Improving the Management Process of Work Instruction Documents

Bachelor thesis

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Improving the management process of work instruction documents
A case study at the manufacturing company Aeronamic

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Preface

This report that lays in front of you is the result of a very enjoyable and interesting time I had at Aeronamic, the host company where I did my research after the management process of work instruction documents. The approach of this research and the solutions found to improve the document management process, are all explained in this thesis. Aeronamic offered me a workspace where I carried out my research from May until August 2018.

I had a great time at Aeronamic, where I was warmly welcomed by the manufacturing engineering department. Aeronamic is a very well-organized organization that spends much care on waste elimination and other improvement projects. The products they make are of very high quality and very interesting to see. I was given the possibility to have a close look at the company's business processes and I felt that my opinion was valued.

During my research period I was supported actively by people from Aeronamic and the University of Twente, which I would like to thank for their support. To start, I would like to thank Ronny Blaauwgeers who was my supervisor during my research time at Aeronamic. Ronny was vey concerned with my progress and we shared thoughts daily, which significantly improved the outcome of this research. Ronny was not only a devoted manager that had great knowledge about the manufacturing and preparation process, but he was also a great mentor whit whom I was able to share experiences and have a laugh with during lunch breaks.

The second person I would like to thank is Tom Hofsté, who was a great help in finding my way in the company and especially with the system Aras. Tom was always available to answer my questions even though he was loaded with challenges himself.

On behalf of the University of Twente I was supervised by Maria Iacob and Adina Aldea. I really appreciate the support they gave me to turn this research, that was mostly practical at first, into a well-structured academic research with this thesis as the result. Therefore, I would like to give special thanks to Maria and Adina.

Finally, I would like to thank all the colleagues of the manufacturing engineering department and my fellow students that did an assignment for Aeronamic at the same time. It is a list of too many names to mention personally, but I learned form the experience of each one of them and they made my time at Aeronamic very enjoyable.

I hope you enjoy reading this thesis as much as I enjoyed my time at Aeronamic and writing it.

Olivier Berghuis

26-10-2018

Management summary

Aeronamic manufactures high speed rotating parts and sub systems for the Aerospace industry. To meet the high-quality requirements of the aerospace authorities it is important to have a good work preparation process and a system that proves that products are created according to the aerospace regulations. At the Manufacturing Engineering department of Aeronamic, certified engineers create, review and release the work instructions documents, used by the operators on the shop floor. The goal of this research was to improve the document management process by making it more structured, more controllable and fully digital. The full digital document management process fits the ambition of Aeronamic to realize a paperless factory. This research shows that a better document management process can realize a paperless production process on the shop floor.

Aeronamic started working with a combination of two IT systems a couple of years ago. The ERP (Enterprise Resource Planning) system called Isah and the PLM (Product Lifecycle Management) system called Aras. The ambition of Aeronamic is to arrange Aras as the leading system for all manufacturing information including the management of work instruction documents. Therefore, the main research question is:

'*How can we improve the document management process at Aeronamic?*'

To gain a good insight in the current process (IST) and the effect of paper files in the process, we decided to use Business Process Modelling and Notation (BPMN) to create workflows of the current process. By creating a workflow of the desired situation (SOLL) as well, we were able to perform a gap analysis (IST vs. SOLL). We made a distinction between the document preparation process within the Manufacturing Engineering department and the use of the documents on the shop floor. The document preparation process is explained in three phases, the creation, review and release phase.

In the theoretical framework we first reflect on the use of BPMN and learn how to correctly model business processes according to the BPMN method. We reflected on the use of PLM for the management of production documents as well before we decided to look for improvements in the document management process using Aras.

With the use of BPMN we started to analyze the current document creation, review and release process of two document types, the ATS (Aeronamic Technique Sheet) and the BV ("Bewerkingsvoorschrift"). Both documents are linked to the process plan(s) of a product and needed for a specific production step or operation. Analyzing the processes of both documents showed us that there was no uniform way of creating, reviewing and releasing work instruction documents and documents were reviewed on paper. It was hard to measure the problem in clear figures like long lead times or high production cost, but the lack of uniformity and the use of paper resulted in some clear inefficiencies:

- Documents were stored in different locations and in different formats (ATS documents are stored after release in Aras. BV documents are stored in a map on the Aeronamic server)
- The uses of printed files in the review loop made the progress hard to trace.
- ATS documents are signed on paper for release and printed as frozen PDF for use by the operators
- By scanning documents text is not recognized as text and digital search functionalities cannot be used.

- Documents are created manually including the generation of document IDs and linking the document to the related items, which is error sensitive.
- The storage of ATS documents in Aras involved the interference of the CMO (Configurations Management Officer) and an extra review loop

The use of paper, the number of manual tasks and the lack of support by a digital system, makes the entire process difficult to trace and sensitive for mistakes. Difficulties to trace documents and big chances of mistakes in the documents and therefore the need to improve the documents, can be time consuming and frustrating. Times needed to create documents and get them reviewed varies a lot, but it has no negative effect on the production lead times, because getting the product approved for production by the authorities takes even more time. Therefore, it was not needed to evaluate on lead times of documents in more detail to measure the process in time units.

We determined to evaluate the process on the use of paper and lack of support by a digital system that together are the cause for inefficiencies, sensitivity for mistakes and lack of traceability. Also, the registration of made chances and other historic records is very difficult with the use of paper files.

With the use of BPMN we were able to get a clear overview of the differences in the creation, review and release process of the ATS and BV documents. Comparing the workflows of the IST and SOLL situations helped us to find the focus points for improvement. Knowing these focus points, we started looking for possible ways to use Aras to improve the process.

We found possible solutions to improve the document management process at Aeronamic with a big role for three functionalities of Aras. Saving documents to Aras, distribute the documents digitally in Aras for review, digitally review the documents in Aras and release the documents automatically without the interference of the CMO can be made possible with the use of three tools.

Aras Office Connector

The Aras Office Connector makes it possible to create documents using the familiar interface of Microsoft Office Word, but controlled by Aras and directly saving the file to Aras. This tool supports automatic number generation and the use of templates.

Workflow in Aras

The use of digital workflows in Aras makes it possible to distribute documents digitally in Aras and assign review tasks to specific users. The workflow starts automatically when a document is saved to Aras.

Visual Collaboration

The Visual Collaboration tool offers the opportunity to digitally review the documents without the reviewers changing the content.

The correct implementation of these tools in Aras and a better use of document states can realize a big improvement of the document creation, review and release process for every document type. The workflow we created of the suggested situation using Aras to manage document shows us a fully digital, traceable and paperless document management process.

Just like in the work preparation process, the use of paper causes inefficiencies on the shop floor as well.

The information needed by the operators for production is presented using a shop traveler. The shop traveler is a ring binder containing the printed production order, including the linked documents. All the information in this shop traveler is presented using paper files which means that there is no direct link with the database. Operators must manually search for the documents that are referred to in the shop traveler. The ATS documents are retrieved directly from Aras by the operator. Since Aras is a management system it is not meant to be used as an user interface on the shop floor.

Electronic Shelve Labels
One of the running pilots at the assembly department at Aeronamic showed us an alternative way of presenting document to the operator using a barcode and a scanner. Combining this solution with the use of Electronic Shelve Labels (ESL) could be a good solution to improve the way information is distributed on the shop floor and make the process completely paperless. The ESL system is not used before on a production floor but could be very suitable.

Recommendations
The research showed big advantages of the implementation of the three tools within Aras to improve the document creation, review and release process. We could find any big disadvantages and therefore we would recommend Aeronamic to start working with Aras as their document management system for each document type using the tools as explained in this thesis.

After the implementation of this solution Aeronamic should focus on arranging the process plans within Aras. Managing the process plans in Aras is needed to make use of the barcodes for the digital distribution of information on the shop floor as explained in chapter 4 of this thesis.

After arranging the process plans in Aras, Aeronamic can start with further testing the possibilities of the use of Electronic Shelve Labels to present the needed production information to operators, in combination with the use of barcodes as explained in section 4.2 of this thesis. This recommendation is focused on the realization of a paperless manufacturing process. To be sure the use of ESL is suitable for the production process, Aeronamic is recommended to consult with a company called Pricer, that developed a system for retail businesses, like supermarkets, that uses ESL to present product information to customers.

The last improvement to make the entire process easier and less error sensitive is the communication between Aras and Isah. After arranging the process plans in Aras and realizing the document creation, review and release process in Aras, database records of the process plans and documents should be copied to Isah automatically, to create the production order of a product and maintain the production data within Aras. Work preparation data is than managed in Aras and actual production data in Isah according to the IT strategy.

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Terms and definitions

Table 1.1: Terms and definitions

Term	Abbreviation	Definition
Aeronamic	AEC	Name of the host company
Aeronamic Technique Sheet	ATS	The ATS is a work instruction document type that explains the operators how a technical process, within a production step, needs to be executed. The ATS is a very specific instruction for the execution of the process for a specific part.
Bewerkingsvoorschrift	BV	The BV work instruction document explains operators how a certain production step needs to be prepared or the after treatment after a machining step. The difference between the ATS and BV is that the BV are more general instructions with less risk, for example how to deburr the products that come out of the machine.
Configurations Management officer	CMO	The CMO is responsible for the Engineering configuration of the ICT systems at Aeronamic. The use of configurations is explained in section 1.2
Engineering Change Notice	ECN	An ECN is created when the design of a product changes. The ECN is a notification that the impact of the change in the design to the configuration of data in the system, need to be evaluated and when needed changes need to be made.
Ist vs. Soll analyses		Ist vs. Soll are German terms that are commonly used to identify the evaluation of a change process. Ist vs. Soll means that the current situation (IST) is compared with a desired future situation (SOLL).
Lead Engineer	LE	Lead Engineers are the certified engineers that prepare the manufacturing process for the products that are designed by the client.
Manufacturing Engineering Change Notice	M-ECN	The M-ECN is the notification that a change in the design of a product can possibly have an impact on the manufacturing process and therefore the manufacturing configuration needs to be reviewed and changed.
Process Plan		Process Plan is the term used by Aras to name the list of all production steps needed to produce a certain product with the linked documents attached.
Product owner		The product owner is the Lead Engineer responsible for the successful creation of the product. This product owner has the most knowledge about the product and request of the client. The product owner is responsible for gathering all materials needed to create the process plan / routing to produce the product.
Production Order		Production order is the term used by Isah to name the list of all production steps needed to produce a certain product with the linked documents attached. The production order is related to one product and has a unique number

Production Step		A production step is a station in the production process were a certain operation is executed before the product is send to the next production step.
Routing		Routing is the term used by Isah to name a possible sequence of production steps to produce certain products. Aeronamic for example produces rotors and turbine wheels which we call part groups. Within these part groups, individual parts have different characteristics but follow the same sequence of production steps. The details of the operations vary. The routing is a possible order of production steps that can be used as the base to create a production order that is part specific.
Shop traveler		The shop traveler is a ring binder filled with the production order and measuring data list. The shop traveler carries all the needed information or references to information files needed by the operators to produce a part. The shop traveler travels over the shop floor, along with the production batch that is linked to the production order. In section 3.3.1 more explanation about the essence of the shop traveler is given.
Special Process Specialist	SPS	The SPS are certified engineers that are specialist in certain special production processes. The SPS is the only engineer that is certified to create ATS documents for the special technical production process he or she is certified for.
Werkkaartnummer		A number that represents the relation between a production step for a certain production order.
Bill of Materials	BOM	List with materials needed to create a product
Engineering Bill of Materials	E-BOM	The design is created by the client and the E-BOM shows which materials are needed according to this design. An example is the raw material needed for the part.
Manufacturing Bill of Materials	M-BOM	The M-BOM is the list of materials needed after the design of the client is translated to a production process at Aeronamic. Work instruction documents are an example of an item that can be present on the M-BOM but not on the E-BOM
Work in Progress	WIP	Parts or other products that started the production process but are not finished yet.

1. Introduction

This document is the final thesis of my bachelor study Industrial Engineering and Management at the University of Twente. For this thesis I had to find a bachelor assignment to graduate as a Bachelor of Science. After a short search I encountered Aeronamic. They were very happy to offer me an assignment focused on improving the document management process for work instruction documents created at the manufacturing engineering department of Aeronamic.

I got introduced to the problems around the current way of creating, reviewing and releasing the work instruction document used in production. During my problem analysis I realized that changing this process on the front hand, can also have an impact on the way these documents are distributed to and used on the shop floor. Aeronamic started a long-term project of continuous improvement five years ago. A lot of engineers followed courses to become black belt LEAN engineers. In the spirit of this continues improvement I found it important to not only limit my research to improving the document creation, review and release process but also understand how the possible improvements in this process can form a base for improvements in the way these instruction documents are used on the shop floor.

The total scope of this thesis is not only the creation, review and release process of documents but the entire document management process, including the maintenance and revision of documents. The process of creating, reviewing and releasing documents is used as the base to evaluate the document management process. The way the documents are presented to the operators on the shop floor is referred to as the document distribution process.

Aeronamic

Aeronamic develops, manufactures, test and maintains high-speed rotating systems for the aerospace industry. Aeronamic is a Dutch company located in Almelo with one extra facility in Sibiu Romania.

Aeronamic manufactures subsystems with highly accurate rotating parts for nearly three decades as this originally tied in well with the nature of the ultra-centrifuge manufacturing of Urenco Nederland B.V., its former parent company.

Aeronamic produces and maintains systems for customers like Honeywell, Parker and UTC. All these customers operate in the aerospace industry which forces Aeronamic to comply with the aerospace standards and adhere to regulations determined by aerospace authorities. To meet all the requirements to be certified for production of aerospace subsystems, Aeronamic arranged its entire work environment around the rules set up by the authorities. This is an important factor that needs to be considered when evaluating business processes at Aeronamic and designing possible solutions.

1.2 Problem statement

The problem that I got introduced with at the Manufacturing Engineering department of Aeronamic, was that the current way of creating and reviewing work instruction documents for production was inefficient. The current way of preparing the work instruction document does not fit the ambition of Aeronamic and is therefore an improvement project that I was assigned to do for Aeronamic.

The Lead Engineers and Special Process Specialists, who create and review the documents, show their dissatisfaction with the current way of working. The creation and review process requires a lot of actions and the progress is difficult to track.

Aeronamic produces for the aerospace industry, so they must meet the Aerospace quality norm. To prove that the products are produced conform the aerospace quality norms, the entire production process is prepared, documented and tracked. The production process at Aeronamic is divided in three separate configurations, the *As Designed, As Planned* and *As Built* configuration. Figure 1.1 shows the configurations structure at Aeronamic

As Designed

The *As Designed* configuration is based on the design of the product that is created by the engineers of the client. Aeronamic processes the design and assignment from its clients in Aras. The product is stored in Aras as a part and all the materials needed according to the design are linked to the part. We call this list of needed materials the E-BOM, Engineering Bill of Materials. The Configurations Management Officer (CMO) at Aeronamic is responsible for the As Designed configuration.

As Planned

The *As Planned* configuration is the configuration in which the way Aeronamic addresses its resources to produce the by the customer designed part. In the *As Planned* phase the production routing is determined. The routing is a road map of the product through the shop floor from raw materials to product. Each production step including the related machine, tools, materials and time needed are planned before production. The resources needed to produce a product are listed in the Manufacturing Bill of Materials, or in short M-BOM. For each product a product specific routing is created by a certified engineer. At each production step certain activities need to be performed by the operators. These steps are explained in the different work instruction documents, for example the ATS (Aeronamic Technique Sheets) and the BV ('Bewerkingsvoorschrift' *operation instructions*). The package of documents, related to a production step, give the operator all the needed information to perform his task.

The *As Planned* configuration is most relevant for my research since I focused on the management of the documents that should be managed in the As Planned configuration.

As Built

Next to a good planning it is very important to register the actual production activities and used resources (P-BOM). This is done in the *As Built* configuration. Saving records of the actual activities is needed as prove that products are indeed produced *As Planned* by a certified engineer. If there are big inconsistencies between the *As Planned* and *As Built* data, it is important for Aeronamic to find out the reasons for these inconsistencies and determine if they are a threat for the quality of the current production order and future production orders. Saved production data can also be used to make better planning estimates for future production orders. Examples of production data are

production times, measurement data and other test data. Figure 1.1 shows the configurations structure at Aeronamic

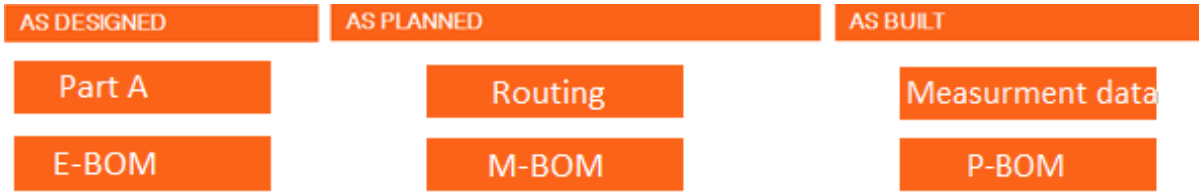


Figure 1.1: Configurations structure

A good document management system is important to assure high quality production. Aeronamic has different information management systems that they use to manage all the manufacturing data, but the systems are not utilized by their full potential. Aeronamic has a Product Lifecycle Management system (PLM) called Aras, meant to manage all the manufacturing engineering and quality management data. Next to the PLM system Aeronamic uses an Enterprise Resource Planning systems (ERP) called ISAH, to manage all transactional data, production orders and 'As Built' production data. In the problem analysis chapter of this thesis I reflect more on the unused potential of mainly the PLM system.

In the current situation, work instruction documents are created manually by Lead Engineers or Special Process Specialists and printed for review by other Lead Engineers or the Quality and Development department. The use of paper documents is the reason for some of the problems that are time consuming and frustrating for the employees involved in the process. I listed some of the problems caused using paper in the preparation process below:

- Distributing and localizing the documents is difficult and time consuming
- Many actions needed to print, sign and scan the documents
- Version control is difficult with paper documents
- Documents are frozen by scanning the documents as images. By doing so it is not possible to use any digital search functionality in the documents.
- No active link with database records of linked items.

Not only the use of paper, but also the process of manually creating the documents and its content creates room for errors. The engineers have freedom in their way of working because of the manual creation process. This is the cause for some of the problems. Problems that can occur because of the manual creation process are:

- Mistake with typing document numbers
- Engineers create their own document types
- Documents are saved and stored in different forms and locations
- Different formats of content

The problems all together make the process, both in the creation of documents as the use in production, time consuming and difficult to guarantee good quality.

Figure 1.2 shows the problem cluster of the document management process.

In chapter 3 the current situation at Aeronamic is explained in more detail.

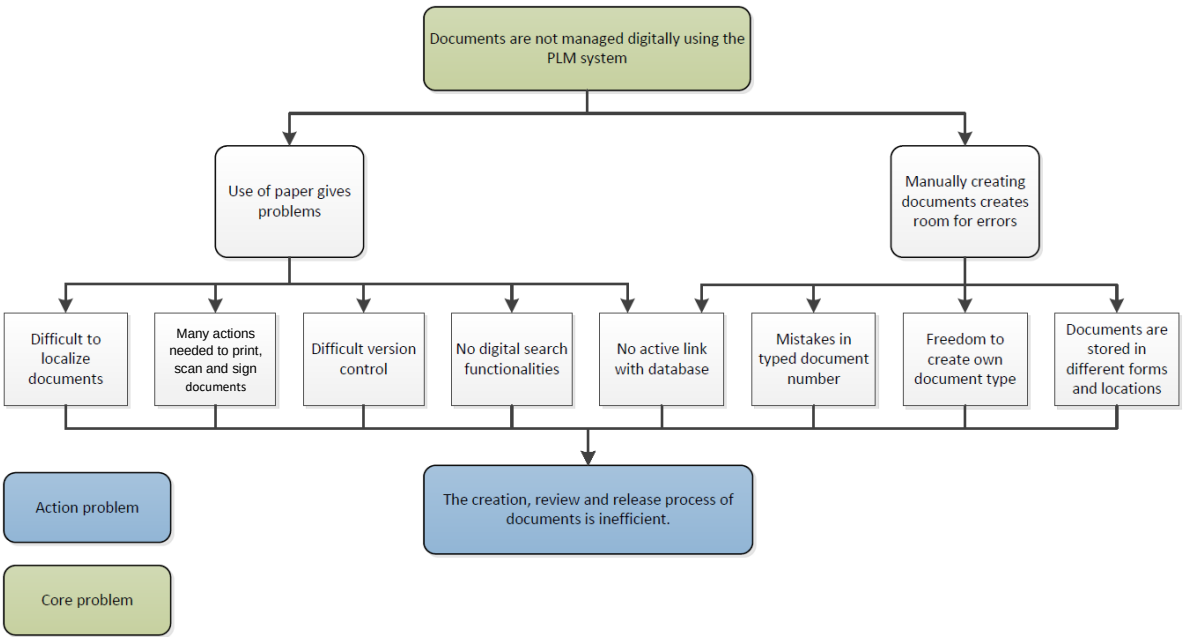


Figure 1.2: Problem cluster of the document management process

1.2 Research goal

The wishes at Aeronamic are to have a clear structured process of creating, reviewing and releasing production documents, managed digitally in the Product Lifecycle Management (PLM) system with active links to database records of linked items. Not only the creation, review and release of new documents must be a structured process, the change process of existing documents that need to be adjusted because of internal changes in the manufacturing process or external changes in the design of the product or international standards must be a clear structured process as well. My goal was to find a structured method for the entire document management process that suits the way of working at Aeronamic and adheres to Aeronamic's translation of the aerospace regulations.

1.3 Norm versus Reality

The problem of the inefficient document management process is hard to translate to one measurable concept like long lead times or high production costs. A problem does not always have to be a difference in digits.

Aeronamic experiences a problem because they identified a gap in the wished and actual performance. Prostacos et al (2002) introduced us to the concept of performance imperatives. The performance imperatives are concepts that are valued by a company as essential elements to be competitive. Prostacos et al. stated that the two performance imperatives acknowledged by most production companies in 2002 were flexibility and innovations. This comes very close to the theory of Charles Darwin that 'the ones that are most adaptable to change are most likely to survive'. This maybe is a little philosophic and off topic, but I believe that this nowadays is still applicable for most companies. Aeronamic understand that they must be flexible and already invest in experiments with innovative production methods. Aeronamic presented some desired outcomes to me as the norm, which is in line with the imperatives flexibility, productivity and innovation. The innovative goal for Aeronamic is to create a full digital factory.

Table 1.1 shows these wishes set against the current situation. I will reflect on the gap in performance between the desired situation (SOLL) and current situation (IST) in detail in chapter 3.

Table 1.1 Norm versus reality variables

Reality	Norm
Every document is printed for review - Signatures *set on paper with pen* - *Document brought on paper to reviewer by creator* - *Version control is difficult (is the paper copy the correct version?)* - *Documents are frozen as images*	No more use of paper copies to review documents *- Digital signatures or alternative digital solutions for prove of approval.* *- Digital distribution of documents for review* *- At all time know the status of a document* *- Document revision numbers change automatically* *- Active link to related database records*
Work instructions manually created in Word *- Manually generating document number* *- Very limited templates in Word for different documents* *- Creator scans document to freeze it and the configuration officer stores the scanned pdf file in ARAS* *- Documents saved locally and at different locations*	Work instructions directly generated in ARAS *- Automatically document number generating in ARAS* *- Templates in ARAS for different document types* *- Creator creates, freezes and saves document in ARAS directly* *- Documents are all stored and managed within ARAS*

1.4 Scope of the research

The future goal for Aeronamic is to have a content driven system instead of a document driven system. At the current situation documents are saved digitally but the content is not digital. Documents are saved as an image by scanning the paper file to a PDF format. The text is not recognized as text in the file and therefore the content is not digital. We agreed that investigating the possibilities to create a content driven system exceeded the scope of my research and therefore I did not focus on creating digital content. I focused on improving the way documents are created, reviewed and stored digitally, without the focus on digitalizing the actual content. I decided to include the reflection on the impact of the use of documents on the shop floor.

Aeronamic recently started working with Aras as their PLM system that communicates with their ERP system called ISAH. Aeronamic is still improving the way these systems are used and their wish is to continue working with these systems. During my research period I therefore did not investigate using possible other systems but focused on investigating whether these systems suit the needs of Aeronamic. My research is focused on how to design a new and more efficient way of creating, reviewing and releasing work instruction documents, using Aras as the data management system for the production documents.

I will limit the designed method to two of the documents, the ATS and the BV. An Overview of all document types is given in appendix 1. The ATS and the BV are both work instruction documents that are used in the routing of a part. After consulting with Ronny, we concluded that the differences between these two document types give a good insight in the problem. Finding a uniform method for these two types will give Aeronamic enough insight in the possible improvements for all documents.

1.5 Stakeholders

I will do my assignment for the manufacturing engineering department of Aeronamic. The assignment is focused on improving an internal process. To find a good solution for the improvement of the process it is important to understand who the stakeholders are and who will potentially benefit from the generated solution.

The work preparation process can be divided in three stages: creation, review and release. After the release stage the document is ready for use. The use stage is important for the distribution process of the documents on the shop floor.

Different departments are involved in the different stages of the work preparation process. Table 1.2 shows the different departments involved related to the four stages.

Table 1.2: Stakeholders

Department /Team	Cycle stage	Role and connection with work preparation
Lead Engineers	Creation, review and release	The Lead Engineers create the work instruction documents and are responsible that the right people review the instructions. After the review of for example the quality department, the Lead Engineer signs for final release and sends the document to the configuration officer or saves the document on the local server. Figure 3.1 shows the workflow of this process.
Quality Development Engineer	Review	QDE is responsible for the quality control loops within the manufacturing department of Aeronamic. They can review documents and judge whether all requirements are met.
Configurations Management Officer (CMO)	Release	For some documents the CMO is responsible for the storage of the document in the PLM system ARAS in the current situation. I will come back to this in chapter 3.
Operators	Use	The operators are the target group for the work instructions. They are the ones who need to work with the documents and therefore need to have access to the right information at the right time. The right information needs to be presented in an understandable way.

As shown in table 1.2 multiple departments and employees relate to the work instruction documents lifecycle. The goal is that they will all benefit from a better and more efficient way of creating, reviewing and releasing the work instruction documents and the way the documents are presented to the operators.

Evidently one of the individual stakeholders, not mentioned in table 1.2, is de Director Manufacturing Engineering, Ronny Blaauwgeers who is responsible for the progress of the entire department. As my internal supervisor at Aeronamic he closely monitored my progress to make sure my proposed solution fits the norms and standards of Aeronamic.

1.6 Deliverables

The goal of my research is to find one uniform and digital way to create, review and release all work instruction documents, needed for production, and managed by the PLM system Aras. To show that the method I found is indeed a solution to the problem, I did a proof of concept for the digital distribution and review loop using Aras within the manufacturing engineering department for text documents. This report is written to explain and support my findings.

I also evaluated possible improvements of the distribution of the document on the shop floor because of the improvements of the digital management of the documents. I visualized a possible solution in this thesis.

In this document I worked out an IST versus SOLL analysis that Aeronamic can use to determine if they will implement the recommendations I give at the end of this thesis. For this IST versus SOLL

analysis I made workflows of the document creation, review and release process, using the Business Process Modelling Notation, v2.0 of the Object Management Group (2011). I will provide Aeronamic with these models in presentation form to explain and enforce my findings.

1.7 Research approach

My research involves the use of Information Systems for the improvement of the document management process. I decided to use the Design Science Research Process (DSRP) method of Peffer (2006). Peffer concluded that little models exist concerning the use of design science for research after Information Systems. Peffer designed the DSRP model which supports researchers to carry out a design science research in a structured way and forms a model to present the research to readers and reviewers. Figure 1.3 shows the schematic view of the DSRP of Peffer (2006). The process model consists of six activities in a nominal sequence:

1. *Problem identification and motivation*

'Define the specific research problem and justify the value of a solution. Since the problem definition will be used to develop an effective artifactual solution, it may be useful to atomize the problem conceptually so that the solution can capture the problem's complexity. Justifying the value of a solution accomplishes two things: it motivates the researcher and the audience of the research to pursue the solution and to accept the results and it helps to understand the reasoning associated with the researcher's understanding of the problem. Resources required for this activity include knowledge of the state of the problem and the importance of its solution.'

The use of paper causes a lot of inefficiencies in the document management process of Aeronamic. Figure 1.2 shows the problem cluster of the problem. The inefficient way of working does not fit the progressive vision of Aeronamic. The problem identification is all based on empirical data gathered by conducting interviews and observing the process.

2. *Objectives of a solution*

'Infer the objectives of a solution from the problem definition. The objectives can be quantitative, e.g., terms in which a desirable solution would be better than current ones, or qualitative, e.g., where a new artifact is expected to support solutions to problems not hitherto addressed. The objectives should be inferred rationally from the problem specification. Resources required for this include knowledge of the state of problems and current solutions and their efficacy, if any.'

The objectives of a solution are given in section 1.2 and 1.3. The document management process must be fully supported within Aras and the use of paper most be excluded from the process. Table 1.1 shows the norm of the desired solution.

3. *Design and development*

'Create the artifactual solution. Such artifacts are potentially, with each defined broadly, constructs, models, methods, or instantiations', Hevner et al. (2004). This activity includes determining the artifact's desired functionality and its architecture and then creating the actual artifact. Resources required moving from objectives to design and development include knowledge of theory that can be brought to bear as a solution.'

For the design and development activity we decided to use Business Process Models of the IST and SOLL situation to map the document management processes of the current and desired situation, to be able to evaluate the improvement of the suggested solution. To correctly create the business models and evaluate the use of PLM as a document management system we consulted theoretic sources. In chapter 2 the theory is evaluated and in chapter 3 the problem analysis using the theory is explained.

4. *Demonstration*

'Demonstrate the efficacy of the artifact to solve the problem. This could involve its use in experimentation, simulation, a case study, proof, or other appropriate activity. Resources required for the demonstration include effective knowledge of how to use the artifact to solve the problem.'

For the demonstration of the suggested solution we did a proof of concept. The proof of concept is presented in chapter 4 of this thesis.

5. *Evaluation.*

'Observe and measure how well the artifact supports a solution to the problem. This activity involves comparing the objectives of a solution to actual observed results from use of the artifact in the demonstration. It requires knowledge of relevant metrics and analysis techniques. Depending on the nature of the problem venue and the artifact, evaluation could include such items as a comparison of the artifact's functionality with the solution objectives from activity 2 above, objective quantitative performance measures, such as budgets or items produced satisfaction surveys, client feedback, or simulations. At the end of this activity, the researchers can decide whether to iterate back to step 3 to try to improve the effectiveness of the artifact or to continue to communication and leave further improvement to subsequent projects. The nature of the research venue may dictate whether such iteration is feasible or not.'

For the evaluation of our solution we used Business Process Modelling to compare the model of the suggested solution with the current situation. We use the selected norm in section 1.3 to reflect on the suggested solution.

6. *Communication.*

'Communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences, such as practicing professionals, when appropriate. In scholarly research publications researchers might use the structure of this process to structure the paper, just as the nominal structure of an empirical research process (problem definition, literature review, hypothesis development, data collection, analysis, results, discussion, and conclusion) is a common structure for empirical research papers. Communication requires knowledge of the disciplinary culture.'

The analysis of the given problem and the possible solution are presented to Aeronamic in this paper. For the structure of this paper a common structure for empirical research is used, the Managerial Problem Solving Method of Hans Heerkens (2012). (Problem Identification, Problem Solving Approach, Problem Analysis, Formulating alternative solutions, Choosing solution, Implementing solution & Evaluation of the chosen solution). This thesis is also published for free use by anyone that is interested in the improvement of document management.

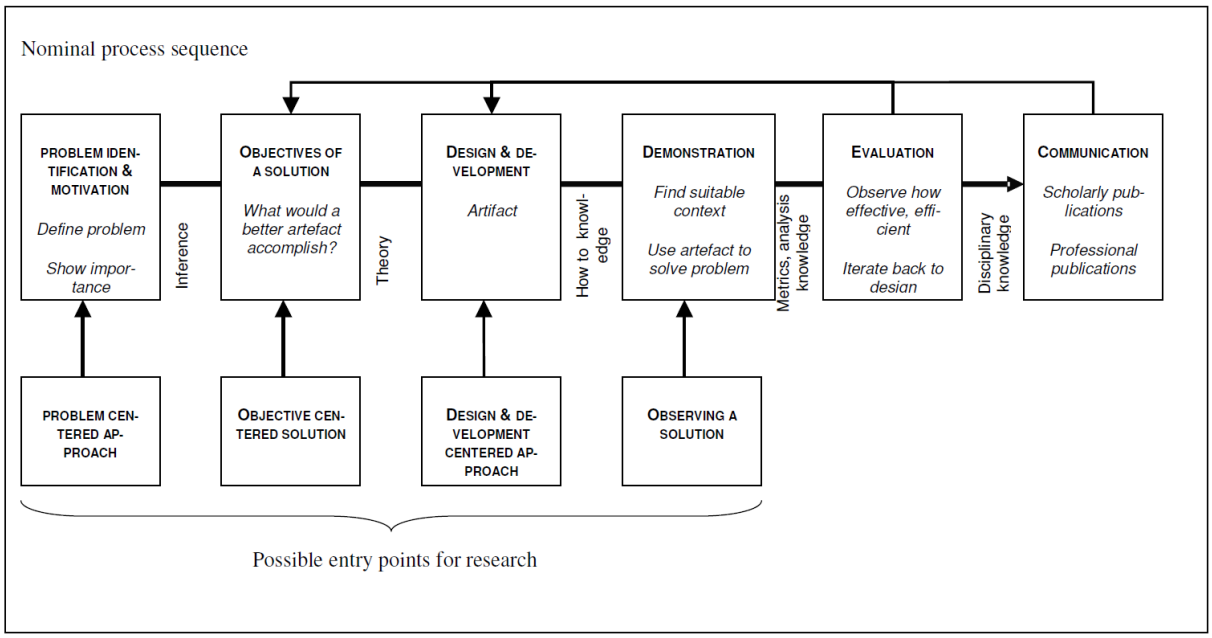


Figure 1.3: Design Science Research Design model by Peffer (2006)

Peffers design science research model can be used with different centers of approach. The process is structured in a nominal order, but it is not expected that every researcher follows the process in sequential order from activity 1 to 6. Researchers can start at almost every activity and move outward.

Objective centered Approach

Aeronamic introduced me with a clearly stated problem that the document management process at the Manufacturing Engineering department is inefficient. The Objective was to improve the document management process by digitalizing the process and make it more structured and easier to trace the documents along the process. Using Aras PLM as the document management system must support the outcome and realize the reduction of the use of paper files in the process. The objectives were very clear, so I started analyzing the problem with the objectives as a starting position.

1.7.1 Interviews

Part of the research approach to gather all the needed information, is conducting interviews with everybody participating, or otherwise involved, in the document management process. We will look critically at the empirical data that we gather with these interviews to lower the risk of bias. We will interview Lead Engineers, Special Process Specialists, Quality and development Engineers, Director Manufacturing Engineering and Operators. The different perspectives of these people should provide a good understanding of the process.

1.7.2 Literature Review

The focus of this research is to improve a business process. We will use Business Process models to do a performance analysis of the process. Literature about BPM and BPR (Business Process Re-engineering) will help us to understand how to create business process models and compare the current with the desired situation.

1.7.3 Desk Research

Next to the papers used to understand BPM we can use a lot of materials and information about the document management process at Aeronamic that are available within the company. Examples of research activities we can do at our desk at Aeronamic are: evaluate the work instruction documents, consult manuals of Aras, navigating through the systems Aras and walk the process of creating, reviewing and releasing a document.

1.8 Research questions

The research approach is meant to help me find the answers to the research questions in a structured way. The answers to these questions give me the needed information to find a solution for the core problem. In this section the research question and sub-questions that are prepared because of the problem identification are presented.

1.8.1 Main research question

In section 1.1 I explained the problem around the work preparation at the Manufacturing Engineering department. The most important action problem that was noticed by Ronny Blaauwgeers, Director Manufacturing Engineering, is that the current document creation, review and release process is inefficient. The core problem that we found is that documents are not managed with the support of a digital system. So, the main research question is:

'How can we improve the document management process at Aeronamic?'

To be able to answer this main research question we first need to get a better understanding of the current situation at Aeronamic and gain more knowledge about document management using theory. Therefore, we divided the main research question into a couple of sub-questions

1.8.2 Sub-questions

1. ***How is the current document management process at Aeronamic arranged?***

The answer to this question must tell us how documents are created, reviewed and released in the current situation and by whom. By investigating how the process works we evaluate which systems are used to support the process and what are the limitations. We need to understand the process of the current situation to find reasons for the problems and formulate possible solutions.

2. ***How can we model the current situation?***

Modelling the business process can help us to evaluate the problem by presenting the process in an understandable and clear manner. Theory about business Process Modelling can help us in creating the models.

3. ***What elements are causing inefficiencies in the process?***

The evaluation of the process must tell us what parts and elements of the process are the cause of the inefficiencies. Understanding the causes for the inefficiencies may help us to find solutions that realize the objectives set for this research.

4. ***What examples of solutions exist to improve document management?***

After identifying the problems and reasons for inefficiencies we can focus on finding solutions to the problems. Theory about document management can help us find ways to improve the process. Given the large number of reports about the data management and the elimination of paper in production processes, Aeronamic is not the only company that is concerned with the improvement of document management. Consulting with other companies may help us in creating possible solutions.

5. ***How can we design a possible solution to realize the desired solution?***

For the analysis of the problem and a possible solution it is important to understand the intended outcome of the research. One of the activities of Peffers model is to set objectives that we did in section 1.3. To select a possible solution for Aeronamic we must reflect the solutions to the objectives and the aerospace requirements.

2. Theoretical framework

To find answers to the research questions, especially 2 and 4, and evaluate the IST and SOLL situation, I used theory found by doing literature research.

2.1 Enterprise Architecture

The goal of the research is to improve a business process with the intention of using IT systems to make the process paperless. We will evaluate the use of an IT system as a structured element of the business. The concept of evaluating how a company is structured to perform its operations and reach its goals is called Enterprise Architecture. Enterprise Architecture's focus is to set clear guidelines and principles how a business should operate and implement change. The structure of the company, its business processes, the information flow and the contribution of IT systems to the operations can be modelled using business process modeling techniques. Enterprise Architecture helps us to understand the coherence between the business operations and IT. Jelle (Value Blue). (2017). *Wat is enterprise architectuur*? and HORA. (2016). *De rol van enterprise-architectuur.* We did not make big changes in the IT structure of Aeronamic during our research, we focused on restructuring the current IT systems used by Aeronamic as we explain in chapter 4. Therefore, it is enough to understand the basic principle of Enterprise Architecture, but we will not dig any deeper into this concept. For the evaluation of business processes, including the support of IT systems we will, use theory about Business Process Modelling.

2.2 Business Process Modeling

Using business process models to get a better understanding of a certain process is an element of the Business Process Management discipline. Business processes are part of the operations needed to keep the company running and reach the company goals. 'A business process is the combination of a set of activities within an enterprise with a structure describing their logical order and dependence whose objective is to produce a desired result.'(Aguilar-Savén R. S. (2003). *Business process modelling*).

Business Process models are used to generate a better understanding of the process and support the evaluation of its performance. Business Process Models are often used in a change process to compare models of the current situation with the desired situation. The creation and evaluation of these models with the intention of improving the process is called Business process re-engineering.

2.2.1 Business Process Re-engineering

Business process re-engineering (BPR) is a concept that came forth out of the need for companies to obtain drastic improvements to meet constantly increasing customer requirements.

> 'The reengineering of business processes is concerned with fundamentally rethinking and redesigning business processes to obtain dramatic and sustaining improvements in quality, cost, service, lead times, outcomes, flexibility and innovation' (Al-Mashari M., Irani Z., Zairi M. (2001). *Business Process Reengineering: a survey of international experience*)

Business process re-engineering or redesign is a well-known concept since the 1990's and a lot of literature can be found about it. Many examples can be found of organizations explaining a situation in which they successfully used BPR. Although many success stories about the use of BPR exist, the concreteness and richness of the BPR concept is criticized. Al-Mashari, Irani and Zairi (2001) criticize the lack of an integrative and holistic view of BPR. Reijers and Mansar (2004) criticize the fact that

despite the many examples of successful use of BPR, no uniform and clear approach exists. Their paper is meant to offer a heuristic approach for finding the best practice that suits our organizations by evaluating empirical data from a big set of companies.

2.2.2 BPMN

The use of Business Process Management was mostly based on heuristic rather than clear methodologies. In the last decade BPM developed into a mature discipline, with a well-established set of principles methods and tools that can be used to improve business processes (Van der Aalst M.P., La Rosa M., Santoro F. M. (2016). Business Process Management).

One of the tools for modelling business processes is the modelling languages, Business Process Model and Notation, in short BPMN. This is the latest developed modelling notation which is used by many bigger companies to model their business processes. The BPMN languages helps us to model business process following clear guidelines. This makes BPMN models understandable for more people than just the ones who created the models. The latest version of BPMN is BPMN 2.0.2 which was launched in December 2013. Figure 2.1 shows an example of a business process modeled using BPMN.

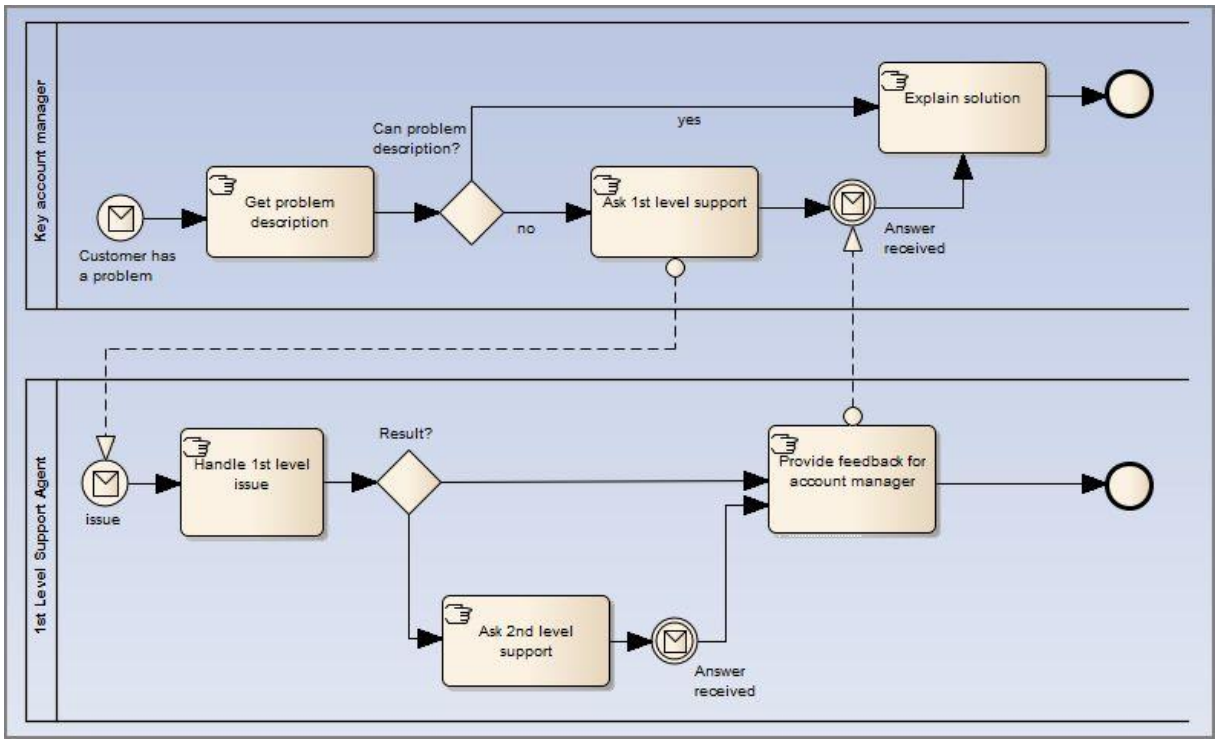


Figure 2.1: Business process modeled in BPMN 2.0

Business process model are used for different reasons and with focus on different elements of the process, we call this, perspectives of business process modelling. The *control-flow perspective* has its focus on modelling the correct order of activities and events. The *resource perspective* is about modelling the organizational units like, units, roles, authorizations, IT systems, equipment etc. Data, data carriers and decision can also be the focus of a model. This perspective is called the *data or artifact perspective.* The *time perspective* is about modeling durations deadlines etc. The *function perspective* is used to explain activities and their relationship with applications. The *control-flow perspective* is seen as the backbone of the models and used most often. Business process models that focus on the flow of activities can be model using workflow model techniques.

Workflow technique is one of the methods to model a business process. 'A Workflow is a flow of tasks between computer applications or people in an organization.' (Aguilar-Savén. (2003)). Workflows are not only very useful to model business processes, workflows can be used to analyze and improve a business process by modelling the process. Software systems are developed to create, manage and execute workflows as a computer driven representation of the business process. Workflows support the analysis of a process by visualizing a business process in separate parts to get a quick overview of the process and the sequence of tasks. Workflow management is a very suitable way to model business processes that have both human as computer automated tasks.

For my research it was important to model the flow, order and amount of activities to find out if we can make the process more efficient and improve the quality by eliminating error sensitive activities. The control-flow perspective fits best with this goal but the research was not only about the order and quality of activities. During the process, data items are generated. We also evaluated the data process methods and the support of IT systems in this process. Therefore, it was important to use some principles of the *data perspective* in combination with the *flow-control.* The workflow models of the current and desired situation for the data management at Aras are presented in chapter 3.

The reason for the development of new and better modeling languages was the belief that better process and flow models result in better processes. The models were created to get a better insight in the business process and show this to relevant people within the company. Business process models are used, as mentioned before, to create and compare models of the current and desired situation. The idea behind the use of BPM changed in the last years. Important critique about the use of BPM is that the models were not connected to the actual process and. This causes two important shortages in the way BPM is used.

The models that are created for performance analysis may not resemble reality. The models can mainly be based on information of those who participate actively in the process because the creator is one of the participants in the process or all information is gathered by doing interviews. The result is that the models are influenced by knowledge bias, personal preferences or organizational norms (Van der Aalst. (2001))

Second, the models are rarely used in the implementation process of an automation solution. New conceptual processes are created using BPM, but little companies use BPM technology to run or support their processes. (Van der Aalst M. P., La Rosa M., Santoro F.M. (2016). Business Process Management). Most companies use standard systems or custom-made systems were processes are hard coded or not supported at all. BPM systems are experienced as too restrictive and very expensive; therefore, we do not expect that the little use of BPM technology will change soon.

For this research the first goal for using BPM and workflow models using the BPMN language is to gain a better understanding of the business process, the inefficiencies and the desired situation. In first instance they were meant to visualize a complex process using understandable flow models. The models that I created for the analysis of the process are not supported by a digital BPM system, but in the solution generation the models are translate to digital workflows in an IT system that was already used by Aeronamic called Aras.

2.3 Use of PLM

PLM is often used as a product information system. PLM systems are designed to manage all product information through its entire lifecycle, including the work instruction documents needed for production. Many companies use PLM in combination with ERP when they started with the digitalization of data management. Aeronamic uses this formula as well with Aras as their PLM system and ISAH as their ERP system. The study of the Aberdeen Group, Integrating PLM & ERP (2008) tells us that the integration of PLM with ERP is likely to be a good base for improvement of the business performance.

For a company like Aeronamic that work according to high quality standards, proper data management is very important. Not only to get the right documents with the correct revisions to the right operator at the right time, but also to manage the production data is very important to control the production process.

Some of the possible problems with the use of paper in production are mentioned in section 1.1. Aeronamic is not the first company that faces problems caused using paper in production. The goal for a lot of companies now and for the past few years is to realize a paperless factory. The use of PLM and ERP give Aeronamic the possibility to make their production a paperless process.

Documents are not distributed as paper copies for review and on the shop floor, but the use of PLM makes it possible to digitalize this workflow. All documents can be shown on screen by authorized users. Also, data like measuring result do not have to be filled in with pen on a paper sheet. PLM has the functionality to present the same sheet on screen, so the operator can fill in the data digitally. This way of working with digital files instead of paper documents is called paper on glass.

2.4 UML

The way the systems are used in the document management process is presented in the BPMN models, but the way these systems are arranged and operate is not shown in these models. For the modelling of the functionalities and structure of a software systems we can use a different modeling language that is called UML (Unified Modeling Language). UML is created to make the functionality of difficult software systems more understandable for everybody.

The goal of UML is to have a common and visual modeling language for the construction, the design and implementation of complex software systems, for the structure as well as the behavior of the software system (Lucid Software Inc, 2018). UML is no programming language, but it is used to analyze and design systems in an object-oriented way. UML describes the structure and the behavior of a system and the related objects.

We use UML in this thesis in chapter 4, to show how items and data objects are structured in the generated solution using the PLM system Aras. The biggest difference between BPMN and UML is that BPMN is used to model business processes and UML is used to model structures of a system.

2.4.1 Class diagram

Class diagrams are a way to visualize the structure of classes and attributes within an information system using UML. For example, take a passenger that books a flight ticket at a certain airline. The passenger is an example of a class. Because the passenger is a general item. In a flight there can be more passengers that all have different characteristics. So, the passengers have attributes like a name, date of birth, age and address. When the passenger books a ticket for a flight he also gets the attribute 'flight number' allocated. For every passenger the attributes can be different. A second Class in this example can be 'flights'. The airline has different flights to different locations at different times. So, the class flight is filled with attributes like; flight number, plane type, departure time and arrival time.

This example shows us how to organize data and information in a structured way. Figure 4.39 in chapter 4 shows the class diagram that shows how the documents and information can be managed at Aeronamic using the suggested solution. Figure 2.2 below shows the class diagram of the example of the ticket booking system.

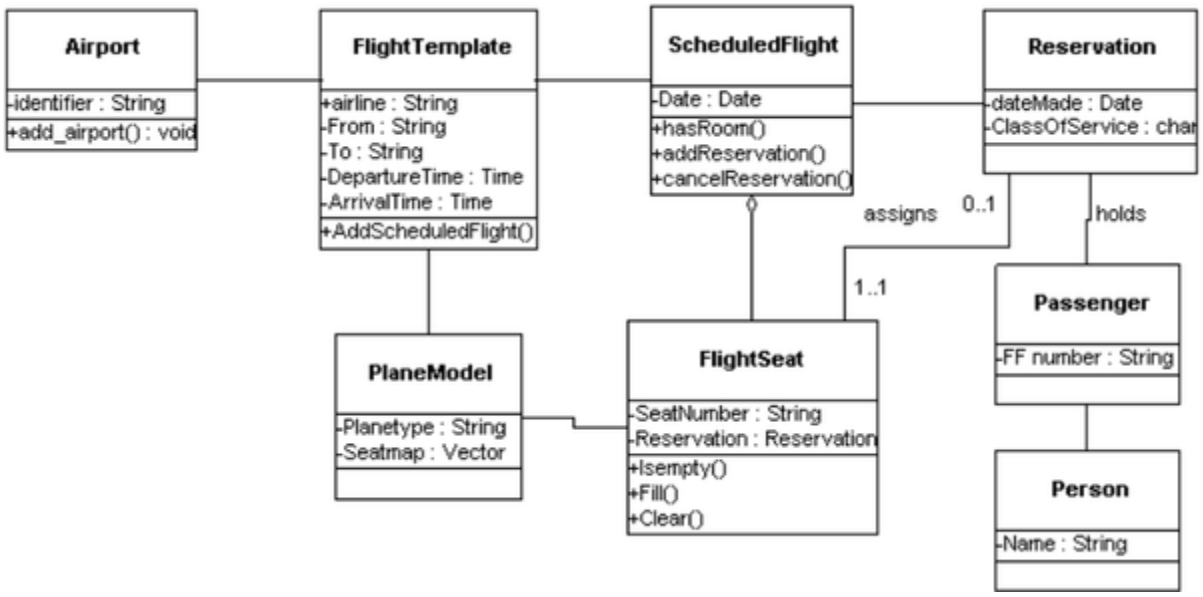


Figure 2.2: Class diagram flight reservation system

3 Problem analysis

Now that we have presented the problem statement, formulated research questions and studied relevant literature, we can start with mapping the current situation to analyze the problem in more detail. In this chapter we will analyze the stated problem further by comparing business process models of the desired situation (SOLL) with models of the current situation (IST). The purpose for the evaluation of the workflows is to get a clear view of the steps that need to be taken and the way the documents are distributed and managed along the process. This IST vs. SOLL analysis helps us to identify the steps needed to improve the process. Next to the business process model of the desired situation we will also show a model of the process with a possible solution (figure 4.27) in chapter 4.

I gathered the information needed to understand the current situation by conducting interviews, look through the management system and Quality Management System of Aeronamic and my own observations.

The purpose for the evaluation of the workflows is to get a clear view of the steps that need to be taken and the way the documents are distributed and managed along the process. I did not use workflow creating software that support functionalities to simulate lead times and other performance measures. After the interviews with multiple Lead Engineers I found out that the time to finish this process is not an important measure. The process to get the approval to start the actual production for a part takes a lot longer.

3.4 Current situation (IST)

As mentioned in the problem statement, Aeronamic produces with support of many instruction documents. These documents are created by Lead Engineers and Special Process Specialists. The creation of these documents is done manually using Microsoft Office Word and templates that are stored in the Aeronamic Management system. During the analysis of the problem I found out that different document types are created in different ways and stored in different places. This means that there is not one uniform method for creating reviewing and releasing of the different work instruction documents. In this chapter I will use the process of two document types as the base for my research. These are the Aeronamic Technique Sheet (ATS) and the 'Bewerkingsvoorschrift (BV)' (translated from Dutch: operations instruction). The difference in language for the names of document types is a very simple example of an inconsistency. Next to that the BV's are stored as Word files on the Aeronamic server under Manufacturing Engineering Data and the PDF file is stored in a different folder on the server. The ATS documents are saved as adjustable Word file and one PDF on the Aeronamic server, in a different folder structure than the BV, and the PDF file is stored in Aras.

Every work instruction document for production is created by a certified engineer and must be reviewed before it is released for production. Figure 3.1 shows the simplified main creation review and release flow for each document.

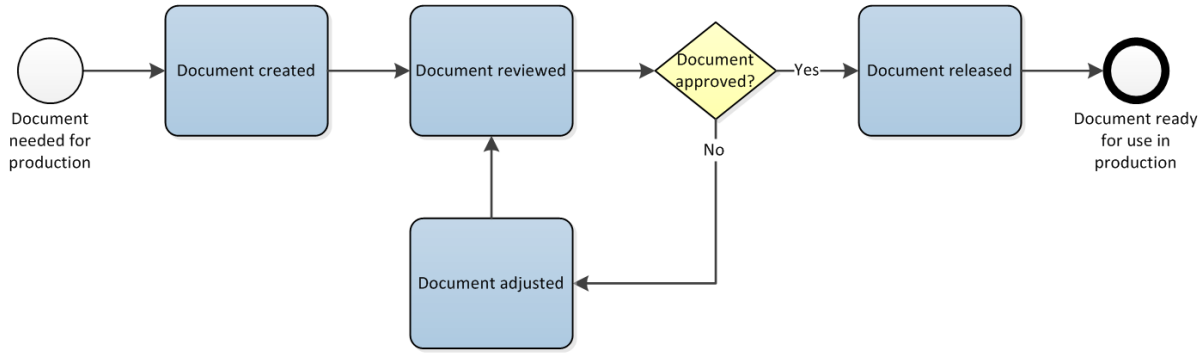


Figure 3.1: Main creation, review and release flow for each document

The type of document that must be created determines which engineer is authorized to create the document, who must review the document and if the document needs a second review loop. The creation and review rules for the documents are set up by the Quality Department of Aeronamic. Appendix 1 shows the authorized creators and reviewers per document type.

3.1.1 IST 'Bewerkingsvoorschrift'

The BV document is an instruction for the operator how to use the tools and machines at the workstation to correctly perform the operation. Examples of BVs are an assembly instruction or deburr instruction. The BV is created by a Lead Engineer with the input of the operators, because they are the people with experience in practice. A second Lead Engineer reviews the BV. The released document is presented to the operator as a printed document and as a PDF file on the server. The printed document is stored in a drawer cabinet close to the work station.

The Word file is saved on the server. Everyone at the Manufacturing Engineering department of Aeronamic has access to the respective map on this server. The world files are not protected so if one of the Manufacturing Engineers wants to they could adjust it or accidentally delete the file. A frozen and signed PDF file of the BV is stored in another map on the server that is accessible for operators. This is because operators only use released files that are signed for approval. A second reason that the PDF's are stored in another folder is to prevent that the operators accidentally change the document while using them in production.

Figure 3.2 shows the creation, review and release cycle of the BV document.

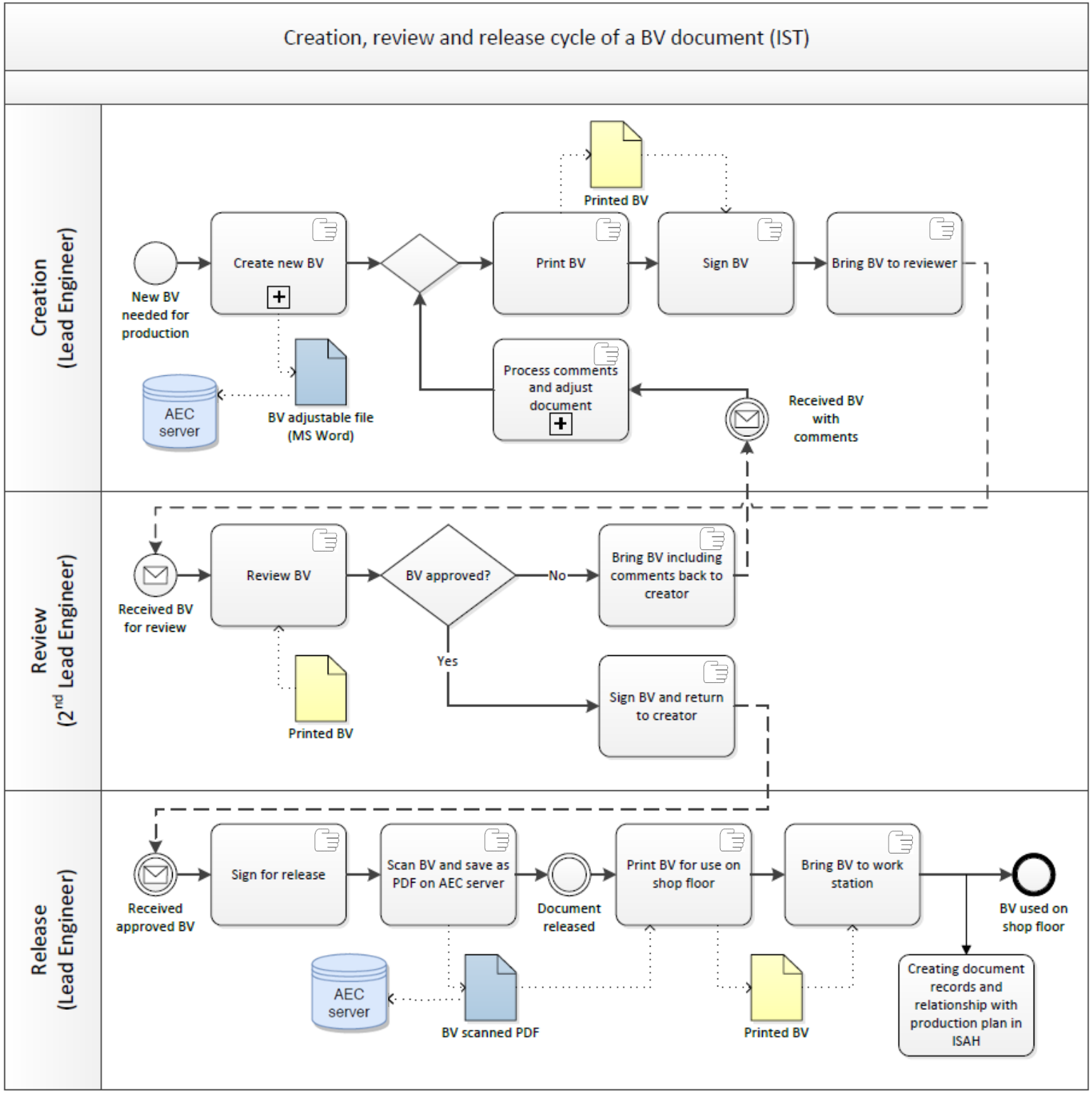


Figure 3.2: IST workflow BV

The main process model in figure 3.1 showed three main stages of the process: creation, review and release. These three stages determine the structure of all the business process models in this chapter. This structure is added to the model with the use of swimming lanes. Explanation about the symbols in the models can be found in appendix 1.

To keep the main models as short and clear as possible I used sub processes in the main model. When relevant we will take a closer look at the sub processes.

When evaluating the models, we look at four important elements:

1 The document format and storage location
2 The task types
3 The roles involved in the process
4 The amount of actions needed in the process

The moment in the process where we can see the impact of these four elements are highlighted with numbered and colored rectangles in figure 3.3.

3.1.1.1 Identified problems IST model BV

1. Document format and storage location

The IST model for the BV shows documents with two colors, blue and yellow. The blue documents represent a document that has a digital format but is not managed by Aras. The yellow documents represent paper files.

The model shows that a BV is printed for release, scanned to save the signed BV on the server and printed again for use on the shop floor. From the moment the document is printed it is impossible to track the document and the progress with live data. The document can get lost as well and you can never be shore that the paper document is the latest version. The printed BV is Work in Progress (WIP) that is very hard to register. The Word file is saved on the server. Everyone at the Manufacturing Engineering department of Aeronamic has access to the respective map on this server. The world files are not protected so if one of the Manufacturing Engineers wants to they could adjust it or accidentally delete the file. A frozen and signed PDF file of the BV is stored in another map on the server that is accessible for operators. A negative effect of scanning the document to freeze it as a PDF is that a scanned document is an image. In an image text is not recognized as text anymore. This makes it impossible for operators to use digital search tools like ‘ctrl+f’.

The document is not linked to an IT system and has a format that is not uniform and free to adjust. This gives the creator a lot of freedom to make changes and a mistake is easily made. Everyone could create a file with the name BV because there is a lack of a system that can correct this by recognizing the creator. When analyzing existing documents, I even found a few documents that were released by the same person that was the creator. That is the result of the freedom the engineers get using paper because it is hard to monitor changes that are made.

The high error sensitivity can have a negative effect on the time needed to create the document, the daily use of documents and even the lead times of production. If the operator finds a flaw in the document and does not know himself how to correct it, he or she walks to the office to discuss the problem with the responsible Lead Engineer.

2. **The task types**

The model shows that every task in the process is a manual task. This is a result of the fact that the document is not managed by a digital system and causes the same problems as mentioned above.

One of the biggest mentioned problems of the manual tasks, is that it cost the engineer more time to create the document and control his own actions. For example, to determine the document number that must be unique, the engineer must look up the last created document. The document number of the new BV must be the number of the latest BV plus 1. This is a lot of work just to give the document a number.

Manual tasks are not supported by any digital system. Therefore, there is no link with database records and no system will correct mistakes made during the task.

3. **The roles involved in the process**

The creation of the BV is simple if you look at the roles involved. A Lead Engineer creates the BV and a second Lead Engineers reviews the BV. If the second Lead Engineer approves the document the first Lead Engineer signs for release. The BV is seen as a low risk document, because it is not an instruction document for a special process that is determined by the customer and needs to be executed by a certified operator. Therefore, a single reviewer is considered sufficient.

4. **The number of tasks needed in the process**

The main process shows a lot of actions needed to print, sign and distribute documents before and after release. Although good prepared documents are very important for Aeronamic, these actions do not add any value to the product. All these time-consuming actions are non-value-added actions (NVA). The tasks to create review and release documents are all NVA so it is important to make this process as efficient as possible.

3.1.1.2 Important findings

The most important reasons for inefficiency in this process are:

- The creation process is error sensitive
- The use of paper documents in the review loop causes time consuming actions
- The WIP is difficult to trace

The analysis clearly shows that the use of paper files and the lack of support by a digital information system are the reasons for the problems within the creation review and release process of BV documents. Before we can conclude that this will be the focus for us to improve the process we first evaluate the process for the ATS as well.

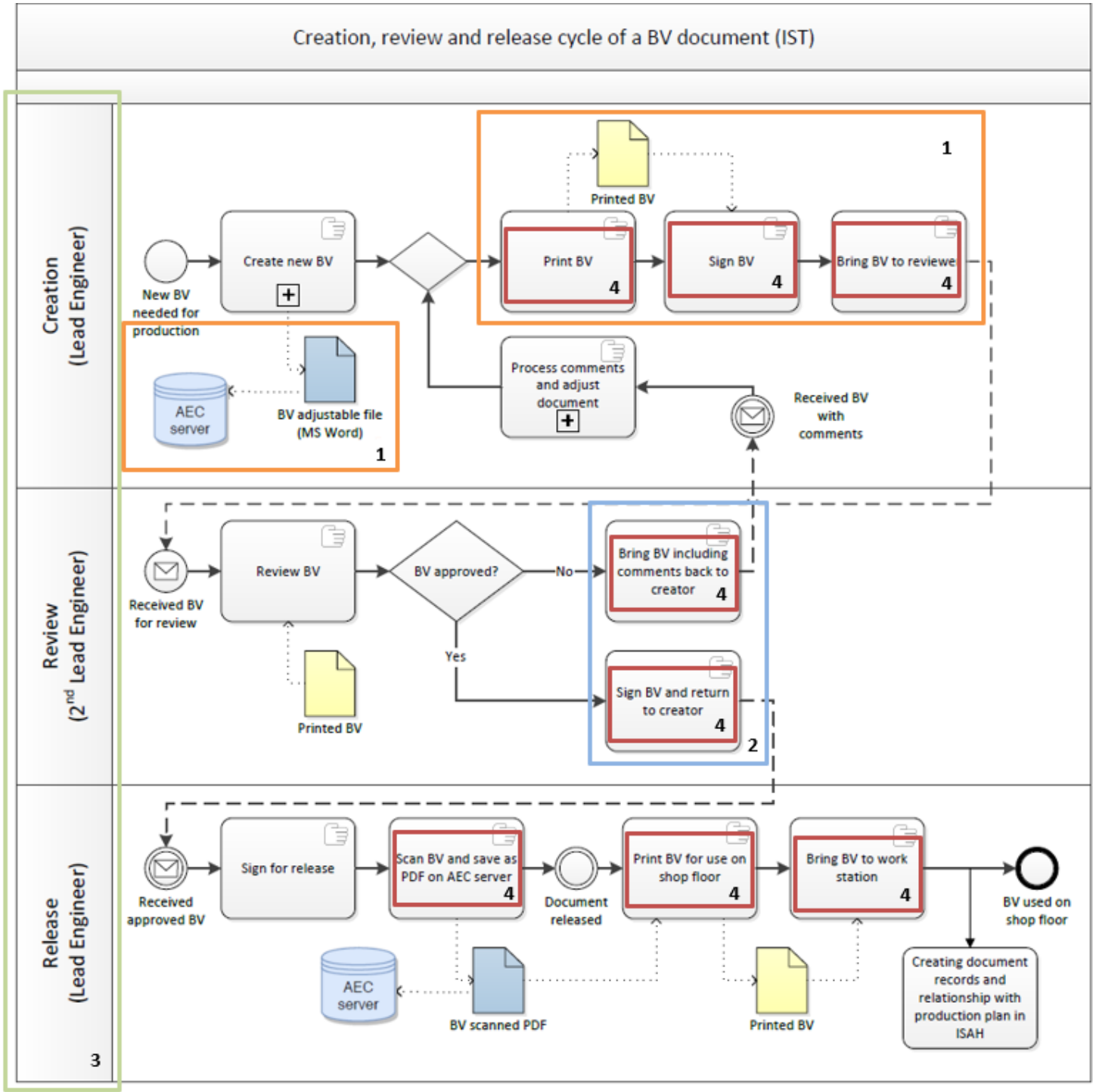


Figure 3.3: Workflow BV (IST) including colored and numbered highlights

3.1.2 IST Aeronamic Technique Sheet

The Aeronamic technique sheets are instructions for a certain production step. ATS is the classification of a work instruction document for a technical operation that is part of the production process planned to meet the customers design standards. The ATS documents can be classified per operation using sub types. Appendix 2 shows an overview of the documents with type ATS and the subtypes.

ATS documents are written for every technical production process including the special processes. The Technical Process Specialists are responsible for the special processes. They are the only engineers that are allowed to create ATS documents for the special processes. The ATS documents are reviewed by a Lead Engineer and the Quality Development department. The reason for the double review loop is the importance of the documents. As mentioned in section 1.2 the documents used in production are not only an instruction for the operators, they are the proof that Aeronamic produces following the aerospace norm. The Quality and Development department of Aeronamic is responsible that production adheres to the aerospace norm. Quality and Development therefore reviews the ATS documents on clarity, structure and correct referencing. The Lead Engineers review the documents on content and terminology.

In contradiction to the BV the ATS documents are not used on the shop floor as printed documents. The ATS documents are saved as Word files and a nonadjustable PDF with revision number at the same server domain as the BV word files. This PDF file is, unlike the PDF file of the BV on the server, not signed yet. The signed and scanned PDF files of the ATS documents are not stored on the server. These documents are stored as a document item in Aras by the Configurations Management Officer (CMO). The operators retrieve the required ATS from Aras. The way the documents are retrieved form Aras is evaluated in more detail at the end of this chapter. First let us have a look at the current creation, review and release process of ATS documents.

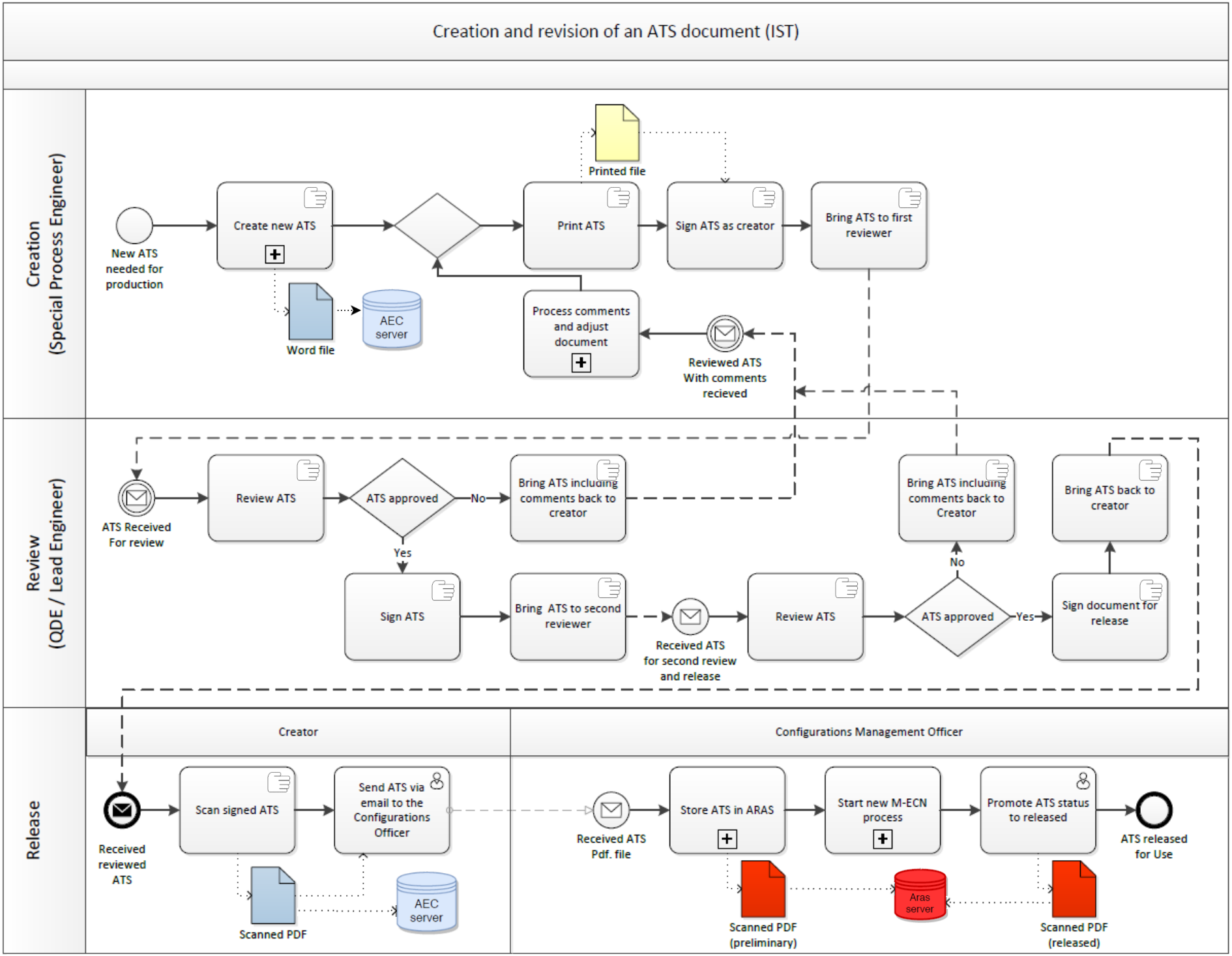


Figure 3.4: IST workflow ATS

3.1.2.1 Comparison BV and ATS current situation

The structure of the ATS model is the same as for the BV. This makes it easier for us to compare both document types. The first thing that is striking compared to the BV model is the red color of two document item symbols in the last swimming lane. The red color indicates that the document is managed with the support of Aras. In between the brackets underneath the data icon, the status of the document in Aras is given. In the last swimming lane, it becomes also clear that not a Lead Engineer but the CMO is responsible for the release of the document for use in production. The storage of the ATS in Aras is a big difference compared to the way the BV is stored and presented to the shop floor. I will reflect on the two sub-processes in the last swimming lane in the next section.

In the second swimming lane it is clearly visible that the ATS has a second reviewer. Only when both reviewers approve the document, the ATS can be scanned and send to the Configurations Management Officer. The models show that the approved ATS is first returned to the creator before the creator send the scanned ATS via email towards the CMO. The paper copy of the ATS is useless from that moment on so it will be destroyed to prevent confusing situations.

The storage of the document in Aras with the support of the CMO and the second reviewer are the biggest differences compared to the BV workflow. Just like the BV the ATS is also created manually in Word, signed on paper and distributed physically for review.

3.1.2.2 Identified problems IST model ATS

In the current situation Aras is used for the final storage of ATS documents, but the process before the documents are stored in Aras does not differ much from the creation and review process of the BV document. This means that many of the same problems occur in the creation and review process for the ATS as for the BV. Figure 3.7 shows the highlighted sections of the process that show the problems explained below.

1. **Document format and storage location**

Most of the documents along the process are not digitally managed or even paper copies. This causes the same problems as mentioned for this element for the BV documents. The way the ATS is stored in Aras in the current way does not solve the problems in the creation and review phases of the process.

One of the benefits of storing the ATS documents in Aras is the assigned document status. The document status tells us whether a document is ready for use in production or not without the need for us to open the document and search for the signatures. The document can have two different statuses, preliminary or released. Preliminary means that the document is still being created or reviewed. When the document has the released status, it is frozen and ready for use on the shop floor. We will reflect in more detail to the use of statuses and the management of documents in section 4.3.

One other advantage is the possibility to let the PLM system control who can and cannot add, open or adjust the ATS file in Aras. This makes the storage and use process of the document better manageable.

2. **The task types**

Most of the tasks for the creation and review of the ATS are just as for the BV manual tasks. We noticed that ATS are specific documents for specific technical processes. The sub-type for the needed new ATS determines which Special Process Specialist creates the document. The current way of creating the ATS

documents gives the creator a lot of freedom in the design and layout because there are no non-adjustable templates. Every engineer and Special Process Specialist has his or her own method for creating documents.
In the workflow for the ATS we can find a few user task types in the process of saving the ATS to Aras. These are all just additional actions compared to the process of the BV, only to save the document to Aras. The documents are stored in Aras in addition to stored document on the server. Figure 3.4 shows the collapsed view of the sub-process 'Store ATS in Aras'. This shows the steps needed to be done by the Configurations Management Officer to store the ATS in Aras.

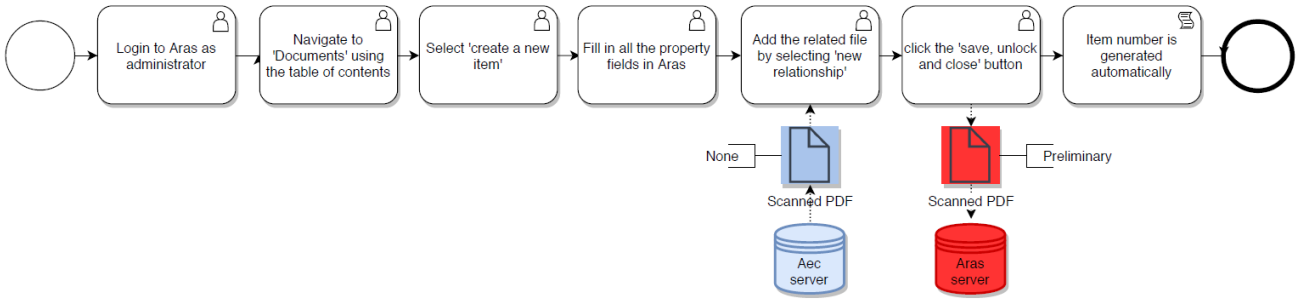


Figure 3.4: Collapsed view sub-process, Store new ATS in Aras (IST)

Figure 3.4 shows that the use of Aras makes it possible to automatically generate document numbers. Next to that the document also receives a status. The administrator in Aras determines which statuses can be applied to the documents. The use of Aras also makes it possible to link documents to other items like products or other documents. Aras has the functionalities to have a clear document storage system. Documents stored in Aras are presented to the user in a clear table. Figure 3.5 shows the document table of the documents in Aras. Aras has the functionality to filter the items on name, ID, type or other properties identified on the item. For the table in figure 3.5 I filtered the documents on type ATS.

Document ID	Name	Revision	Description	Type	State
ATS000008	ATS-BT-008	00	Technique Sheet Balancing LC350 rotating st...	ATS	Released
ATS000004	ATS-BT-004	01	Technique sheet Balaning PN 362851-all	ATS	Released
ATS000016	ATS-BT-018	00	Technique Sheet Balancing	ATS	Released
ATS000019	ATS-PT-009	01	Penetrant Testing Type I, Method A, Sensitivi...	ATS	Released
ATS000044	ATS-LT-001	02	Pressure test	ATS	Released
ATS000048	ATS-MT-202B	04	Technique sheet Magnetic Particle Inspection	ATS	Released
ATS000031	ATS-CP-111	00	Chemical Surface Treatment Alkaline Cleaning	ATS	Released
ATS000020	ATS-BT-033	00	Technique Sheet Balancing	ATS	Released
ATS000026	ATS-CP-106	03	Technique sheet chemical surface treatment	ATS	Released
ATS000022	ATS-CP-101	03	Technique sheet Chemical surface treatment	ATS	Released
ATS000021	ATS-BT-041	00	Technique Sheet Balancing	ATS	Released
ATS000001	ATS-BT-001	01	Technique Sheet Balancing	ATS	Released

Figure 3.5: Screenshot of presentation of documents in Aras

Aras is a PLM system that is suitable for document management but in the current situation it is also used by operators to find the document for production. Ronny agreed with me that Aras is a PLM system that is meant to manage document and is not a user interface that should be used on the shop floor. The use of Aras on the shop floor will be evaluated more in section 3.3.

3. The roles involved in the process

In the ATS creation, review and release process four roles are involved, the creator, two reviewers and the Configurations Management Officer (CMO). The two reviewers are a quality restriction determined by the quality management department. For this research we will not question the necessity of the two reviewers. The role of the CMO is worth evaluating.

The CMO is responsible to maintain and structure the As Designed configuration and the E-BOM in Aras. In the current situation we can see that the CMO also has an active role in the creation of document items in Aras, although work instruction documents are part of the M-BOM and the As Planned configuration as explained in section 1.2. The role of the CMO in the release process off the ATS does not fit the configuration structure as supposed. The problem is that the CMO is the only authorized person to add items in Aras. Interviews told me that this role of the CMO cost him a lot of time while it is work that should not be done by him. The As Planned structure should be managed by the Lead Engineers (LE) of the Manufacturing Engineering department. We must find out a way that the CMO is not the only authorized person to add or change items in Aras without increasing the risks of mistakes and loss of structure within the system.

4. The number of tasks needed in the process

The creation and review process is not much different than the creation and review process for the BV. Just as for the BV the task needed to create, review and release ATS documents are NVA activities. The biggest difference between the BV and the ATS is the interference of the CMO. As the main process shows the CMO triggers two sub-processes, the storage of the ATS in Aras and the start of an M-ECN (Manufacturing-Engineering Change Notification). The M-ECN is a notification that changes in the digital records are made or need to be made. According to this notification actions need to be executed or a control loop is activated. Figure 3.6 shows the flow of an M-ECN started for the release of the ATS document in Aras. The general concept of the M-ECN is explained further in section 4.7.

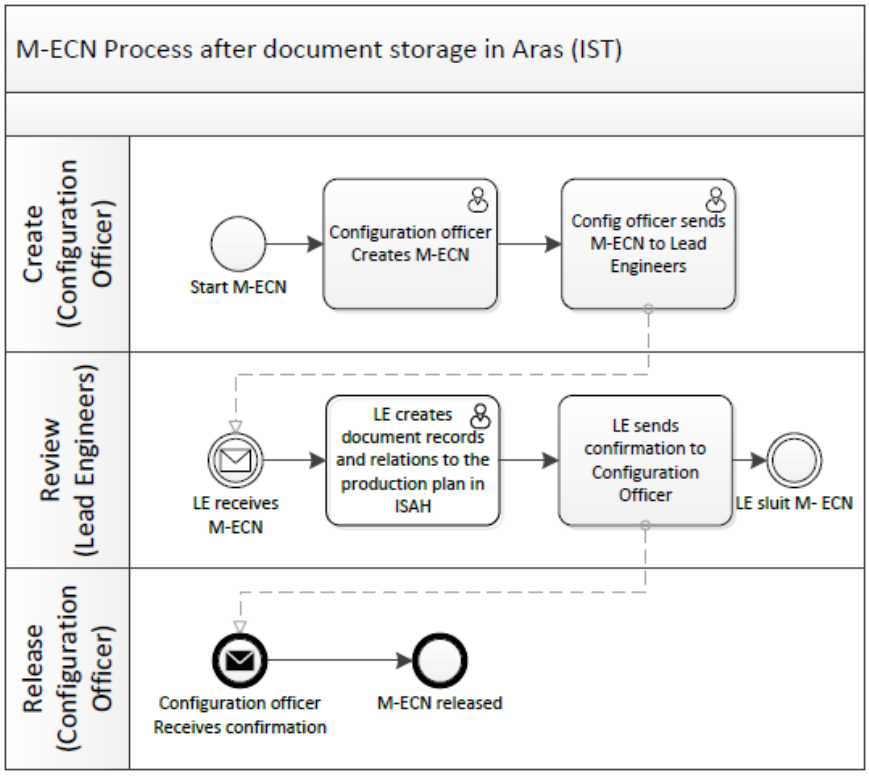


Figure 3.6: M-ECN flow for the release of an ATS in ARAS

The M-ECN in the release phase of the ATS is a notification that the ATS is saved in Aras and changes are made in the configuration in Aras. The documents are linked to parts and production steps. The routing or manufacturing process plan is managed in Isah, so the changes in Aras need to be translated to Isah as well. The M-ECN triggers the Lead Engineer that is responsible for the routing of that product to add the changes made in Aras to Isah. This is done manually.

During the process of translating the changes in Aras to Isah the Lead Engineer controls if the CMO has stored the ATS in Aras correctly with links to the correct items. If the Lead Engineer concludes that everything is stored correctly, and he finished translating the changes to Isah, he closes the M-ECN and informs the CMO that everything is correct, and all changes are translated to Isah. The CMO then changes the status of the new ATS from Preliminary to Released.

The review loop for evaluating the content of the document and for controlling the storage in the digital system are two separate processes. We must evaluate if we can change the creation, review and release process in such a way that the storage of the document in the digital system is integrated in the process in such a way that we only need one review loop to control the content and the correct links of the document to other items in Aras. Furthermore, the translation from these changes in Aras to Isah are done manually and it is desired that we can send the information from one system to the other automatically.

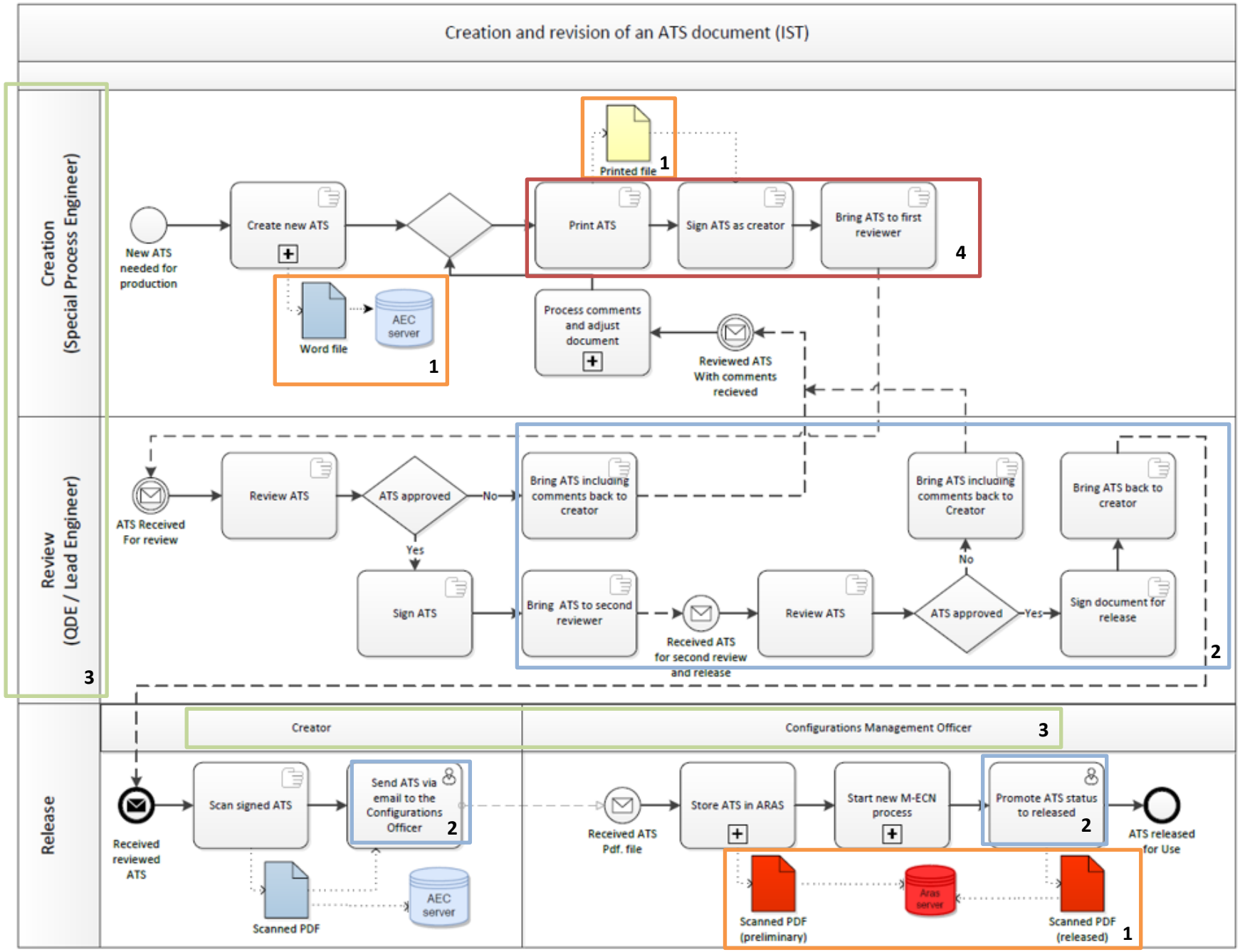


Figure 3.7: Workflow ATS (IST) with highlighted sections

3.1.2.3 Important findings

After evaluating the IST workflow for the BV, we concluded that the lack of support by an information system and the use of paper was the cause of multiple inefficiencies. Although the information system Aras is used in the release process of the ATS, the use of paper in the process is not limited and the same inefficiencies occur because of the use of paper.

The use of Aras to store the ATS documents forces the interferences of the CMO in the release phase of the document in the current situation. This is not desired since the work instruction documents are part of the M-BOM in the As Planned configuration that should be managed by the Manufacturing Engineers.

The use of Aras helps to get a clear overview of the documents, the linked items and its status. The use of Aras to manage documents has the potential to make the process clearer and more efficient but it still needs a lot of improvement. For example, the way a state is appointed to a document at the current situation does not represent the actual state of the document. The document is fully approved and signed for release but when stored to Aras it first gets the status Preliminary. Preliminary suggests that the document is still in the creation phase. The reason for this state is that the CMO stores the document in Aras and first wants the product owner to review if the document is stored correctly in Aras and translate the changes made in Aras to Isah. The document state represents the status of the storage process instead of the state of the document itself.

The desired improvement of this process would be to integrate the storage of the document to Aras with the creation process in such manner that only one review loop is needed, to review both the content of the document as the way it is stored in Aras. In fact, the linked items for each document are mentioned on the document itself in a special reference table. This reference table is filled manually by the creator of the document. This table is the source of information for the CMO to link the document with other items in Aras. Figure 3.8 shows the information table with linked items for the document. In the M-ECN loop the Lead Engineer is reviewing his own work and controlling if the CMO processed his information correctly. There must be a way that the creator of the ATS is able to directly link the document to other items digitally instead of first manually write down de item IDs of these linked items in the reference table on the document.
The CMO should be excluded from the process or get another less time-consuming role in this process.

No.:	ATS-LT-714	UNCLASSIFIED TECHNIQUE SHEET	AERONAMIC AIRCRAFT SUBSYSTEMS
Issue:	00		
Date:	11-06-2015		

Pressure Test *Pressure Testing,EMS52310, Type III, Class A at 4.8 Bar overpressure*			
Part Number	**Part Name**	**Material**	**Distribution List**
3827459-1	Housing bearing inlet	C355 0-T6 Casting	Aeronamic
Issue / **Date**	**Remarks**		
00 / 11-06-2015	First issue		
Applicable Documents			
Ref# 1, EMS 52310	Pressure Testing.		
Ref# 2, DWG5063-157-001	Housing bearing inlet		
Ref# 4, MC9014	Marking of products for identification.		
Ref#5, ATS-CP-110	Alkaline cleaning		

Figure 3.8: Screenshot of reference table of an ATS document

After this analysis we could say that the use of Aras is not improving the current creation, review and release process of the ATS but only extending it. The use of an IT system alone is not enough to solve the problems. The way the system is configurated is important. Before implementing an IT solution, it is important to understand what the intended outcome is.

3.2 Desired situation (SOLL)

After evaluating the IST situation for the BV and ATS document we were able to identify inefficiencies. Before we can determine the interventions needed to improve the process, we must understand the desired outcome. In this section we will model the SOLL situation that shows the document creation, review and release process as desired by Aeronamic. This model helps us to find possible solutions that are steps towards realizing the desired situation.

3.2.1 IT strategy

The SOLL situation is highly related to the objectives of the research set in the second stage of Peffer's Design Science Research Process. To set the objectives and model the SOLL situation we must consider the IT strategy of Aeronamic. In section 2.3 I already explained the combination of an ERP system and a PLM system used by Aeronamic. The strategy for the use and combination of those two systems is already determined by Aeronamic.

As explained in section 1.1 Aeronamic works according to the as designed, as planned and as built structure. Both IT systems will play a certain role within the three configurations. They will not be used as two individual systems, but they will be related and able to communicate with each other. Figure 3.9 presents the IT strategy of Aeronamic showing the role of both the ERP and the PLM system in each of the three configurations.

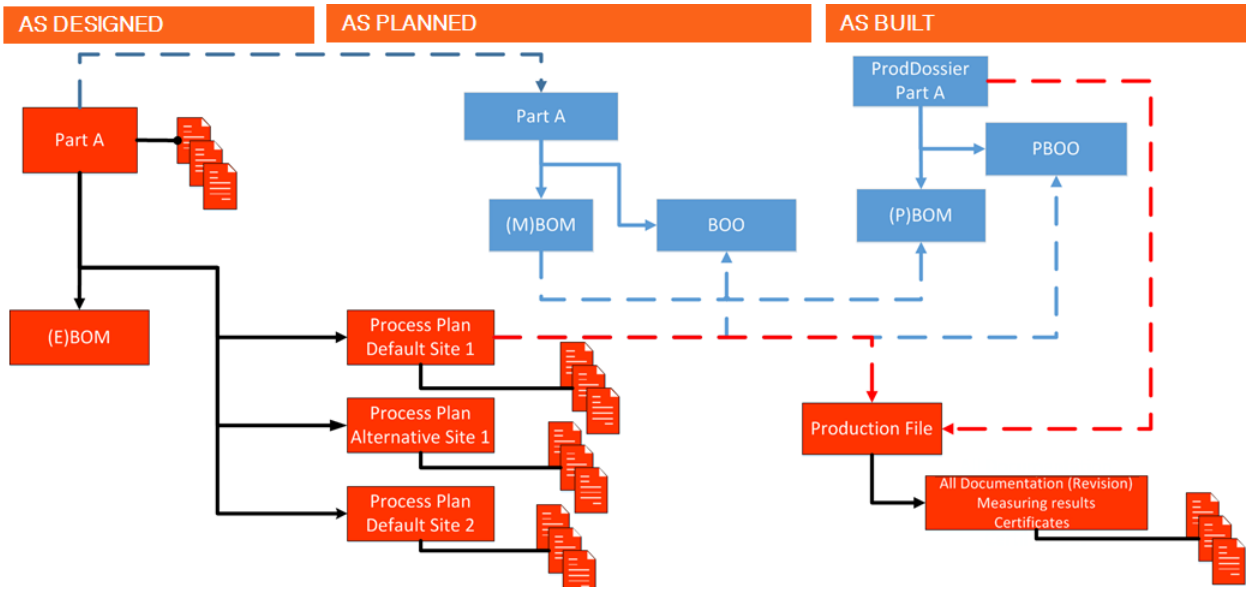


Figure 3.9: Aeronamic IT strategy ERP + PLM

The orange colored symbols represent data managed by the PLM system Aras and all the blue symbols represent data managed by the ERP system Isah. This schematic view of how the systems should be used is a future strategy of Aeronamic for the near future. This IT structure is proven to be successful in a pilot project for a small section of the company.

The core idea of the strategy is that Aras will be the leading system for the management of all (production) documentation and information. Isah will remain the logistic system for the production schedules. Therefore, it is important that production data managed in Aras is copied to Isah. Isah for example needs information about production times, workstations and needed materials to plan the production and indicate if at a certain moment enough materials are in stock to start production.

The dashed lines indicate communication between Isah and Aras. All information needed by Isah to create the production routing will be copied as snapshots from Aras to Isah. Database records like document ID's and process plan numbers will be copied to Isah either with a push or pull structure. The content itself will only be managed in Aras.

The benefit of managing all production information in one place is not only that the management process is easier and clearer, retrieving the information for use on the shop floor will also be easier to arrange.

3.2.2 Document management in Aras

Figure 3.9 shows the IT strategy for the management of the production data including the relation between PLM (Aras) and ERP (Isah). My research is focused on just a small part of the whole strategy, the document management in Aras. Despite the focus on a small part of the entire strategy it is important to recognize the possible impact of the research to create a solution that is in line with the rest of the strategy.

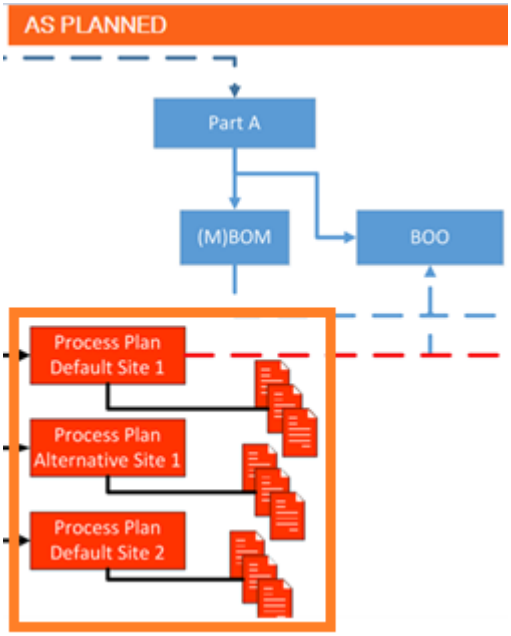


Figure 3.10: Research focus area

The part of the IT strategy marked by the orange square in Figure 3.10 shows the focus of my research. The figure shows that the strategy is to manage the process plans and the production document in Aras. The documents are linked to the process plans. Process plan is the equivalent name for the routing, also known as Bill of Operations used by Aras. We introduced the term routing in section 1.2.

In the current situation process plans are not managed in Aras. The routing is created manually in Isah by the Lead Engineer. The reference to the work instruction documents is entered by the Lead Engineer manually as well, as explained in section 3.1.2.2. The Lead Engineer links a document to a routing step by filling in the document name. This reference is not a digital link to the related document but just a database record. The documents are managed separately in Aras. Managing the documents digitally in Aras and the process plans as well, makes it possible to link documents, not just a record, to the process plans and is a good base for realizing the rest of the strategy.

For my research I did not have to investigate the possibility to manage process plans in Aras. Aeronamic has proven that this is possible in a currently running pilot in production at the assembly department. This pilot is explained in section 4.2.2. In this thesis we do not evaluate the management of process plans in Aras in more detail, but it is important to know that the documents managed in Aras will be linked to the process plan.

3.2.3 SOLL model work instruction documents

With the gained knowledge about the IT strategy we can model the SOLL situation for the management of work instruction documents. In the desired situation work instruction documents are fully managed by the PLM system Aras. Documents will not only be stored in Aras and retrieved from Aras during production, but the entire life cycle of the document, from creation till use, will be managed in Aras. The use of paper must be eliminated completely, and documents will be distributed and reviewed digitally. The same rules apply for creating and reviewing the different document types as in the current situation, but the documents will all be stored in the same way. The document creation, review and release process for all documents will be uniform. The only difference is the need for a second review for some document types. This extra reviewer does not change the process substantially other than the addition of one more review loop.

The creator of the document is not only responsible for the content of the document but needs to link the document to the related items, like the process plan, as well. In the current situation the Configurations Management Officer was responsible for the storage of the document in Aras and linking the document to the related items, using the reference table on the document as input. The work of the Configurations Management Officer had to be reviewed by the Lead Engineer. Inefficiencies of this process were that the storage of a document to Aras is not seen as a responsibility for the Configurations Management Officer and the process has an extra control loop.

Figure 3.11 shows us the creation, review and release process of the desired situation, knowing that Aras will be used as the document management system for the work instruction documents. The model shows that the Configurations Management Officer does not play a role in the release phase anymore. The creator creates the document and makes sure all related items are linked. The first reviewer checks the content and the second reviewer makes sure the layout is correct and the document is stored in Aras correctly with the correct linked items. If both reviewers approve the document, the document is automatically released, and the creator receives a notification.

Next to that no paper files are used anymore, and the documents are digitally distributed. Every task is either a user, service or script task. This means that every task is supported by Aras. When arranged correctly Aras can control and correct the process to prevent mistakes to be made or tasks being executed by non-authorized persons.

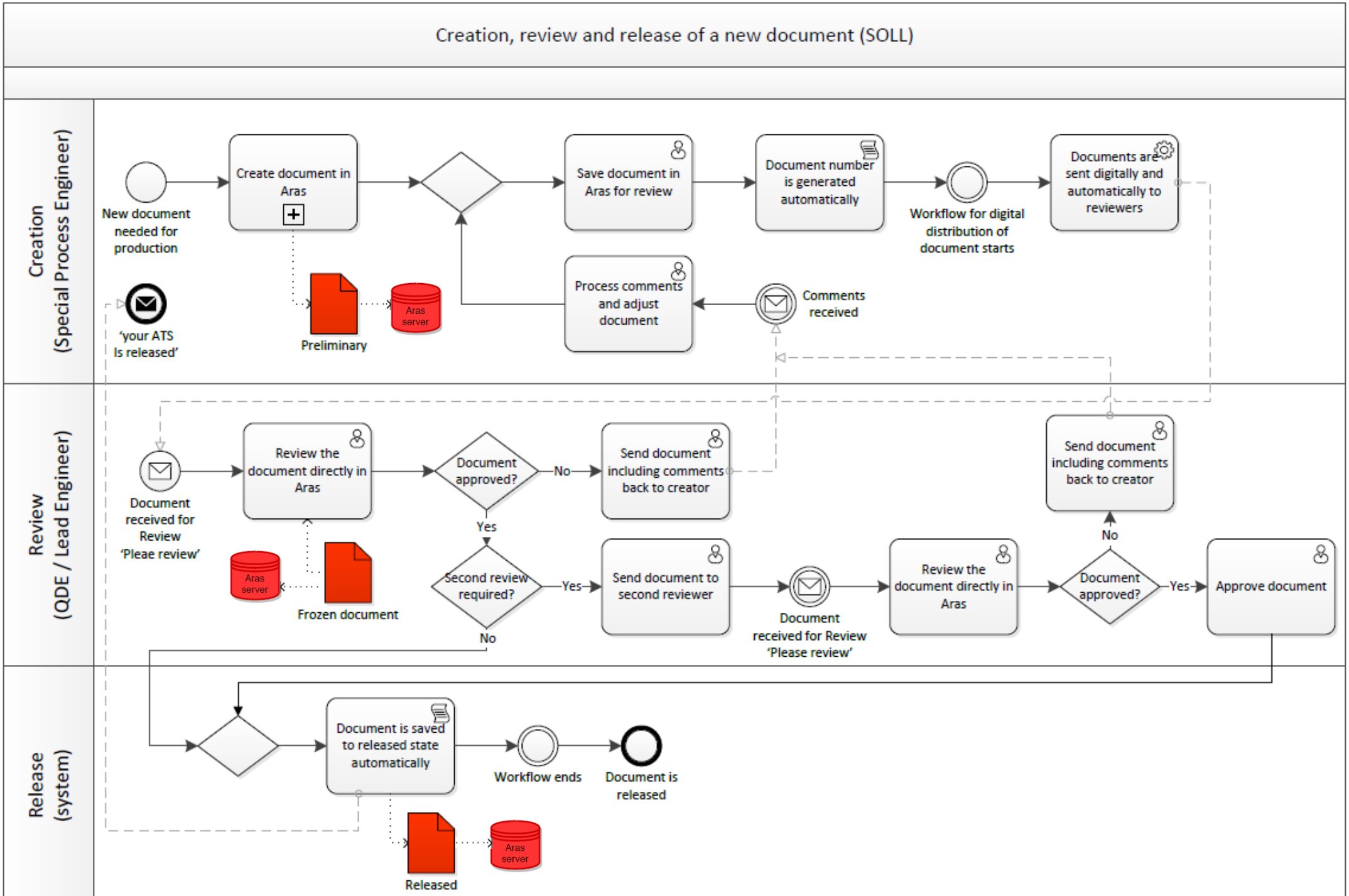


Figure 3.11: Soll workflow of the document creation, review and release process

Figure 3.12 shows the collapsed view of the creation process of a new document in Aras. The goal is to arrange this in such a manner that the creation of the document and the storage in Aras with links to the related items is integrated in one process. If we can realize this in the start of the creation, release and creation process the review of the content and the correct storage in Aras can also be combined in one review loop. This explains why we only modelled one review loop in the SOLL model of the creation, review and release process for a new document.
The creation of the document with a direct link to Aras gives us the opportunity to assign a state to the document at the beginning. This assures that the status of the document reflects the state of the document and not the status of the storage process as mentioned in section 3.1.2.3
Figure 3.12 shows the task 'select content for document'. In the SOLL situation Aras is arranged as a content driven system. It that case instruction documents can be created by selecting building blocks of content. In this model we assume that instructions are still presented in documents. In the future this can change to presentations, images or even virtual reality. For this thesis we limited the research to improving the management of work instruction documents.

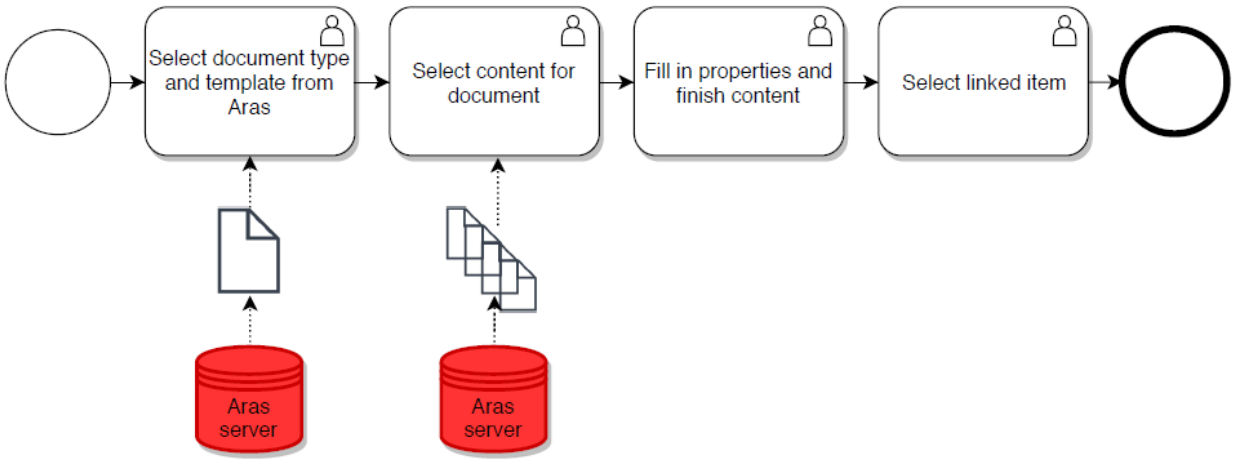


Figure 3.12: Collapsed view sub-process, Create new document in Aras

3.3 Document distribution Process

During the problem analysis we noticed that not only the creation, review and release process of the documents within the Manufacturing Engineering department of Aeronamic can be improved but also the translation of this improvement to the distribution of the document on the shop floor. We noticed that, a lot of inefficiencies in the way the documents are presented to operators exist because of the way documents are managed. To improve the entire document management process, which includes the creation, review, release, use and change process of the documents, it is important to understand the way documents are used and how the management of documents by the Lead Engineers is related to the distribution of these documents on the shop floor. In this section we will reflect on the inefficiencies of the way documents are distributed on the shop floor.

The use of paper plays an important role in this part of the process as well. To produce a production order a lot of paper is used. All the paper needed to produce one production order is called the paper trail. We explained in section 3.1.1 that BV documents are presented to operators as paper files. A solution to that problem is given but a lot of paper containing product information and instructions for operators travels along with the production order. Most of the paper files are stored in a black ring binder called a shop traveler.

3.3.1 Shop traveler

The shop traveler is a ring binder containing the production order representing every production step and the related documents the product needs to go through to reach its final form. In the shop traveler we can also find lists to fill in measurement data or other required production test data. Figure 3.13 and 3.14 show the layout of the production order in the shop traveler. Every column of the production order shown in figure 3.14 represents the needed information and related documents for one specific production step. A short description of the production steps and document numbers of the related instruction documents are given within these columns.

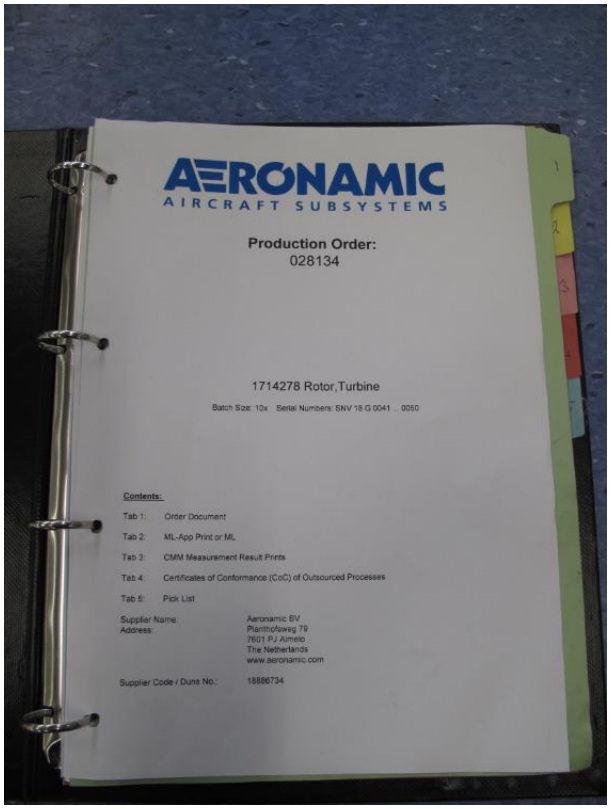


Figure 3.13: Production order in shop traveler

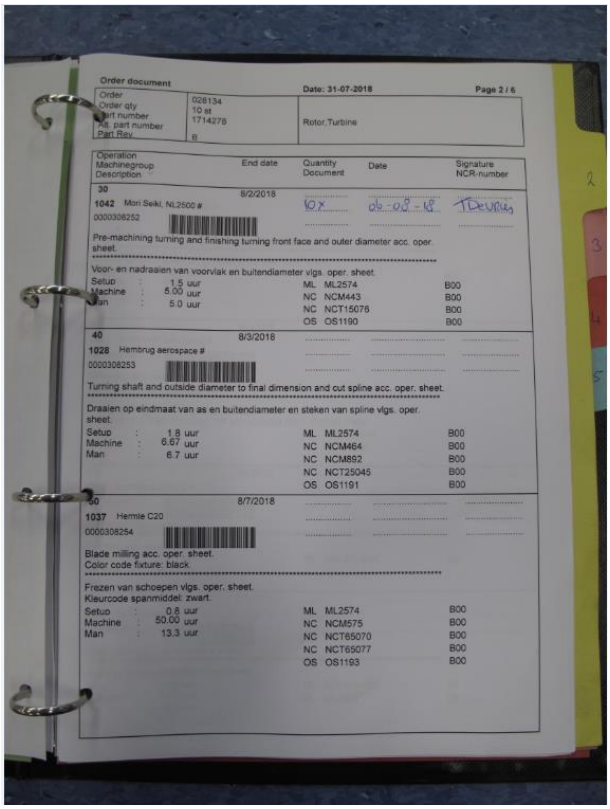


Figure 3.14: Presentation of production steps and related documents in the shop traveler

The shop traveler needs to stick with the production order at all time and can only be at one workstation at the time. Figure 3.15 shows the shop traveler on top of a crate that contains one product of the production order.

Figure 3.15: shop traveler on top of the product

The order number on the shop traveler needs to match the order number on the paper document that is clamped on the crate. The document clamped on the crate is called in Dutch the 'kratkaart' (crate card).

3.3.2 'Kratkaart'

The crate card is another paper information carrier. The crate card presents information about the product, the production order and the production planning. Figure 3.16 shows a close-up from a crate card. On every crate a crate card is clamped because in every crate one product is kept and we cannot put information on the product itself.

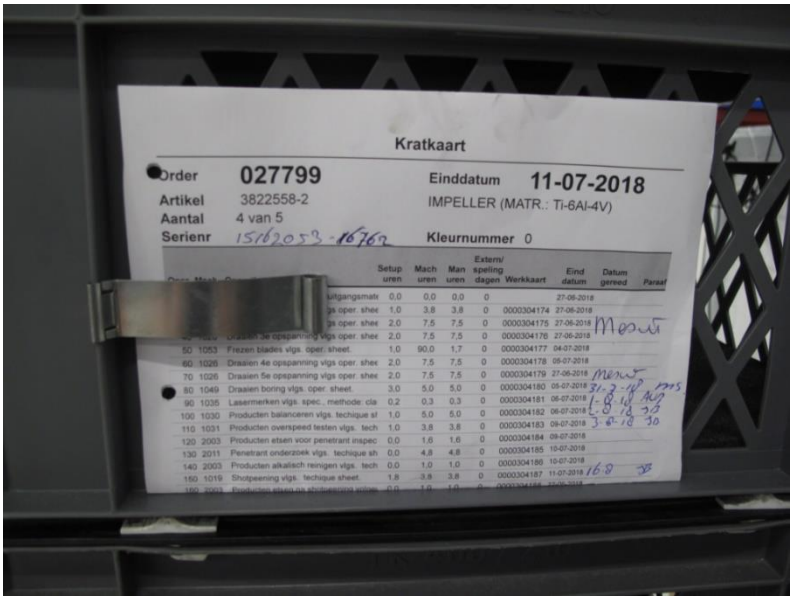


Figure 3.16: Close-up of a 'Kratkaart' clamped to the crate containing the product

The crate card shows the routing for the product. The operator responsible for a production step signs off his task on the crate card when finished. The operator must sign of the production order in his column of the production order in the shop traveler after he performed his production step for all products of that order. The production steps on the crate card are the same as the production steps mentioned in the shop traveler. The only difference is that the shop traveler is used for the entire production order and the crate card is used per product, so the shop traveler is production order related and the crate card product related. That is why the document files are only named in the shop traveler because the same documents are related to all the products in that production order.

In this process we again see that the use of paper results in manual tasks like signing of a production step for each product and the production order.

3.3.3 Inefficiencies in the document distribution process

We decided to analyse this process in more detail to find a good solution for the process. We will do analysis of this problem less elaborate than for the creation, review and release process, because this part is less critical and relies on the implementation of a good solution to digitalize and improve the document creation, review and release process.

3.3.3.1 No link with the database

The paper documents, used to provide the operator all the needed information, are not linked to a database. Document numbers mentioned on the production order need to be typed in to Aras manually to retrieve an ATS. Other documents are either stored in a drawer cabinet or provided in the shop traveler. Often measurement lists are added to the shop traveler and filled in with pen. This means that this list needs to be processed in a later stage to store the data in a database, which is extra work.

A problem that is mentioned before is the difficulty with version or revision control of the document mentioned on the production order. The production order is a printed record of the production order in Isah. Because the paper file has no link with Isah we can never be sure that we have the last updated version in front of us.

3.3.3.2 inefficient way of providing information to the right person

When looking at the shop traveler the first thing we noticed next to all the paper files in it, is that all information for each operator is included. All this information passes by every operator while just a very small part of it is meant for each operator. This is not efficient and at every production step there is the risk of losing the traveler, especially in the transition of production steps. Figure 3.17 shows a picture of how I found two shop travelers somewhere on the shop floor. Figure 3.15 showed us how it is supposed to be when the shop travelers are not in use.

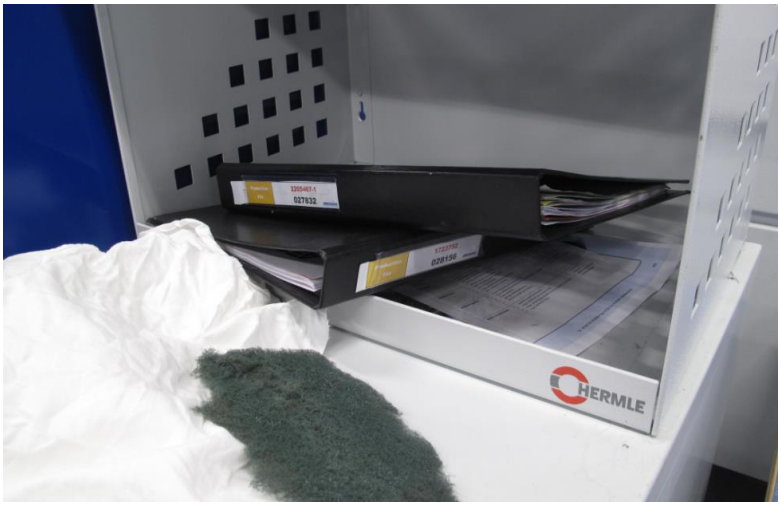


Figure 3.17: Two shop travelers not on the right place on the shop floor

3.3.3.3 decision freedom for operators

The shop traveler is not more than an information carrier that tells the operator which part he is producing, and which documents he needs to use to support his work. The traveler itself does not provide all the work instructions. It is the initiative of the operator to retrieve the documents. At Aeronamic the type of products that are produced do not vary a lot. Operators can decide not to retrieve an instruction document because they believe they know the process by head. Although the product itself does not change much, international production standards or customer specific standards can change. If the operator does not open the documents, he will not see the notification of the change. Changes do not always have a big influence on the product, but it is possible. If late in the process is noticed that one of the process steps is not executed as desired and the product is marked scrap, a lot of valuable time and materials are wasted.

3.3.3.4 Aras as user interface

Another problem we mentioned before with retrieving the documents is that the documents are retrieved by the operators directly from Aras. Aras is a management system meant to manage and prepare instruction documents for production and should not be a user interface for operators. It is possible to limit the freedom of actions in the system with authorisations but hard to hide data that should not be used or seen yet. The operator retrieves the documents from Aras by navigating through the system and manually search on the document ID that is mentioned on the shop traveler.

3.3.4 Necessity of product information

The crate card is something we cannot just take out of the process. It is important to understand that every product must be identified on the floor and no information can be brought onto the product itself because of the precision of the products, measures, balance and surface. Some sort of information carrier must be with each product on the shop floor.

3.3.5 Role of Isah in the production process

As mentioned before the production orders are prepared in Isah. The production orders are the routing of a product with the added documentation attached to it. Isah is not only used to prepare production orders. The operators also use Isah to sign off production orders and record their hours. Operators sign off their work both on paper as in Isah. This is in line with the IT strategy that the *as built* data is mainly managed within Isah as shown in figure 3.8

4 Solution design

In chapter 3 we analyzed the problems in the current document management process and modelled a desired situation according to the ambitions and strategy of Aeronamic. In this chapter we formulate a solution design and we will evaluate in what extend the solution improves the inefficiencies of the current situation stated in chapter 3. The generation and modelling of a possible solution represents the demonstration phase of Peffer's Design Science Research Process.

In chapter 2 we reflected on the use of BPM to improve business processes and Workflow management to automate these processes. By using BPMN modeling techniques we discovered that a lot of inefficiencies are a caused by the many manual tasks and the use of physical files. We decided to focus on finding a digital system that is suitable for digital document management. We soon found out that Aras PLM can digitally manage documents. As concluded in chapter 2, developers often chose to use other software systems to arrange digital workflows than the available BPM software. In our case we found out that we can arrange digital workflows and create automated tasks using the Aras software that is already available and familiar at Aeronamic.

In this chapter we will show possible solutions to improve the document management process using Aras. For these solutions we had to rearrange the Aras environment a little bit and implement adjustments and new tools. To prove to Aeronamic that Aras PLM could be used as the leading document management system and the purchase of a new expensive system is not necessary, I did a small proof of concept. For the document type ATS I arranged the Aras environment and the tools to realize a full digital creation, review and release process. The outcome of the proof of concept is explained in this chapter. The detailed description and visualization of the Aras environment for the suggested solution is given in appendix 4.

To be clear the software behind the system is created by Aras Innovator. I did not create a new software system but used and structured Aras functionalities to create a suitable environment for the needs of Aeronamic.

Next to the solution to improve the digital management of the documents we will also explain a possible improvement for the document distribution on the shop floor that potentially leads to a full paperless production process. This suggested improvement is supported by theory and not by a proof of concept.

4.1 Suggested improvements for the creation, review and release process

4.1.1 Aras software structure

In this chapter we will explain the way Aras can be used to improve the document management process. To get a better understanding of the Aras PLM systems infrastructure and the structure of the managed items in Aras, we first show the application logic model of Aras.

4.1.1.1 Application Logic Aras

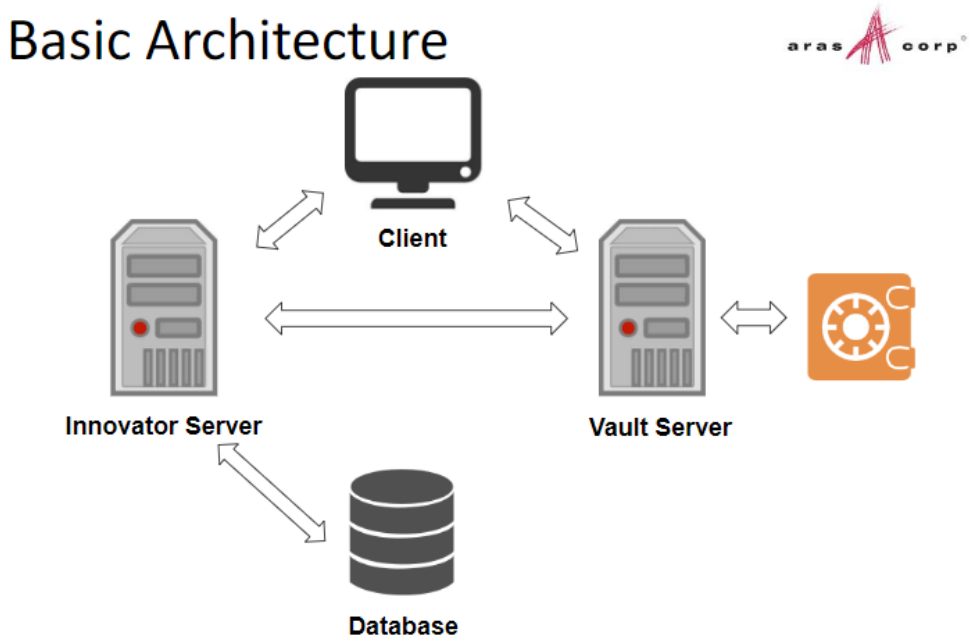


Figure 1.38: Basic application architecture of Aras

Figure 4.38 shows the basic structure of the Aras PLM configuration. Aras PLM is a web-based application based on the Microsoft .NET platform. Figure 4.38 shows the main components needed.

Client

Aras is a web-based browser interface that runs on Chrome, Internet Explorer or Mozilla Firefox. Users can access the Aras environment by running an URL in the web browser or use a shortcut on your desktop and login with their personal credentials. Aras has low resource requirements for the client which makes it very easily accessible.

Innovator Server

Running an application based on the Microsoft.NET platform requires connection with the Microsoft Windows Server Platform. The Innovator Server makes it possible to run the Aras application.

Database

All configuration rules, codes and solution business objects are stored in the Microsoft SQL database server. Aras is an SQL driven system. We can communicate with the SQL database using different programming languages as, Java Script, CSharp and Visual Basic.

Vault Server
The vault server is a separate server application were information about files that are linked to objects in the SQL database are maintained. Information like item numbers, creator ID's and linked items.

Vaults
Vaults are directory location that are linked to the vault server to store physical files.

It is possible to arrange multiple vaults and servers to create different environments within the Aras application. Reasons to do so can be the option to have a development environment. Changes and experiments done in this environment do not affect the live production environment. At Aeronamic multiple test environments are created. One of these environments was used for the proof of concept of the suggested solution in this thesis.

4.1.2 Aras Office Connector

The first solution that I decided to implement to improve the creation process of the documents is the Aras Office connector tool. The Aras Office Connector is a Microsoft Office ad-in that supports communication between Office applications and Aras. The Office Connector provides the ability to store, edit, search and manage documents in Aras while working with the familiar Microsoft Office applications. The Office applications are the familiar user-interfaces while Aras is working on the background.

I was looking for ways to improve the current creation, review and release process of work instruction document, with the restriction that Aras is used as the management system, I decided to work out the possibilities with the Office Connector for the creation and storage in Aras part of the process. The Lead Engineers and Special Process Specialist are used to creating documents in Word, so I anticipated that the implementation of the Office Connector will not have a big impact on the way of working for the creators of the documents. After downloading the Office connector and trying to work with it, I found out that this connector is a good solution to make it easy for creators of work instruction documents to directly store documents in Aras, without the interference of the Configurations Management Officer. The use of the Office Connector is explained in appendix 4.1.

At Aeronamic, Aras PLM is arranged in a way that every document saved in Aras initially receives the status 'Preliminary'. So, now we know how to create and save documents to Aras, but we can only use these documents in production after they are reviewed and approved to get the 'released' status. In the IST model for the ATS, figure 3.4, we showed that the Configurations Management Officer was needed to store the ATS file in Aras and assign the released state to the document. What we have found, is a solution to save documents in Aras without the interference of the CMO and the need to scan a printed document to freeze the content. Figure 4.27 shows the release phase without the interference of the CMO. Figure 4.32 and 4.33 show how the storage of the file in Aras is changed as responsibility of the CMO to an integrated process in the creation process of the file by the Lead Engineer. The other inefficiency we identified, is the use of paper in the review loop. We found a solution for this problem using Aras as well by arranging workflows in Aras as explained in the next section.

4.1.3 Workflows in Aras

Aras has the integrated functionality to design digital workflows and assign an item type to it. Using this functionality, we designed the review loop for the document item type in Aras. Aras can recognize users as mentioned before which makes it possible to authorize users to perform specific tasks in the workflow and assign the task to a user. Figure 4.12 shows the Workflow I created for the documents that are saved to Aras. The workflow starts when a document is saved to Aras.

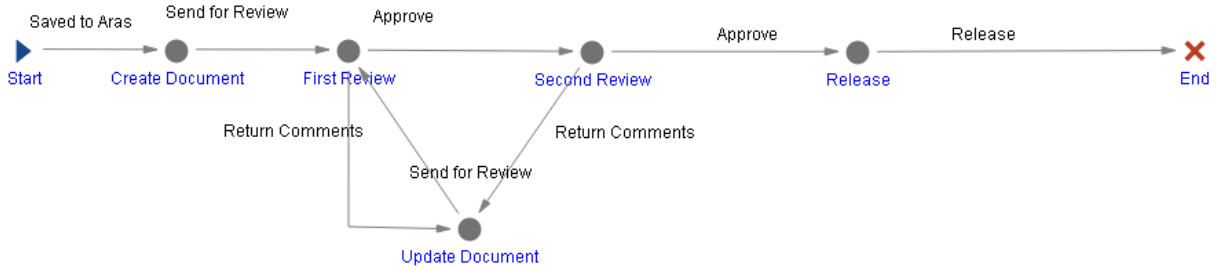


Figure 4.12: Workflow of a document in Aras

The use of the workflow in Aras supports us to control the distribution of documents for review and improves the traceability of the documents. The workflow in Aras is a flow of assignments. For each assignment we can appoint a user. This user performs the assignment and then votes the document to the next stage of the workflow. Although the workflow maybe suggests otherwise, the document does not move. The item has a fixed position and at every assignment a link to the document is given.

The workflow of a document is supported by the life cycle of the document that is also managed in Aras. This life cycle determines the possible states the documents can be in and whom are authorized to promote the document from one state to the other. Different identities or identity groups can be authorized to perform a certain promotion. Every possible promotion of the document in the workflow must be supported by the life cycle. Figure 4.12 shows the life cycle I defined for a document in Aras. The document can be in four states: Preliminary, In Review, In Update and Released. The with grey covered part can be disregarded in this section. In section 4.3 I will reflect in more detail on the different states defined in this life cycle and in section 4.7 we will reflect on the life cycle after the release state is reached. In appendix 4.2 the structure and use of workflows for the document management arranged in Aras for Aeronamic, are explained in more detail.

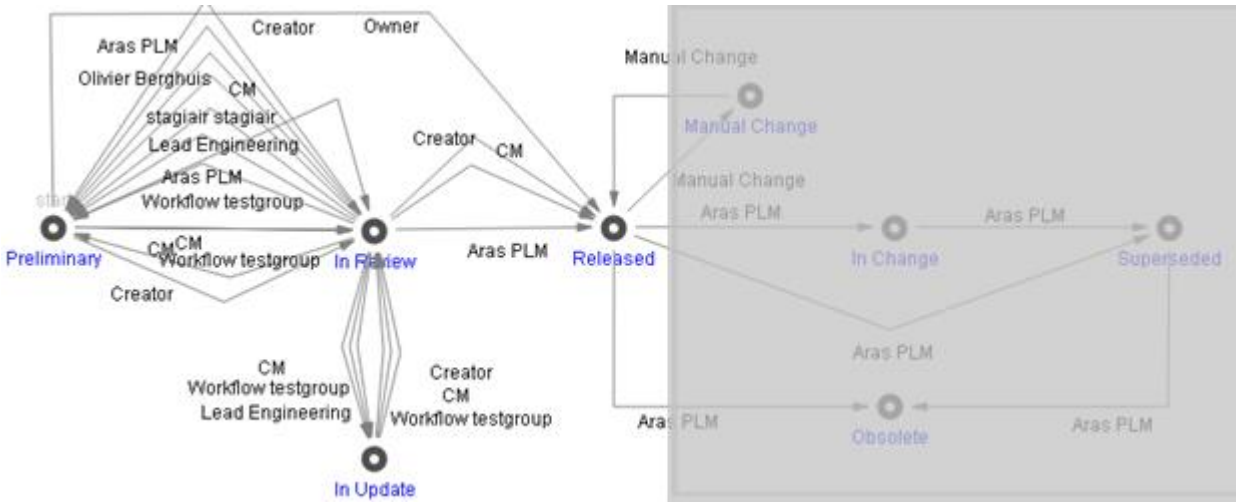


Figure 4.13: Document Life Cycle in Aras

The use of the workflow in Aras helps us to assign user to tasks, digitally distribute the document form user to user and show the progress using states. Aras automatically saves all actions and promotions including the records of the user IDs and specific times and dates of the performed activities. These track records provide full traceability of the document history.

4.1.4 Document states

In the IST situation only two states were assigned to a document along the entire creation review and release process, the Preliminary and the Release state. This was explained because the entire review loop was not managed in Aras and the state reflected the storage process of the document to Aras instead of the state of the document itself. Now we can manage the review loop in Aras with the support of workflows, we got the option to use more different states to track the progress of the process more easily. In the IST situation the document could be in the Preliminary state while it was already finished and saved to Aras by the CMO. Documents were also returned to the preliminary state when a change needed to be made. Preliminary suggest that the document must be created and fully reviewed afterwards while in fact only a small change need to be made and reviewed.

To visualize the progress better, we added the In Review state and the In Update state. The In Review state shows that the creator finished the document and sent it for review. The In Update state tells us that the document is finished and was reviewed at least once already and now is being improved before it is reviewed again before release. A document in the Preliminary state needs a review loop and with a big chance it needs an improvement before it is released. With this use of states, it is a lot easier to see where in the process the document is. After a document is released, changes can be suggested for a document for different reasons. The document than has to go to the In Change state as well. For this research we left this part untreated in the proof of concept within Aras. Table 4.1 shows the possible states a document can be in from creation to release.

Table 4.1: List of document states

State	Meaning
Preliminary	In this state the document is being created and not ready to be reviewed
In Review	The document is being reviewed. No distinction is made between the first and second review
In Update	The document has been reviewed and some changes are suggested. The creator is updating these suggested changes in the document.
Released	The document is reviewed and approved and ready for use in production

Figure 4.17 shows how the states are presented in the document column. As you can see it is possible to use conditional formatting to give a cell a color depending on the data in the cell. This makes it easy to interpret that the ATS000538 is ready for use because of the green color.

Restric...	Document ID	Revision	Description	Type	State	Authoring Tool
None	ATS000532	00	How to write a thesis part 1	ATS	Preliminary	Microsoft Word
None	ATS000534	00	How to write a thesis part 2	ATS	In Review	Microsoft Word
None	ATS000536	00	How to write a thesis part 3	ATS	In Update	Microsoft Word
None	ATS000538	00	How to write a thesis part 4	ATS	Released	Microsoft Word

Figure 4.17: table of documents with different states

4.1.5 Visual Collaboration

We showed that Aras can be used to manage the digital workflow of a document. This is a solution for the distribution of paper document through the Manufacturing Engineering department. The review of the documents used to be done on paper, but we found an easy and clear way to do this digitally as well.

Aras has the Visual Collaboration functionality. The Visual Collaboration tool makes it very easy to add comments to a file without affecting the file itself. The reviewer opens the document item in Aras and selects the PDF viewer tool (figure 4.21). Aras shows the PDF version of the document file (figure 4.22). When we start working with the Visual Collaboration tools, Aras adds a layer over the document. When working in this layer we do not affect the original file. A detailed description about the use of the visual collaboration tab is given in appendix 4.3.

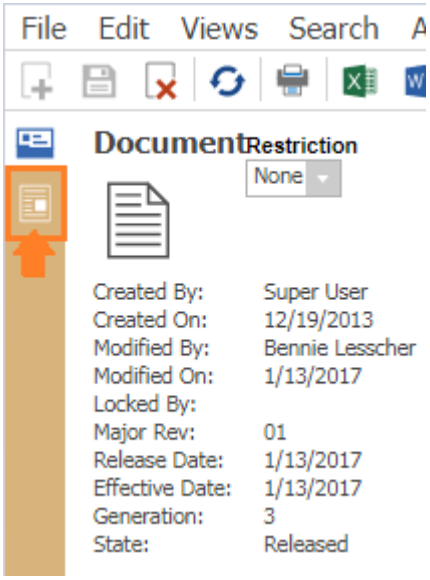


Figure 4.21: PDF viewer icon in Aras

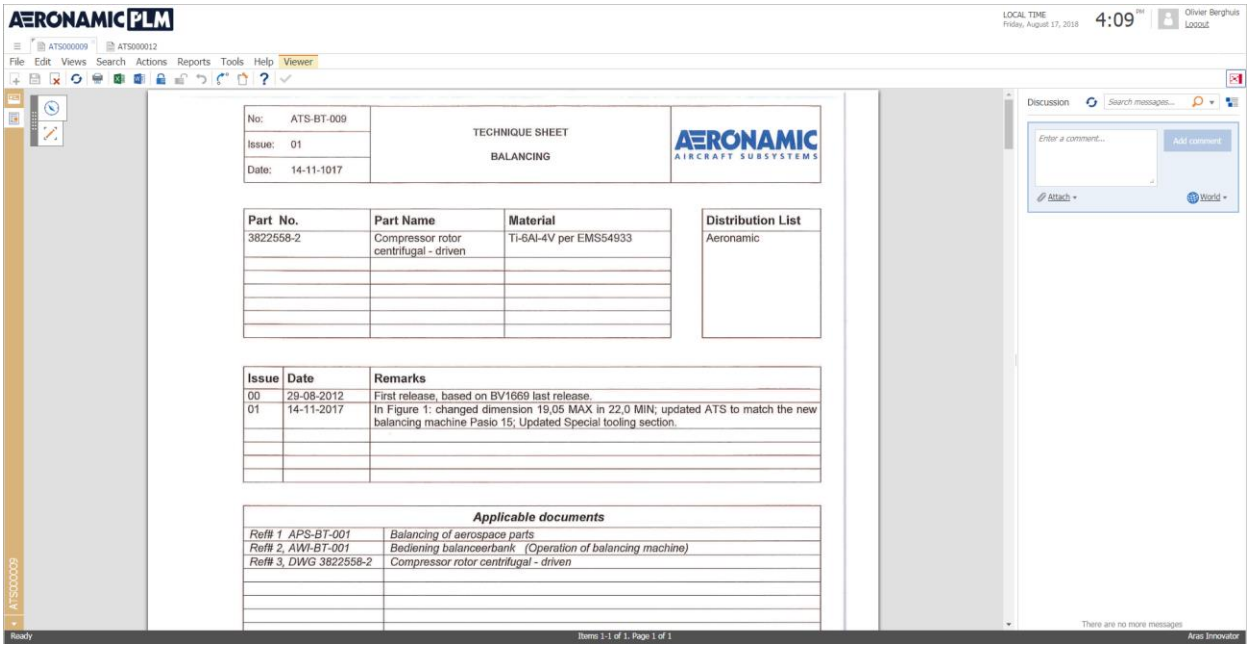


Figure 4.22: PDF file in Aras

Instead of making notes on paper files and adding sticky notes with comments to the files we now can digitally add comments to the document. The comments that were lost with the use of paper, at the moment the adjusted document was scanned, and the paper files shredded, are now saved and directly linked to the related document. All Information about who added the comment and when it was added is registered by the system and shown in the discussion.

The Visual Collaboration tool supports our digital review process and manages all comments and improvement steps. The Visual Collaboration tools are added to all Office applications as part of the Office Connector. The layer added over the PDF file in Aras is available in Word as well when adjusting the document. With this option it is easy for the creator of the document to implement the suggested improvement to the document having direct access to the digital comments. The Visual Collaboration functionalities support our goal to review documents digitally and makes sure that all information is saved and managed.

In this chapter we showed with the implementation and good use of three tools, the Office Connector, Workflows in Aras and the Visual Collaboration tool, that we can create, review and release documents digitally without the use of any paper file. Let us have a look on how the Business Process Model of the situation with the suggested solutions integrated looks like.

4.1.6 Business Process Model suggested situation

Figure 4.27 shows the main workflow of the document creation, review and release process with the suggested solutions integrated. The workflow itself does may not directly show the improvements of the process, therefore we will explain with support of the workflow how the suggested solutions improve the process. For the reflection on the suggested situation we will use the same elements as used before when we evaluated the IST situation in Section 3.1.

- The document format and storage location
- The task types
- The roles involved in the process
- The amount of actions needed in the process

1. The document format and storage location

The first thing that catches the eye in figure 4.27 must be the red data objects. This is highlighted with the orange rectangles. The red color of the data objects, means that these documents are managed in Aras. In the suggested situation the document is managed within Aras in each phase of the process. The state of each document is mentioned below the data icon. We mentioned that in the IST situation of the ATS the state of the document not actually reflected the state of the document. We saw that the document in the release phase had the preliminary state while it was already reviewed and approved by the reviewers. In the model in figure 4.27 we can see that the document always has a state assigned and the state fits the phase of the process the document is in.

In the creation phase the document can be in the Preliminary and In Update state. These are both states that tell us that the creator is working in the document and the document still must go through the review loop.

In the review phase the document can only be in the In Review state. We do not distinguish between the first and second reviewer.

In the release phase the document is in the released state and ready for use.

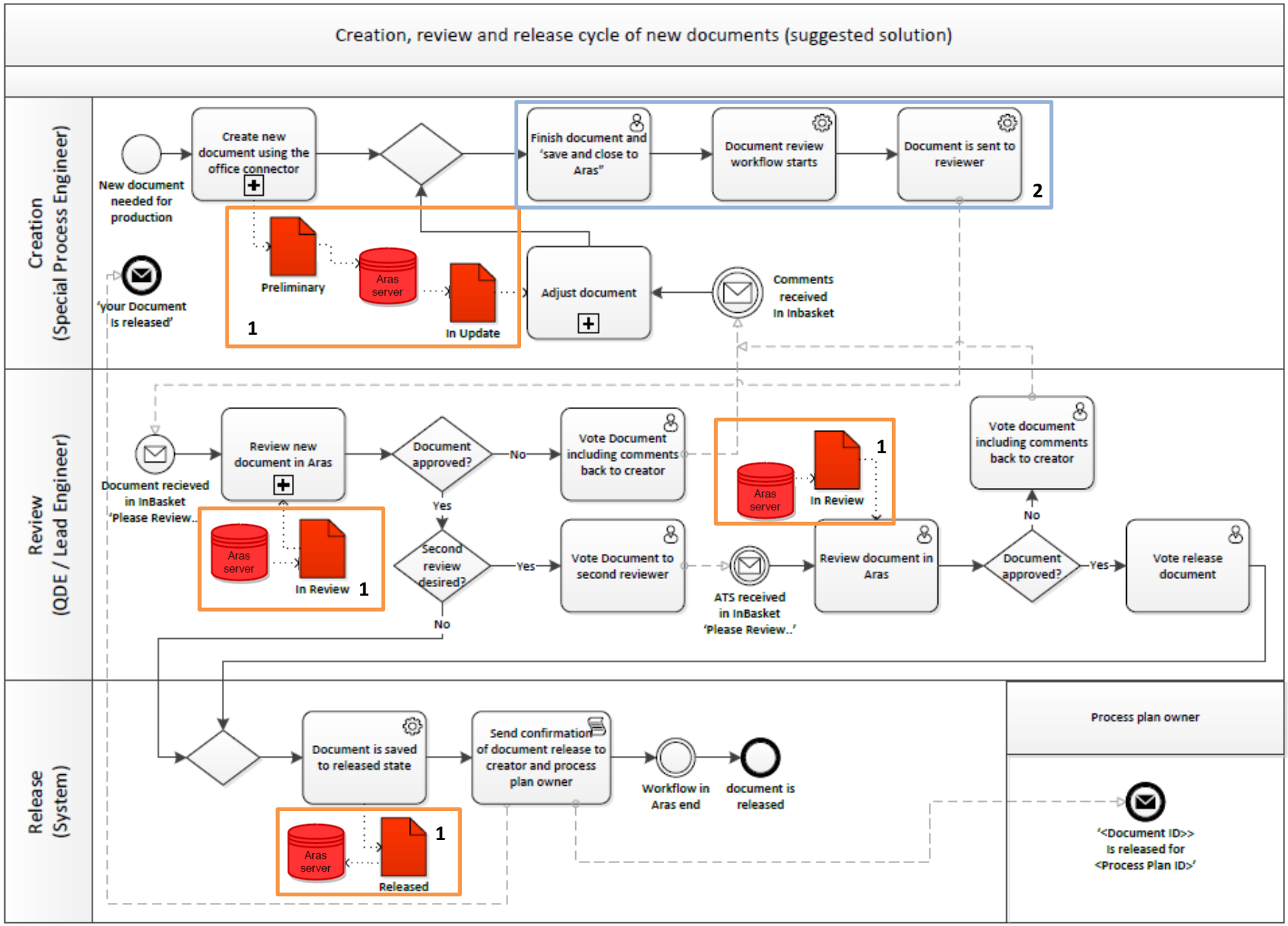


Figure 4.27: Workflow of the digital document management process using the Office Connector and Aras functionalities.

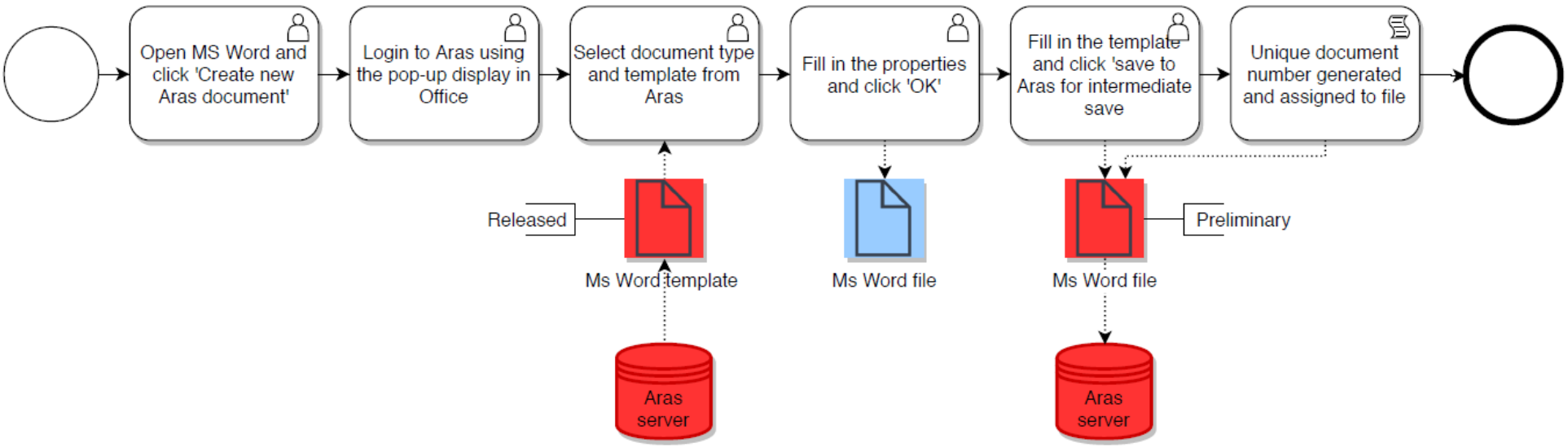


Figure 4.28: Collapsed view of Create new document sub-process (Solution)

To show that the document is managed in Aras along the entire process we have a look at the sub-processes of the creation and review process of the documents. The creation of the document starts with retrieving a template that is managed in Aras. During the creation of the document by typing the content in the file the document is not managed in Aras until the first 'Save to Aras' as explained in appendix 4.1.

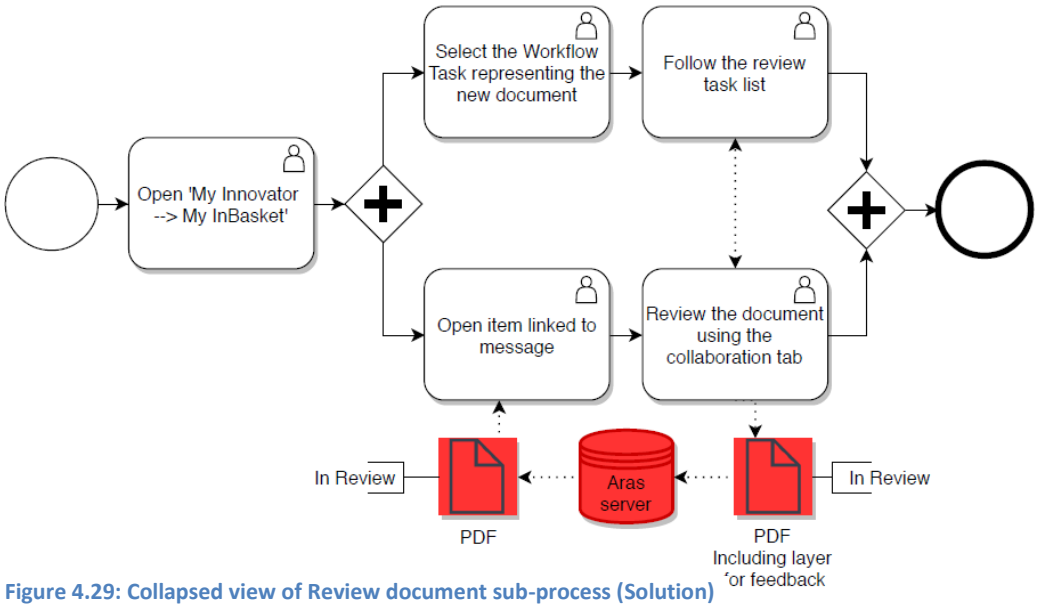


Figure 4.29: Collapsed view of Review document sub-process (Solution)

In the review loop the documents are managed in Aras in the PDF format. In section 4.5 about the visual collaboration we explained how this process works. In the sub-processes we show the different file formats that can be managed in Aras. This shows that it is possible to easily save a document to a frozen file without scanning it and saving the file as an image. With this way of saving a document to the PDF format, the text is still recognized as text which gives the user the possibility to use a digital search tool to search through the content of the file. Evaluating both sub-processes quickly, shows us that the documents can be fully managed within Aras without the use of any paper files.

2. *The task types*

The main process and collapsed views of the sub-processes clearly show that none of the tasks is a manual task. This means that the risk of human mistakes is significantly reduced, and we easily control the authorization of tasks and register the progress of the activities. We showed this by highlighting the tasks of the creator with a blue rectangle. Both figure 3.3 and 3.7 showed us that in the IST situation these task were all manual. Using the office connector, the Aras workflows and the Visual Collaboration functionalities, each activity is registered and controlled by the PLM system. The interference of the PLM system realizes the interaction with the database along the process and automatic activities. A few examples of automatic activities are: document number generation, generating a PDF file, updating state of document, sending documents for review to the right reviewer and sending informing messages of document release.

3. *The roles involved in the process*

The workflow of the main process shows that the release phase of the process is fully automatic. No user is involved. Our goal was to find a way the CMO would not need to interfere in this process. The model shows that the CMO has no role in the process anymore. Most of the tasks the CMO had in the IST situation of the ATS document are taken over by the creator of a document, with the support of the Aras office connector in the creation phase of the process. Because the creator already stores the document in Aras in the creation phase, the creator is also filtered out from the release phase, since the creator does not need to scan and send the document to the CMO anymore. Figure 4.30 and 4.31 show the big difference in the release phase of the process between the IST situation and the suggested solution. We can easily tell that the process is shortened substantially. The two sub-processes in the IST situation are filtered out. Most of the tasks of the 'Store ATS in Aras' sub-process is taken over by the creator in the creation phase and the tasks of the 'Start new M-ECN process' are not needed anymore because the review of the correct storage in Aras is blended in into the digital review loop of the solution. Figure 4.32 and 4.33 illustrate the switch in tasks between the CMO and the creator.

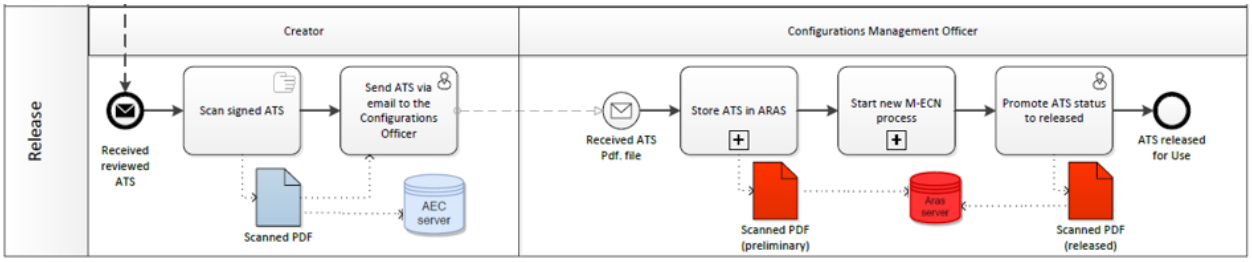


Figure 4.30: Release phase IST for ATS

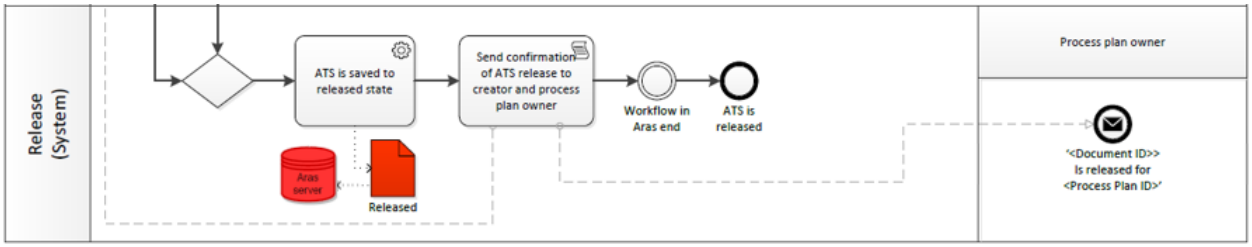


Figure 4.31: Release phase documents suggested solution

An extra positive aspect of the use of the Office Connector and the workflow in Aras is that we can automatically send an E-mail to the creator of the document and the process plan owner, who needs to know if all work preparation materials are ready to be used in production, with the message that the document is released. The process plan owner used to be informed after the Lead Engineer filled in the

document record in Isah. The functionality of the automated E-mail is not tested in the proof of concept for this thesis but Aeronamic already uses this functionality for other processes.

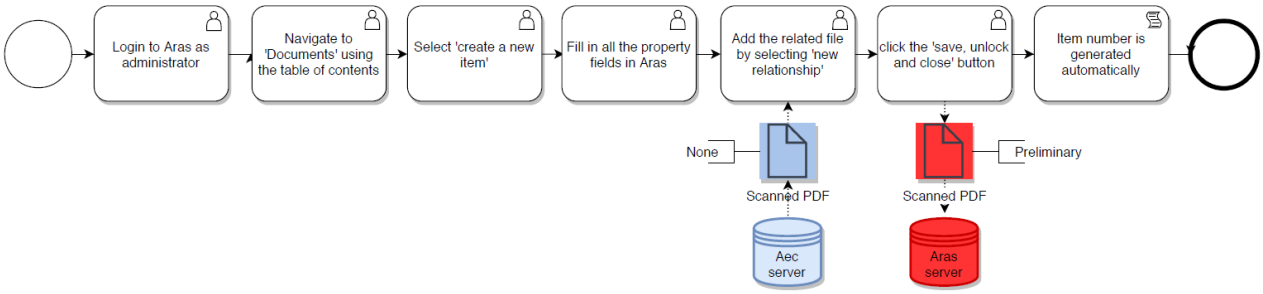


Figure 4.32: Collapsed view of sub-process Store document in Aras (IST)

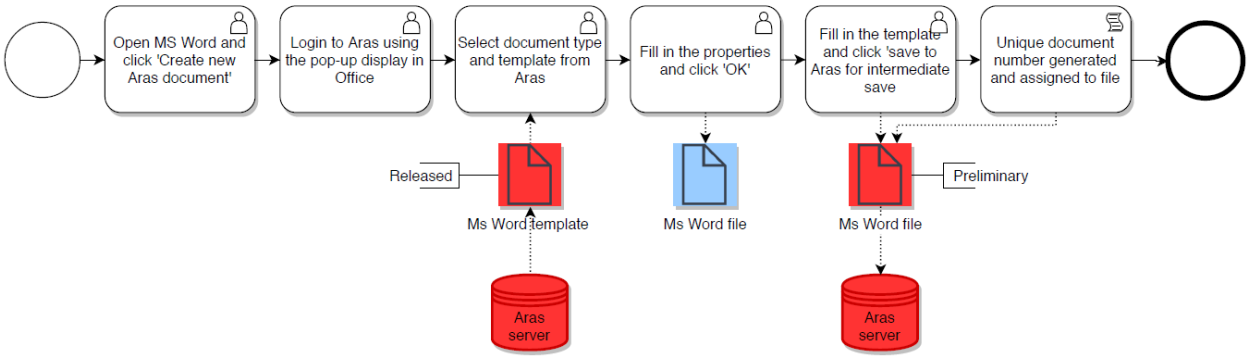


Figure 4.33: Collapsed view of sub-process Create new document in Aras (Solution)

Figures 4.32 shows the process of the tasks the CMO had to do to store a document in Aras in de current situation and figure 4.33 the tasks the creator needs to do to save the created file directly to Aras in the situation of the suggested solution. The processes look very much alike if you look at them, but there are differences that need to be mentioned. The first thing we can say when looking at both processes is that it is good to see that the process of directly saving the document to Aras by the creator is not more complex than the process for the CMO. In fact, the process is a lot more efficient and I will explain why.

The first difference is the ease of navigating in the system. The CMO needed to navigate himself through the Aras interface to reach the location where he can create a new document item. He had to manually fill in all properties except for the document number and upload the right document to Aras.
When creating a new document using the Office Connector the property bars in the dialog window give you predefined properties to choose from. With every selection you make, the system recognises your selection and limits the options for other properties to only the options that can be used in combination to the first selected property. So, the system supports you to select the correct properties. You do not have to navigate through the Aras interface, you just must select a few properties and start working in the template that is offered to you by Aras. The process with the support of the Office Connector was explained in section 4.1.2.

Another important difference is that the document created with the Office Connector receives a status that fits the actual progress of the document.

The most important improvement is that these tasks are taken out of the hands of the CMO and picked up by the creator. We believe that this work should be the responsibility of the creator. He already had to fill in all the properties on the document for the reviewers to review and the CMO to use for the

storage in Aras. Now the creator must do the same, but then directly linked to the Aras database, with the support of Aras that corrects him if he makes a mistake and Aras automatically generates the document number and file name. The task to send the document to the CMO is also filtered out. So, work is where it should be, double entering of document properties is prevented and the new process does not ask more time from the creator. With this development in the process quality is guaranteed better and both manual labour and throughput time are decreased.

4. ***The amount of actions needed in the process***

In the IST situation we concluded that especially the amount of actions needed by the CMO where seen as a problem. We can be very short by saying that the entire release process is automated, so no human actions are needed in this last phase of the process, not from the CMO nor from the creator. The creator took over the actions from the CMO, but his process is not extended because the creator does the same tasks not on paper but directly in Aras.

In this chapter we showed that with three relatively simple solutions the process of creating, reviewing and releasing a new document can be much more efficient and managed fully digital. Important is to see if this process is efficient to use in managing a document after it is released. As we saw before in figure 4.13 in Section 4.1.3, the life cycle of a document does not finish after it is released. Often changes in the document need to be made because the client's specifications or international standards change. In that case the document needs to be revised. In the next section we will shortly explain how this works at Aeronamic and what this means for the effectiveness of our suggested solution.

4.1.7 M-ECN

The term M-ECN is mentioned before in section 3.1.2. M-ECN is the term for the notification that changes need to be made within the M-BOM configuration. So, the M-ECN announces that changes in documents or structures within the PLM system Aras need to be made. An M-ECN is often the result of an E-ECN that is initiated by changed customer specifications or international standards. Changes need to be implemented in a structured way. The M-ECN is the process tool Aeronamic developed to realize a structured implementation of changes in the M-BOM configuration.

Figure 3.6 shows the M-ECN process that is initiated because a document is added to the configuration. Adding items to the system is a change that needs to be implemented in a structured way as well. The question is if our suggested process of adding a new document to the system is structured enough but we will come back on this in the next section. The process shown in figure 3.6 is in principle the way an M-ECN is executed in the current situation. The CMO creates an M-ECN which is a notification for the Lead Engineers or Special Process Specialists that items in the M-BOM configuration need to be changed. The Special Process Specialist are responsible for the chance of content in the affected document, the Lead Engineers update the revision numbers of the items in Isah. The changes made in the documents because of the M-ECN need to be reviewed the same way as for a new created document. The M-ECN is sent within the Aras environment. An M-ECN is received in the InBasket just like the workflow tasks as explained in appendix 4.2.

The M-ECN triggers the update process for an existing document that is released and needs a revision. This process is almost the same as the creation, review and release process of a new document. The only difference is that instead of creating a new document, we revise an existing document and do not create a new item but increase the revision number. In the old process the change is easily made since all properties were set manually. In the suggested situation this is a little different. We explained the

process of using the Office connector to create a new document and automatically generate a document number that initially has revision 00. Now we must open a released document in Aras without creating a new document number but update the existing file and increasing the revision to 01. This is possible with the use of the Office Connector and the review loop using the Aras workflow and Visual Collaboration tool.

Instead of opening Word and select the 'New Aras document' command, we go to the document in Aras and select 'Create new Revision' under the actions tab. The system automatically changes the state of the document from Released to In Change and set the revision number to 01. We can change the file and save the new revision to Aras. After saving the file to Aras the review workflow is started again and the rest of the process is the same as the review and release process of figure 4.27. When the creator receives the notification that the document is released, he sends a confirmation to the CMO and closes the M-ECN. Our suggested solution is not only suitable for the creation of new documents but assures that adjusting an existing document can be managed fully digital as well. This is quite important because a change in a document occurs more often than the need to create a completely new document.

At Aeronamic they are working on the improvement of the M-ECN process, to make it more automated and with better links to database records in Isah, but that is out of scope for the assignment that is the subject of this thesis.

4.1.8 Class Diagram

The Aras PLM system identifies objects as items. Documents for example are defined as items and items can have certain properties. Users are also items. Items are the classes in a class diagram of the Aras configuration. Figure 3.39 shows the class diagram of the items related to documents managed within Aras.

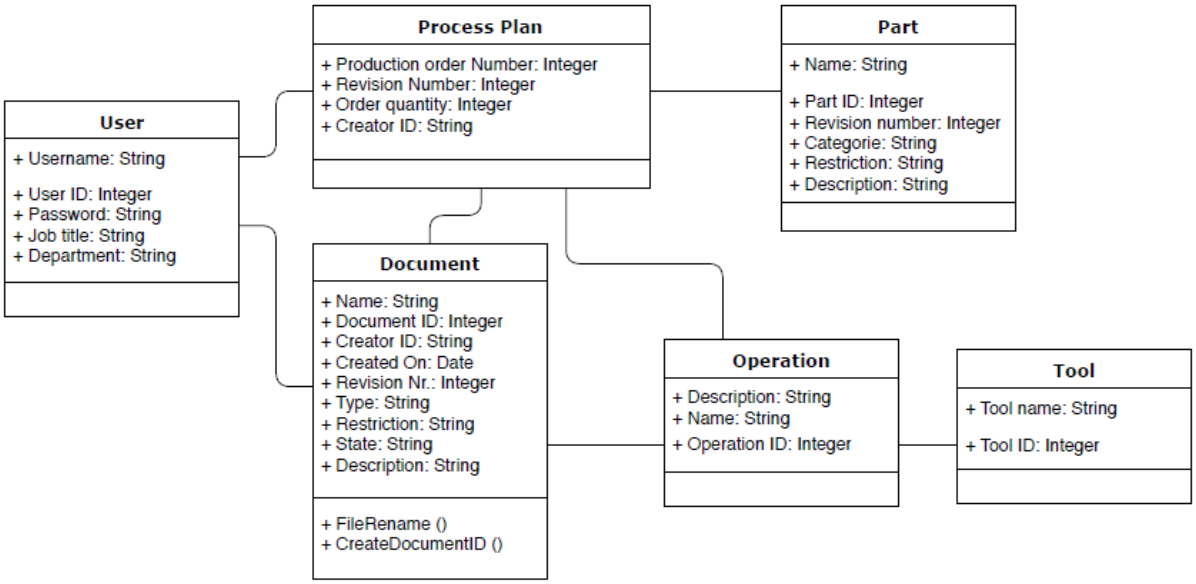


Figure 4.34: Class Diagram of document Structure in Aras

This class diagram shows how the items within Aras are structured and related in the desired situation. The process plans in Aras are the core of the structure. In the current situation, work instruction documents are linked directly to a part while the part is an element of the E-BOM configuration and the documents are part of the M-BOM configuration. In the new situation documents are connected to an operation within a process plan. The process plans are linked to a part, so the documents are indirectly linked to the parts. The process plan for each part had a unique number. This does not mean that every process plan is unique. Multiple parts can follow the same order of operations only with a different result. The order of operations that can be used for multiple parts are called 'Stam routes' (Base routings), as explained in the table 1.1 *terms and definitions.* The combination between an operation and a process plan has a unique number called the 'werkkaart nummer' (work order number). Documents will be linked to that unique number. In section 4.3.1 this is explained in more detail.

4.2 Suggested improvement for the document distribution process

We found a few elements for improvement in the distribution of information over the shop floor; the use of paper, the paper files in the shop traveler have no link with the database, risk of losing the shop traveler, all information in the shop traveler passes by every operator and the operator retrieves document directly from Aras.

4.2.1 Running pilot at Assembly

One of the problems mentioned above can be solved as proven by a pilot that is running at the assembly department at Aeronamic.

The shop traveler in figure 3.13 shows a barcode in the column for every production step. This barcode is the translation of what we call the 'werk order nummer' or in English work order number. This work order number is a unique number of the combination of the production step and the order number. Since we linked the documents to the production steps of a routing for a specific part, the documents needed for each production step are linked to this work order number when the production order is made. At Aeronamic they started using this work order number in the form of a barcode to retrieve all the linked documents automatically form Aras by scanning the barcode, instead of manually searching for the document IDs one by one. For this way of working a programmer and developer at Aeronamic programmed and designed a small web-based user interface. Figure 4.34 shows how the documents are presented to the operators after scanning the barcode.

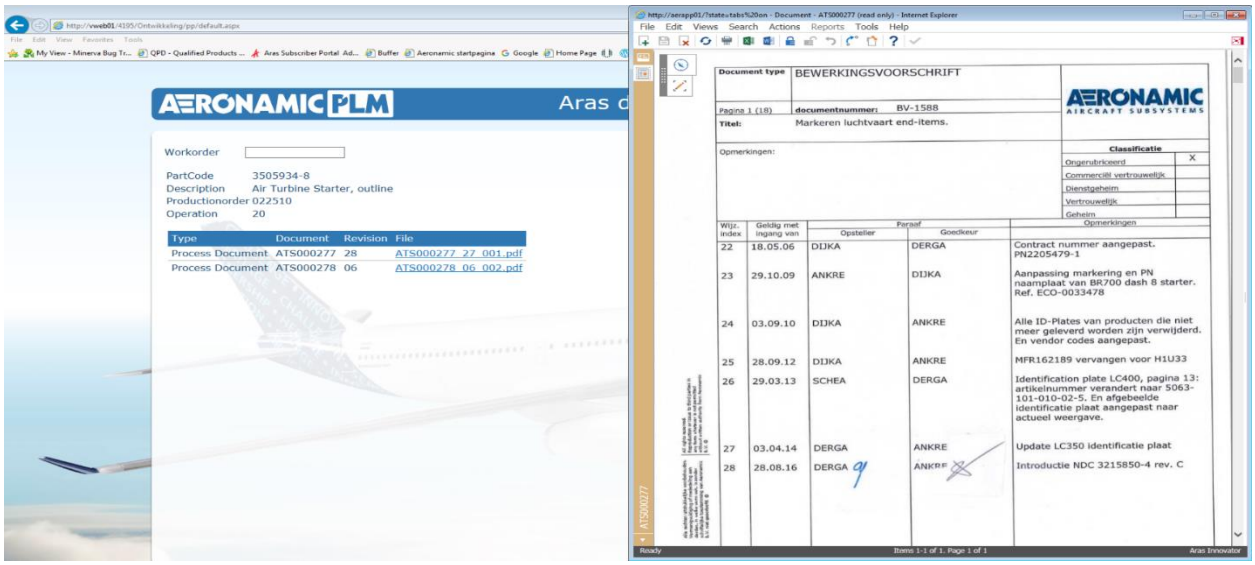


Figure 4.35: Interface of work instruction pilot

Figure 4.34 shows all the documents that are linked to operation 20 for production order 022510 that is the production order for the Air Turbine Starter. We see that two ATS documents are linked to the work order number. The operator can select the document to open the file. Only two very simple actions are needed to open the needed instruction file.
The links direct the operator to the file that is stored in Aras as we can see on the right part of figure 2.4.1. This means that documents are not transferred, or an extra database is needed for the interface. The interface makes use of the existing systems and uses links to the Aras database.

If we arrange the Visual Collaboration functionality in Aras it is possible to give the operators the authority to place comments in the documents as well if they find small mistakes or suggest changes. Especially for the BV documents this can be a very useful tool, because it is use full to create the BV with

input of the operators. Sometimes operators find smarter ways to do prepare machines or products for production. They can add the suggestion in the discussion layer. For documents like the ATS it is very important that suggested changes by operators are approved by a certified engineer before it is used.

The pilot at the assembly shows us that this way of working makes it very easy to retrieve the documents needed for a production step. The interface is very simple and easy to use. We can say that it is a good solution for part of the problem. Important to know is that this system only works when the process plans in Aras are Arranged. That is not the case yet for every product and that is why this solution is not implement in the entire factory yet. Another remark is that it does not change anything about the use of paper on the shop floor. Therefore, we kept looking for another solution.

4.2.2 Digital price labels

The pilot at the assembly department showed us that we can use barcodes to retrieve documents easily from Aras without the operators navigating through Aras themselves. These barcodes are presented to the operator in the shop traveler. The question we want to answer is whether it is possible to change this process and replace the shop traveler for a digital solution.

The first idea is to stop working with document IDs and start using the barcodes. These barcodes represent the work order number. This work order number or `werkkaart nummer´ is given on the crate card as well. We concluded that it is important to carry information on the crate with the product in it. The idea is to move the barcodes to the crates and see if we can work without the shop traveler. If we can manage all document digitally and retrieve them using he barcode, we can add the measuring list or other sheets that need to be filled in by the operator to the work order number. These lists were in the back of the shop traveler. If we can make them digital and move the barcodes to the crate card, we do not need a shop traveler anymore.

The idea of changing the work order numbers on the crate card to bar codes is simple to implement. Still we have two problems that are unsolved, the use of paper and that all information passes by all operations.

Using a tablet instead of paper to present the production order and the barcodes to the operator is not the best solution. These tablets are a lot heavier, need charging and are lot more vulnerable than paper. We need smaller less energy consuming and less vulnerable solution. To be able to use smaller solutions we need to limit the amount of information that is presented on the screen. This is in line with the vision that we only want to offer the information to the operators that is relevant for his production step. If we want to offer the information per production step, we need to change the information every time a product is finished at one stage and is placed in the buffer zone of the next stage. Of course, we do not want this change of information to be done manually. This is another action and with risks of mistakes. Our search was for a small digital display that can change the information it presents at a transition from one stage to the other. We found a system that can do so.

We are inspired by the digital price labels that we have seen in the Media Markt and some supermarkets. The idea of this digital labels is that prices and product information can be changed on the screen automatically. The time-consuming actions to change all the paper labels on the shelves are not needed anymore. The concept of this system is introduced by multiple companies. One of them is called Pricer.

4.2.3 Pricer

Pricer introduced the use of Electronic Shelf Labels (ESL) for the stores branch. The idea behind the ESL is that the employees do not spend their time on changing price labels and there is no confusion at the register when there is a difference in the price on the label and at the register. The prices on the labels are update directly when a change in price is made in the system of the store. An infrared transmitter sends a signal to the related label when a price update or promotion changes the price of a product. Every label is connected to the system and an infrared transmitter is used to communicate with the labels. Live changes are directly implemented on the shop without the need of an employee locating the related product an manually change the label. We believe that the concept of this ESL can be perfectly used to have a digital way of presenting the barcodes for the documents to the operator that change between every production step. If we can let this system communicate with our ERP system Isah, the labels can change information after an operator signs off his work in Isah. This communication between Isah, Aras and this ESL system is something that needs to be investigated further. Figure 4.36 shows an example of the ESL.

Figure 4.36: Example of an ESL

4.2.3.1 Layout of the display

We see in figure 4.36 that more information than just a price or a bar code can be presented on the screen of the ESL. To show every operator or director of manufacturing, which products are in which crates on the floor, it is convenient to see the product information on screen. To have an overview which products are from the same batch, the production order number will be presented as well. Next to the product information the barcode that is used to retrieve the documents will be presented as well and the identification of the active production step. The presentation of the production step is not only useful to inform the operator that he can start his operation, it also helps the operator to determine to which buffer zone he must bring the product after signing off his operation because the label than changes information. Figure 4.37 shows the suggested layout of the ESL used in production at Aeronamic.

Figure 4.37: Suggested layout of ESL

According to our findings the information that is shown on the ESL of figure 4.37 must be enough to show the operator what he needs to do, give enough information about which product is in the crate and which production order the product is part of. It is possible that an operator has work from multiple production orders in his buffer. To prevent that the operator picks the wrong product form the buffer in his flow of operations the crate cards in the current situation have a different color per production order. Figure 4.38 shows a buffer with products from two different orders.

Figure 4.38: Buffer zone with products from different production orders.

For the operator it is very clear that he first needs to finish all the product with the white crate card before he can start working on the products with the red crate card. The displays of the ESL are very simple and only have the functionality to show black images and text. We believe that it is a good idea to color code the production orders, so we need to find another solution. Possibilities can be to order displays with different colored housings. If that is not possible we can create different colored holders that support the attachment of the displays to the crates. At Aeronamic a lot of testing with the possibilities of 3D-printing is done. 3D-printing can be done with materials in different colors. We can try to design holders in different colors that can be clicked to the crates and used to hold an ESL.

4.2.3.2 Benefits of the ESL

The use of the ESL has a couple of benefits.

- The ESL is light weighted. Although it is a digital system the displays are very light and small. This makes is very easy to use them as labels on the crates containing the products
- The ESL consume very little energy. The wireless labels run on batteries but because of the low energy consumption the labels can run on one battery for a long time. Long enough to work for at least the time needed to complete a production order.
- The system is already used in a lot of stores and it has proven to be successful. We do not have to completely design new technology, but we must adjust it in a way that it suits the purpose of a production company. The benefit of this use of the system is that we can be the first production company to use a system like this and we broaden the market for companies like Pricer. We could make a good deal to present ourselves as a pilot company for the new production company branch.
- The use of ESL is a way to realize a full paperless manufacturing process.

5 Evaluation of suggested solution

In chapter 4 we elaborately explained a possible solution for the document creation, review and release process that is a combination of three tools, the Aras Office Connector, workflows in Aras and the use of the Visual Collaboration tab. We evaluated the benefits of these solutions separately and took a closer look on the Process Models of the situation with the three solutions combined. Next to the improvement of the document creation, review and release process we also introduced a solution that improves the document distribution on the shop floor and is a step towards the paperless factory. Before we can draw our conclusion we first want to summarize our findings and reflect the generated solution against the norm according to step 5 of Peffer's design Science research method (2016).

The goal of this research was to create a clear structured process of creating, reviewing and releasing production documents, managed digitally in the Product Lifecycle Management (PLM) system with active links to database records of linked items. This goal came forth out of clear wishes from the Director Manufacturing Engineering. In section 1.3 we set the norm for an improvement within the document management process at Aeronamic. Table 1.1 showed the norm vs. reality table. In this chapter we will set the solution out vs. the norm, to see in one overview to what extend our suggested solution meets the norm.

The norm was divided in two parts, no more use of paper in the document review loop and directly creating and managing work instruction documents in Aras. For both goals we found a solution. The workflows in Aras and the use of the Visual Collaboration tab realize a paperless review loop managed in Aras. The use of the Office Connector makes it possible to create and adjust documents in a familiar Office application and directly store and manage them in Aras. With the information given in this chapter we can fill the norm vs. solution table.

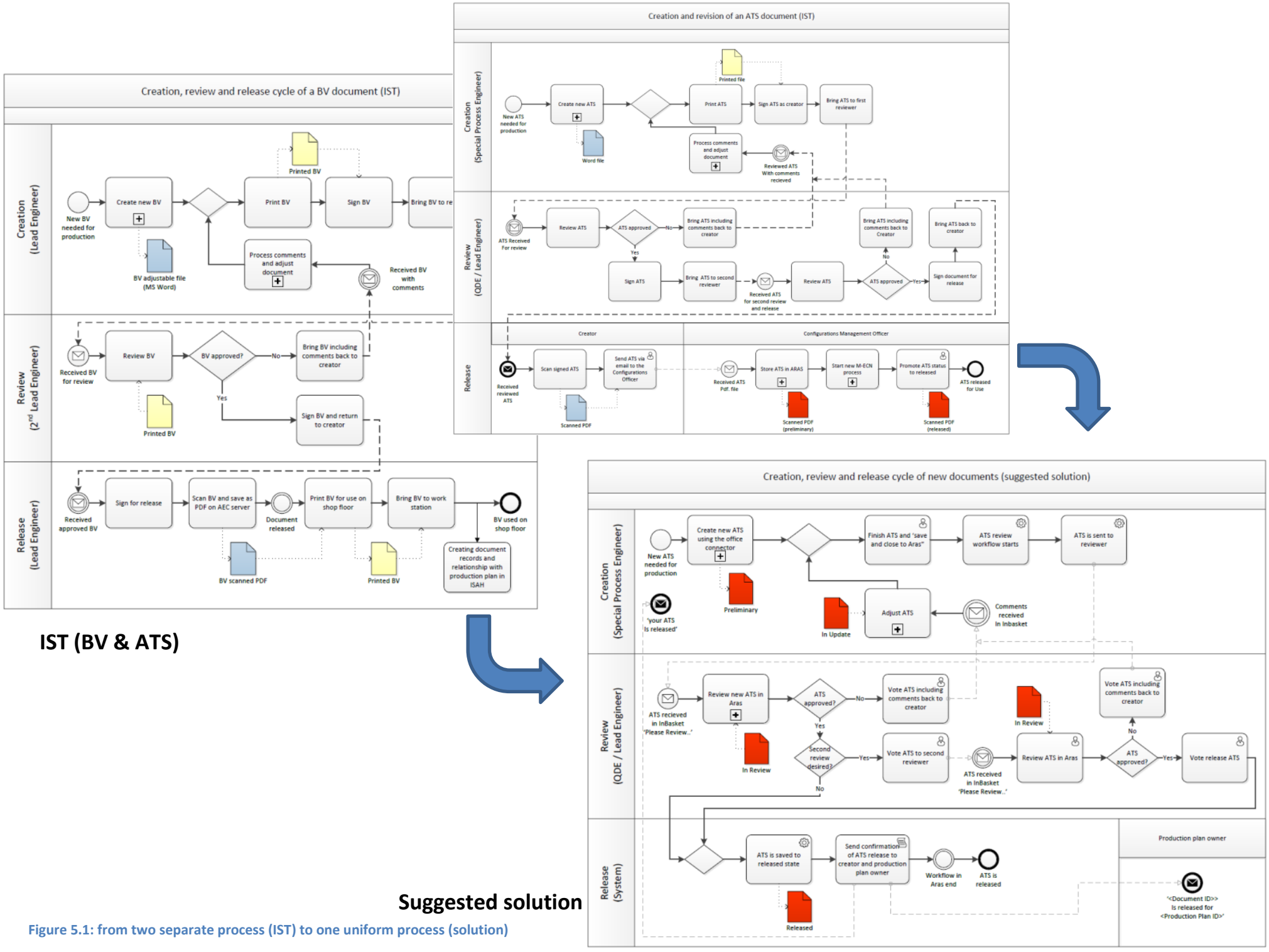
Table 4.2: Norm vs. Solution

Norm	Solution
No more use of paper copies to review documents *- Digital autographs or alternative digital solutions for prove of approval.* *- Digital distribution of documents for review* *- At all time know the status of a document* *- Document revision numbers change automatically* *- Active link to related database records*	Digital workflow in Aras arranged to create a digital review loop. *- Authorized engineers review the document and vote to next stage. Digital autographs or passwords can be used for authentication* *- Documents are assigned to a workflow and workflow tasks are presented to users in the InBasket in Aras* *- Documents have a clear assigned status that change automatically related to the stages of the workflow the document is in.* *- The change process of released documents supports automatic revision numbering* *- The Office Connector supports communication from Aras to Office and the other way around. We cannot add links to related items on the document itself, but we created a table in Aras that shows all items that are linked with the document.*
Work instructions directly generated in ARAS *- Automatically document number generating in ARAS* *- Templates in ARAS for different document types* *- Creator creates, freezes and saves document in ARAS directly* *- Documents are all stored and managed within ARAS*	The Office Connector supports the creation of new Aras documents *- Document numbers are automatically generated depending on the selected type and subtype of the document* *- Pre-determined templates can be presented by the Office Connector and defined as required for each document type* *- By using the 'Save and Close' command Aras automatically creates a read only PDF file* *- Documents are created, reviewed and changed within the Aras environment.*

Table 4.2 shows that the solution meets all requirements set in the norm. The combined solution of the three tools realizes a paperless document management process, fully managed in Aras. We did not only improve the creation review and release process of a new document, but changes can be implemented following the same process. The proper use of document states and the automatic workflow improved the visualization and traceability of the progress.

As part of the evaluation I presented my work to the manufacturing engineering department during a team meeting to find out what their first reaction to my concept was. The Lead and Manufacturing Engineers reacted positively to my suggestions, especially to the elimination of paper files and the improvement of the control and visualization of WIP, but they had some questions about the user friendliness of the system. I evaluated the proof of concept with the Aras Development team within Aeronamic and some of my suggestions are implemented. I found out that most Lead and manufacturing Engineers already must work with Aras guided by the tasks they get in their InBasket, so I anticipate that the new way of working I suggest in this thesis will not be that hard to adopt by the Lead and Manufacturing Engineers. All the necessary tools and support software for the suggested situation are implemented in the live environment of Aras. The transition to start working with it and arranging the old data within Aras to fit the new process is one off the next steps in realizing the change.

We found the solutions for improvement of the document management process by conducting an IST vs Soll analysis. Figure 5.1 schematically shows how we created one uniform process for every document type from two separate process for the ATS and BV document types. Although we showed that the generated solution meets all the requirements of the norm, we can still improve the process to meet the optimal situation. In section 6.4 we explain the limitations of the research and advise future work.



IST (BV & ATS)

Suggested solution

Figure 5.1: from two separate process (IST) to one uniform process (solution)

6. Conclusion

In this thesis we evaluated the document management process at Aeronamic and investigated possible solutions to improve the method to create, review and release work instruction documents managed digitally in the PLM system. With this research we tried to find the answer to the main research question:

'How can we improve the document management process at Aeronamic?'

To find the answers to this main question we first tried to find the answers to the sub-questions of section 1.8.

6.1 Evaluation of research questions

1. *How is the current document management process at Aeronamic arranged?*

By conducting interviews with different people of the manufacturing engineering department, we learned that physical files are used within the process that are a cause for most of the problems in the current process. Documents are created manually by Lead Engineers and reviewed and signed with pen on paper. The process is not uniform for every document type. ATS documents are released by the Configurations Management Officer in Aras PLM while BV's are stored on the local server or even printed for use and stored in a drawer cabinet.

2. *How can we clearly model the current situation?*

Literature research taught us the business process modeling languages BPMN. BPMN and the theory about workflow management of Aguilar-Savén R. S. (2003) taught us how to model the workflows of the document management process at Aeronamic.

3. *What elements are causing inefficiencies in the process?*

To find out what causes the inefficiencies in the process we created a business process model of the current document management process at Aeronamic as shown in chapter 3. We compared this model with a model we made that represents the desired situation.

The use of physical files and the lack of connection to a document management system, makes the process difficult to control, monitor and error sensitive. Most of the activities are done manually and therefore rely on the capabilities of the creator and reviewer. Human mistakes are common, and we should try to eliminate the possibilities to have human influence as much as possible. The focus of the research therefore should be to improve the quality of the process by using software to support the process and limit the human influence.

4. *What solutions exist to improve document management?*

We found out that multiple systems exist that are suitable for document management and can be combined with other manufacturing systems. A likely combination we found in literature that is proven to be effective is the combination between ERP and PLM as explained in section 2.3. This is the combination that is already being used by Aeronamic with Isah (ERP) and Aras (PLM). Next to the systems that are mentioned in literature we got introduced with a custom in house developed system at Machine factory Ara. This system was developed for the use of the documents on the shop floor, while we focused on the entire management process, including the creation, review and change management

5. ***How can we design a possible solution to realize the desired solution?***

For the possible solution we found that Aras as, the PLM system used by Aeronamic, could be arranged as a document management system that reaches all our goals, as explained in chapter 4. To realize this, we had to improve the structure within Aras and implement tools that are provided by Aras. These tools are, the use of automated workflows, the visual collaboration tab and the Office connector. For the distribution of documents on the shop floor we need to do some extra research after the use of ESL. The use of ESL could potentially eliminate all paper in the production process of Aeronamic which is explained in the last section of chapter 4.

6.2 Contribution to Aeronamic

In chapter 5 of this thesis we showed, by comparing the models of the current and new situation (IST and SOLL), that we can significantly improve the document management configuration, using Aras as the leading system. Documents can be created, reviewed, released and revised digitally following one uniform process for each document type. The digital process improves the traceability of documents, the visibility of the progress and the registration of performed activities. All historic data about the changes made and by whom are registered by the system and very easy to retrieve. All documents are managed fully digitally in Aras. This is the realization of a full paperless work preparation process.

The digital managing of documents in Aras and the reduce of paper and manual tasks in the process, will result in better quality of the documents and less loss of time, caused by mistakes that need to be corrected, or uncertainties about the correctness of the paper documents that need to be clarified.

Finally, we showed that with the suggested solution, documents are managed within the right configuration and by the right people that should manage this configuration. The CMO is not needed to manage the storage of documents within Aras as shown in chapter 4. The proper use of Aras functionalities supports a controllable and structured method to create, review, release and change documents, with the management of these documents in Aras as an integrated part of this process.

We can conclude with confidence that the suggested solutions are a good improvement for the digital document management process. The solution relies on Aras as the leading IT system for the document management process which is in accordance with the IT strategy of Aeronamic explained in section 3.2.1.

6.3 Contribution to science

The focus of this assignment was to find a practical solution to improve a certain process at Aeronamic but that does not mean we did not contribute to science at all. Aeronamic is our test environment we used to see if PLM is suitable for document management in a production environment. This thesis is another example of a successful use of PLM to manage product workflows and information. We also showed that the use of PLM can contribute to realizing a paperless manufacturing preparation process. In this thesis we showed the structure of the way documents are managed in a PLM system, including the relations to other elements like the process plans and parts. This paper can be used as an example of how documents can be managed paperless within a PLM system and how the relations with other elements can be structured.

Paperless manufacturing is a relatively new concept with little academic papers written so far. Most papers are about heuristic approaches and examples how to realize paperless manufacturing. We showed a new concept to make a production process paperless, by using PLM to manage the documents paperless and using the concept of Electronic Shelve Labels to provide the needed information on the

shop floor. We did not find papers that present systematic methods to realize a paperless factory. This thesis does not provide a methodology to create a paperless manufacturing environment but provides a new concept how to realize the paperless process using existing systems of other markets. The use of ESL is an example how to realize a paperless production process for companies with a flow-line shop floor layout like Aeronamic.

6.4 Limitations and future work

The biggest limitation for this research was the time limit of 10 weeks. This time limit resulted in a couple of research limitations.

6.4.1 Workflows not modelled using a digital modeler

The workflows are not digitally supported to measure the throughput time of the process. We used the workflows to compare the current and desired situation to show how the documents are managed and quickly give an insight in what different forms and database the documents are stored. In the current situation data of the process was not logged and the documents were difficult to trace. In the desired situation all changes and progress is logged automatically. This makes it a lot easier to investigate the efficiency of the progress and therefore offers a good base for future research after the throughput time of the process. The research is also mostly based on empirical data gathered by interviews with the people who participate actively in the process. The new way of working can provide us with actual measurable data.

6.4.2 Limited to PLM system Aras

For the digitalization and improvement of the document management process and workflow we limited our research to the use of the PLM system Aras. We did not compare Aras wit BPMN systems or other IT systems that are possibly suitable for document management. The research is subject of Aeronamic that desired the use of Aras for document management, since they chose to work with this system a few years ago.

6.4.3 Limited to two document types

In this research we compared two of the document types to get insight in the inefficiencies of the document management process. In future work Aeronamic must investigate whether the suggested management process is suitable for the other document types as well.

6.4.4 Improving the templates

The focus of this research was to improve the way documents are, created and stored before use. Although we mentioned the use of templates and the way the documents are distributed on the shop floor, we did not look at the format of the files. The improvement of the template to fit the new process is the first step to be done in the future looking at the file format. Next to that Aeronamic could consider changing the format of the information carrier more drastically and investigate the use of a step by step instruction presentation or even a Virtual Reality work instruction.

6.4.5 Consult with Pricer

For the distribution of the documents on the shop floor, we did a theoretical research to find a paperless system to present the needed information to the operators. The solution we found is a system that is used in the retail business. The limitation is that we did not consult with Pricer if the system can communicate with the ERP and PLM system that are used by Aeronamic. We also must know whether the system will be disturbed by the many machines on the shop floor, since the system works with wireless signals. Consulting with Pricer to discuss the possibilities is one of the future activities to further improve the process. If Pricer is interested, Aeronamic could consider joining Pricer in a cocreation

project, to extend their market and create a system for the production industry in addition to the retail businesses system.

6.4.5 Use phase of the document excluded from document management workflows

Furthermore, the use phase of the document life cycle is not presented in the workflows in this research. The first reason why we did not add the use phase to these workflows is because we started evaluating this process as a separate process later during the research. After considering adding the use phase to the workflow we concluded that the moments in the process where the documents are used do not change. Therefore, the new way of presenting documents does not change the workflow substantially. If we want to model the way documents are presented to the operators, we believe is better to use data-oriented models, instead of the process flow models that we used for the document management process in this thesis. To keep the workflow models as simple as possible we decided not to add the use phase to the model. We used a UML model to show how the data is structured within Aras and visualized the use phase by using pictures and images of every stages in the process.

6.4.6 Cost calculations

The last important limitation of this research is the lack of cost calculations. The research was focused on improving the flow of the process, but this can influence the costs of the process, like the reduction in costs of paper for example. Often the suggested improvements result in lower costs in the process but also ask for an initial investment to realize this cost reduction. Making a cost-benefits analysis of the suggested improvements could be a new research as such, since data of the current process is hard to gather, and the investment needed for the improvements is not a given number. The use of Aras tools does not require an investment since the tools are already part of the software package. The time needed to restructure the system and the investment in the Pricer system are numbers that need to be found by research. Although this thesis does not provide Aeronamic with a clear cost-benefit analysis we are confident that Aeronamic can make a good estimation of the benefit of the suggested solutions with the results of this research.

6.5 Recommendations

After this research and the given conclusions in mind, I would like to do some recommendations towards Aeronamic which actions they need to do first to improve their document management process.

The first thing I would like to recommend to Aeronamic is to arrange the new document management process, using the tools as explained in chapter 4, within Aras and digitalize every document in this structure. It is important that all document properties like document names and ID's are changed to fit the suggested method and the storage location is consistent. The automatic number and file name generation will only work if all historic numbers and names are structured in the same way. This process will take some time but will make the future processes a lot quicker, easier and will prevent confusion about historic data that differs from the current data structure. Arranging the tools as suggested in chapter 4, should be an easy and quick process because Aeronamic already has access to the tools as part of the Aras PLM software package.

Next to implementing the suggestions that improve the digital management of the documents I recommend Aeronamic to have a look at the templates and revise them in a way that less properties and relations need to be filled in manually and unnecessary text fields can be removed.

The pilot at the assembly department showed that presenting files by using barcodes works. One important condition to make it work is the arrangement of process plans in Aras. I recommend Aeronamic to focus on copying all routings to process plans within Aras for two reasons:

- The IT strategy of Aeronamic is to make Aras the leading system for all manufacturing data. Process plans are an important element were a lot of manufacturing data is linked to. This is now managed as routings and production files in Isah but can be transformed to process plans in Aras.
- Arranging the process plans in Aras gives us the base to realize the use of barcodes and eventually the use of ESL not only at assembly bot at every stage on the shop floor, to make the entire production process paperless.

At last, after the paperless work preparation process is realized, the distribution process of documents on the shop floor can be implemented. To make sure the concept of using ESL is possible, I recommend Aeronamic to consult with Pricer about the options to combine their system with Isah. The full system developed by Pricer is almost a full ERP system for retailers. Therefore, we expect the price of the system to be comparable with the investment Aeronamic did to use the Aras or Isah software. Although we are not familiar with the actual figures, we can expect that this investment will be too high for the result. Therefore, it would be great if we could only use the parts of the system that we need complementary to the ERP and PLM system.

References

Aberdeen Group. (2008). *Integrating PLM & ERP: It's not just a one way street*
https://www.plm.automation.siemens.com/zh_cn/Images/5244-RB-integrating-plm-erp_tcm78-67672.pdf

Aeronamic Management systeem. (2018)

Aguilar-Savén R. S. (2003). *Business process modelling*
http://secure.com.sg/courses/ICT353/Session_Collateral/TOP_04_ART_03_ARTICLE_AGUILAR_Biz_Proc_Modelling.pdf

Al-Mashari M., Irani Z., Zairi M. (2001). *Business Process Reengineering: a survey of international experience*
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.456.391&rep=rep1&type=pdf

Aras Innovator © (2018) *User Guide & Administrator Guide*

BiZZdesign © (2008) *BPE-Handboek*

Dumas M., Mendling J., Reijers H. A., Rosa La M. (2013) *Fundamentals of Business Process Management*
https://link.springer.com/content/pdf/10.1007/978-3-642-33143-5.pdf

Hayes J. (2017) *Is PLM the answer to your Product Workflow and Data challenges?*
https://www.engineering.com/PLMERP/ArticleID/15898/Is-PLM-the-Answer-to-Your-Product-Workflow-and-Data-Challenges.aspx

Heerkens H., Van Winden A. (2012). *Geen probleem*

HORA. (2016). *De rol van enterprise-architectuur*
https://hora.surf.nl/index.php/De_rol_van_enterprise-architectuur

Jelle (Value Blue). (2017). *Wat is enterprise architectuur*?
https://www.valueblue.nl/wat-is-enterprise-architectuur/?gclid=Cj0KCQjw0dHdBRDEARIsAHjZYYAcVJIGFs9LU8KTCFKmkPaObOOYyWO1oNESLuKvORHZwMz2KEC52xMaAu-PEALw_wcB

Lucid Software Inc. (2018). UML Class diagram tutorial
https://www.lucidchart.com/pages/uml-class-diagram#top-info

Object Management Group. (2011). *Business Process Model and Notation (BPMN) version 2.0*
https://www.omg.org/spec/BPMN/2.0

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). *A Design Science Research Methodology for Information System Research.*
http://geni15.wrsc.org/sites/default/files/documents/000designscresearchproc_desrist_2006.pdf

Pricer © (2018)
http://www.pricer.com/en/Solutions/Electronic-Shelf-Labels/Electronic-Shelf-Label-System/

Pricer © (2018) *Brochure*
http://www.pricer.com/Global/Pricer%20Digital%20Shelf-Edge%20Solutions%20BREN17-04-1_Web.pdf

Prostacos et al. (2002).

Reijers H. A., Liman Mansar S. (2004). *Best practices in business redesign*
http://is.ieis.tue.nl/education/bpmcourse/papers/Reijers%20(2005)%20- %20Best%20practices.pdf

Sparx Systems. Example BPMN 2.0 Collaboration Diagram. Retreived from:
https://www.sparxsystems.com/enterprise_architect_user_guide/14.0/model_domains/bpmn_2_0_collaboration_toolbox.html

Tsang C. (2017)
https://www.quora.com/How-can-you-make-a-class-diagram-of-an-airline-reservation-system

Van der Aalst M.P., La Rosa M., Santoro F. M. (2016). Business Process Management
https://link.springer.com/article/10.1007%2Fs12599-015-0409-x

Aeronamic employee's:

Blaauwgeers R. (2018) *Director manufacturing Engineer*

Blom L. (2018) *Process Engineer and Developer*

Derking A. J. (2018) *Process Engineer*

Hofsté H. (2018) *Manufacturing Engineer and Developer*

Jansen U. (2018) *Manufacturing Engineer*

Troost P. (2018) *Quality and Development Engineer*

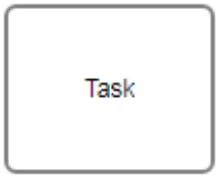
Appendices

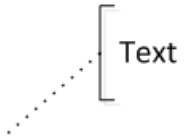
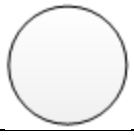
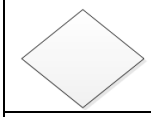
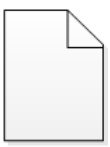
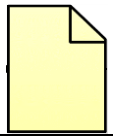
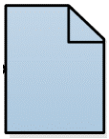
Appendix 1: Document types and authorized creators/reviewers

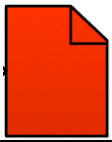
Document type	Prepared	Reviewed	Remarks
CAD Model review (01)	N/A	CAD/CAM	
Parts Risk Assessment (PRA) (01)	LE	N/A	
Framework FAI (Ballooned customer drawing, AS9102 Form1-2-3) (01)	LE	QDE	
PBOM (routing, multipartslist) (02)	LE	QDE	If the routing contains NDT activities, it also needs to be reviewed and signed by the NDT Level 3.
NCT (02)	CAD/CAM	N/A	
NCM (02)	MT	LE	
ATS, API (02)	SPS	LE, QDE	For other special process documents see AQPR-4.80.
OS (02)	CAD/CAM	MT, LE	
BV (02)	LE	2nd LE	
ML (02)	LE, MT	2nd LE	
DIP (02)	LE	QDE	
FAI Package (03)	LE	QDE	
Mfg Data analysis (yield, NCR's, Cpk) (04)	LE	N/A	
PID	CAD/CAM, LE	N/A	
TS*	This is Legacy data		*TS documents have been replaced by ATS

LE Lead Engineer
MT Metrology Technician
QDE Quality Development Engineer
SPS Special Process Specialist

Appendix 2: Overview of BPMN symbols and notations

Group	Symbol	Name	Explanation
Participants		Pool	A pool assumes process control over the process steps taken in the pool's lanes (next symbol). So the pool assigns the tasks to the responsible ones for the lanes.
		Lane	Lanes can be used to assign responsible actors (for example persons, roles or departments) to tasks when multiple actors are involved in a business process. Lanes are only useful when there is some sort of interaction and interrelation between the tasks of the different actors.
Activities		Task	A task is a single activity within the workflow that needs to be performed by an actor. This symbol is just for undefined taks types. Task can be performed by different actors and with different frequencies. Using additional symbols helps to easily show the task type.
		Manual Task	A manual task is executed by a human being without the support of technology and that does not affect the process engine
		Service Task	Service tasks are done by software systems. These are program functions applied automatically when a process is executed.
		User Task	User tasks are executed by a human being but are, in contrast to the manual task, assigned by the process engine, which may place these task in the users task list. The humans task is supported and controlled by the process engine. The process engine expected confirmation of the human finishing its task by including data input or a button click.
		Script task	Script tasks are task executed directly executed in the process engine defined by a written script. This script needs to be written in a language that the process engine can interpret
		Subprocess	A sub process is a collapsed sequence that shows that there is a detailed sequence hidden behind it. The subprocess describes the detailed sequence but does not take more space than a regular task in the parent process. Using subprocesses in a business process model is often usefull to keep the parent process small and understandable. We can only use subprocesses if the use of this activity does not limit the understanding of the parent process. the task in the hidden sequence may therefore only influence the sub process and no other activity of the parent process.

Artifacts		Text Annotation	Annotations can be used to provide extra information about elements of our diagrams. The annotations can contain almost any information you find useful.
Events		Start event	The start event symbol shows the trigger that starts the business process. Events are not actions by itself but are results of triggers or are triggers that start an activity.
		End event	End event shows the end of the process triggered by the completion of a final task or activity
		Intermediate event	Intermediate events occur during the business process.
		Start message	The start message event shows that the message is the trigger to start a task or sequence of tasks.
		Intermediate message	The intermediate message event occurs during the business process.
		End message	The end message event occurs when the completion of the final activity triggers the message event to happen.
Gateways		Exclusive gateway	Exclusive gateways symbol shows that the process can follow different paths. Exclusive gateways tell us that only one of the paths can be followed. The followed path depends on the answer to the question that is asked at the gateway.
		Parallel gateway	The parallel gateway splits up the process in two or more sequences that can be executed independent from each other. Parallel work can save time in the total process. The rest of the process continues after all parallel sequences are fulfilled.
Data		Data object	A data object represents information flowing through the process, such as documents, e-mails or letters.
		Paper file	The yellow data object represents paper documents
		Digital file	The blue data objects represent files that are created and saved digitally but not managed in the Aras database.

		Aras managed file	Red data objects are fully managed in Aras.
Connecting objects		Sequence flow	The sequence flow shows the direction of the workflow. The sequence flow appoints the next activity in the flow
		Physical distribution flow	This flow line indicates that someone or something has te be physically moved to start the next activity
		Message flow	The message flow indicator indicates that a message is sent from one actor to another
		Association	The association line shows the relation between information and flow objects. The association can have direction indicators one way and both ways.
Database		Database (Aras)	The database symbol indicates that a digital file is stored in a database. In this report a red database symbol represents the Aras database
		Database (Aeronamic local)	The blue database symbols represents a local server or other digital database location used at Aeronamic which is not linked to Aras

Appendix 3: All workflow models including collapsed views of subprocesses

Appendix 3.2 Workflow models IST of BV

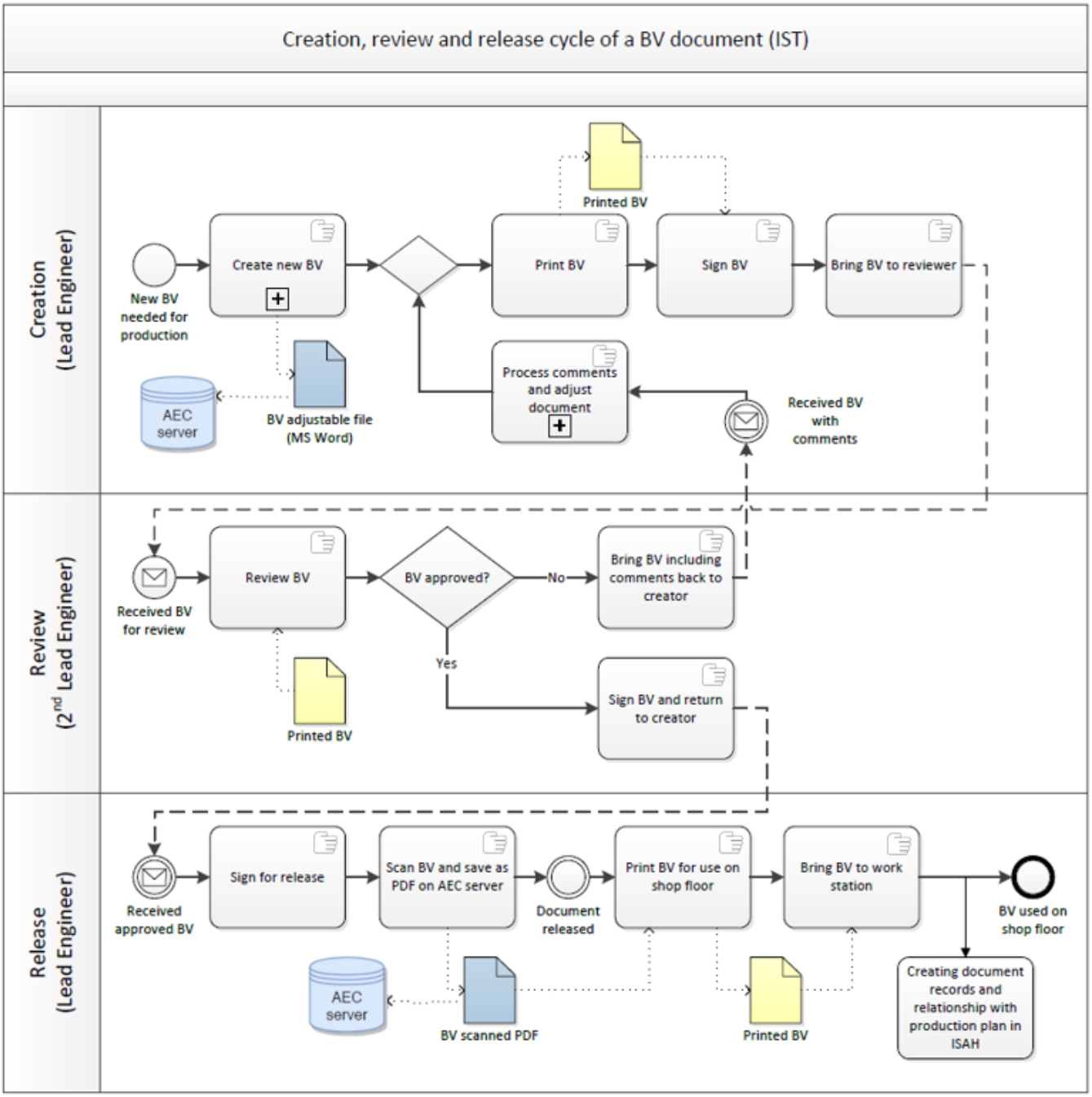


Figure 2.2: Workflow BV (IST)

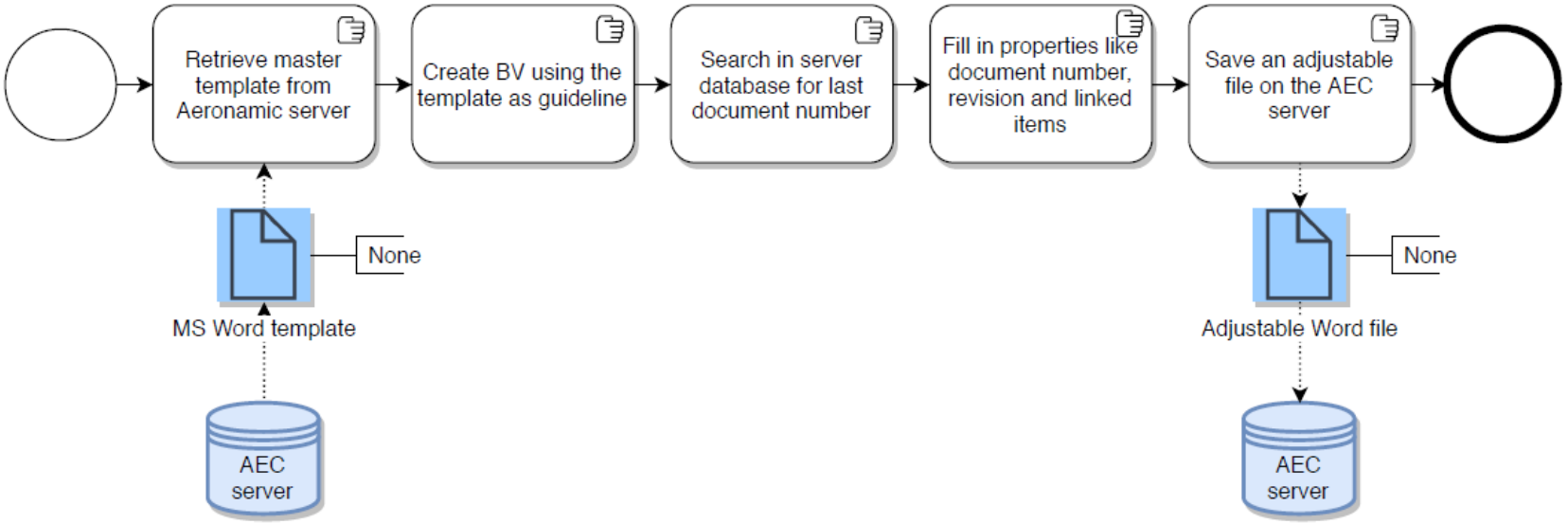


Figure 3.18: Collapsed view of *Create new BV* sub-process (IST)

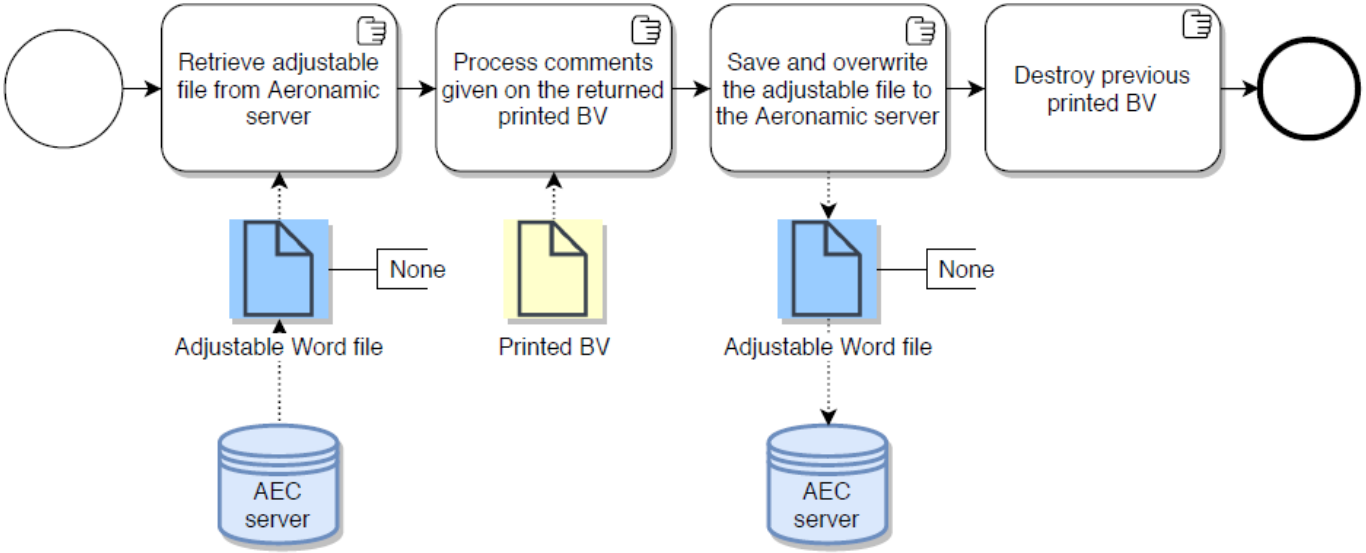
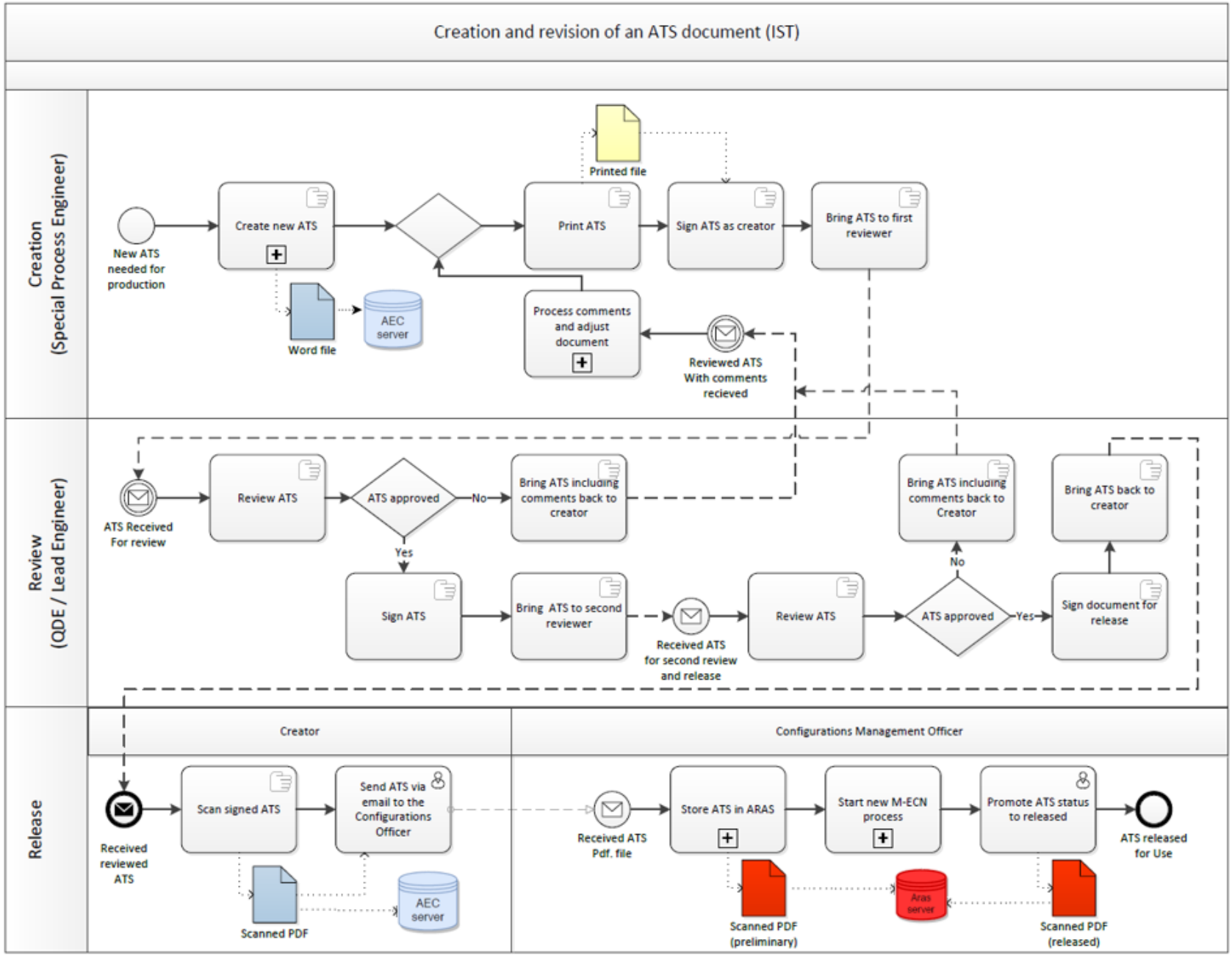


Figure 3.19: Collapsed view of *Process comments and adjust BV* sub-process (IST)

Appendix 3.3 Workflow models IST of ATS



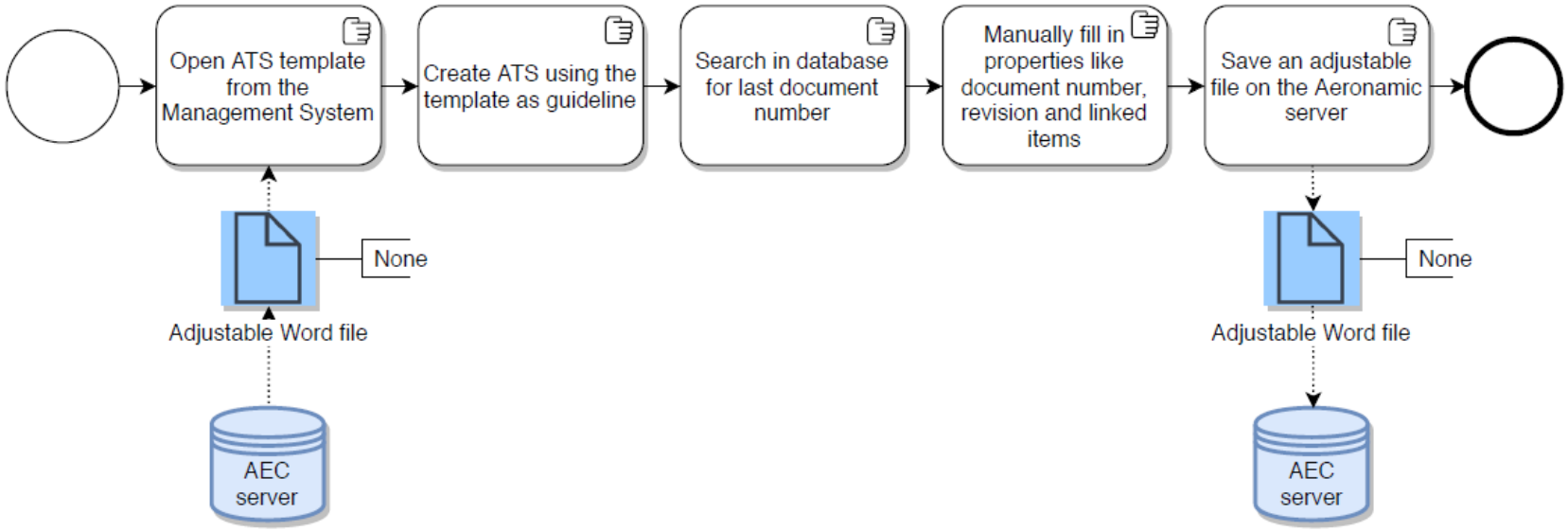


Figure 3.20: Collapsed view of *Create new ATS* sub-process (IST)

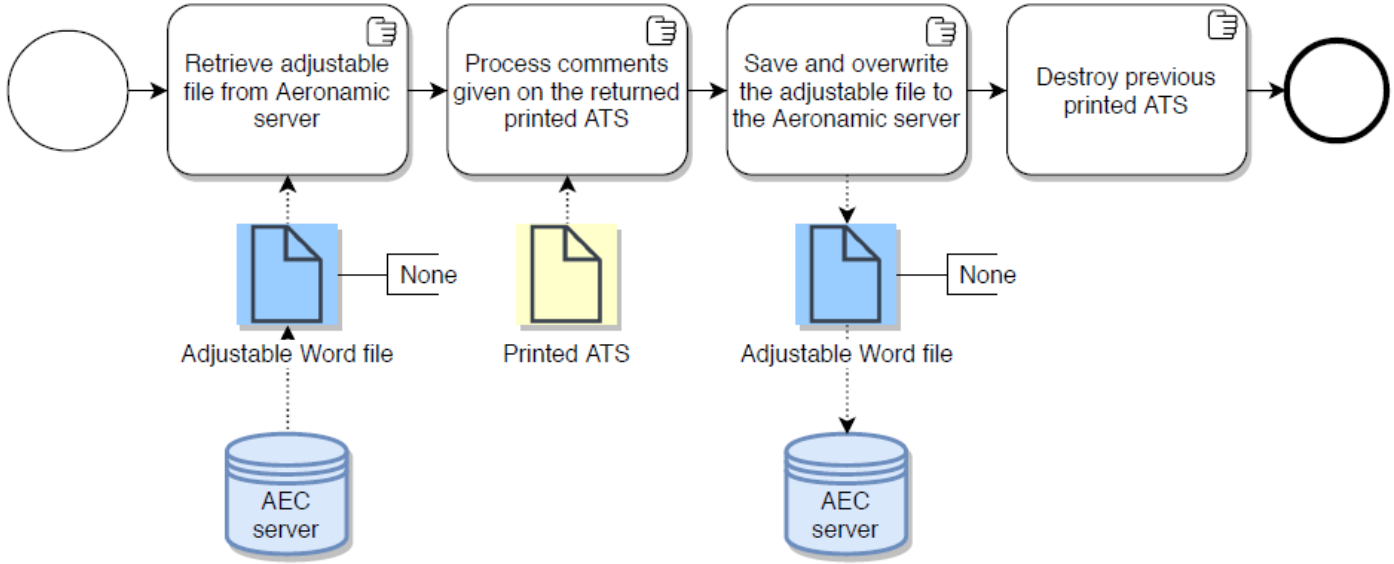


Figure 3.21: Collapsed view of *Process comments and adjust ATS* sub-process (IST)

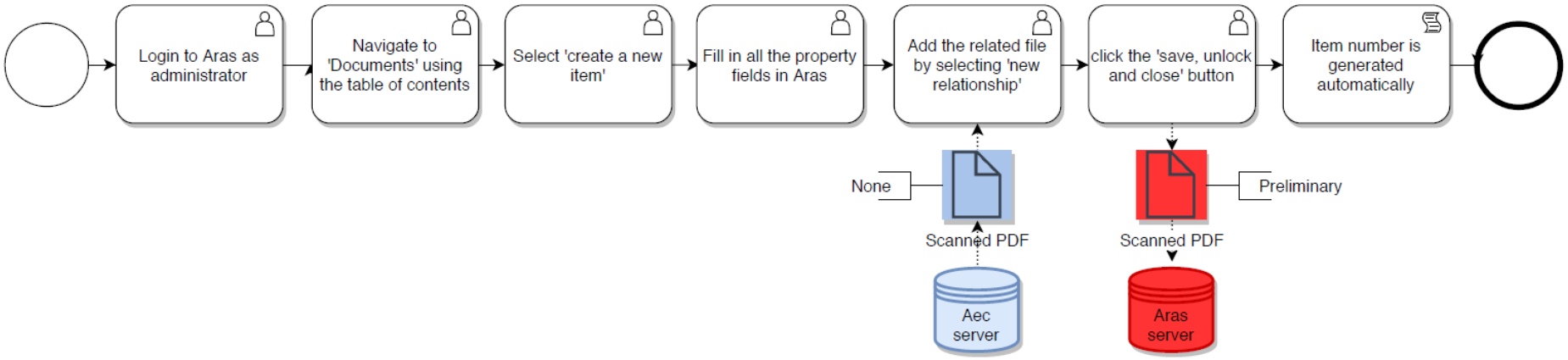


Figure 3.4: Collapsed view of *Store new ATS* in Aras sub-process (IST)

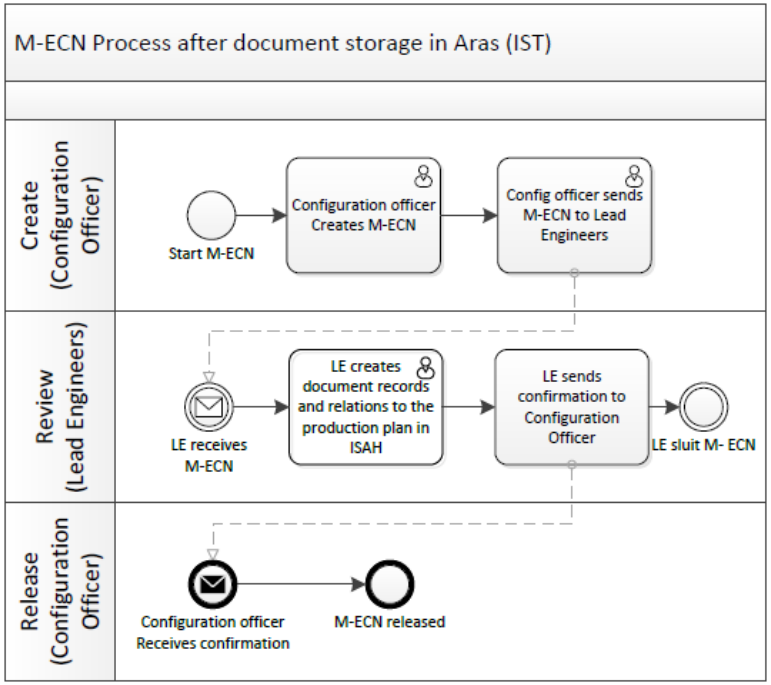


Figure 3.6: M-ECN flow for the release of an ATS in ARAS (IST)

Appendix 3.4 Workflow models of suggested solution

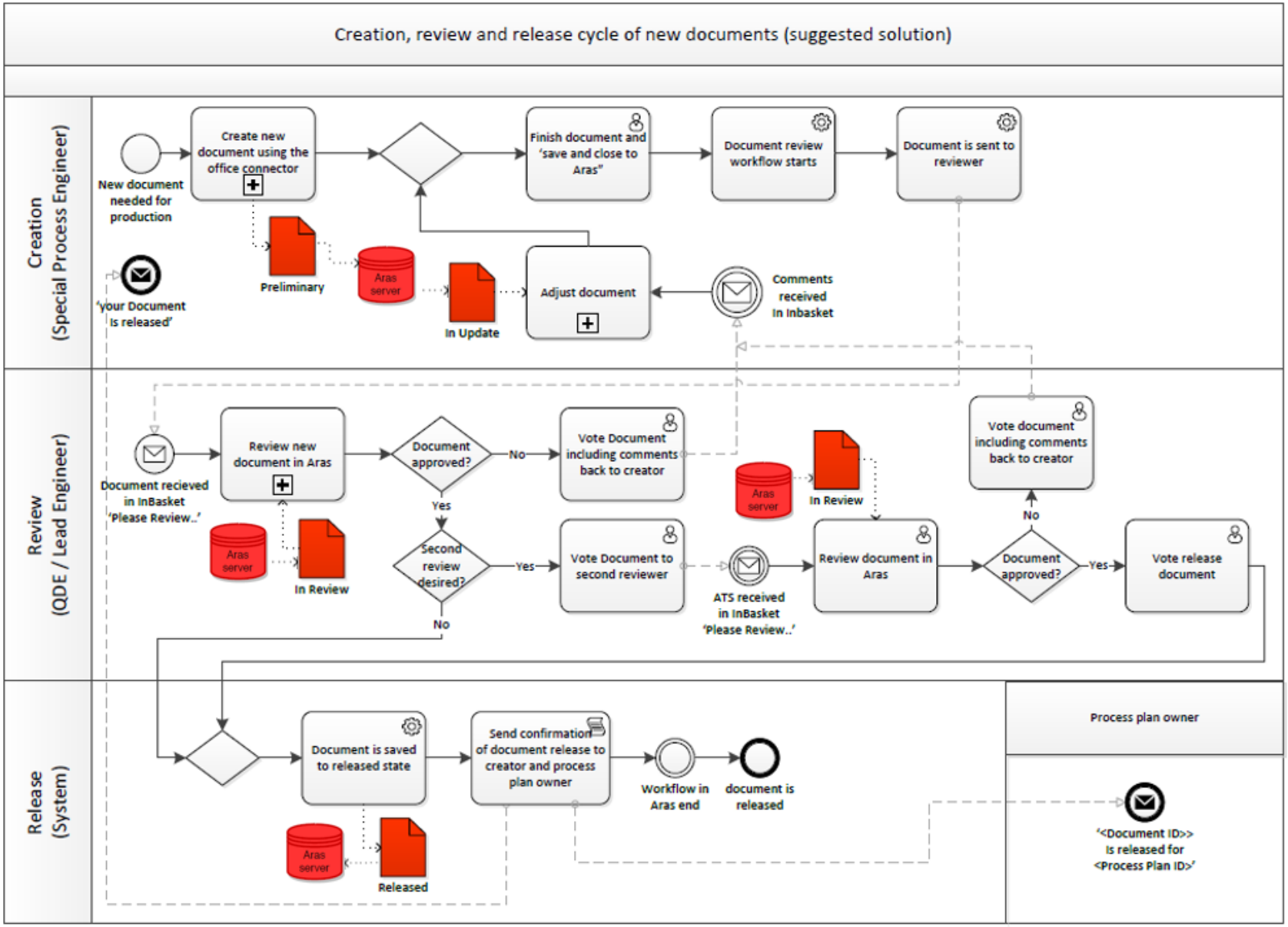


Figure 4.27: Workflow of the digital document management process using the Office Connector and Aras functionalities.

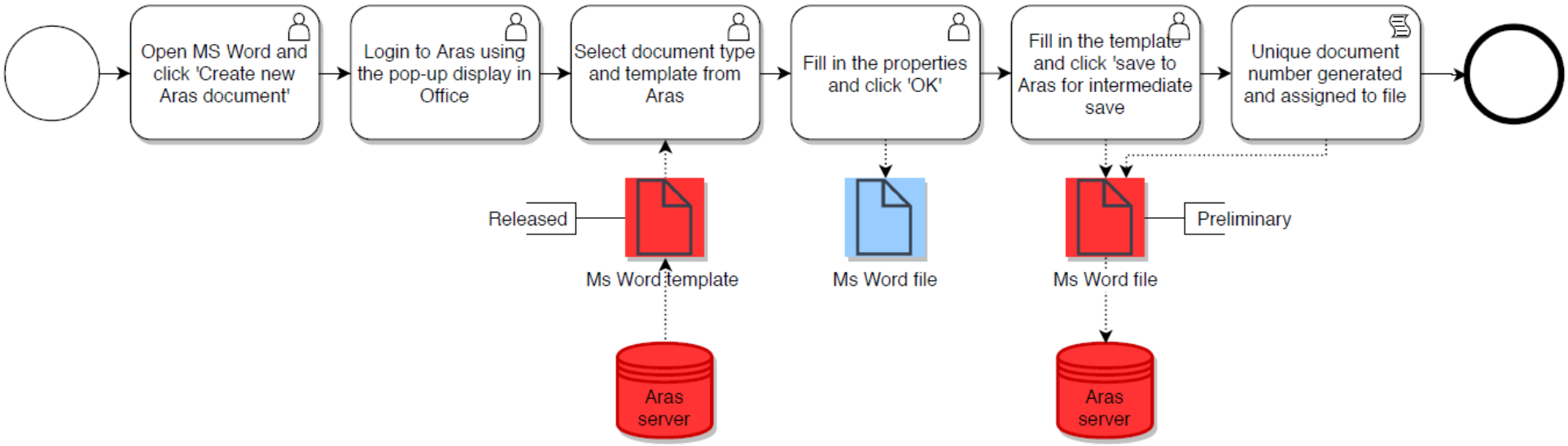


Figure 4.28: Collapsed view of Create new document sub-process (Solution)

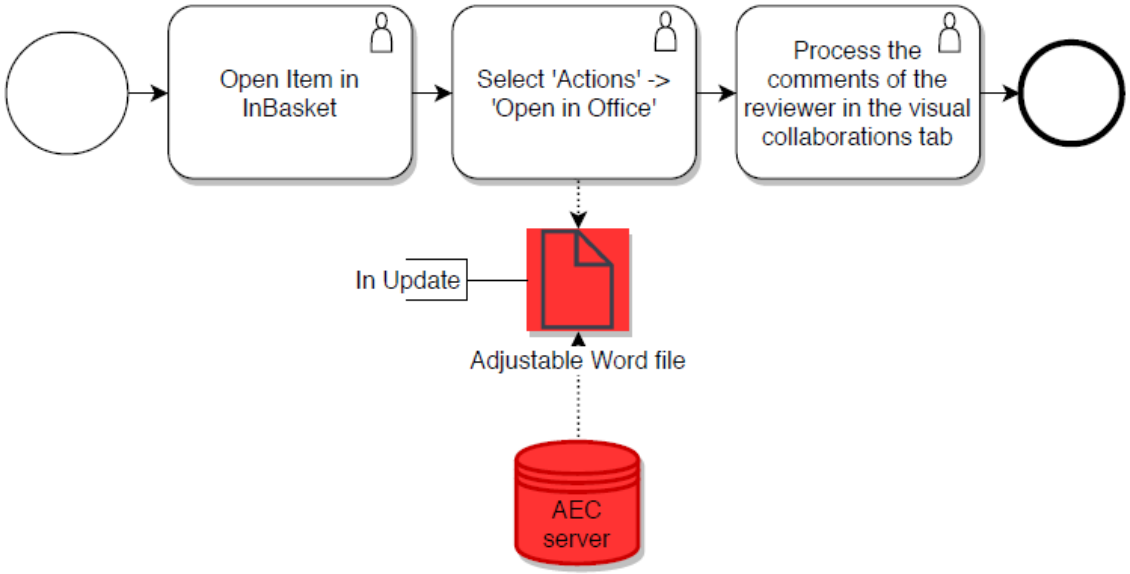


Figure 3.22: Collapsed view of *Adjust* sub-process (solution)

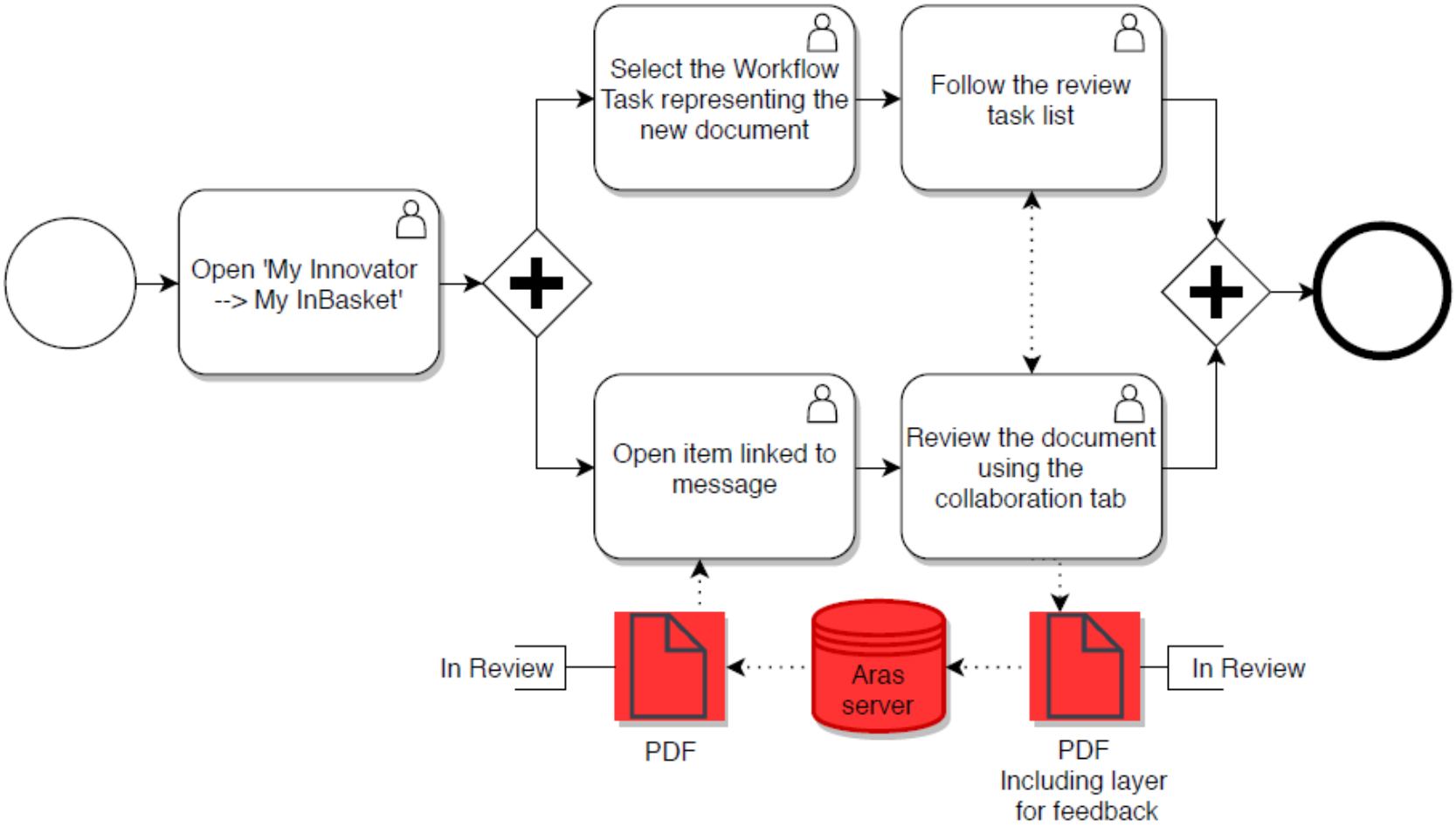


Figure 4.29: Collapsed view of *Review document* sub-process (Solution)

Appendix 4: explanation proof of concept Aras tools

Appendix 4.1: Aras Office Connector

The use of the Aras Office Connector

When the Aras Office is installed, it adds an Aras ribbon within the Office applications Word, Excel, Outlook and PowerPoint. This ribbon is our tool to communicate with Aras. Figure 4.1 shows the Aras ribbon in Microsoft Office Word.

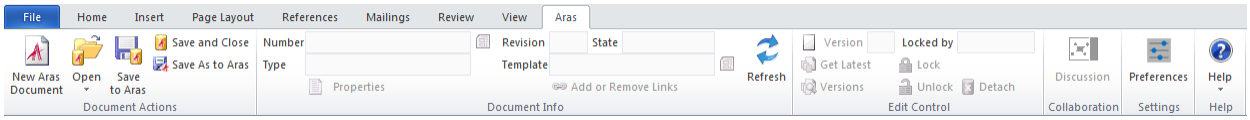


Figure 4.1: Aras ribbon in Office application

To create a new document the user must click the “New Aras document” command tab on the far left of the ribbon. To use the Aras Office Connector, you first have to login to Aras with a personal username and password. With this login Aras can identify the user identity. The administrator has given every user certain authority within Aras. After the user logs in, Aras knows the identity of the user and can control his or her authority to perform actions like creating a new document in Aras. After starting an Office application and selecting a command from the Aras ribbon, a pop-up dialog will appear that asks you to log in before you can execute any action. Figure 4.2 shows the log in dialog.

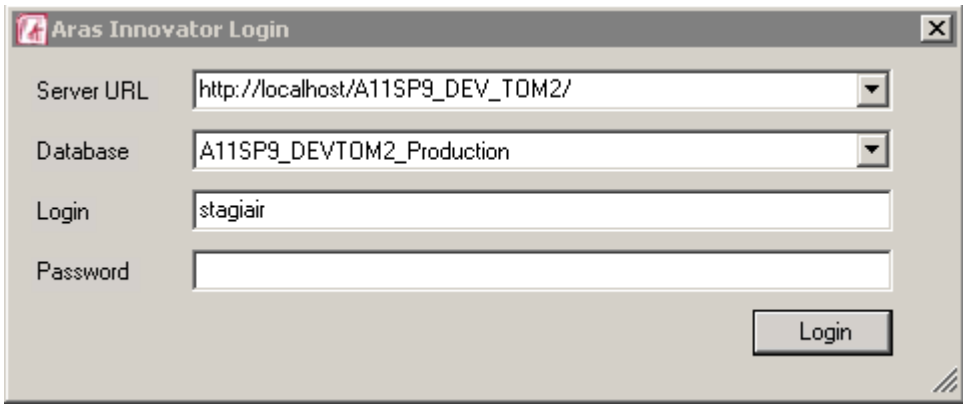


Figure 4.2: Login dialog Aras Office Connector

Aras is a web-based system that runs on a server. In the top dropdown selection list, you can choose the URL of the instance on the server you want to login in to. An Aras instance can communicate with different databases. In the second dropdown selection list you can select the database you want to work with. When selected the URL and database you can login with username and password.

After login we can start working in Office using the Aras Office Connector. Figure 4.3 shows the dialog that pops up after selecting the ‘New Aras document’ command tab.

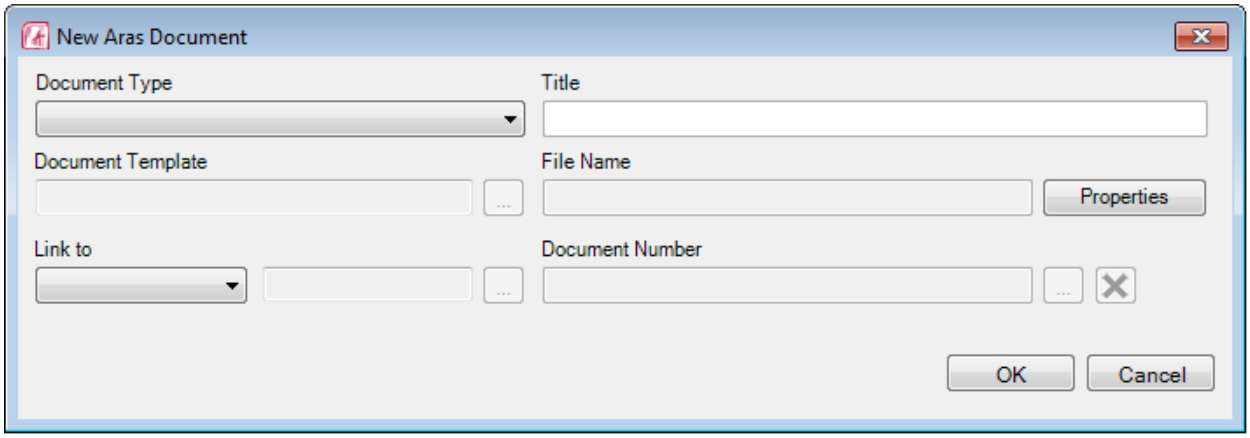


Figure 4.3: New Aras Document pop-up dialog

The dialog shows multiple properties for the document that the user must fill in. The layout of the dialog is non-adjustable but the rules for setting properties can be determined by Aras administrators. The direction of communication between Aras and Office can work in two directions, from Aras to Office or from Office to Aras. The document type property for example is a property with the direction from Aras to Office. In Aras the types of documents Aeronamic uses are determined. Figure 4.4 shows the table of document types set in Aras that can be selected by the user to be created.

Label	Item Type [...]	Classification
Document / API	Document	API
Document / APS	Document	APS
Document / AWI	Document	AWI
Document / ADS	Document	ADS
Document / ATI	Document	ATI
Document / ATS	Document	ATS

Figure 4.4: Document types that can be created in Office defined in Aras

The user selects one of the types he wants to create. It is possible to set different rules and restrictions for every document type in Aras. For some documents a template can be required for others not. Figure 4.5 shows the page in Aras where the administrator can set the rules and properties for each document type that can be created using the Office Connector. The figure shows the page with the settings for the ATS document type.

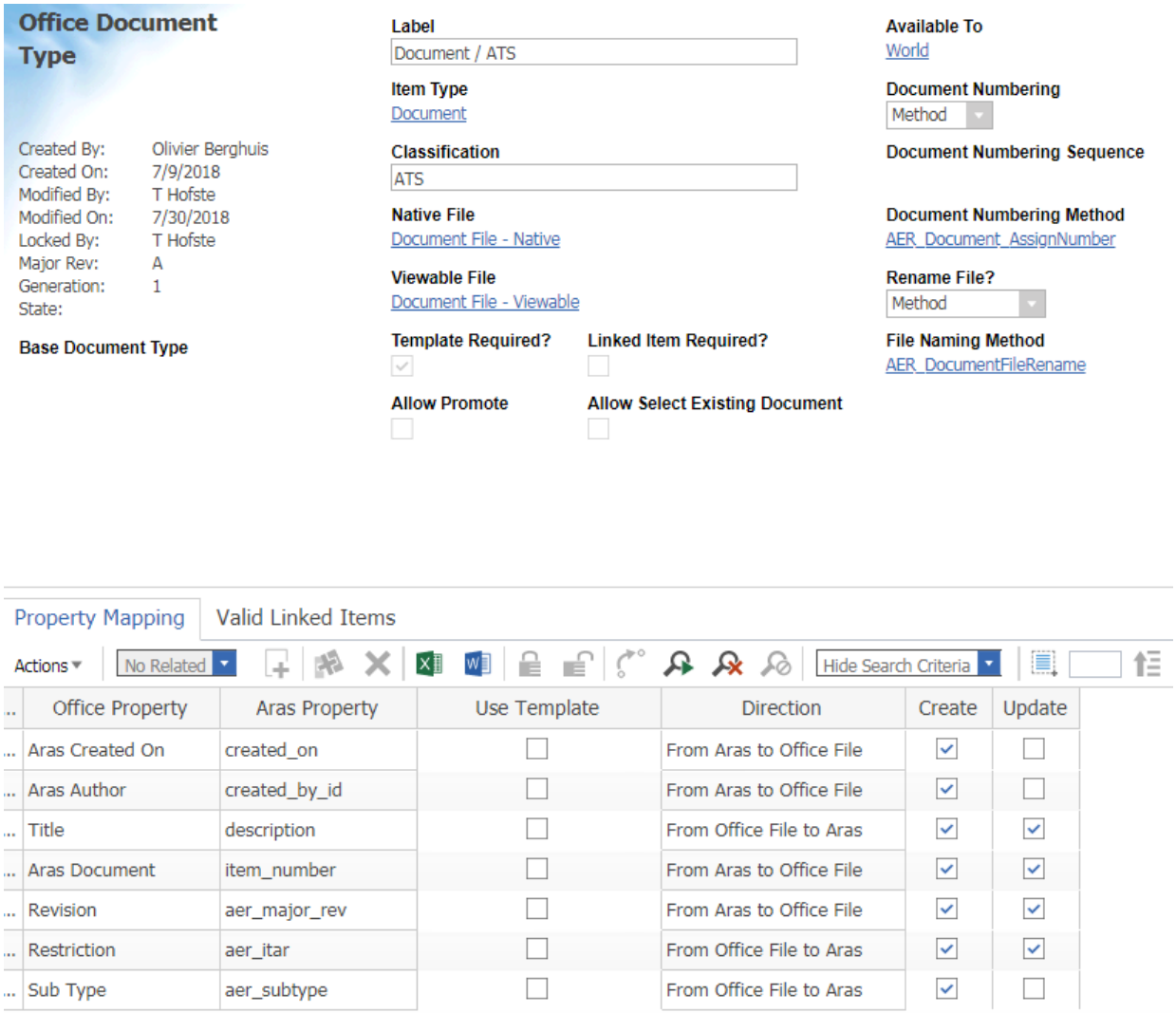


Figure 4.5: Office connector settings ATS document Type

The properties and identities set by the administrator influence the behavior of the dialog that is shown in figure 4.3.

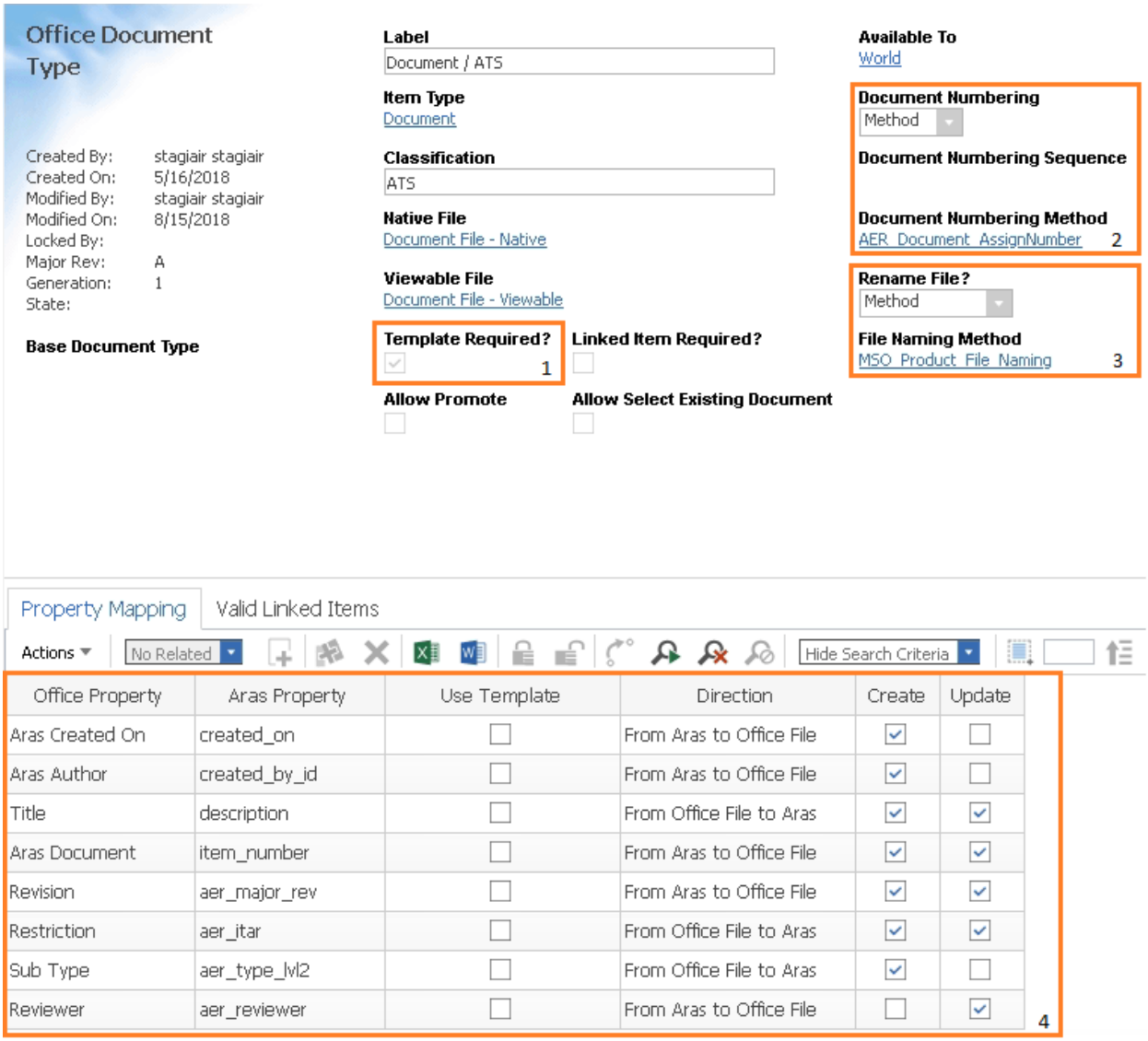


Figure 4.6: Highlighted settings for Office Connector

The four highlighted settings in figure 4.6 play an important role in improving the document creation and storage process using the Office Connector. I will explain the effect of these settings shortly and how they influence the behavior of the connector dialog.

1. **Template requirement**

The template required checkbox determines if a template is required for the creation of a new document. If the box is checked, a template needs to be selected before starting the creation of the document. The templates that can be selected are saved in Aras as template and must be released for use. We can link a different template for each document type. If a template is required but the user tries to continue without selecting a template an error occurs that prevents the user to continue. Using the template required option helps to assure that every document of a certain type has the same format. Figure 4.7 shows the search dialog for released templates and figure 4.8 shows the error when no template is selected when required.

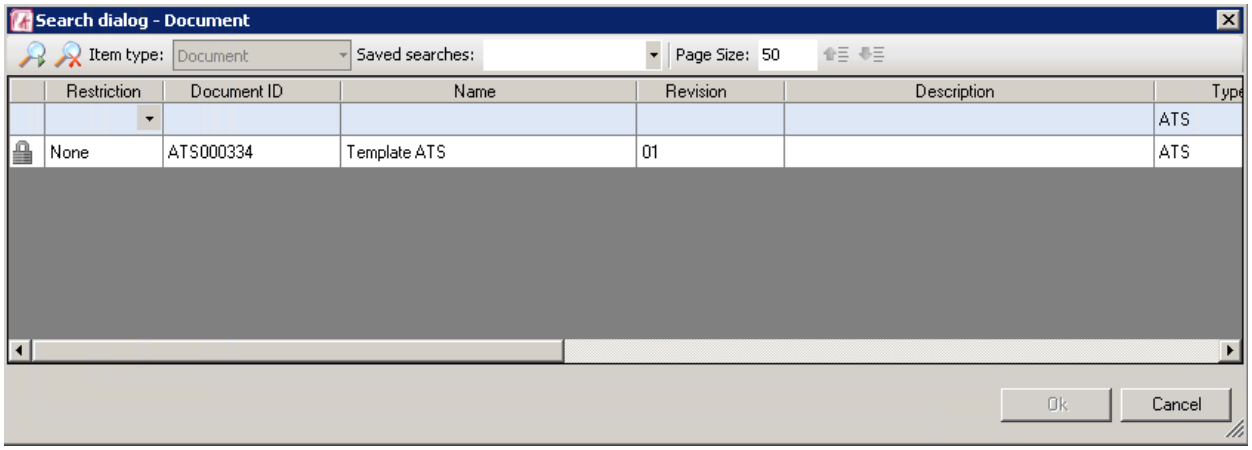


Figure 4.7: Search dialog for templates

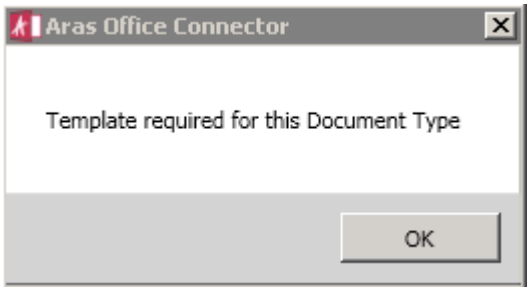


Figure 4.8: Error pop-up when no required template is selected

2. Document numbering

Using Aras gives us the possibility to generate document numbers automatically instead of manually filling in the document number with a big risk of type errors. Aras provides two options of generating document numbers, the document numbering sequence and the document numbering method. When using the sequence, we can define a prefix of the sequence like 'ATS' and the system will add a number that ads up with a step value that we can define ourselves as well. A sequence for example can be ATS1, ATS2, ATS3, ….. ,ATS135 etc. or ATS10, ATS20, ATS30, ….. ,ATS250 etc. A method gives us the freedom to program or own document numbering system. Aras understands the programming languages CSharp, VB and JavaScript. For the management of the work instruction document we created a numbering method that uses the file type classification to create a unique number. The document numbers are structured as follows: DocType – Classification – Three-digit number, for example ATS-CP-003. This method assures a uniform structure for all document numbers and eliminates the chance of mistake with the manual creation of document numbers.

3. File Naming Method

The File Naming Method is just like the Document Numbering Method a written script in VB, JavaScript or CSharp that automatically creates the file name after saving. An example of a structure for the file name can be: document type – title – revision number. Figure 4.9 shows how the dialog window for creating a new document looks like when methods or a sequence are selected for the Document Number and File Name. The system does not permit the user to manually create the document number and filename. We implemented the use of the file Naming Method for the same reasons as the use of the document numbering method, eliminating the chance of mistakes and a uniform file name structure.

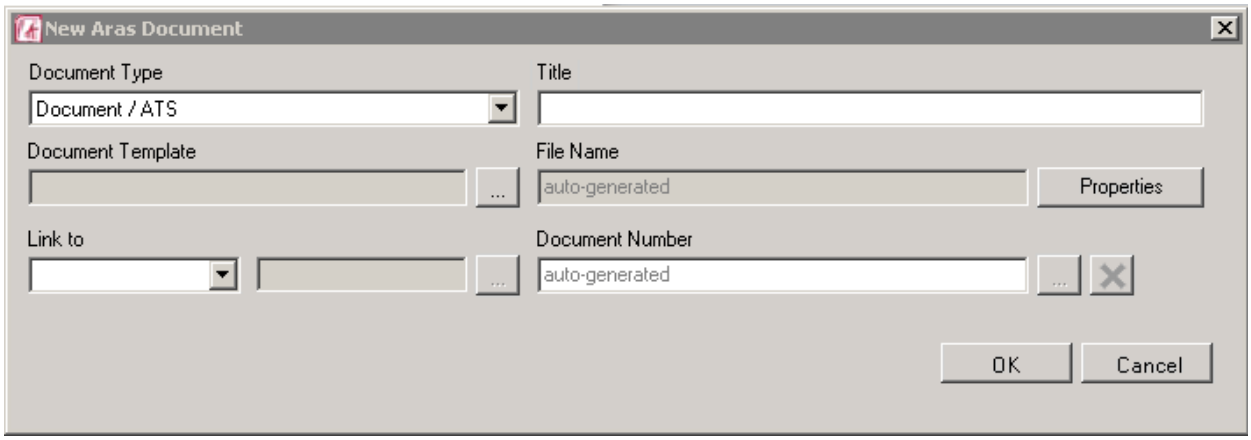


Figure 4.9: Dialog window when methods are selected for Document numbering and File naming

4. Property Mapping

Both Aras and Office have the concept of properties. Properties are textual information that describes a document. In Aras properties are used for every item type including document. The Office Connector provides the capability to map properties between the Office file and Aras, in both directions and at different points in the process. The properties can be saved on the initial save of the document or on the subsequent update saves. The administrator can decide when properties are mapped and the direction.

The author property for example is mapped from Aras to Office on the initial save. This makes sense since Aras identified the Author of the document after log in and only with the first save we are sure that this is done by the author. Subsequent saves can be done by creators. Properties that are mapped from Office to Aras are properties that are selected by the creator or adjusted during an update in Office. The administrator can add or remove properties from the list. Most of the properties return in the tabular overview of a document in Aras as shown in figure 3.5.

The Aras ribbon shows a section 'Document Info' with a small overview of the Aras properties of the document. After filling in all the required properties in the pop-up dialog of figure 4.3 and clicking OK we can start with the creation of the document. Although we already filled in the properties the section Document Info in the Aras ribbon remains empty.

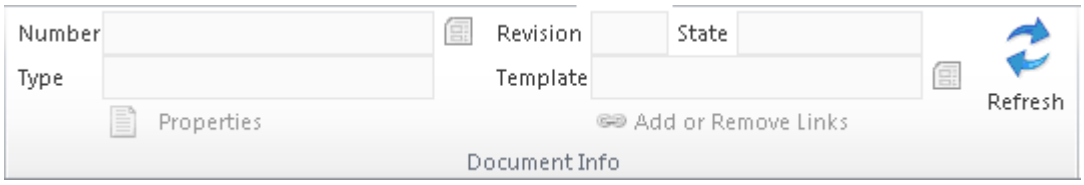


Figure 4.10: Document info while creating the document

After saving the document to Aras the Ribbon will fill itself.

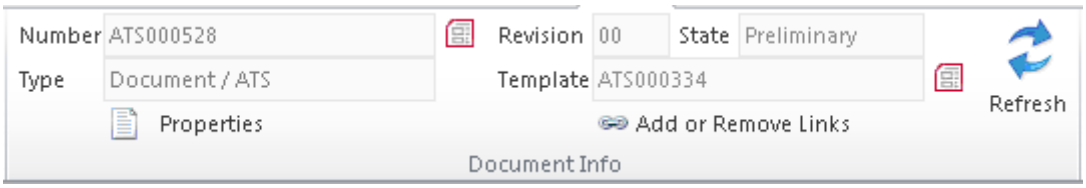


Figure 4.11: Document info after Save to Aras

Saving Documents to Aras

The user can save the Office file directly to Aras in different ways. The creator has three command options, ‘Save to Aras’, Save as to Aras’ and ‘Save and Close’. All options save the file to Aras but in a slightly different way

Save to Aras

The Save to Aras command saves the document in the current format to Aras just like the regular save button in Office to save a document to the local file map. Save to Aras can be chosen to save intermediate changes and overwrite the previous file without changing any properties.

Save as to Aras

The Save as to Aras command saves the document as a new item with the option to change the file properties like the document title. By using this option, you create a new item in Aras without overwriting or deleting the Aras item of the initial document you were working in. After clicking the Save as to Aras command the dialog of figure 4.3 shows again to allow you to make changes to the properties.

Save and Close

The save and close command saves the Office file to Aras and creates a non-adjustable pdf file as an extra file attached to the document item in Aras. After selecting the Save and Close button the Office application closes directly. If the document did not have the released status, both the pdf and office file get overwritten. If the document had the released state only authorized persons can change the content and only the Office file gets overwritten. A new PDF file with a higher revision number will be generated.

Appendix 4.2: Workflows in Aras

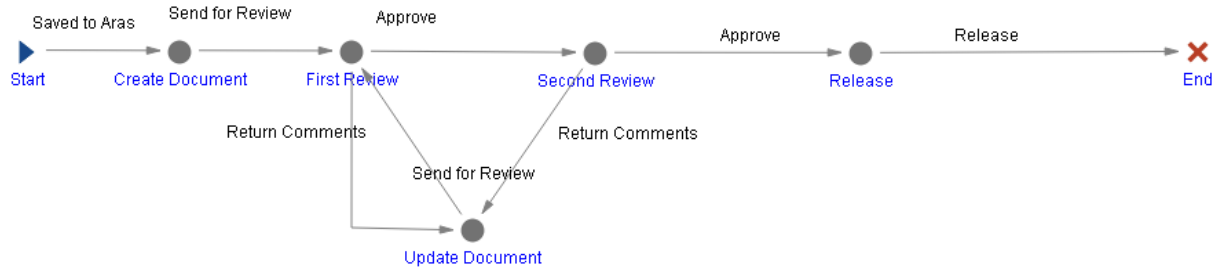


Figure 4.12: Workflow of a document in Aras

Figure 4.14 shows the assignment tab for the first task of the document workflow 'Create document'. This task is assigned to the creator of the document. This task is added to the workflow to give the creator the initiative to send the created document for review. This workflow is assigned to all documents that are saved to Aras. After an intermediate save using the 'Save to Aras' command as explained section 4.1.2 the workflow is already triggered to start. To prevent that the document is not finished when send for review, the creator first gets the task assigned to finish the document and vote the workflow to the next stage when ready.

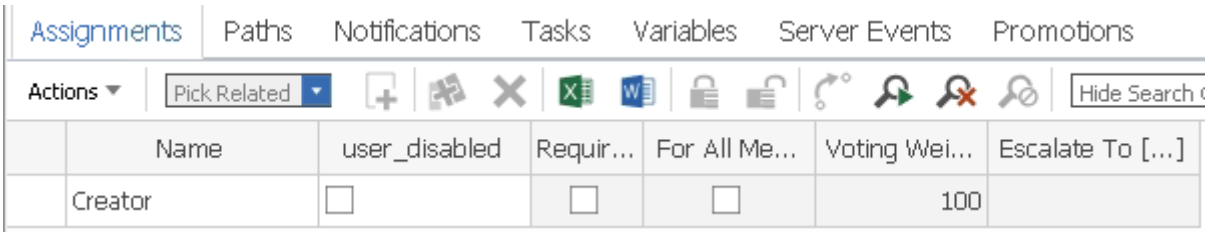


Figure 4.14: Assignment of the 'Create document' task in the document workflow

We can appoint multiple users to complete the task. The voting weight assigned to each user determines when the workflow is voted to the next stage. Figure 4.15 shows an example of a user and a user group both with the voting weight 100. 100 is the maximum weight which represents a 100% authority to complete the task and choose the path to the next task. This means that it is enough if either Olivier Berghuis or one of the users from the Workflow testgroup completes the review task and determines if the document is approved for second review or needs to be adjusted. The weight could also be split 50 – 50. This means that both identities must complete the task and vote for the next stage. The 50 – 50 division of the voting weight does not work when a task has multiple outgoing paths. Both identities need to agree on the voted path to continue the workflow. Therefore, it is possible to give one of the identities a higher voting weight than the other, to make the opinion of one identity superior to the other. The sum of the weights of the given votes must reach 100 to activate the next activity of the workflow.

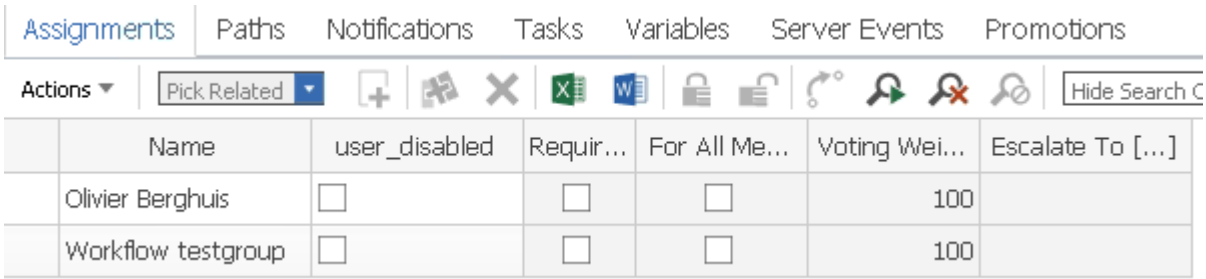
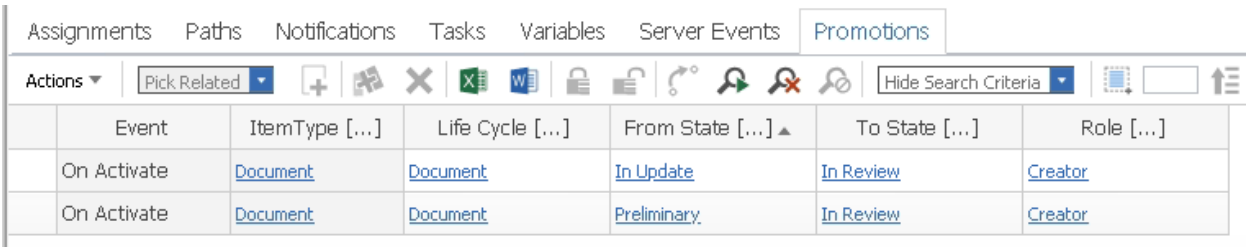


Figure 4.15: Appointed user to complete the first review task

When the workflow reaches or leaves a certain activity, the item related to the workflow can be promoted to another state. In our case the item is the document. The states the document can be in are defined in the life cycle shown in figure 4.13. Figure 4.16 shows the possible promotions of the document state when the First Review activity is activated. The figure shows that the document receives the In Review state when the First Review activity is activated. The First Review activity can be reached by two paths, one from the Finish Document activity and one from the Update Document activity. Both activities are assigned to the creator, so the creator is authorized to promote the document to the In Review state. The life cycle in figure 4.13 might be a little difficult to understand but it shows that the creator identity is authorized to promote the document from In Update and Preliminary to the In Review state.



Event	ItemType [...]	Life Cycle [...]	From State [...]	To State [...]	Role [...]
On Activate	Document	Document	In Update	In Review	Creator
On Activate	Document	Document	Preliminary	In Review	Creator

Figure 4.16: Promotion of document states in workflow

By defining the promotions in the workflow, the document automatically reaches a new state when a new activity of the workflow is being executed. The use of the workflow in Aras helps us to assign user to tasks, digitally distribute the document form user to user and show the progress using states. Aras automatically saves all actions and promotions including the records of the user IDs and specific times and dates of the performed activities. These track records provide full traceability of the document history.

InBasket

We explained that every task can be assigned to a certain person within the organization, using the workflow in Aras. The person that gets the task assigned to needs off course needs to be informed when work is expected from him. Tasks assigned to a person are presented using the personal InBasket. Every user of Aras has his or her own account. In the TOC under the header 'My Innovator' every user finds the tab 'My InBasket'. Figure 4.18 shows the My Innovator part of the TOC.

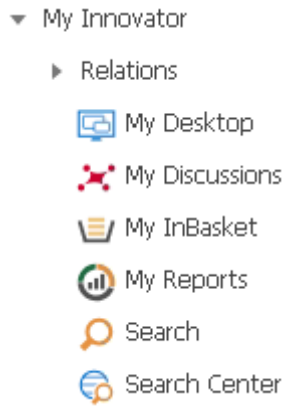


Figure 4.18: TOC Aras

The InBasket is a personal inbox for the user. Every task that is assigned to a user in the workflow is shown in this InBasket. The related item to the task is attached to the task with a direct link to it. The tasks in the personal InBasket can have three states, Pending, Active and Closed. The InBasket does not only show the activities that are already triggered in the workflow (Active) but the activities that you can

expect (Pending) and that you finished (Closed). It is possible to filter on the activity status. Figure 4.19 shows an example of ones InBasket

Type	View Item	Activity	Instructions	Workflow	Start Date [...	Status	Assigned To [...]
				ats*			
Workflow Task	ATS000530	Second Review	Please Review...	ATS000530		Pending	stagiair stagiair
Workflow Task	ATS000437	Second review	Please Review...	ATS000437		Pending	stagiair stagiair
Workflow Task	ATS000389	Create ATS		ATS000389	6/6/2018	Closed	stagiair stagiair
Workflow Task	ATS000389	First review	Please Review...	ATS000389	6/6/2018	Active	Workflow testgroup
Workflow Task	ATS000390	Create ATS		ATS000390	6/6/2018	Closed	stagiair stagiair
Workflow Task	ATS000390	First review	Please Review...	ATS000390	6/6/2018	Active	Workflow testgroup

Figure 4.19: InBasket

By clicking on the task, a pop-up dialog appears with more information and the command buttons to vote the task to the next stage. Figure 4.20 shows this dialog.

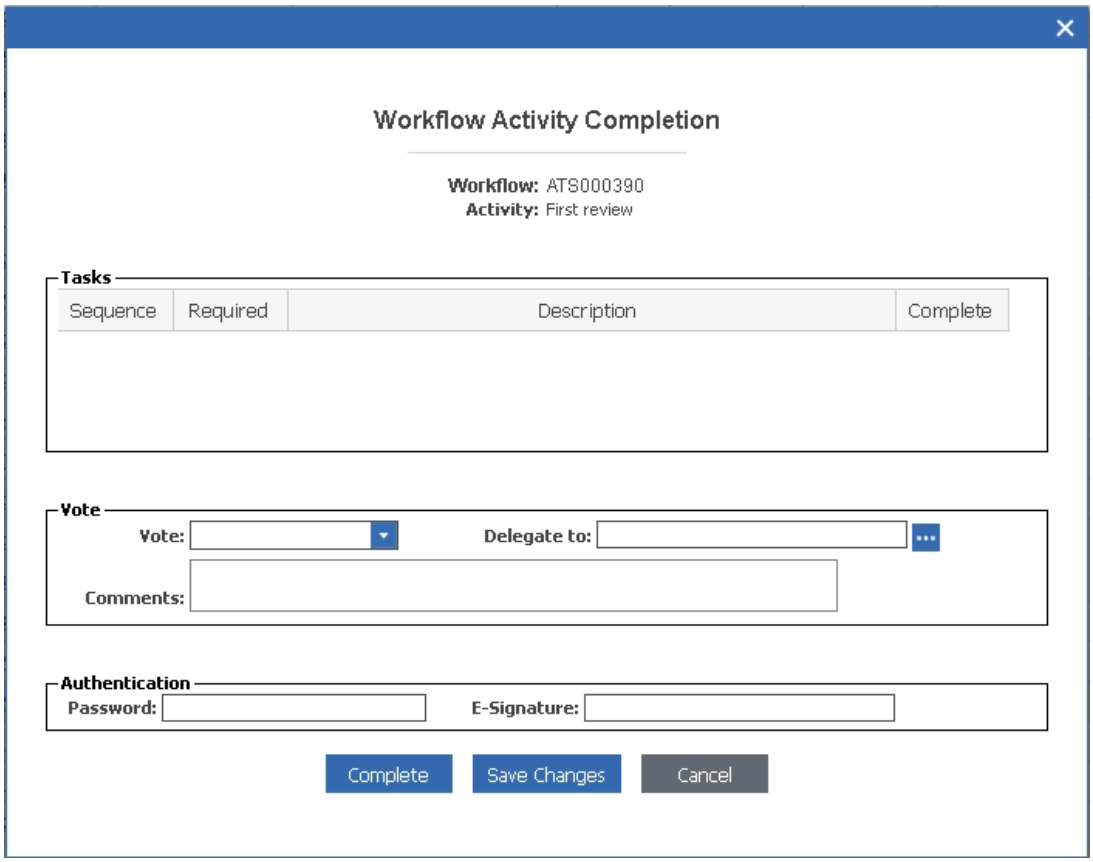


Figure 4.20: Activity dialog

The activity window shows three segments, Tasks, Vote and Authentication. The 'Tasks' segment can show a checklist with tasks that together assure the completion of the activity. The list of tasks must be defined in the workflow by one of the administrators. In the 'Vote' segment is where the user determines which path the workflow will follow next. The 'Authentication' segment can be used to let user sign-off their work. This can be done by using a password or an E-Signature. This is an extra safety measurement to be sure that no other user than the user that is logged in, is voting activities in the InBasket. The use of one of these two authentication types can be a good alternative for the autographs on the paper documents that were used to authenticate the approval and release of documents, which is one of the prerequisites for the digital Aerospace factory. Clicking 'Complete' will finish the activity and activate the next activity in the workflow you voted for. The status of the activity in your InBasket will be changed from Active to Closed.

Appendix 4.3: Visual Collaboration tab

The Visual Collaboration tool offers multiple ways to make notes and highlight the parts that need to be improved. Figure 4.23 shows the toolbar with the different review tools like highlighting, labeling or scribbling.

Figure 4.23: Visual Collaboration review tools

Figure 4.24 shows an example of the use of the highlighting tool. The color of the highlighted section can be adjusted. The highlight on its own does not tell the creator much. To explain the highlight the reviewer can use the discussion tab.

Part No.	Part Name	Material
3822558-2	Compressor rotor centrifugal - driven	Ti-6Al-4V per EMS54933

Figure 4.24: Example of highlighted section

The discussion tab can be used to start a discussion directly related to the document. In figure 4.22 we can see the discussion tab on the right side of the screen. The reviewer can add a comment to the document and explain highlighted sections or labels. Figure 4.25 shows the discussion tab section where we can enter comments to the document.

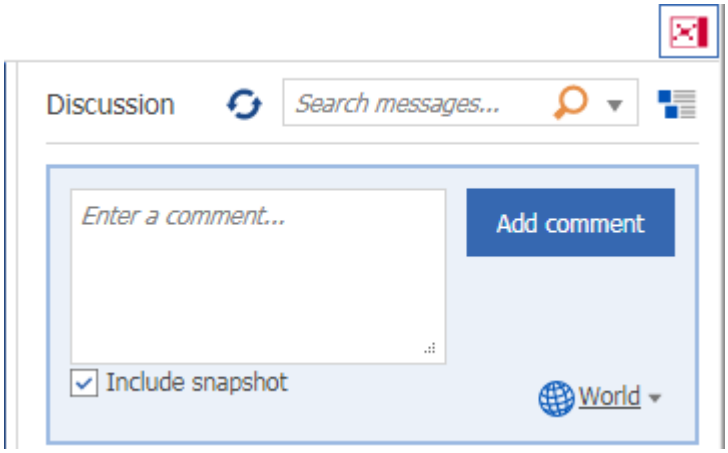


Figure 4.25: Discussion tab comment box

To relate the comment to the highlighted section it is possible to include a snapshot of the document with the highlighted section. When reading the comment, you can click on the snapshot and you are directly directed to the section that is highlighted. The discussion tab is not only a tool to add comments to the document but gives user the possibility to react on the comments as well. Figure 4.26 shows how a snapshot is added to a comment.

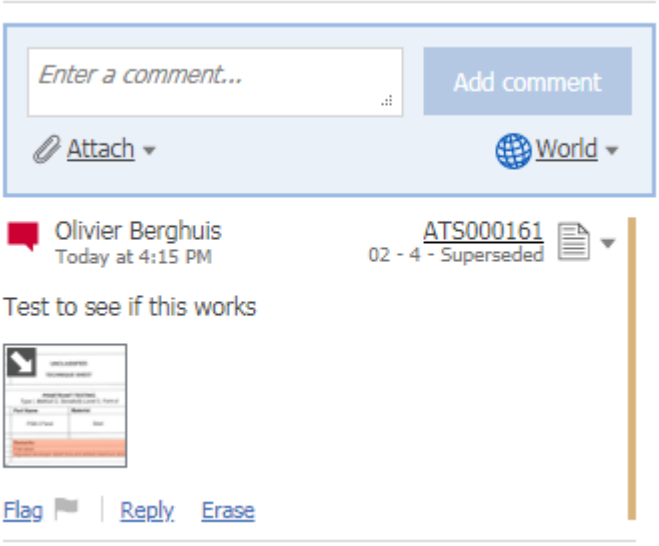


Figure 4.26: Use of snapshot in comments