.2 Interviews

The approach for understanding the process of Failure Analysis begins with interviews of different stakeholders of the process. The preparation for the interviews starts with the selection of the interviewees. This is an important step, because the selection of interviewees has a great impact on the results of the interviews (Kaiser, 2014). Gläser and Laudel give three criteria for the selection of experts for interviews (Gläser and Laudel, 2010):

1. Which expert has the relevant information?
2. Which of these experts are most capable of providing accurate information?
3. Which of these experts are most willing and available to provide this information?

These questions show, that the selection of interviewees depends on the research question(s). This requires the researcher to have some knowledge of the process to be analyzed. According to this, the relevant persons for the process should be already known.

It could be sufficient to know already one expert to interview. This person could provide references to additional persons in interviews already conducted and facilitating access to persons who might not have been recruited without this reference (Kaiser, 2014).

After selecting the interviewees, there is the question how to contact them. This includes both the method of communication and the provision of background information. Contacting an interviewee via E-Mail seems to be the easiest way. To ensure, that the interviewee does not ignore the E-Mail, it is necessary to provide explicit but not too many background information. If an initial telephone contact appears necessary, a written invitation with background information should still be sent out afterwards (e.g. by E-Mail) (Kaiser, 2014). Kaiser (2014) deals with a concept, which background information should be provided:

- A short description of the research topic
- A reason why the contacted person is considered an expert
- Information on the organisational background (student research project, third-party funded project, etc.)
- Information on the intended use of collected research data (student thesis, scientific publication, internet blog, etc.)
- Information on the technical implementation of the interview (tape recording yes/no) and the estimated time required
- Information on the period during which the expert interview is to be conducted
- Information on the possibility of keeping data generated in interviews confidential

Another impact on the interviews is the location. The usual way of performing an interview, face to face, is just as possible as using communication tools on the Internet like Webex or Google Meet (Mey and Mruck, 2020). Due to Covid-19 and the possible distribution of people in different locations, both possibilities will be used.

As described before, this thesis deals with expert interviews. These interviews will be semi-structured interviews with open questions both objective and subjective. A semi-structured interview provides the best setting for the interviewed experts and specialists of the process. The interview covers all relevant topics and questions but offers the interviewed person a certain degree of freedom in their answers. The interviewer takes care that all topics and questions are handled but the order of these is free and usually results from the interview (Misoch, 2019).

To ensure, that all relevant questions are asked, the researcher develops a guideline for the interview. This type of interview is called guided interview which is a kind of a semi-structured interview (Misoch, 2019). The guide provides a rough structure of the interview. It contains the questions and contents that the researcher definitely wants to discuss. However, the order of the questions is not fixed. Care should be taken only to ensure that an easy introduction to the topic is given before asking the more in-depth questions. Also, the researcher should provide a finishing phase to reflect on the interview. This is useful to give the interviewee the opportunity to add previously unmentioned but relevant topics. The final phase also has the function of leading the interviewee out of the interview situation (Kaiser, 2014; Misoch, 2019). Please see below a structure for the guideline given by Misoch (2019):

1. Information phase
2. Warum-up
3. Main phase
4. Finishing phase

The guidelines of the interviews for this thesis are displayed in section A.1 and section A.2. As mentioned in section 3.1, this thesis is prepared in coorperation with the Airbus Operations GmbH. The transnational organisation of this company leads to interviewees with an international background. The interviewees speaking German will be interviewed in German to ensure that no information get lost due to translation inaccuracies (Bogner et al., 2014). There will be also interviewees speaking only English, so an English guideline is provided. The guidelines are identical in their questions beside the used language. Both guidelines are based on the structure given by Misoch (2019). The interviews will start with the Information phase. This part is not displayed on the guideline, because this phase starts with the invitation to the Interview containing a brief approach to the topic. At the beginning of an interview, the researcher will pick up this information and put it in concrete terms to provide a smooth start into the interview. The interviewees are also informed about the confidential treatment of their data (Misoch, 2019).

The guidelines include a few questions for the warm-up phase. This part consists of basic questions like the position and the period of employment with the company. But it contains also the more open and broader question "What are your daily tasks?" (see section A.2). According to Misoch (2019) and Bogner et al. (2014), it triggers the interviewee taking up a narrative position and thus to overcome the often observed initial shyness before the interview.

The main phase contains the questions to ensure that all relevant topics are covered (Bogner et al., 2014; Misoch, 2019). This guideline is divided into two sections, because this thesis shall connect the two topics Failure Analysis and Knowledge Management. The Main phase starts with questions concerning Failure Analysis with the intention that the interviewees feel comfortable with this topic, because they are picked as experts on Failure Analysis. At the beginning, the interviewees are invited to find their role(s) inside the official Airbus Failure Analysis process diagram. The process diagram is displayed in Figure C.1. The diagram appears in an internal Airbus document and has been identically modeled, omitting company sensitive data. Afterwards the interviewees shall sketch their own understanding of the process. With this feature, the interview generates additional useful insides for the later analysis of the process (Schmid, 2018). Finishing the Failure Analysis section, the interviewee will be asked more open questions about Knowledge Management. This topic is identified as the possibly more unknown part of the interview for the interviewee. This assumption is based on the fact that Knowledge Management has been researched for a long time, but is not openly used in all companies (de Jesus Ginja Antunes and Pinheiro, 2020). The guideline closes with the invitation to the interviewees to give their opinions on improvements for the process of Failure Analysis as well as for Knowledge Management within this process. The interview ends with a thank you to the interviewee and a short outlook on the further procedure (Bogner et al., 2014; Misoch, 2019).

As described above, the interviews are performed both face to face and via digital communication tool. In this case, the tool of choice is Google Meet. Airbus provides a secure and stable video connection via this tool. Due to corporate policies, it is not allowed to record the interviews. But it is possible to prepare a written record. This record is called memory protocol. The memory protocol is created right after the interview. This should ensure that as much memory as possible is written down (Mey and Mruck, 2020). It is then less about what the interviewees implicitly reveal "between the lines", but rather about what they explicitly want to communicate. A protocol reveals the interviewees' understanding of a topic and, by reading it back, enables them to check and confirm whether or not the subjectively meant meaning has been captured (Kaiser, 2014; Vogel and Funck, 2018). Often such a memory protocol is sufficient if the interviewer is well acquainted with the topic in question (Kaiser, 2014). The interviews were performed with a prepared guideline for the interviewer to take notes during the interview. This is recommended by Kaiser (2014). As described above, the memory protocols were prepared right after the interview. These are sent out to the respective interviewee to review and approve the content.

In Appendix B, you will find the interview memory protocols for all performed interviews. Please note that:

- All answers are written in italics for a better differentiation to the questions
- Questions that are changed from the generic guideline are colored blue
- Sometimes, a note is inserted to catch additional statements

The interviews thus generate the inside memory protocol and process sketch as output. The memory protocols were used for the Qualitative Content Analysis.

The results of the interviews were analysed by qualitative content analysis as mentioned before. The results of the Qualitative Content Analysis are displayed in Appendix D, in Table D.1 to Table D.11.

3.3 Qualitative Content Analysis

The memory protocols of the interviews provide information about the process of Failure Analysis. They are therefore regarded as written sources of which the content must be extracted. Qualitative Content Analysis, as described by Mayring (2015) in particular, is methodologically suitable for this purpose. It originates from the social sciences and serves primarily as a method of analysis for texts and other forms of recorded communication processes. The material is systematically structured and reduced on the basis of search patterns in accordance with a research objective. The applied systematics and the theoretical background, on which the analysis is based, are also important. Case studies are ideally suited as a field of application for information retrieval using Qualitative Content Analysis (Mayring, 2015).

According to Kuckartz (2016), main terms should be defined for the qualitative content analysis. Usually, the terms "Sampling Unit" and the "Unit of Analysis" are treated separately. But in this case, the two terms coincide because the Sampling Unit is a transcript of an interview. In this case, no further sub-units are formed (Kuckartz, 2016). Please see in section 3.2 why a memory protocol is a kind of a transcript. So each interview represents one Unit of Analysis, because all are one-to-one interviews presenting one case (Kuckartz, 2016).

The interviews are thematically separated into the topics of Knowledge Management and Failure Analysis. These topics also form the first categories for the qualitative content analysis. The qualitative content analysis is intended to gradually build up a category system that corresponds to the information contained. This will be further refined through several runs (Mayring, 2015).

In concrete terms this means that the analysis starts with two categories (Failure Analysis and Knowledge Management). Then further categories, called codes, are formed inductively on the basis of the material. According to Mayring (2015) the inductive categorization is called summary content analysis. The material is then ran through for a second time to back-check the codes formed (Meier, 2014).

The results of this step are a code system and a matrix, called the interactive segment matrix. The code system is a table showing all used codes with their frequency in the used material. The interactive segment matrix is structured by the codes displayed in the columns and the several interviews (cases) in the rows. This offers the opportunity to get the statements by the interviewees on every topic separately. This is called the theme-oriented perspective (Kuckartz, 2016). Because of the big dimension and the resulting unreadability, the interactive segment matrix is divided into smaller matrices. All matrices show the five interviews in the rows but differ from the displayed codes in the columns. All codes will be mentioned.

Qualitative content analysis with its very systematic procedure is particularly suitable for implementation with the help of computer software. Therefore, the software MAXQDA, which is provided by the ifib (Institute for Information Management Bremen) at the University of Bremen, is used for this thesis.

3.4 Process Model

After evaluating the interview data, the process of failure analysis will be modeled with the Business Process Modeling Notation (BPMN). BPMN is the tool of choice, because it pursues the goal of correctly depicting business processes both from the perspective of the business unit and from the perspective of IT. In order to achieve this goal, the BPMN process diagrams must depict in detail both the technical process steps and the necessary information flows that are required for the successful implementation of a process. For this purpose, the BPMN provides symbols with which business and IT specialists can model and document business processes and workflows to the same extent. The BPMN thus attempts to close the gap between organization and IT (Proboard, 2019; Rücker and Freund, 2019). Another purpose of this step is to make the process more transparent. Rücker and Freund (2019) list three categories why business process modeling is used:

1) Existing processes should be improved by IT organizationally.

2) Existing processes should be documented.

3) New processes should be introduced.

In this work, the first two criteria are applicable, because the process of failure analysis should be improved by IT / knowledge management and as well documented in the current and the future structure. Also the third category is somehow true, because it is possible that new sub-processes are implemented while improving the process of failure analysis. After analyzing and modeling the process, it is the target to optimize it by means of knowledge management. It is possible that there are other things that could be improved. According to Rücker and Freund (2019), the first priority is the implementation of knowledge management and then other improvements are possible.

The development of the process model is an iterative process. Nevertheless, a good guideline for the beginning was necessary. To identify the important items for modeling the process, the following checklist was used (Proboard, 2018):

1. Name the process
2. Define start event
3. Define end event
4. Collect outputs
5. Collect inputs
6. Collect sub-processes and sort chronologically
7. Install parallel-gateways
8. Install or-gateways
9. Determine executing roles
10. Visualize process flow

This checklist is a good start to the modeling process. First, it was used to collect all results concerning Failure Analysis without filtering out for example duplicates. Second, all duplicates were eliminated. Especially the items one to six and nine are helpful to get a complete overview about all objects of the process. For a better overview, the results according to these items are displayed in Table 3.1.

Table 3.1: Important items of FA process - overview.

1. Process name	Process of Failure Analysis
2. Start event	FA Request or Failure Event
3. End event	Close FA Investigation
4. Outputs	Final report, Investigation results, Interpretations, FA Request, Preliminary report
5. Inputs	FA Request, Databases, Masterlist
6. Sub-processes	Create FA Request, Register FA to Masterlist, Analyze and Complete FA Request, Allocate Priority of FA Request, Allocate FA Site, Check costs and feasibility, Organize weekly Laboratory-Meeting, Weekly-Meeting, Present FA Requests, Assign FA Investigator, Discuss investigation plan, Determine investigation plan, Kickoff-Meeting, Give Feedback on investigation plan, Present investigation plan, Edit investigation plan, Perform investigations, Summarize results, Check for incompleteness or conspicuities, Give Feedback on the results, Prepare preliminary report, Give Feedback on preliminary report, Distribute preliminary report, Prepare final report for signature, Sign final report, Approve and sign final report, Authorize final report, Store final report, Close FA investigations
9a. Process roles	FA Requestor, Customer, FA Administrator, Senior FA Expert, FA Expert, Head of Integrated Laboratory, Integrated Laboratory Coordinator, FA Investigator, Chief Engineering, PKCR-Manager, Relevant Engineering Specialist, Test Engineer, Approving authority, Laboratory staff
9b. Process pools	FA people, Integrated Laboratory, Aircraft-program Chief Engineering

To accomplish item six, collecting sub-processes started at the Airbus process diagramm (Figure C.1). All steps displayed there were written down in the modeling software, followed by the steps shown in the interviewee's figures (Figure C.2 to Figure C.5) and the ones in the interactive segment matrix (Table D.11). Next, identical steps were deleted and the remaining ones were sorted chronologically.

Chapter 4

Results

4.1 General

A total of six interviews were conducted. Fortunately, four interviews could be conducted face to face under the necessary hygiene conditions. The fifth interview could be conducted via an online meeting tool. Three interviewees stated that they already had more than 15 years of experience in damage analysis. The remaining two interviewees had experience of more than three years and just under two years, respectively. Interviewees 1 and 4 are both FA experts. Interviewee 1 also takes on the role of the PKCR manager. Interviewee 4 also acts as an FA Investigator. The role of laboratory coordinator is performed by Interviewee 5. Interviewees 2 and 3 are so-called test engineers. Interviewee 2 performs this role at Testia GmbH, while Interviewee 3 is employed by Airbus. Testia is a subsidiary of Airbus (Testia GmbH, 2020).

4.2 Failure Analysis and process model

As described in section 3.4, one important result of the interviews should be a business process model of the actual Failure Analysis process. This chapter merges the interview results concerning Failure Analysis and the steps to develop the process model.

Fortunately, the interviews covered several roles in the process like Test Engineer, FA Expert, Laboratory Coordinator and more. But some roles, for example the FA Administrator, only appear in the Airbus process definition. The challenge was to merge the Airbus process definition, the interviewee's sketches and the results from the qualitative content analysis, summarized in the interactive segment matrices, to a process model.

The first model is shown in Figure C.6 and Figure C.7. Because of its size and better displayability, the model is separated into two parts. This model should include all identified process steps. Basically, it follows the sequence of the Airbus process definition. However, since this seems very undetailed, the other results refine it. According to the results there are many intermediate steps like the Feedback-Loops, the regular meetings of the laboratory team and the joint development of an investigation plan. Furthermore, only the interview results provide the exchange between the different roles. The most common example is the exchange between the FA Investigator and the FA Expert. A view on the used data objects is completely missing in the Airbus process definition. The interview results provide used data objects like the FA Request, investigation plan preliminary report and final report. Additionally, a high amount of databases was identified (ECM, Masterlist, ASDM and more) and included in the model.

The complete process model (Figure C.6 and Figure C.7) is a very detailed one. Fortunately, there are many results, to display the process in detail. The mentioned meetings, Feedback-Loops and data objects could be included as well as all identified roles. After finishing the model, the impression was that it was too detailed to achieve the goal of this thesis. Accordingly, a second model was developed. The first model served as a template. The approach was to identify the most important steps and roles needed to display the process usefully. It was also necessary to ensure that all important elements were represented where it was possible to implement aspects of knowledge management. The actual, compact process is illustrated in Figure 4.1.

During the evaluation and modeling process, six roles were identified as necessary to run the process and important for the aim of this work:

- FA Requestor
- (Senior) FA Expert
- FA Investigator
- Integrated Laboratory Integrator
- Integrated Laboratory Staff
- PKCR-Manager

The FA Requestor is identified as important, because this role starts the process by registering an FA Request when a failure occurs. Also, this role is responsible for further steps based on the Failure Analysis results after the process. The technical authority in this model is the role of the (Senior) FA Expert. The (Senior) FA Expert is responsible for the technical approval of reports and results. By doing this, she/he should notice conspicuities like unusual results or events. During the evaluation and modeling process, the roles Senior FA Expert and FA Expert were merged. This happened because the differences were identified in their experience (not visualizable) and their different tasks in sub-process, which are out of the scope of this thesis. The Integrated Laboratory Coordinator is responsible for the distribution of FA Requests and other tasks to coordinate the FA Investigators and the Laboratory Staff. The FA Investigator is the role responsible for the whole investigation and evaluation process. This includes the independent execution of investigations as well as the delegation of investigation tasks to the Laboratory Staff. Additionally, the FA Investigator should summarize the results first and then prepare the FA report. The Integrated Laboratory Staff takes on a supporting role by being able to execute the investigations for the FA Investigator. At the end, the PKCR Manager should manage all relevant information from the FA reports and prepare them for reuse (**P**roduct **K**nowledge **C**apitalization and **R**euse). For a better overview, the roles were summarized in one pool. The pool is called Failure Analysis as a synonym of the main activity.

The compact process model is clearer, but no less detailed in the sections that are important for this work. This process model is used to discuss the main question of this thesis.

The roles and tasks were identified by the interviews (see protocols in Appendix B), the sketches made by the interviewees (see Figure C.2 to Figure C.5) and an official process diagram published in an internal Airbus document (see Figure C.1).

4.3 Knowledge Management

Besides developing a model of the actual process, the interviews shall provide a first approach to the employee's understanding of Knowledge Management. Additionally, the interviewees should give their impressions, which Knowledge Management methods are used and which problems they notice. With regard to Knowledge Management, both, the Airbus process definition (Figure C.1) and the Failure Analysis process flow chart according to the Association of German Engineers (Figure 2.1) either do not include Knowledge Management at all or mention it very shortly. So the interviews were necessary to identify interfaces for Knowledge Management in the process of Failure Analysis.

One major understanding of Knowledge Management is the distribution of existing and new knowledge or experiences. The distribution should work via developed standards, specifications and lessons learned. Also, the effective and sustainable integration of lessons learned to the way of working is part of the interviewee's Knowledge Management understanding. Last but not least, the way of distributing knowledge and experiences (speed, simplicity, tools) belongs to their KM understanding.

In the interviews the role of the PKCR-Manager was mentioned, who is responsible for the identification of interesting topics to be prepared for further use in the scope of Failure Analysis. Care is taken to mix the teams more often so that knowledge is distributed more diversely, which is identified as used Knowledge Management. The interviewees also mentioned, that some Best practices and a Kickoff-Guideline are already in use. Additionally, the interviewees report from the sharing of knowledge during the weekly meeting.

However, the interviewees also noticed some problems. To some interviewees, the term PKCR and the PKCR-Manager was unknown. Some mentioned databases are not appropriate to search for documents (the searchers have to know exactly, what they search for). Also, many reports and documents are saved locally, so people have to know, that they exist. One interviewee is in the role of the PKCR-Manager. The amount of reports, documents and other information is too high to extract the most important or interesting topics. Also, the PKCR-Manager role is performed in addition to the main position of the interviewee. This results in an overload of tasks, so that the role as PKCR-Manager could only play a subordinate role.
The results from Qualitative Content Analysis are displayed in Appendix D, Table D.5 and Table D.6.

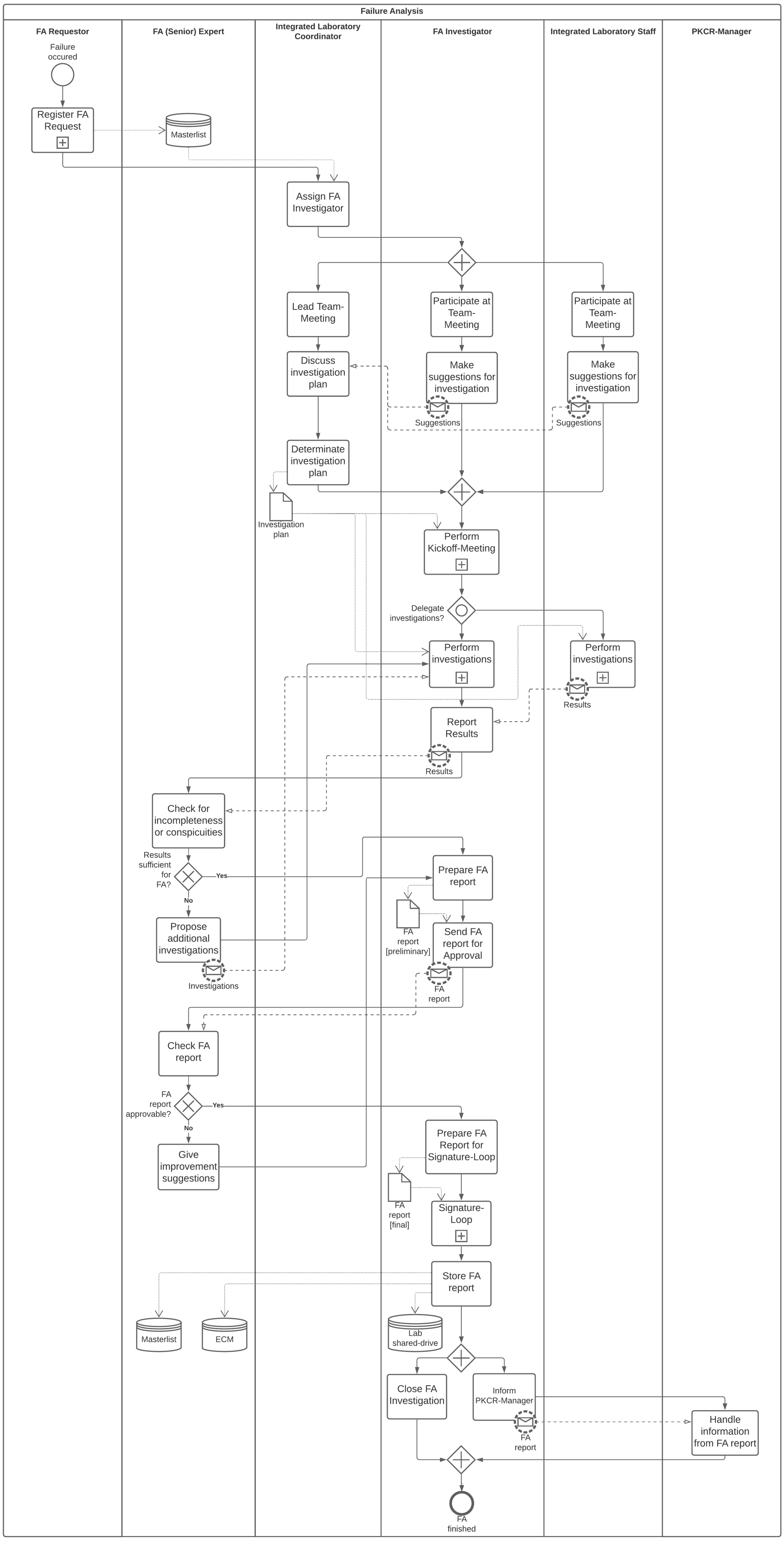

Figure 4.1: Actual Failure Analysis process model based on research

Chapter 5

Discussion

The aim of this thesis is to find out which aspects of Knowledge Management could be implemented in a highly specialized working environment within the process of Failure Analysis. To achieve this goal, five interviews with different stakeholders of the Failure Analysis process at Airbus Commercial were performed. First, the results were used to create a process model (Figure 4.1). Second, insights into the already used aspects of Knowledge Management were gained. Technical and organizational infrastructure and encouraging knowledge sharing were identified as three main aspects of Knowledge Management (section 2.3). After analyzing the interviews, this discussion shall give ideas to improve or include these aspects in the process of Failure Analysis at Airbus.

Organizational and technical infrastructures are necessary requirements for efficient knowledge sharing (Probst et al., 2012). To gather information, interviewees use many different data storages (for example: Masterlist, ECM, EDMS, Normmaster and more; all Airbus proprietary databases) as well as own drives and personal contact via phone or mail (see Table D.4 and Table D.3). This makes information hard to find. Although there are a lot of databases for research, either they are not easy to handle or for example reports, can only be found by the exact title. (the searchers have to know exactly, what they search for). This may indicate insufficient key-wording and / or non-uniform naming of documents (see Table D.6). Furthermore, some interviewees mentioned the improvement suggestion to develop one database for the whole Failure Analysis process. This database should provide useful filter options and sensible, comprehensible key-wording. In line with the filter options, the database gives out all relevant documents like a complete history matching the filters and key-wording. Additionally the database deals with the matching specifications for materials, aircraft type, components and more. Furthermore this database also includes best practices and lessons learned. In view of the fact that this database could contain both explicit knowledge, such as specifications or drawings, and tacit knowledge (best practices, lessons learned), this improvement suggestion seems to be a good idea and is one aspect of Knowledge Management. The Failure Analysis community would bundle their knowledge in one big database. In this case, the database should be based on a relational data structure. This ensures a rigid classification of data and structured storage of documents (Harrington, 2016). To ensure good key-wording and filter options, it is necessary to prepare all documents, like reports and specifications, with the appropriate key words. Possible methods are a controlled vocabulary and an automatic key-wording (Probst et al., 2012). An organization could continuously build up a mandatory controlled vocabulary to tag their documents with keywords. This method ensures, that new documents get tagged with known keywords for easier research. Furthermore, documents could always be updated, if new keywords are applicable. Its disadvantage lies in the high cost of maintaining and enforcing the language. Automatic key-wording tags the documents autonomously based on word frequencies. Although these methods are becoming more and more sophisticated and are constantly improving due to the active use of the system and corresponding feedback, the hit rate for targeted searches is still frustrating for most users today (Probst et al., 2012). Using automatic key-wording, the risk seems to high to "loose" documents due to the keywords. Thus, a controlled vocabulary is recommended, although its expenditure could be higher. During the upload, the user could be forced by the system to tag the uploading document(s) with matching keywords from the controlled vocabulary. Additionally, the document(s) should be classified in predefined categories. In this case, these categories could be for example Aircraft-Program, Material and Component number. This would ensure the required filter options and key-wording. This thesis deals with proposal filter-options in Table 5.1.

Table 5.1: Proposal for filter options in database.

Aircraft Type	**MSN**	**Year of delivery**	**ATA-Chapter**	**Component number**	**Material**
A350	074	2016	20-80-03	Wing-Rib-10	Aluminium

The option MSN means the Manufacturer Serial Number. This serial number is a unique code assigned usually in sequence to an aircraft by the manufacturer (Watts, 2012). The ATA-chapters (ATA = Air Transport Association) form a system to uniquely identify all components of an aircraft. Among other things, this facilitates production, Failure Analysis and maintenance (Air Transport Association, 2018; Rossow et al., 2014). These two options could be necessary to identify aircraft components exactly. These options are only a proposal and could be added or changed. Furthermore, the filled-in columns serve only as an example. In this case, it is a specification, i.e. explicit knowledge. If some of these filter-options are applied, the database should output all matching documents (FA reports, specifications and more).

Interviewee 1 mentioned another interesting improvement suggestion. To help the PKCR-Manager with the high amount of data, the person responsible for the final report of the Failure Analysis investigation, should fill in a form after finalizing the report to facilitate the identification of PKCR-relevant topics. Furthermore, Interviewee 1 suggests an additional Feedback-Loop between the FA Investigator and the PKCR-Manager to identify relevant topics. This Feedback-Loop secures the findings of an analysis. This can be both implicit knowledge (how the investigator proceeded with the investigations and analyses) and explicit knowledge, for example new findings about a material.

The PKCR-Manager could play an important role for the Knowledge Management. The interviews showed, that the PKCR-Manager is unknown to three Interviewees and only one knows the nominated person. Interviewee 1 takes the role of the PKCR-Manager. The description of the PKCR-Manager corresponds to the one given by Probst et al. (2012), that there is a manager responsible for a particular, important competence field inside the whole company structure. The manager's task is to network the internal experts in a field of competence and to collect and condense the expertise that exists internally and externally on the topic (Probst et al., 2012). Interviewee 1 mentioned during the interview, that this role is difficult to fulfill, because of the large amount of data as well as the daily workload is too high to take the role as PKCR-Manager additionally. The suggestion to fill in a form after investigation seems to be good. This would be one aspect to encourage knowledge sharing.

The role of the PKCR-Manager needs to be discussed. The idea is to create an independent position for the PKCR-Manager, so this role is not taken additionally to another position. The process diagram (Figure 4.1) showed the involvement of different stakeholders. As described above, the PKCR-Manager networks the different stakeholders to collect and condense the existing expertise. Furthermore, the PKCR-Manager brings the experience of the Failure Analysis community into corporate decisions and is responsible for providing and maintaining the infrastructure (database, best practice workshops, etc.) of the competence field (Probst et al., 2012). This is an aspect of Knowledge Management concerning the organizational infrastructure. The implementation of an PKCR-Manager as an independent position could strengthen the organizational infrastructure for Knowledge Management. Moreover, the company could implement a network of PKCR-Managers for all competence fields. They could meet regularly for an interdisciplinary exchange. Maybe Airbus already has PKCR managers for the competence fields. Then it would be useful to network them and put them under the control of a CIO. Airbus currently employs a CIO named Catherine Jestin (Airbus S.A.S., 2020). Further research is needed to investigate the benefits of such an enterprise-wide infrastructure of knowledge managers. However, this is beyond the scope of this paper.

The independent position of the PKCR-Manager could also ensure the suggestion of an additional Feedback-Loop between FA Investigator and PKCR-Manager. This would be one of the key tasks for the PKCR-Manager and there are no further workload problems. Additionally, the PKCR-Manager would be responsible for the controlled vocabulary and the correct uploading of documents to the database.

The Failure Analysis community could perform a regular meeting all together, like once a month. The PKCR-Manager takes up the role as host of the meeting. Comparable methods are already in use, for example in hospitals. Doctors from a common specialty meet regularly and exchange their everyday experiences. Common standards are discussed and elaborated in the group. The result of these regular meetings is sharing of individual knowledge with the community (Bahrs et al., 2001). Best practices and lessons learned are developed. If this regular meeting is implemented, the whole community is encouraged to share their knowledge, experiences and lessons learned. This is another aspect of Knowledge Management, ensuring the sharing ob explicit and tacit knowledge.

The application of Nonaka's SECI model in these meetings seems to make sense (see Figure 2.2). The method is ensured by discussing experiences together. This should encourage the FA community members to share their expertise and then prepare best practices and lessons learned together. As seen in the EUREKA-project at Xerox, the individual experts need a joint discussion to put their experiences and knowledge in a reusable form. The problem at Xerox was, that Xerox technicians were overstrained when they had to put their way of working in words, if they deviated from the general rules (Bobrow and Whalen, 2002).

Because an aircraft structure consists of many different materials and production processes, the Failure Analysis Team has to have a broad knowledge in different disciplines (Megson, 2016; Tawancy et al., 2004). The above mentioned meeting offers the opportunity for an exchange between the Failure Analysis community and departments specialized on these materials and processes. The host of the meeting could invite each time a specialist from another department. This would cause an interdisciplinary exchange inside the company with advantages for both sides. This would be another method to encourage individual knowledge sharing.

The Kickoff-Meeting seems to be an important step in the process of Failure Analysis. The step is used to present the planned investigations to the customer. Then the customer expresses wishes and suggestions for the upcoming investigations. One result of the interviews was the wish for better documentation of meetings and especially the Kickoff-meeting. One idea could be the defining of a meeting protocol. For example the PKCR-Manager could prepare a first version for this protocol. The meeting protocols could differ between Face-to-Face-Meeting, Kickoff-Meeting and weekly laboratory meeting for example. The first version of the meeting protocol should be improved continuously. The improvement happens iteratively with every meeting by noticing weak points and improving them with the next version (Jonker et al., 2005). Worth highlighting is, that there is already a developed Kickoff-guideline. This strengthens the process of the Kickoff-meeting as well as this facilitates the preparation of a Kickoff-meeting protocol. It is necessary to share this guideline with the whole FA community, maybe via the possibly launched database.

Based on the above mentioned aspects, another process model was developed. In the new process model, the described database is named "FA DBase". To ensure better presentability, the model was cut in two parts. Part one (Figure 5.1) shows the process from the very beginning until performing the Kickoff. Part two (Figure 5.2) starts at the task "Store FA report" and ends at the end of the FA process. The steps inbetween were cut out, because there was nothing added to the process. All additions and modifications are colored blue.

Figure 5.1 shows the implementation of the discussed database for the whole FA community, called "FA DBase". Also, an interviewee's suggestion is included by displaying the task "Prepare for Kickoff, Collect all Data". This task is meant to be used to search for all relevant documents in the "FA DBase" to be prepared on all relevant aspects for the upcoming Failure Analysis.

Figure 5.2 clarifies, that the "FA DBase" should replace all other databases and personal storages. Also this model realizes the implementation of the suggested Feedback-Loop for PKCR. This starts with the completion of a form for the PKCR-Manager to identify important topics. The PKCR-Manager should now prepare relevant information according to this topic. Afterwards, the PKCR-Manager and the FA Investigator discuss the results/information bilaterally and decide whether this is a relevant topic for the FA community workshop. Because these process steps are modeled before the ending event, the feedback loop is at least theoretically obligatory. Therefore the PKCR-Manager is responsible to ensure the execution.

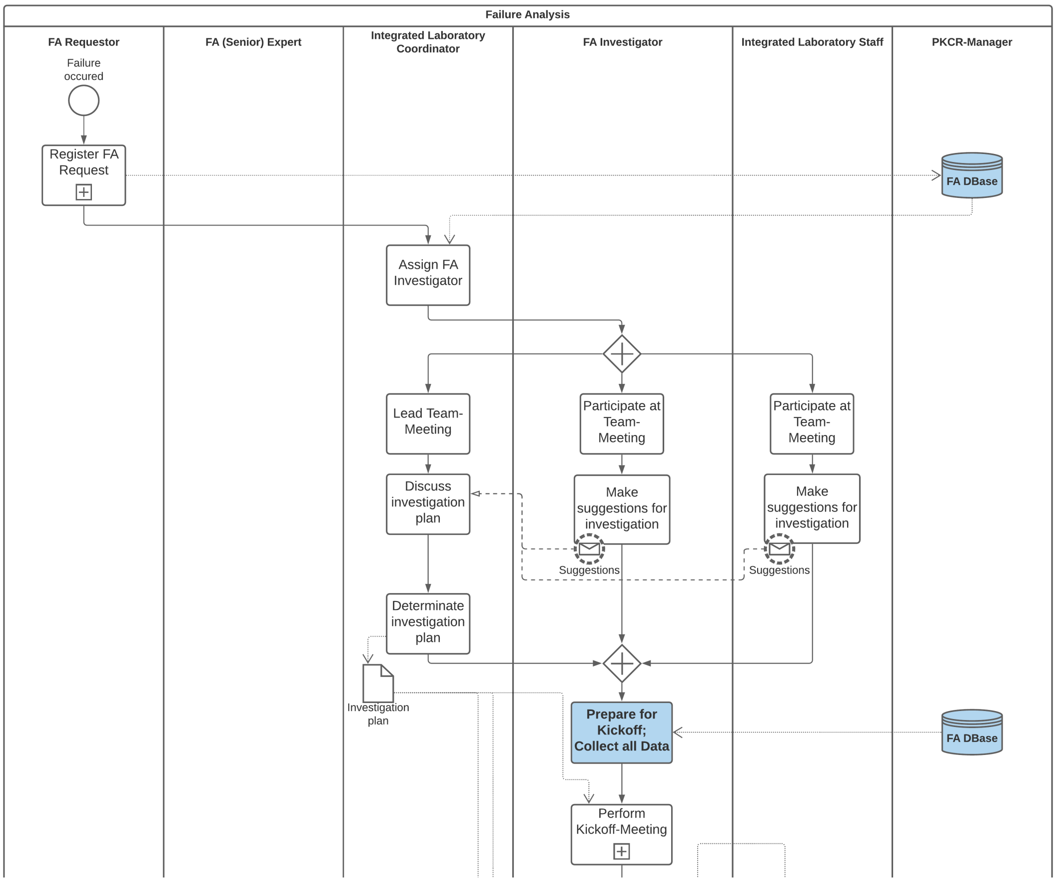

Figure 5.1: Actual Failure Analysis process model improved, part one

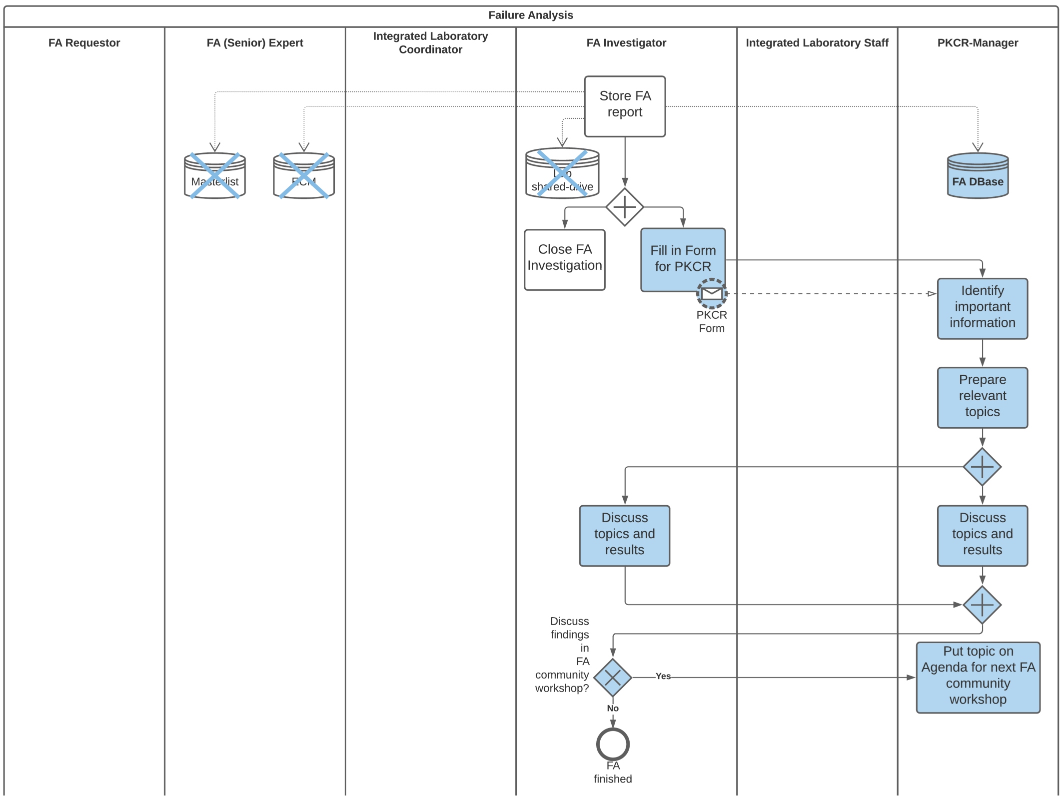

Figure 5.2: Actual Failure Analysis process model improved, part two

As written above, Figure 5.2 already mentions the FA community workshop. This is the intended name for the monthly meeting of the FA community. The initial agenda for this workshop could include the following:

1. Welcome
2. Meeting host (PKCR-Manager) presents the agenda
3. Approve protocol from last workshop
4. Appoint minute taker
5. Host reports interesting or new topics from PKCR community
6. If invited, guest from an other department presents possible FA relevant topic
7. Present the most recently discussed best practices as a preliminary document.
   (a) Decide whether approve and upload best practice document or revision necessary
8. Present the most recently discussed lessons learned as a preliminary document.
   (a) Decide whether approve and upload lessons learned document or revision necessary
9. Present new interesting topics from recently FA investigations by responsible FA Investigator
   (a) Discuss possible best practices
   (b) Discuss possible lessons learned
10. General discussion
11. End

Prima facie, the agenda appears very long. But some items may not take so much time and this workshop is performed only once a month. For a better planning, the participants should find a fixed time slot with a fixed duration (for example 90 minutes), so that the majority of the FA community could participate regularly.
The first four items on the agenda build the standard introduction into the workshop. The fifth item alludes to the previously mentioned network of PKCR managers. If such a network was implemented, it would be helpful for the FA community to receive interesting information from the other competence fields via the PKCR-Manager. The idea

that a guest from another field of competence can present new / important topics is captured in the sixth item. Item seven and eight shall ensure, that best practices and lessons learned from former meetings are shortly discussed again. The idea is, that the community prepares the main content of new best practices or lessons learned together, which is captured in item nine. After the joint discussion, the presenter of the topic is responsible to prepare a proposal document for best practice or lessons learned until the next FA community workshop. This proposal is then evaluated again in the community. If everybody agrees with the proposal, this document will be approved and uploaded to the "FA DBase" by the PKCR-Manager. The topics discussed at item nine could for example result from the Feedback-Loop in the FA process between the FA Investigator and the PKCR-Manager. The workshop ends with a general discussion, which is useful to answer short questions inside the community. This agenda is an initial proposal. This can be refined or changed over time. At least it is a start to structure this possible workshop.

The workshop may also be useful in agreeing on a uniform naming of documents. Here is a suggestion on how to name the documents:

FA-report	**2021_02_05**	**Aluminium**	**A350**	**Corrosion**
Document-Type	**Year_Month_serial-number**	**Material(s)**	**A/C-Type**	**Failure cause**

The document-type shall ensure, that a searcher could for example filter out only FA-reports or best practices. This is followed by a number-code. This identifies the document by the year and month of publication and an over the year incrementing number. The material(s), aircraft type (A/C-Type) and the failure cause could be helpful for the searcher to identify documents at first sight. If the FA community agrees on a uniform naming of documents, it would simplify the search for documents. The whole FA-process would benefit from this because it means a relevant time saving. This is a technical aspect that also has a direct impact on the process.

Chapter 6

Conclusion

The aim of this bachelor thesis was to find out which aspects of Knowledge Management could be implemented in the process of Failure Analysis.

Failure Analysis is an important process in a manufacturing company because it can have a major impact on many areas. As described in section 2.1, Failure Analysis not only determines the cause of a failure. It has also major impact on the future product development. In this case, Airbus is a competitor in a tough market with main focus on the safety of their products. Every failure could cost lives, money and reputation. Not surprisingly, this work has identified a complex process. But it also shows that the process involves and produces a lot of knowledge. However, in order to be able to use this knowledge more sensibly and efficiently, adjustments are needed.

In order to find out which aspects of knowledge management can be implemented, interviews with experts / process stakeholders were performed in addition to a literature research. A process model in BPMN was developed from the results of these qualitative methods. The modeling process showed that a more compact but focused model is needed to answer the research question. Therefore, a second more focused process model was developed. In the course of the interviews, it was investigated whether and which aspects of knowledge management are already being applied.

The results show a complex process in which a lot of knowledge is needed, used and created. Furthermore, it shows that Knowledge Management methods, known from the literature, such as best practices or lessons learned, are already known. However, it also comes to light that the application and distribution of these methods has potential for improvement. Furthermore, an organizational function can be identified, i.e. position of the PKCR manager, which appears to be important for the further development of

Knowledge Management. For this to happen, however, it would have to be strengthened.

As this work was intended to identify aspects of Knowledge Management that can be implemented in the process of Failure Analysis, relevant aspects were discussed. The proposed aspects were classified into the categories technical infrastructure, organizational infrastructure and encouraging knowledge sharing, respectively. In the following, the most relevant aspects should be evaluated.

At the beginning, probably the most elaborate change is assessed. It follows from the discussion that the role of the PKCR manager should be strengthened and above all be defined independently. Due to the role of Failure Analysis, there should be a company-wide network of PKCR managers who regularly exchange information in detail. The PKCR managers should report to the CIO. This is an aspect that would greatly change the organizational infrastructure. However, if one looks at the discussed consequences on a smaller level, one can see great advantages. Of course, it is also obvious that such a change requires a lot of courage. Moreover, it would probably be very costly and time-consuming. But the long-term advantages could outweigh the short-term disadvantages. The second major aspect has an impact on the technical infrastructure. As suggested by some interviewees, a unified database for the FA community should be introduced. This should then contain all important data, such as specifications, FA reports, best practices, lessons learned and more. Here, too, it must be mentioned that the development and, above all, the integration of such a database can be very cost- and time-intensive. In addition, filling the database with all the required data can be very time-consuming as well. But again, the initial costs can be outweighed by the potential time savings and subsequent cost savings. Possibly, more important could be a risk reduction in future failures, which actually could be more relevant than any cost or time savings. In addition, all important findings can be better used for the development of future products. Furthermore, the introduction of the unified database would also justify the strengthening of the position of the PKCR manager.

It becomes apparent that a functioning Knowledge Management requires a corresponding organizational and technical infrastructure. The third aspect, encouraging knowledge sharing, follows from these two aspects.

Future research should determine the actual costs and benefits (time and money) of implementing the above mentioned aspects. This should be contrasted with the savings (time and money) over a longer period of time. It would also be very interesting to find out what impact the aspects offered have on employees. Does the daily work change?

Is it made easier or more difficult? What impact does it have on the morale of the employees. These interesting questions should be explored in the future.

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Appendix A

Interview guidelines

A.1 German guideline

Date: **Location:**
Start: **End:**
Type of Meeting:
Interviewer:
Topic: Schadensanalyse und Wissensmanagement.

1. **Einstiegsfragen**
   - Wie lange arbeiten Sie für Airbus?
   - Wie lange arbeiten Sie für Testia?
   - Was ist Ihre genaue Stellenbeschreibung?
   - Was gehört zu Ihren täglichen Aufgaben?
2. **Schadensanalyse**
   - In welcher Rolle und in welchem Schritt sehen Sie sich in diesem Diagramm? (see Figure C.1)
   - Wie würden Sie den Prozess skizzieren?
   - Was ist Ihre Aufgabe in dem Prozess der Schadensanalyse?
   - Wie werden Sie über Ihre Aufgabe informiert?
   - Informieren Sie sich über das gegebene Problem (Schaden) (Materialeigenschaften, Historie, vergleichbare Schäden) und wenn ja, woher beziehen Sie ihre Daten?

- Halten Sie sich an einen klaren (evtl. dokumentierten) Prozess während Ihrer Aufgabe?
- Gibt es eine Regel, an wen oder was Sie ihre Ergebnisse berichten?
- Können Sie beschreiben, wie mit Ihren Ergebnissen weitergearbeitet wird?

3. **Wissensmanagement**
    - Bitte beschreiben Sie ihr Verständnis von Wissensmanagement.
    - Wo glauben sie wird von Wissensmanagement in dem Prozess der Schadensanalyse Gebrauch gemacht?
    - Welche Aufgabe nimmt bei Airbus der PKCR-Manager ein?

4. **Fragen zu Verbesserung**
    - Haben Sie Verbesserungsvorschläge für den Prozess der Schadensanalyse?
    - Haben Sie Ideen wie man Wissensmanagement generell oder besser einsetzen könnte im Prozess der Schadensanalyse?

A.2 English guideline

Date: **Location:**
Start: **End:**
Type of Meeting:
Interviewer:
Topic: Failure Analysis and Knowledge Management.

1. **Introductory questions**
   - How long have you been working for Airbus?
   - How long have you been working for Testia?
   - What is your exact job description?
   - What are your daily tasks?
2. **Failure Analysis**
   - Which role and which step fits to yourself in this diagram? (see Figure C.1)
   - How would you sketch the process?
   - What are your tasks in the Failure Analysis process?
   - How will you be informed about your task?
   - Do you inform yourself about the given problem (damage) (material properties, history, comparable damage) and if so, where do you get your data from?
   - Do you comply with a clear (possibly documented) process during your task?
   - Is there any rule about who or what you report your results to? Can you describe how your results will be used further?
3. **Knowledge Management**
   - Please describe your understanding of knowledge management.
   - Where do you think Knowledge Management is used in the Failure Analysis process?
   - What is the role of the PKCR manager?
4. **Questions for improvement**
   - Do you have any suggestions for improving the Failure Analysis process?
   - Do you have ideas on how to use Knowledge Management within the Failure Analysis process in general or in a better way?

Appendix B

Interview memory protocols

B.1 Interview 1

Date: 26.11.2021 **Location:** Airbus Bremen, Office
Start: 10:05 am **End:** 11:15 am
Type of Meeting: Face to Face
Interviewer: Felix Ziegler
Topic: Failure Analysis and Knowledge Management.

1. **Einstiegsfragen**

   - Wie lange arbeiten Sie für Airbus?
     Seit ungefähr 15 Jahren.
   - Wie lange arbeiten Sie für Testia?
     Never worked for Testia.
   - Was ist Ihre genaue Stellenbeschreibung?
     Expert for Failure Analysis for metallic materials und PKCR Manager for Failure Analysis
   - Was gehört zu Ihren täglichen Aufgaben?
     - *Technische Freigabe von Berichten*
     - *Beratung bei der Durchführung von Schadensuntersuchungen*
     - *Ausfertigung von Guidelines / Test specifications für Untersuchungen*
     - *Mitarbeit bei der Ausführung und Erklärung von Ergebnissen in Root Cause Untersuchungen*

2. **Schadensanalyse**

- In welcher Rolle und in welchem Schritt sehen Sie sich in diesem Diagramm? (see Figure C.1)
  - *Rollen: Failure Analysis Requestor, Failure Analysis Investigator*
  - *Schritte: Register FA Request, Perform Kickoff, Investigation and Compile FA report, Close FA Investigations*
- Wie würden Sie den Prozess skizzieren?
  see Figure C.2
- Was ist Ihre Aufgabe in dem Prozess der Schadensanalyse?
  - *Im Kickoff: Anweisungen geben für die Untersuchungen (Welche, Wie viele, etc.)*
  - *Im Feedbackloop über die Ergebnisse und Interpretationen entscheiden*
  - *Resultate interpretieren und Berichte prüfen*
  - *Rolle des PKCR Managers einnehmen*
- Wie werden Sie über Ihre Aufgabe informiert?
  Über Telefon und/oder E-Mail
- Informieren Sie sich über das gegebene Problem (Schaden) (Materialeigenschaften, Historie, vergleichbare Schäden) und wenn ja, woher beziehen Sie ihre Daten?
  - *Eigenes Archiv (Festplatte/Laufwerk, eigenes Know-How)*
  - *Schlagwortsuche in Airbus-Datenbanken (EDMS, ECM, Normmaster und mehr)*
  - *Suche von öffentlicher Literatur*
  - *Kollegen fragen über Anruf/E-Mail/Persönlich*
- Halten Sie sich an einen klaren (evtl. dokumentierten) Prozess während Ihrer Aufgabe?
  Der Bericht, der vom Test Ingenieur angefertigt wird, durchläuft immer einen Feedbackloop. Das ist eine Art Prozess, der nicht dokumentiert ist. Dabei wird der Bericht von einem FA Experten geprüft und muss eventuell nachgearbeitet werden vom Test Ingenieur bis der Bericht genehmigt ist vom FA Experten.
- ~~Gibt es eine Regel, an wen oder was Sie ihre Ergebnisse berichten?~~
- Können Sie beschreiben, wie mit Ihren Ergebnissen weitergearbeitet wird?
  - *Arbeitsanweisungen vom Kickoff werden umgesetzt*

  - *Formulierungen und Interpretationen aus dem Feedbackloop gehen in den Bericht ein*
  - *Entscheidende Ergebnisse werden an den Requestor zurückgegeben*
  - *Überprüfung von Erkenntnissen, die außerhalb von Airbus bestehen und ob diese adaptiert werden können/sollten*

3. **Wissensmanagement**

- Bitte beschreiben Sie ihr Verständnis von Wissensmanagement.
  - *Vermittlung von bestehendem und neuem Wissen ins Kollegium*
  - *Rasche, effektive und nachhaltige Übermittlung/Integration von Lessons Learned*
  - *Erkenntnisse die aus der Bearbeitung einer spezifischen Aufgabe gewonnen werden global zugänglich zu machen (in der Firma/Abteilung)*
  - *Der Requestor entscheidet dann über die Weiterverarbeitung der Erkentnisse*
- Wo glauben sie wird von Wissensmanagement in dem Prozess der Schadensanalyse Gebrauch gemacht?
  - *Unregelmäßig Lessons Learned Workshops*
  - *Lessons Learned aus ASDM-Plattform (sollten frei zugänglich sein und leicht zu finden)*
  - *Teams werden häufiger durchgemischt bei der Abarbeitung der Schadensanalysen, sodass Wissen divers geteilt wird*
  - *Kickoff-Guidelines und Best practices wurden erstellt*
  - *Allerdings sind diese nicht frei verfügar (auf lokalen Laufwerken) und man muss wissen, dass sie existieren*
- Welche Aufgabe nimmt bei Airbus der PKCR-Manager ein?
  - *Bedeutung PKCR: Product Knowledge Capitalization and Reuse*
  - *Theoretisch: Regelmäßige Abfragen/Interviews durchführen mit Mitarbeitern der Schadensanalyse um Themen zu identifizieren, die aufbereitet und näher betrachtet werden sollten*
  - *Probleme: Wie wird der PKCR Manager über diese Themen informiert? Außerdem ist die Arbeitsbelastung so hoch, dass der PKCR Manager diese Rolle sehr eingeschränkt zusätzlich ausüben kann*

4. **Fragen zu Verbesserung**

- Haben Sie Verbesserungsvorschläge für den Prozess der Schadensanalyse?
  Note: Please find the answers in the next item.
- Haben Sie Ideen wie man Wissensmanagement generell oder besser einsetzen könnte im Prozess der Schadensanalyse?
  - *Fertiger Bericht:*
    * *Verpflichtender Rückmeldungsloop (regelmäßig) mit PKCR Manager um die relevanten Themen zu identifizieren*
    * *Berichtersteller füllt eine Art Formblatt aus, wo er aufzeigen kann, was für PKCR relevant sein kann*
  - *Eine einfache Oberfläche/Datenbank die einfach, effizient die gesuchten und relevanten Daten liefert zu jeder Zeit des Prozess der Schadensanalyse*

B.2 Interview 2

Date: 26.11.2021 **Location:** Airbus Bremen, Office
Start: 12:45 am **End:** 13:50 am
Type of Meeting: Face to Face
Interviewer: Felix Ziegler
Topic: Failure Analysis and Knowledge Management.

1. **Einstiegsfragen**

   - Wie lange haben Sie für Airbus gearbeitet?
     1 Jahr, bis Ende Februar 2020
   - Wie lange arbeiten Sie für Testia?
     Ungefähr 8 Monate, seit dem 01. März 2020
   - Was ist Ihre genaue Stellenbeschreibung?
     Test Engineer
   - Was gehört zu Ihren täglichen Aufgaben?
     - *Metallographie*
     - *Mikroskopie*
     - *Präparierung von Materialien*
     - *Untersuchung von Materialeigenschaften und Oberflächen*
     - *Technische Auswertung & Berichterstellung*

2. **Schadensanalyse**

   - In welcher Rolle und in welchem Schritt sehen Sie sich in diesem Diagramm? (see Figure C.1)
     - *Schritt: Perform Kickoff, Investigation and Compile FA report*
     - *Rolle: Teile vom FA-Investigator (Untersuchungen durchführen, Ergebnisse im Bericht darstellen)*
   - Wie würden Sie den Prozess skizzieren?
     Note: The Interviewee sketched the process as an enumeration.
     1) *Requestor/Kunde stellt Request auf Masterlist*
     2) *Lab-Koordinator prüft auf Durchführbarkeit und schätzt Kosten ab*
        a) *im Team-Meeting werden neue Requests den Mitarbeitern zugeteilt*
     3) *Failure Analysis Investigator übernimmt Request*

   - *Failure Analysis Investigator legt Deadline fest (Liefertermin)*
   - *Nimmt Kontakt mit Kunden auf und hält den Kunden auf dem neuesten Stand*

4) *Nach Fertigstellung des Reports wird dieser auf die vorgesehen Workspace gespeichert*
   - *Report wird an Verteilerliste geteilt (Verteilerliste wird im Report definiert)*
   - *Lab-Koordinator & gegebenenfalls Senior Expert genehmigen/authorisieren Bericht*

5) *Report wird dem Kunden zur Verfügung gestellt*

- Was ist Ihre Aufgabe in dem Prozess der Schadensanalyse?
  - *Laboraufgaben: Untersuchungen/Präparierung selber durchführen, aber auch delegieren und koordinieren unter den Labormitarbeitern*
  - *Technische Auswertung*
  - *Kundenkontakt aufbauen: Besorgung der zu untersuchenden Teile, Vorstellungen der Kunden klären, Umfang der Materialprüfung erörtern*
- Wie werden Sie über Ihre Aufgabe informiert?
  - *Es gibt ein wöchentliches Team-Meeting mit Labormitarbeitern, Test Ingenieuren und dem Labor-Koordinator*
  - *FA Requests werden vom Requester in die sogenannte "Masterlist" eingestellt*
  - *Labor-Koordinator verteilt diese Requests an die Mitarbeiter*
- Informieren Sie sich über das gegebene Problem (Schaden) (Materialeigenschaften, Historie, vergleichbare Schäden) und wenn ja, woher beziehen Sie ihre Daten?
  - *Recherche über die "Masterlist" zu früheren Schadensfällen (frühere Berichte suchen)*
  - *"Normmaster" zur Suche von Spezifikationen (Material, Prozess, etc.)*
  - *Geteiltes Laufwerk für frühere Dokumente und Spezifikationen*
  - *Öffentliche Literatur*
- Halten Sie sich an einen klaren (evtl. dokumentierten) Prozess während Ihrer Aufgabe?
  Durch die individuellen Untersuchungen ist es kaum möglich sich an einen Prozess zu halten.
- Gibt es eine Regel, an wen oder was Sie ihre Ergebnisse berichten?
  Der verfasste Bericht wird in einer Plattform namens "Workplace" hochge-

laden. Von dort wird er automatisch an relevante Prozessbeteiligte und Genehmigende weitergeleitet.

- Können Sie beschreiben, wie mit Ihren Ergebnissen weitergearbeitet wird?
  Nach der Weiterleitung wird der Bericht genehmigt und authorisiert. Gegebenenfalls wird der Bericht vom Genehmigender kommentiert und vom Verfasser überarbeitet.

3. **Wissensmanagement**

- Bitte beschreiben Sie ihr Verständnis von Wissensmanagement.
  - *Koordination von Wissen: Wo wird es abgelegt, wie informieren wir die Beteiligten, Was muss abgelegt werden, Wer ist dafür verantwortlich*
  - *Verfügbarkeit von Wissen: Wer hat Zugriff auf welches Wissen, wie können wir das Wissen am besten verfügbar machen*
- Wo glauben sie wird von Wissensmanagement in dem Prozess der Schadensanalyse Gebrauch gemacht?
  In der Recherche vor dem Kickoff-Meeting und bei der Interpretation der Untersuchungsergebnisse.
- Welche Aufgabe nimmt bei Airbus der PKCR-Manager ein?
  Note: The designation "PKCR-Manager" was unknown to the Interviewee

4. **Fragen zu Verbesserung**

- Haben Sie Verbesserungsvorschläge für den Prozess der Schadensanalyse?
  Vor dem Kickoff mehr Input seitens des Kunden, wie Bauteilgeometrie und Details zum Arbeitsauftrag.
- Haben Sie Ideen wie man Wissensmanagement generell oder besser einsetzen könnte im Prozess der Schadensanalyse?
  Eine Datenbank (Note: Underlining One) zur leichten, vollständigen und schnellen Suche:
  - *Sinnvolle Filteroptionen*
  - *Vernünftige, nachvollziehbare Verschlagwortung*
  - *Vollständige Historie und Spezifikationen passend zu Filtern und Schlagworten*
  - *Best practices auch in der Datenbank veröffentlichen*

B.3 Interview 3

Date: 27.11.2020 **Location:** Airbus Bremen, Office
Start: 10:05 am **End:** 11:05 am
Type of Meeting: Face to Face
Interviewer: Felix Ziegler
Topic: Failure Analysis and Knowledge Management.

1. **Introductory questions**

   - How long have you been working for Airbus?
     For 10 months, since January 2020
   - How long have you been working for Testia?
     For 3 years until end of 2019
   - What is your exact job description?
     Test Engineer
   - What are your daily tasks?
     - *Documentation*
     - *Macroscopy*
     - *Microscopy*
     - *Fractography*
     - *Striation counting*
     - *Preparing reports*

2. **Failure Analysis**

   - Which role and which step fits to yourself in this diagram? (see Figure C.1)
     - *Role: Failure Analysis Requestor*
     - *Step: Perform Kickoff, Investigation and Compile FA report*
   - How would you sketch the process?
     see Figure C.3
   - What are your tasks in the Failure Analysis process?
     - *Documentation of the condition of the failed parts as received*
     - *Perform Failure Analysis investigation*
     - *Prepare report and improve it after Feedback*

- How will you be informed about your task?
  In the weekly Team-Meeting, where the first investigation plan is also determined.
- Do you inform yourself about the given problem (damage) (material properties, history, comparable damage) and if so, where do you get your data from?
  - *Former reports from "Masterlist" or "ECM"*
  - *"Normmaster"*
  - *"ZAMIZ"*
- Do you comply with a clear (possibly documented) process during your task?
  Note: There is no real process to comply with instead of the feedbackloop mentioned below.
- Is there any rule about who or what you report your results to? Can you describe how your results will be used further?
  - *Handover of report to expert and/or specialist*
  - *Expert/Specialist provides ideas for improvement*
  - *Investigator improves the report*
  - *Handover preliminary report to Expert/Specialist*
  - *Interviewee 3 calles this the "offline loop"*
  - *After the offline loop, the official system loop begins including signature loop and approval*
  - *Sometimes, results lead to a deeper investigation resulting in a new request*
  - *Upon request: Investigator discuss a new request, Experts could request a new FA*

3. **Knowledge Management**

- Please describe your understanding of knowledge management.
  Get knowledge from others via implemenented tools
- Where do you think Knowledge Management is used in the Failure Analysis process?
  Not a real Knowledge Management
- What is the role of the PKCR manager?
  Interviewee 3 is not aware of PKCR and the corresponding manager

4. **Questions for improvement**

- Do you have any suggestions for improving the Failure Analysis process?
  - *Kickoff improvement: Introduce template to catch all relevant information*
  - *Better and consistent documentation within the meetings*
- Do you have ideas on how to use Knowledge Management within the Failure Analysis process in general or in a better way?
  - *Free and easy access to the Kickoff results and documentations of meetings*
  - *Database for all relevant information to replace the many databases*

B.4 Interview 4

Date: 01.12.2020 **Location:** Google Meet
Start: 10:05 am **End:** 11:20 am
Type of Meeting: Virtual Meeting
Interviewer: Felix Ziegler
Topic: Failure Analysis and Knowledge Management.

1. **Introductory questions**
    - How long have you been working for Airbus?
      Since 2012 for Airbus, but started working as an FA Investigator in 2006 at Rolls-Royce
    - How long have you been working for Testia?
      Never worked for Testia.
    - What is your exact job description?
      Failure Analysis Expert for Metal Materials
    - What are your daily tasks?
      Understanding of failure events at Airbus airframes to conclude on failure mechanism.
2. **Failure Analysis**
    - Which role and which step fits to yourself in this diagram? (see Figure C.1)
        - *Roles: Failure Analysis Requestor, Failure Analysis Investigator*
        - *Steps: Register FA Request, Perform Kickoff, Investigation and Compile FA report, Close FA Investigations*
    - How would you sketch the process?
      see Figure C.4
    - What are your tasks in the Failure Analysis process?
        - *All different investigations and delegation of these*
        - *Prepare reports*
        - *Give ideas for improvement for other reports*
    - How will you be informed about your task?
        - *Usual way is a Request by customers in the "Masterlist"*
        - *Customers are: A/C-program teams, Chief Engineering, Production, Procurement, Supply Chain*

  - *After Request, there is Kickoff-Meeting with the customer*
  - *Typically, there is a phone call or E-mail from the customer at the beginning of a request. But the official request continues via "Masterlist"*

- Do you inform yourself about the given problem (damage) (material properties, history, comparable damage) and if so, where do you get your data from?
  - *Online literature and books*
  - *Internal documents*
  - *Lessons learned database*
  - *Personal network*
- Do you comply with a clear (possibly documented) process during your task?
  - *There is a team standard for FA / Best practice called "Performing FA"*
  - *Many different technical steps with its own typical process*
  - *Expertise and way of working of the investigator has impact on the steps*
  - *Line of reporting and signature is specified*
- Is there any rule about who or what you report your results to? Can you describe how your results will be used further?
  - *Discussion about the interpretation of the investigation results with other Experts and Senior Experts*
  - *Customer gets the final report and decides on further actions*

3. **Knowledge Management**

- Please describe your understanding of knowledge management.
  To share the way of working and experiences from employees to the colleagues.
- Where do you think Knowledge Management is used in the Failure Analysis process?
  - *Best practices*
  - *Lessons learned*
  - *Kickoff-Template*
- What is the role of the PKCR manager?
  Interviewee only knows, who is the PKCR Manager for FA

4. **Questions for improvement**

- Do you have any suggestions for improving the Failure Analysis process?

  - *Implementation of a Follow-Up of the further steps after the investigation*
  - *Define steps between Kickoff and Release of report*
  - *Visualize the Feedbackloop(s)*
  - *Implement a step to evaluate the results and interpretations to the wider business (impact on other programs, departments, etc.)*

- Do you have ideas on how to use Knowledge Management within the Failure Analysis process in general or in a better way?
  - *Good database and better communication to safe time and money in the future*
  - *Create interface(s) to other departments to share the results of investigation or interesting topics*
  - *Visualize the Feedbackloop(s)*

B.5 Interview 5

Date: 02.12.2020 **Location:** Airbus Bremen, Office
Start: 09:15 am **End:** 10:15 am
Type of Meeting: Face to Face
Interviewer: Felix Ziegler
Topic: Failure Analysis and Knowledge Management.

1. **Einstiegsfragen**
   - Wie lange arbeiten Sie für Airbus?
     Länger als 20 Jahre
   - Wie lange arbeiten Sie für Testia?
     Never worked for Testia.
   - Was ist Ihre genaue Stellenbeschreibung?
     Transnational Failure Analysis Specialist
   - Was gehört zu Ihren täglichen Aufgaben?
     - *Berichte prüfen und korrigieren*
     - *Unterstützung der Labormitarbeiter*
     - *Koordinieren der Labormitarbeiter*
     - *Untersuchungen an Schadensteilen durchführen*
2. **Schadensanalyse**
   - In welcher Rolle und in welchem Schritt sehen Sie sich in diesem Diagramm? (see Figure C.1)
     - *Schritte: Assign Failure Analysis Investigator, Perform Kick-off, Investigation and Compile Failure Analysis Report, Approve Failure Analysis Report*
     - *Rollen: Integrated Laboratory Coordinator, Failure Analysis Investigator, Relevvant Engineering Specialist*
   - Wie würden Sie den Prozess skizzieren?
     see Figure C.5
   - Was ist Ihre Aufgabe in dem Prozess der Schadensanalyse?
     - *Verteilung der Arbeitsaufträge aus der "Masterlist" an die Labormitarbeiter und Test Engineers*
     - *Statusabfrage der laufenden Fälle im wöchentlichen Meeting*

  - *Direkter Kontakt zu den Kunden/Requestor*
  - *Als genereller Ansprechpartner an den meisten Kick-offs teilnehmen*
  - *Upon Request: Untersuchungspläne (Welche Untersuchungen) werden gemeinsam festgelegt*

- Wie werden Sie über Ihre Aufgabe informiert?
  Einstellung eines Request in die "Masterlist"

- Informieren Sie sich über das gegebene Problem (Schaden) (Materialeigenschaften, Historie, vergleichbare Schäden) und wenn ja, woher beziehen Sie ihre Daten?
  - *Normmaster*
  - *ZAMIZ*
  - *SDM+*
  - *TechRequest*
  - *Standardbücher*
  - *Öffentliche Literatur*

- Halten Sie sich an einen klaren (evtl. dokumentierten) Prozess während Ihrer Aufgabe?
  - *Kein permanent dokumentierter Prozess*
  - *Festgelegter Untersuchungsplan wird streng eingehalten, aber man bleibt flexibel für weitere nötige Untersuchungen*
  - *Gewöhnliches Prozedere bei einem Schadensteil:*
    * *Bestandsaufnahme (visuelle Inspektion, Fotos, Materialdaten sammeln)*
    * *Untersuchungen durchführen (Untersuchungsplan, siehe oben)*
    * *Bericht schreiben*
    * *Eventuell Bericht überarbeiten*

- Gibt es eine Regel, an wen oder was Sie ihre Ergebnisse berichten?
  - *Technical Check (Vorabbericht) an den Auftraggeber übergeben*
  - *Den fertigen Bericht in den Signature-Loop geben*

- Können Sie beschreiben, wie mit Ihren Ergebnissen weitergearbeitet wird?
  - *Bericht wird in Datenbank "ECM" abgelegt und in einem geteilten Laufwerk vom Laborteam*
  - *Note from Interviewee: "ECM" ist nicht geeignet zur Suche von Berichten. Man muss genau wissen was man sucht.*

3. **Wissensmanagement**

   - Bitte beschreiben Sie ihr Verständnis von Wissensmanagement.
     - *Entwickeln von Standards und Spezifikationen um Know-How an andere weiterzugeben*
     - *Ausarbeitung von Best practices und Lessons learned um Fehler zu vermeiden und Erfahrungen zu teilen*
   - Wo glauben sie wird von Wissensmanagement in dem Prozess der Schadensanalyse Gebrauch gemacht?
     - *Die Anfertigung von Best practices und Lessons learned ist ein erster Schritt*
     - *Leider sind diese häufig nur lokal verfügbar*
     - *Im wöchentlichen Meeting wird viel Wissen weitergegeben*
     - *Dieses sollte aber in einem Protokoll festgehalten werden*
   - Welche Aufgabe nimmt bei Airbus der PKCR-Manager ein?
     Role of the PKCR manager is not known

4. **Fragen zu Verbesserung**

   - Haben Sie Verbesserungsvorschläge für den Prozess der Schadensanalyse?
     Please see next item.
   - Haben Sie Ideen wie man Wissensmanagement generell oder besser einsetzen könnte im Prozess der Schadensanalyse?
     - *Eigene "Schadensdatenbank" für das Integrated Laboratory, wo nur Schadensfälle gespeichert sind*
     - *Bessere Stichwortsuche in den Datenbanken*
     - *Im Protokoll der wöchentlichen Meetings Kernpunkte festhalten die die Arbeit aller erleichtern/verbessern kann*
     - *Best practices und Lessons learned verstärkt erarbeiten und für alle relevanten Personen veröffentlichen*

Appendix C

Figures

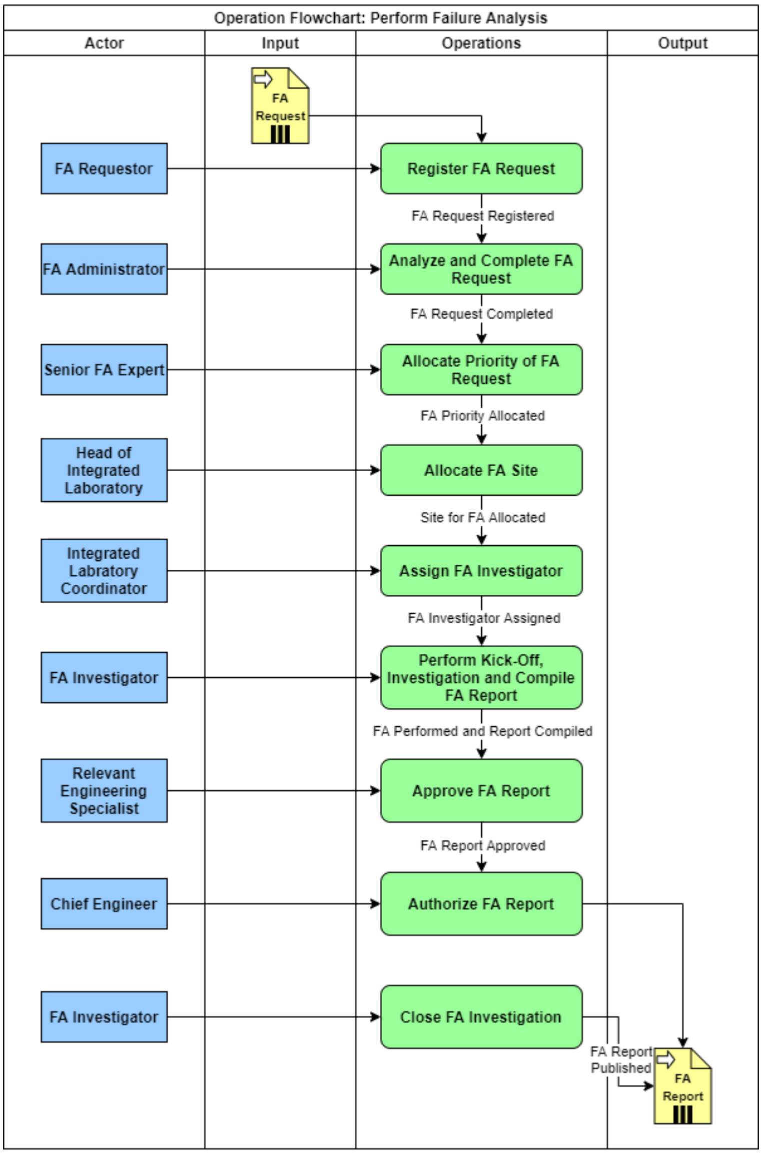

Figure C.1: Airbus process definition of Failure Analysis (Airbus Internal Document)

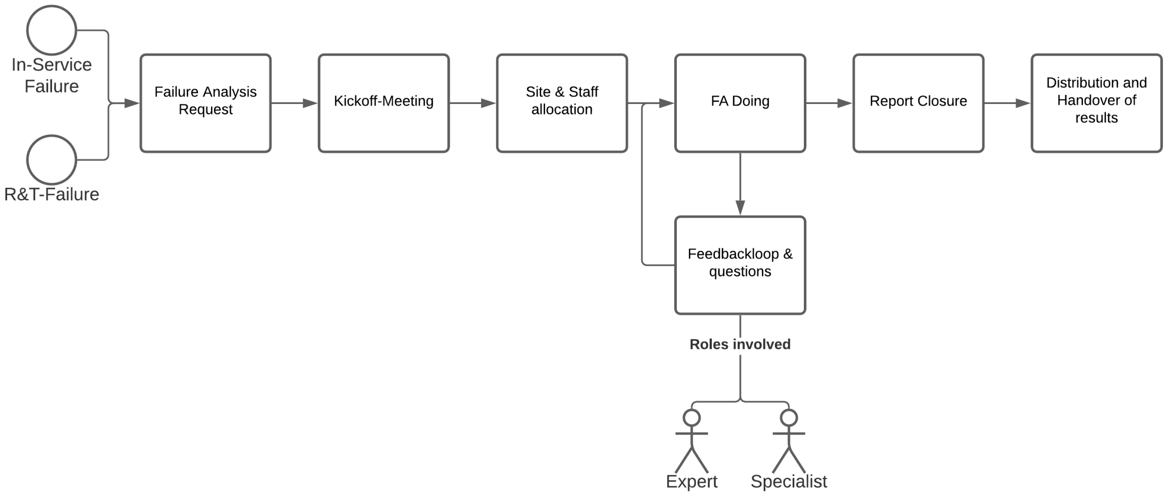

Figure C.2: FA process scetch made by Interviewee 1

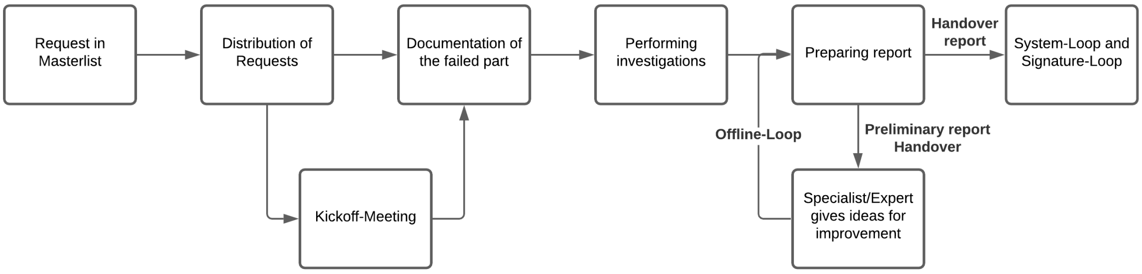

Figure C.3: FA process scetch made by Interviewee 3

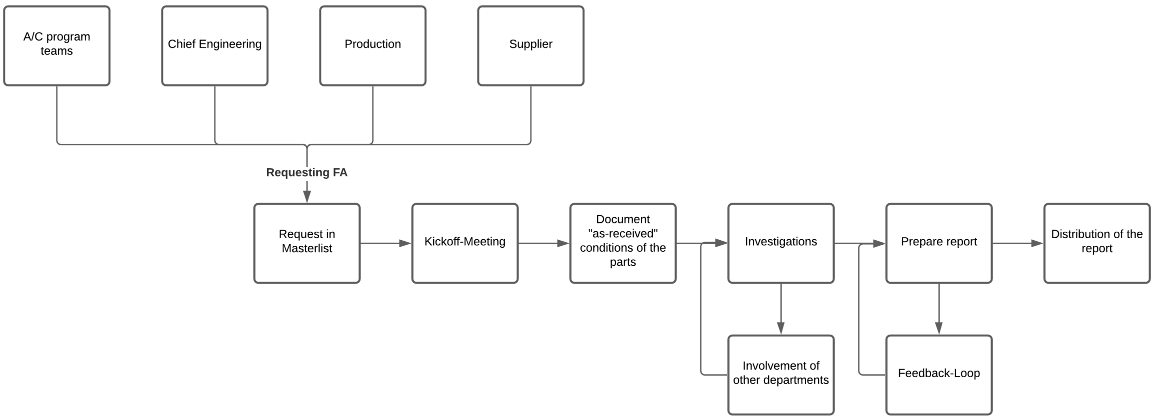

Figure C.4: FA process scetch made by Interviewee 4

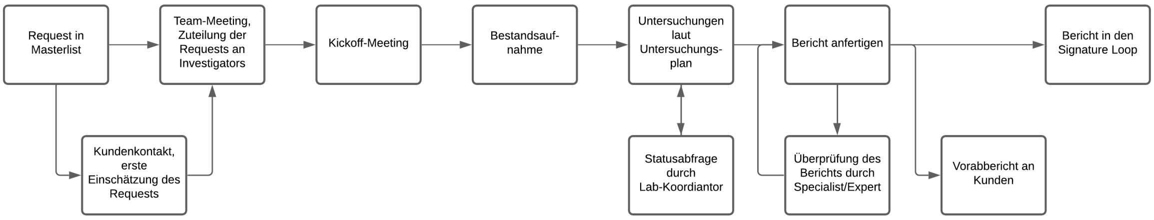

Figure C.5: FA process scetch made by Interviewee 5

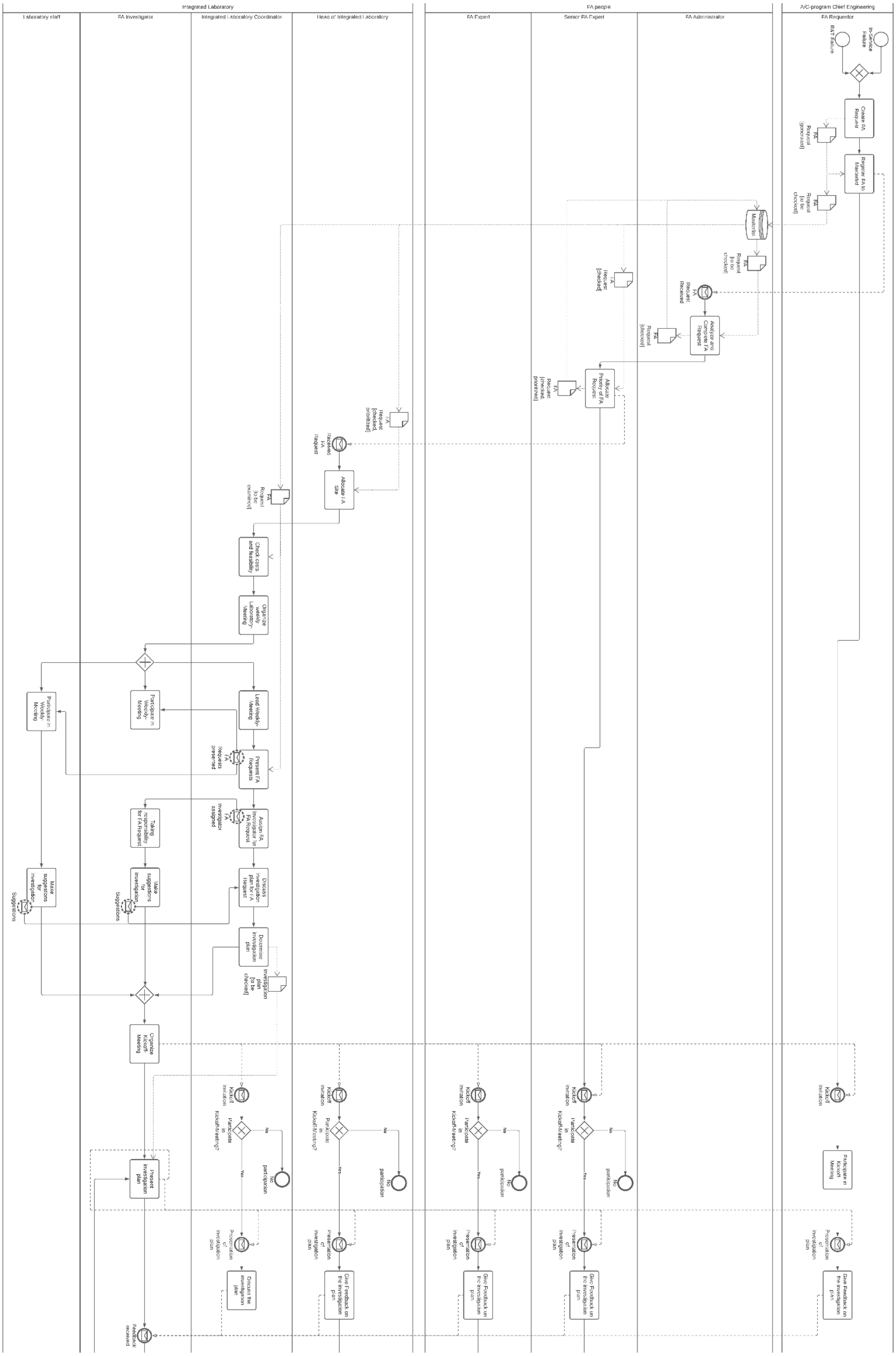

Figure C.6: Complete actual FA process model part one.

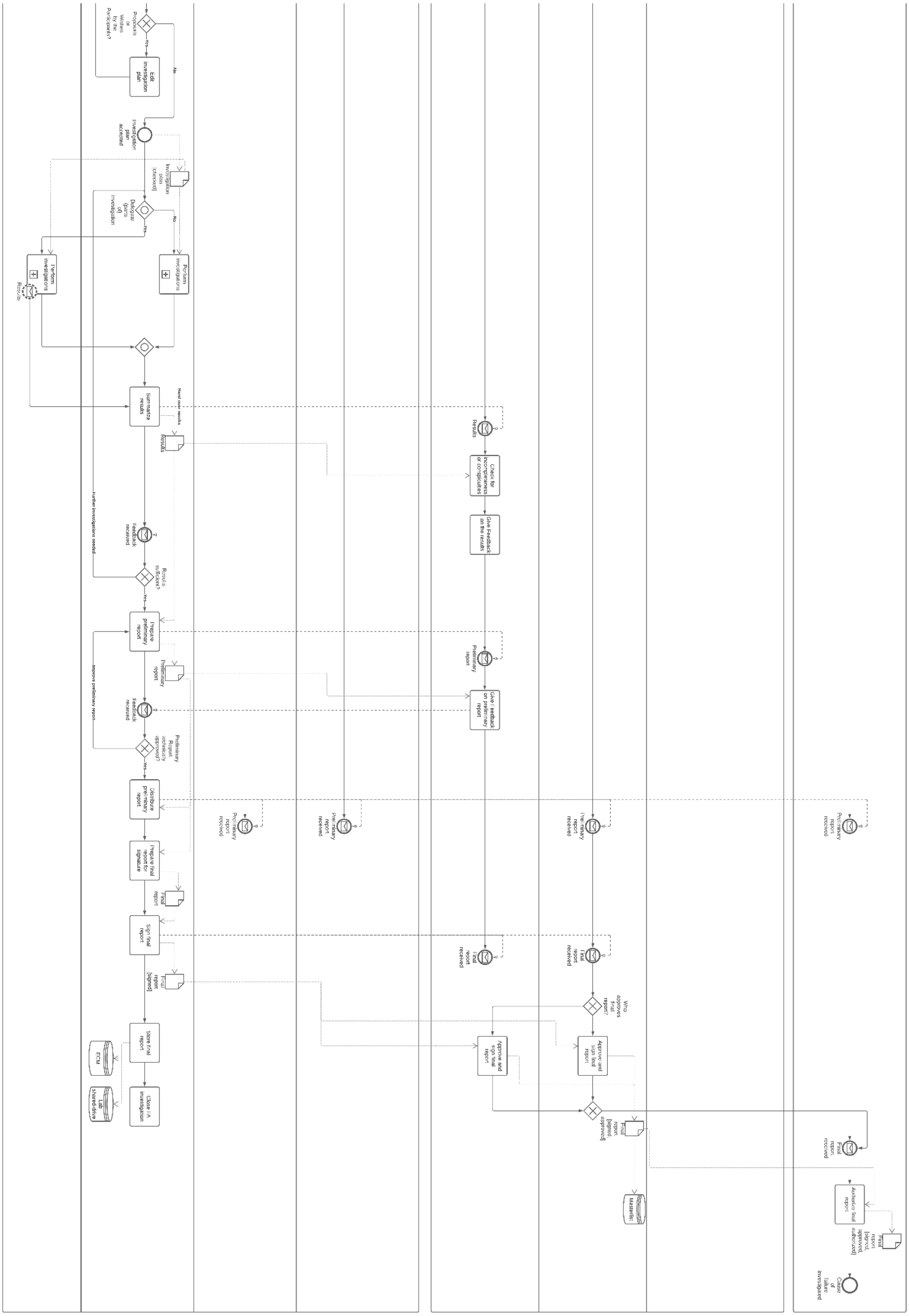

Figure C.7: Complete actual FA process model part two.

Appendix D

Results from Qualitative Content Analysis

Table D.1: Code system after the Qualitative Content Analysis

List of codes			**Frequency**
Code system			265
	Experience in FA		7
	Information gathering		15
	Job description		3
	Data storage		3
		Airbus Databases	21
	Knowledge Management		0
		KM understanding	9
		KM Improvement suggestions	12
		Airbus KM procedure	7
		KM problem	7
		Used method / document	10
	Communication		3
	Failure Analysis		0
		Documented process	3
		FA Improvement suggestions	7
		Process event	9
		Undocumented process	7
		Process output	21
		Process step / task	74

Table D.1 continued from previous page

List of codes			**Frequency**
		Process role	47

Table D.2: Text passages encoded with Experience in FA or Job Description.

	Experience in FA	**Job description**
Interview1 (N=1)	Seit ungefähr 15 Jahren.	Ausfertigung von Guidelines / Test specifications für Untersuchungen
Interview2 (N=1)	1 Jahr, bis Ende Februar 2020 (Airbus) Ungefähr 8 Monate, seit dem 01. März 2020 (Testia)	
Interview3 (N=1)	For 10 months, since January 2020 (Airbus) For 3 years until end of 2019 (Testia)	
Interview4 (N=1)	Since 2012 for Airbus, but started working as an FA Investigator in 2006 at Rolls-Royce	Understanding of failure events at Airbus airframes to conclude on failure mechanism.
Interview5 (N=1)	Länger als 20 Jahre	– Berichte prüfen und korrigieren – Unterstützung der Labormitarbeiter – Koordinieren der Labormitarbeiter – Untersuchungen an Schadensteilen durchführen

Table D.3: Text passages encoded with Information gathering.

	Information gathering
Interview1 (N=1)	Eigenes Archiv (Festplatte/Laufwerk, eigenes Know-How) Schlagwortsuche in Airbus-Datenbanken (EDMS, ECM, Normmaster und mehr) Suche von öffentlicher Literatur Kollegen fragen über Anruf/E-Mail/Persönlich Überprüfung von Erkenntnissen, die außerhalb von Airbus bestehen und ob diese adaptiert werden können/sollten
Interview2 (N=1)	Recherche über die Masterlist zu früheren Schadensfällen (frühere Berichte suchen) Normmaster zur Suche von Spezifikationen (Material, Prozess, etc.) Geteiltes Laufwerk für frühere Dokumente und Spezifikationen Öffentliche Literatur
Interview3 (N=1)	Former reports from Masterlist or ECM Normmaster ZAMIZ
Interview4 (N=1)	Online literature and books Internal documents Lessons learned database Personal network

Table D.3 continued from previous page

	Information gathering
Interview5 (N=1)	Normmaster ZAMIZ SDM+ TechRequest Standardbücher Öffentliche Literatur

Table D.4: Text passages encoded with Data storage, Airbus databases or Communication.

	Data storage	**Airbus databases**	**Communication**
Interview1 (N=1)	lokalen Laufwerken	EDMS ECM Normmaster ASDM-Plattform	Über Telefon und/oder E-Mail Anruf/E-Mail/Persönlich
Interview2 (N=1)		Masterlist Masterlist Masterlist Normmaster Geteiltes Laufwerk für frühere Dokumente und Spezifikationen Workplace	

Table D.4 continued from previous page

	Data storage	Airbus databases	Communication
Interview3 (N=1)		Masterlist ECM Normmaster ZAMIZ	
Interview4 (N=1)		Masterlist Masterlist	Typically, there is a phone call or E-mail from the customer at the beginning of a request. But the official request continues via "Masterlist"
Interview5 (N=1)	geteilten Laufwerk vom Laborteam Schadensdatenbank	Masterlist Masterlist Normmaster ZAMIZ SDM+ TechRequest ECM ECM	

Table D.5: Text passages encoded with KM Understanding.

	KM understanding
Interview1 (N=1)	Vermittlung von bestehendem und neuem Wissen ins Kollegium Rasche, effektive und nachhaltige Übermittlung/Integration von Lessons Learned Erkenntnisse die aus der Bearbeitung einer spezifischen Aufgabe gewonnen werden global zugänglich zu machen (in der Firma/Abteilung)
Interview2 (N=1)	Koordination von Wissen: Wo wird es abgelegt, wie informieren wir die Beteiligten, Was muss abgelegt werden, Wer ist dafür verantwortlich Verfügbarkeit von Wissen: Wer hat Zugriff auf welches Wissen, wie können wir das Wissen am besten verfügbar machen
Interview3 (N=1)	Get knowledge from others via implemememented tools
Interview4 (N=1)	To share the way of working and experiences from employees to the colleagues.
Interview5 (N=1)	Entwickeln von Standards und Spezifikationen um Know-How an andere weiterzugeben Ausarbeitung von Best practices und Lessons learned um Fehler zu vermeiden und Erfahrungen zu teilen

Table D.6: Text passages encoded with Airbus KM procedure, KM problem or Used method / document.

	Airbus KM procedure	KM problem	Used method/document
Interview1 (N=1)	PKCR-Manager Bedeutung PKCR: Product Knowledge Capitalization and Reuse Theoretisch: Regelmäßige Abfragen / Interviews durchführen mit Mitarbeitern der Schadensanalyse um Themen zu identifizieren, die aufbereitet und näher betrachtet werden sollten	Allerdings sind diese nicht frei verfügbar (auf lokalen Laufwerken) und man muss wissen, dass sie existieren Probleme: Wie wird der PKCR Manager über diese Themen informiert? Außerdem ist die Arbeitsbelastung so hoch, dass der PKCR Manager diese Rolle sehr eingeschränkt zusätzlich ausüben kann	Lessons Learned Unregelmäßig Lessons Learned Workshops Lessons Learned aus ASDM-Plattform (sollten frei zugänglich sein und leicht zu finden) Teams werden häufiger durchgemischt bei der Abarbeitung der Schadensanalysen, sodass Wissen divers geteilt wird Kickoff-Guidelines und Best practices wurden erstellt
Interview2 (N=1)	In der Recherche vor dem Kickoff-Meeting und bei der Interpretation der Untersuchungsergebnisse. Note: The designation "PKCR-Manager" was unknown to the Interviewee		

Table D.6 continued from previous page

	Airbus KM procedure	KM problem	Used method/document
Interview3 (N=1)	Not a real Knowledge Management Interviewee 3 is not aware of PKCR and the corresponding manager		
Interview4 (N=1)		Interviewee only knows, who is the PKCR Manager for FA	Best practices Lessons learned Kickoff-Template
Interview5 (N=1)		Note from Interviewee: ECM ist nicht geeignet zur Suche von Berichten. Man muss genau wissen was man sucht. Leider sind diese häufig nur lokal verfügbar Dieses sollte aber in einem Protokoll fest-gehalten werden Rolle des PKCR Managers ist nicht bekannt	Die Anfertigung von Best practices und Lessons learned ist ein erster Schritt Im wöchentlichen Meeting wird viel Wissen weitergegeben

Table D.7: Text passages encoded with KM Improvement Suggestions.

	Improvement suggestion
Interview1 (N=1)	Fertiger Bericht: Verpflichtender Rückmeldungsloop (regelmäßig) mit PKCR Manager um die relevanten Themen zu identifizieren Berichtersteller füllt eine Art Formblatt aus, wo er aufzeigen kann, was für PKCR relevant sein kann Eine einfache Oberfläche/Datenbank die einfach, effizient die gesuchten und relevanten Daten liefert zu jeder Zeit des Prozess der Schadensanalyse
Interview2 (N=1)	Eine Datenbank (Note: Underlining One) zur leichten, vollständigen und schnellen Suche: – Sinnvolle Filteroptionen – Vernünftige, nachvollziehbare Verschlagwortung – Vollständige Historie und Spezifikationen passend zu Filtern und Schlagworten – Best practices auch in der Datenbank veröffentlichen
Interview3 (N=1)	Free and easy access to the Kickoff results and documentations of meetings Database for all relevant information to replace the many databases
Interview4 (N=1)	Good database and better communication to safe time and money in the future Create interface(s) to other departments to share the results of investigation or interesting topics Visualize the Feedbackloop(s)

Table D.7 continued from previous page

	Improvement suggestion
Interview5 (N=1)	Eigene Schadensdatenbank für das Integrated Laboratory, wo nur Schadensfälle gespeichert sind Bessere Stichwortsuche in den Datenbanken Im Protokoll der wöchentlichen Meetings Kernpunkte festhalten die die Arbeit aller erleichtern/verbessern kann Best practices und Lessons learned verstärkt erarbeiten und für alle relevanten Personen veröffentlichen

Table D.8: Text passages encoded with Documented process or Undocumented process (FA).

	Documented process	**Undocumented process**
Interview1 (N=1)		Der Bericht, der vom Test Ingenieur angefertigt wird, durchläuft immer einen Feedbackloop. Das ist eine Art Prozess, der nicht dokumentiert ist
Interview2 (N=1)		Durch die individuellen Untersuchungen ist es kaum möglich sich an einen Prozess zu halten.
Interview3 (N=1)		Note: There is no real process to comply with instead of the feedbackloop mentioned below.
Interview4 (N=1)	There is a team standard for FA / Best practice called "Performing FA" Line of reporting and signature is specified	Many different technical steps with its own typical process Expertise and way of working of the investigator has impact on the steps

Table D.8 continued from previous page

	Documented process	Undocumented process
Interview5 (N=1)	Gewöhnliches Prozedere bei einem Schadensteil: - Bestandsaufnahme (visuelle Inspektion, Fotos, Materialdaten sammeln) - Untersuchungen durchführen (Untersuchungsplan, siehe oben) - Bericht schreiben - Eventuell Bericht überarbeiten	Kein permanent dokumentierter Prozess Festgelegter Untersuchungsplan wird streng eingehalten, aber man bleibt flexibel für weitere nötige Untersuchungen

Table D.9: Text passages encoded with FA Improvement suggestions, Process event or Process output.

	FA Improvement suggestions	Process event	Process output
Interview1 (N=1)			Ergebnisse Interpretationen Resultate Berichte Entscheidende Ergebnisse werden an den Requestor zurückgegeben

Table D.9 continued from previous page

	FA Improvement suggestions	Process event	Process output
Interview2 (N=1)	Vor dem Kickoff mehr Input seitens des Kunden, wie Bauteilgeometrie und Details zum Arbeitsauftrag.	Request Requests Request Deadline (Liefertermin) FA Requests Requests	Reports Report Report
Interview3 (N=1)	Kickoff improvement: Introduce template to catch all relevant information Better and consistent documentation within the meetings		Sometimes, results lead to a deeper investigation resulting in a new request Upon request: Investigator discuss a new request, Experts could request a new FA

Table D.9 continued from previous page

	FA Improvement suggestions	Process event	Process output
Interview4 (N=1)	Implementation of a Follow-Up of the further steps after the investigation Define steps between Kickoff and Release of report Visualize the Feedbackloop(s) Implement a step to evaluate the results and interpretations to the wider business (impact on other programs, departments, etc.)	Usual way is a Request by customers in the Masterlist Request	reports reports Customer gets the final report and decides on further actions report results interpretations results of investigation
Interview5 (N=1)		Einstellung eines Requests	Berichte Technical Check (Vorabbericht) fertigen Bericht Bericht

Table D.10: Text passages encoded with Process role.

	Process role
Interview1 (N=1)	Expert for Failure Analysis for metallic materials PKCR Manager for Failure Analysis Failure Analysis Requestor Failure Analysis Investigator Rolle des PKCR Managers einnehmen Requestor

Table D.10 continued from previous page

	Process role
Interview2 (N=1)	Test Engineer Teile vom FA-Investigator (Untersuchungen durchführen, Ergebnisse im Bericht darstellen) Requestor/Kunde Lab-Koordinator Failure Analysis Investigator Failure Analysis Investigator Kunden Lab-Koordinator Senior Expert Kunden Labor-Koordinator Requester Labor-Koordinator Genehmigende/r

Table D.10 continued from previous page

	Process role
Interview3 (N=1)	Test Engineer Failure Analysis Requestor expert specialist Expert Specialist Investigator Expert Specialist Investigator Experts
Interview4 (N=1)	Failure Analysis Expert for Metal Materials Failure Analysis Requestor, Failure Analysis Investigator customers Customers are: A/C-program teams, Chief Engineering, Production, Procurement, Supply Chain Experts Senior Experts Customer

Table D.10 continued from previous page

	Process role
Interview5 (N=1)	Transnational Failure Analysis Specialist Koordinieren der Labormitarbeiter Integrated Laboratory Coordinator Failure Analysis Investigator, Relevant Engineering Specialist Labormitar- beiter Test Engineers Kunden/Requestor Auftraggeber

Table D.11: Text passages encoded with Process step / task.

	Process step/task
Interview1 (N=1)	Technische Freigabe von Berichten Beratung bei der Durchführung von Schadensuntersuchungen Mitarbeit bei der Ausführung und Erklärung von Ergebnissen in Root Cause Untersuchungen Register FA Request Perform Kickoff Investigation and Compile FA report Close FA Investigations Kickoff Anweisungen geben für die Untersuchungen Im Feedbackloop über die Ergebnisse und Interpretationen entscheiden Resultate interpretieren und Berichte prüfen Der Bericht, der vom Test Ingenieur angefertigt wird, durchläuft immer einen Feedbackloop Dabei wird der Bericht von einem FA Experten geprüft und muss eventuell nachgearbeitet werden vom Test Ingenieur bis der Bericht genehmigt ist vom FA Experten. Arbeitsanweisungen vom Kickoff werden umgesetzt

Table D.11 continued from previous page

	Process step/task
Interview1 (N=1)	Formulierungen und Interpretationen aus dem Feedbackloop gehen in den Bericht ein Entscheidende Ergebnisse werden an den Requestor zurückgegeben
Interview2 (N=1)	Metallographie Mikroskopie Präparierung von Materialien Untersuchung von Materialeigenschaften und Oberflächen Technische Auswertung und Berichterstellung Perform Kickoff, Investigation and Compile FA report Requestor/Kunde stellt Request auf Masterlist Lab-Koordinator prüft auf Durchführbarkeit und schätzt Kosten ab im Team-Meeting werden neue Requests den Mitarbeitern zugeteilt Failure Analysis Investigator übernimmt Request Failure Analysis Investigator legt Deadline fest (Liefertermin) Nimmt Kontakt mit Kunden auf und hält den Kunden auf dem neuesten Stand Nach Fertigstellung des Reports wird dieser auf die vorgesehenen Workspace gespeichert - Report wird an Verteilerliste geteilt (Verteilerliste wird im Report definiert) - Lab-Koordinator und gegebenenfalls Senior Expert genehmigen/autorisieren Bericht

Table D.11 continued from previous page

	Process step/task
Interview2 (N=1)	Report wird dem Kunden zur Verfügung gestellt Laboraufgaben: Untersuchungen/Präparierung selber durchführen, aber auch delegieren und koordinieren unter den Labormitarbeitern Technische Auswertung Kundenkontakt aufbauen: Besorgung der zu untersuchenden Teile, Vorstellungen der Kunden klären, Umfang der Materialprüfung erörtern Es gibt ein wöchentliches Team-Meeting mit Labormitarbeitern, Test Ingenieuren und dem Labor-Koordinator FA Requests werden vom Requester in die sogenannte Masterlist eingestellt Labor-Koordinator verteilt diese Requests an die Mitarbeiter Der verfasste Bericht wird in einer Plattform namens "Workplace" hochgeladen. Von dort wird er automatisch an relevante Prozessbeteiligte und Genehmigende weitergeleitet. Nach der Weiterleitung wird der Bericht genehmigt und authorisiert. Gegebenenfalls wird der Bericht vom Genehmigender kommentiert und vom Verfasser überarbeitet.

Table D.11 continued from previous page

	Process step/task
Interview3 (N=1)	Documentation Macroscopy Microscopy Fractography Striation counting Preparing reports Perform Kickoff, Investigation and Compile FA report Documentation of the condition of the failed parts as received Perform Failure Analysis investigation Prepare report and improve it after Feedback In the weekly Team-Meeting, where the first investigation plan is also determined. Handover of report to expert and/or specialist Expert/Specialist provides ideas for improvement Investigator improves the report Handover preliminary report to Expert/Specialist offline loop After the offline loop, the official system loop begins including signature loop and approval

Table D.11 continued from previous page

	Process step/task
Interview4 (N=1)	Register FA Request, Perform Kickoff, Investigation and Compile FA report, Close FA Investigations All different investigations and delegation of these Prepare reports Give ideas for improvement for other reports Masterlist After Request, there is Kickoff-Meeting with the customer Discussion about the interpretation of the investigation results with other Experts and Senior Experts Kickoff Release of report Feedbackloop(s) Feedbackloop(s)

Table D.11 continued from previous page

	Process step/task
Interview5 (N=1)	Berichte prüfen und korrigieren Koordinieren der Labormitarbeiter Untersuchungen an Schadensteilen durchführen Assign Failure Analysis Investigator, Perform Kickoff, Investigation and Compile Failure Analysis Report Approve Failure Analysis Report Verteilung der Arbeitsaufträge aus der Masterlist an die Labormitarbeiter und Test Engineers Statusabfrage der laufenden Fälle im wöchentlichen Meeting Direkter Kontakt zu den Kunden/Requestor Als genereller Ansprechpartner an den meisten Kickoffs teilnehmen Upon Request: Untersuchungspläne (Welche Untersuchungen) werden gemeinsam festgelegt Gewöhnliches Prozedere bei einem Schadensteil: - Bestandsaufnahme (visuelle Inspektion, Fotos, Materialdaten sammeln) - Untersuchungen durchführen (Untersuchungsplan, siehe oben) - Bericht schreiben - Eventuell Bericht überarbeiten Technical Check (Vorabbericht) an den Auftraggeber übergeben Den fertigen Bericht in den Signature-Loop geben Bericht wird in Datenbank ECM abgelegt und in einem geteilten Laufwerk vom Laborteam