A3PO – A case study on improving knowledge management for software upgrade planning in the offshore industry

Dagfinn Kjærnet
University of South-Eastern Norway
Dagfinn.kjaernet@gmail.com

Gerrit Muller
University of South-Eastern Norway
Gerrit.muller@usn.no

Abstract. As technology evolves, an increasing part of the world's industries relies on automation for production and for maintaining a safe work environment. Such Safety and Automation Systems (SAS) on an industrial scale are complex systems of systems, often with a long lifespan. These systems require maintenance and frequent updates due to cybersecurity concerns, bug fixes, technology improvements, new features and capabilities, and similar drivers. Updating such systems often requires special considerations to maintain plant safety and integrity and to reduce unnecessary downtime during the process. In the case company, project-specific adaptations, risks, and considerations that were difficult to oversee often shaped software upgrade projects. As a result, the company depended on a few key resources to produce a plan and schedule for the customer within a reasonable timeframe. This paper explores that problem through a case study and uses the concept of A3s to develop a tool that facilitates the capture, reuse, and communication of such knowledge. The tool formalizes the knowledge in process models with supporting information to help plan, schedule, and better communicate the software upgrade planning process.

Keywords

Knowledge management, offshore, software, architecture overview.

Introduction

Background. Oil companies are pushing for remote access capabilities to reduce the high operational costs of having personnel located offshore. Offshore oil and gas companies are especially looking at remote solutions for the operation and surveillance of platforms, but also for service and maintenance of computer and automation systems. This creates a potential opening for actors with malicious intent to gain access directly to the plant or its data and creates a possibility of damaging equipment on the plant or disabling systems or subsystems related to production or safety, potentially halting production or even enabling terrorist attacks. To mitigate these risks, automation system suppliers must keep the onboard systems up to date to protect against the latest known weaknesses in the various subsystems and components.

Software upgrade projects vary in scope and size. They can consist of pure software updates and security patches or include substantial changes in logic or even introduce new hardware or equipment to the system. For the engineers planning and performing the updates, they must have the necessary information to make plans and schedules and to be aware of the scope and consequences that the process will have.

The Company. This research was conducted within a maritime technology company established in Norway. The company supplies the maritime market with Dynamic Positioning systems, Safety and Automation systems, Propulsion systems, and a variety of deck and machinery equipment. It also supplies Safety and Automation systems to the offshore oil production industry, especially on the Norwegian continental shelf, and to Norwegian operators on installations abroad.

Challenge. The case company's SAS system consists of several components and subsystems, all of which may affect the production facilities in different ways when upgraded. The study found a lack of consistency in knowledge management and standardization for upgrading these components; the necessary information was often spread across a variety of sources and was difficult to find and gather. In addition, each project included unique adaptations, risks, and challenges that could affect the process, yet these were not necessarily captured or stored systematically. Even when they were captured, they were often buried across multiple sources. As a result, the company relied heavily on the knowledge and experience of a few key resources to plan and perform such upgrades. Another issue was that, between project updates, the personnel involved were occupied with other projects, often for extended periods. When they later returned to plan the next update, they spent time locating and reassembling information they had forgotten in the meantime.

The SAS system comprises both in-house developed hardware and software systems and commercial off-the-shelf (COTS) components, such as the Windows operating system and CISCO switches. While the overall upgrade process should also accommodate planning for the COTS components, this phase of the research is limited to the in-house components, since that is where the immediate need for knowledge capture is most pressing for the case company.

The study also indicated a cultural issue within the case company regarding knowledge management and documentation. Employees tended to hesitate to find and consult the documentation that existed; instead, they had a low threshold for seeking information and knowledge from colleagues. This increased the workload on experienced colleagues, and the quality and validity of the information could vary. Information provided by colleagues might not be up to date and could, in some cases, be based on assumptions.

Research Questions. To remedy the challenges described above, this paper focused on answering the following questions:

- What tool can we develop to help the company reduce the workload on key personnel when planning software upgrades?
- How can the tool help address the cultural issues related to how employees seek knowledge?

This research paper aimed to make use of open and semi-open interviews to capture knowledge, and the problem-solving tool "A3" (Lean Enterprise Institute, 2021) to codify (Nonaka, 1994) the necessary project and product knowledge to plan and schedule complex upgrade projects. While the case study mainly focused on a specific project, the artifacts created could serve as a baseline for similar projects.

In-house interviews indicated that, if the tool were successful, it could reduce the time spent seeking information by at least 50%. It could reduce the workload on experts and lead engineers during such projects by 30%. Interviewees also expected that it would improve the quality and consistency of the project's upgrade planning process.

Literature Review

Software Upgrade Process. When it comes to literature about software upgrades, the opinions and procedures are about as many as there are companies producing software (Microsoft, 2021) (Crowell, 2017). (Henson, 2018) (predictiveanalyticstoday.com, 2020) (Sigmon, 2013). While the number of steps and how detailed each step is varies from source to source, the overall outline and goal roughly remain the same: "Identify upgrade needs", "Identify the installed system(s)", "Analyze the impact of upgrade", and "Communicate and negotiate scope".

In the paper "The Upgrade Planning Process in a Global Operational Environment" (Kääriäinen, Teppola, Vierimaa, & Välimäki, 2014) the authors present a conceptual process model for the upgrade planning process specifically for industrial automation systems. They say that "*the plan* *supports the customer in preparing themselves for the updates, for instance by predicting costs, schedules for downtimes, the rationale for management, etc. For the service team, this provides an understanding of upgrade needs from which they can propose and justify the updates for the customer in a timely manner that maintains the customer's automation system in good condition*".

The authors (Kääriäinen, Teppola, Vierimaa, & Välimäki, 2014) make a point that the automation system consists of both in-house developed hardware and software, as well as COTS (Commercial off-the-shelf) components such as Windows Operating systems, so the plan they have developed and the tools they use have this in mind. However, in this paper, the focus is on the in-house developed components and their related processes.

Knowledge Management. Knowledge management is the process or method of creating, capturing, organizing, distributing, and using information and knowledge within a company. It can serve as a means to assist the company to make the most of its resources spent on researching and building its knowledge and experience by facilitating the capture of said knowledge and its re-use.

In the paper "The Concept of "Ba": Building a Foundation for Knowledge Creation" (Nonaka & Konno, 1998) the authors state that there are two kinds of knowledge in the process of knowledge creation:

- **Tacit knowledge** is the knowledge that exists mainly in a person's head. Such knowledge is gained by experience and can be difficult to formalize and transmit between individuals.
- **Explicit knowledge** can be formalized, documented, and transmitted between individuals in the form of manuals and similar.

The authors have identified four modes of Knowledge that make up a spiraling process of interactions that can be put into practice to make the transition from tacit to explicit knowledge. Figure 1 models this process.

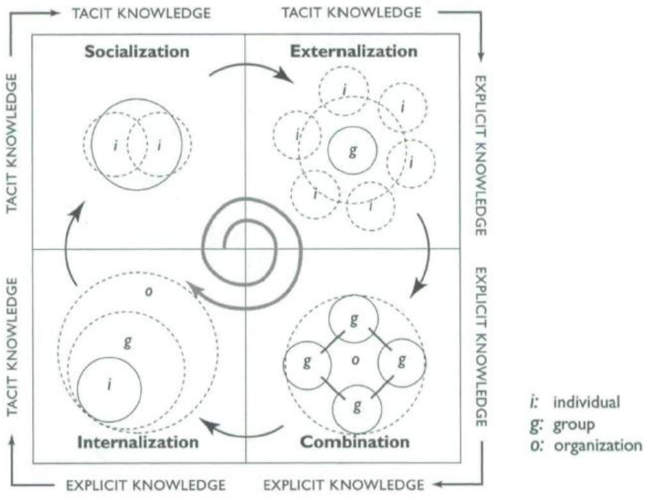

Figure 1 - Spiral Evolution of Knowledge Conversion and Self-transcending Process (Nonaka & Konno, 1998)

Process Mapping. A process can be defined as "*an activity that takes place over time and has a precise aim regarding the result to be achieved. The concept of a process is hierarchal, which means that a process may consist of a partially ordered set of subprocesses*" (Muller, 2011).

"*Process mapping is a graphical representation with descriptions of how things get done. It helps the participants to see the details of the process closely, and it guides them in decision-making*" (Hessing, 2013). Organizations often use process maps to visualize processes to provide insight and to serve as documentation of the process.

Stakeholder management. A stakeholder is an *"individual or organization having a right, share, claim, or interest in a system or in its possession of characteristics that meet their need and expectations"* (ISO/IEC/IEEE, 2015). Stakeholder management is the process of identifying, assessing, and prioritizing the stakeholders. It is important to have good stakeholder management in a development process to ensure the important concerns and requirements of the project are properly understood and identified so that the project meets the stakeholder's expectations. The impact a stakeholder has on a project depends on factors such as role, interest in the project, and power or influence on the project. Once stakeholders are identified, a power/interest grid can be used to map and help prioritize the stakeholders (MindToolsCorporate, 2019).

A3. The A3 tool is a problem-solving and continuous improvement tool used to capture, codify, and share knowledge. The term "A3" stems from the ISO standard 297mm*420mm paper size. The line of thought is that by limiting the amount of space available (to the size of an A3 sheet of paper) the author must make sure the information is short and on point. As a result, you avoid overwhelming the reader with unnecessary information.

The Toyota Motor Corporation first used the A3 tool (Lean Enterprise Institute, 2021) where they introduced the concept of "A3 Reports" which they used to create status reports of ongoing projects, propose changes in design and processes, and perform and document problem-solving in general. The tool has since seen many iterations and adjustments, based on the scenario to which it is applied.

A3AO. Borches (Borches Juzgado, 2010) wanted a tool that supported effective communication of architecture knowledge by making implicit company knowledge into explicit knowledge and used the A3 concept as a basis for a tool he designed and called "the A3 Architecture Overview (A3AO). Borches states that to enable effective communication he aims to format the information in a way that a wide variety of stakeholders can understand. To accomplish this the A3AO avoids modeling languages and architecture standards and instead focuses *"on providing visual representations and simple notations that are easy to understand"*. The A3AO tool makes use of both pages of the A3, where one side contained the main A3 Model and the other was a summary of the A3. Borches noted that the Model page supported discussions while the participants barely used the summary page during meetings. Borches found in his research that the majority (80%) of the participants preferred to read the A3AOs rather than a document detailing the same information. Most of them (73%) even stated that they preferred the A3AOs over documents when learning new topics. Borches also noted that most of the participants (75%) thought the A3AOs helped them to communicate better with the stakeholders.

State of A3AO. The A3AO format has since been researched and applied in many cases where improving communication of knowledge has been a large motivator to start the research. Frøvold (Frøvold, Muller, & Pennotti, 2017) used A3AOs as a means to improve stakeholder communication and as a tool for early validation, it was applied by Viken (Viken & Muller, 2018) as a tool for validation and communication during software development. Johanssen (Johanssen & Zhao, 2019) used it to capture and document best practices of a working process to integrate the use of software tools in the process, and Wiulsrød (Wiulsrød, Muller, & Zhao, 2022) applied it to facilitate working processes for increased performance. J.I. Lillemoen (Lillemoen & Falk, 2020) developed what he called the A3 System Overview (A3SO) to capture and display project knowledge and facilitate the reuse of the knowledge.

Research Methodology

Action Research. This paper applies the "action research" approach. Researchers Willis and Edwards describe this method as a "*family of methods for doing research in the field rather than in a laboratory setting*". Furthermore, they say that it is "*a form of systematic investigation that typically involves attempts to solve practical problems in real-world settings through the involvement of stakeholders who work or live in those settings*" (Willis & Edwards, 2014). Accordingly, this research was conducted as a case study on an ongoing project within the case company.

Case Study. In an article on the case study approach, the authors (Crowe, et al., 2011) describe a case study as "*a research approach that is used to generate an in-depth, multi-faceted understanding of a complex issue in its real-life context*". This case study aimed to identify the key knowledge in a project and capture and document it in a way that could help solve some of the company's current challenges related to software upgrade projects of varying complexity.

Rapid Prototyping. The study used rapid prototyping to quickly iterate and mature the conceptual solution. Rapid prototyping is an iterative approach to development in which a mock-up of the next version of the system is quickly created and introduced to stakeholders early in the development process. The aim is to improve the overall quality and reduce the need for late changes in the solution by gathering feedback early and often. When the stakeholders believed the prototype would satisfy the stated requirements, it was released for implementation and in-the-field testing. Lyndon Cerejo (Cerejo, 2010) states that *"Rapid prototyping helps teams experiment with multiple approaches and ideas, it facilitates discussion through visuals instead of words, it ensures that everyone shares a common understanding, and it reduces risk and avoids missed requirements, leading to a better design faster."*

Data Collection and Validation. Several unstructured and semi-structured interviews were conducted within the case company to collect and validate data. Due to limited access to the relevant resources and stakeholders, the study also made use of informal opportunities such as "drop-in meetings" or "water cooler talks" whenever they arose to gather early feedback, follow-up information, or additional data, especially during the exploration phase. A survey was created to help quantify and validate the data and results. The survey used Likert scales so that participants could rank their level of agreement from "Strongly agree" to "Strongly disagree" for the various statements. The results were plotted using diverging stacked bar charts, as recommended by (Robbins & Heiberger, 2011).

Knowledge creation strategy. The strategy chosen in this paper was to use interviews to capture the knowledge, and the A3 tool to formalize it. The interviews served as a way of socialization and externalization as per Nonaka's spiral model (see Figure 1). The A3s were introduced to, and evaluated by, a mixed group of stakeholders to fulfill the Combination and Internalization modes of the model.

Net Promoter Score. Net Promoter Score (NPS) is a metric used to measure stakeholder satisfaction and loyalty by asking stakeholders how likely they are to recommend a product or service to others (i.e., on a scale from 0 (unlikely) to 10 (highly likely)) (Reichheld, 2003) (Qualtrics, 2018). Based on their responses, the stakeholders are split into three categories: Promoters (9-10), Passives (7-8), and Detractors (0-6). The NPS is calculated by subtracting the percentage of detractors from the percentage of promoters, where the result is measured on a scale from -100 to +100. A high positive score indicates high stakeholder loyalty and satisfaction.

The NPS for the A3PO was calculated to determine the overall satisfaction with the tool, and the likeliness of the participants to recommend the tool for use in other projects.

Research Design. Figure 2 shows the three phases of the research.

- In the *exploration phase,* the study aimed to define the problem, review relevant artifacts, and conduct interviews to determine the as-is and to-be situation, identify stakeholders, perform gap analysis, identify requirements, and capture best practices. A literature review was also conducted to identify viable solutions and shape a conceptual solution. In addition, a survey was conducted to determine the current state.

- When the conceptual solution was ready and the best practices had been captured, the *application phase* could begin. During this phase, rapid prototyping was used to evaluate various proposed solutions. The prototype was reviewed and discussed with stakeholders to gather feedback. Once that feedback had been submitted and processed, the prototype was adjusted accordingly. This process was repeated through several iterations until the prototype was considered ready for release.

- Once the prototype was released, the *verification & validation* phase began. During this phase, the released prototype was introduced to a select group of stakeholders with varying levels of experience and different areas of expertise. These stakeholders were then surveyed and interviewed to determine the effect of the A3POs. Lastly, the study concluded by answering the research questions presented in the Introduction.

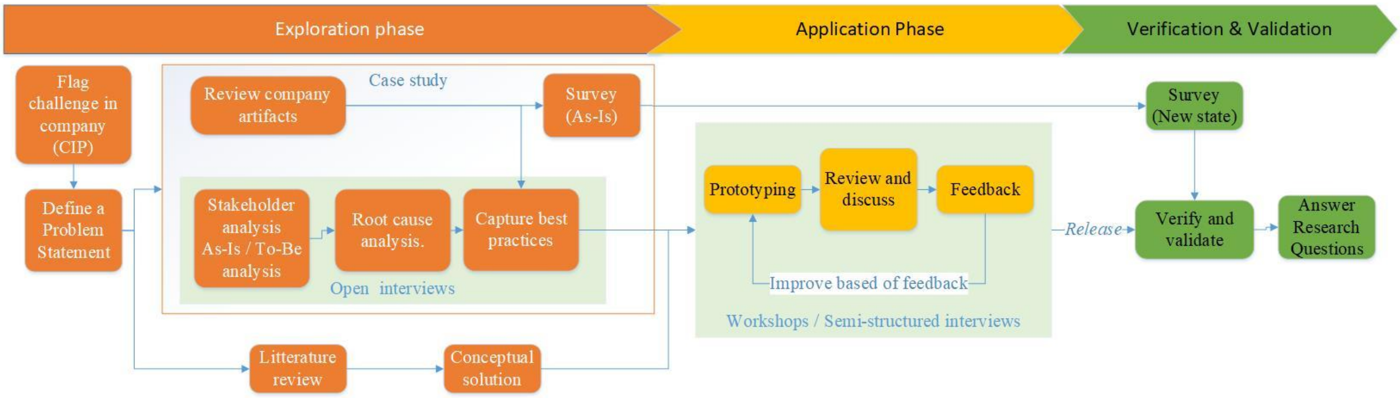

Figure 2 - Research Design

Conceptual solution

Based on the literature review, this study explored the possibilities of developing an A3AO-inspired tool. The tool was intended to facilitate knowledge capture and reuse in response to the challenge introduced in this paper. The reviewed research indicated that A3AO-inspired tools were well suited to capturing and displaying project knowledge (Lillemoen & Falk, 2020); they could also facilitate work and development processes (Viken & Muller, 2018) (Johanssen & Zhao, 2019) (Wiulsrød, Muller, & Zhao, 2022) and improve communication with stakeholders (Frøvold, Muller, & Pennotti, 2017).

In the research of (Wee, Muller, & Martin, 2015) the researchers observed that people making A3s tend to discover that they need multiple levels of A3s at various abstraction levels. Borches notes in his research (Borches Juzgado, 2010) that the participants used the text-based summary page in his two-paged implementation less than the page with visualizations and models. (Viken & Muller, 2018) and (Johanssen & Zhao, 2019) chose to use a single-paged implementation instead where they focused on visualizations and models. (Wiulsrød, Muller, & Zhao, 2022) replaced the text sheet with high-level diagrams and figures to be less text focused.

The study therefore combined these findings into an implementation that focused on single-paged and multilayered A3s with a strong emphasis on visualizations and models. Borches developed a “cookbook” for creating A3AOs, which served as a basis for the conceptual solution, but some adaptations were made to accommodate textual elaborations for models and diagrams where needed, as well as key notes and information that were not easily visualized. The solution used two layers of abstraction. The templates for each layer were quite similar, but the top-level model focused more on supplying a clear system overview, while the lower-layer model focused more on the process model. Figure 3 shows an early version of the conceptual solution.

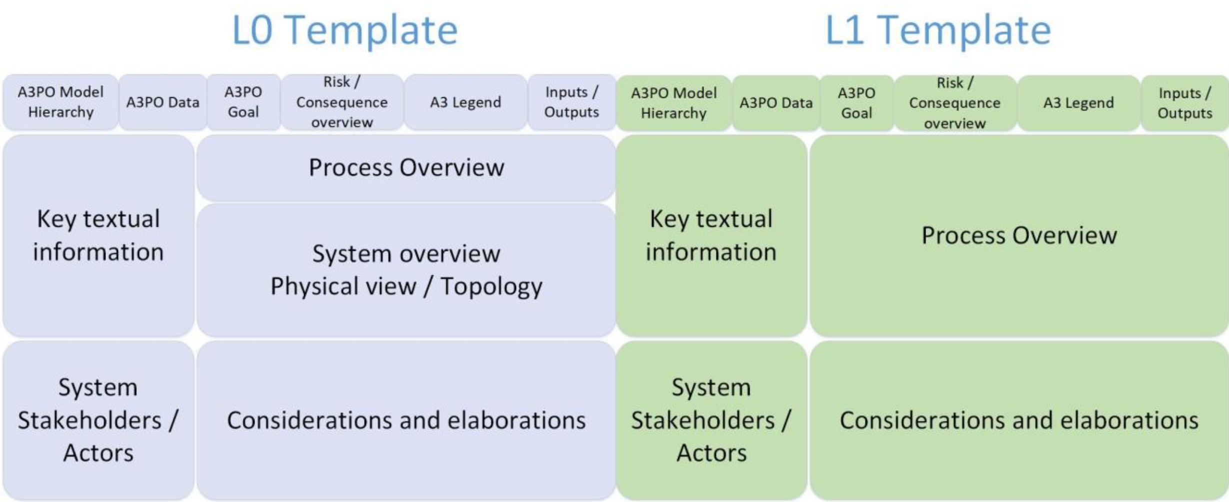

Figure 3 - Early version of the Conceptual Solution template

The conceptual solution was named the "A3 Process Overview" (A3PO) because it focused on facilitating the successful implementation of the process models. The A3POs were modeled in Microsoft Visio, which is commonly used in the case company. However, the A3POs could be modeled in many different, easy-to-access tools. They could even be sketched directly on a whiteboard or on paper, which is especially convenient during interviews and workshops.

The solution consisted of a top bar showing the overall A3PO information such as model hierarchy, document data, goal, expected input, and output artifacts. It also included a condensed risk or consequence overview to give the user an early indication of the risk level based on the comprehensiveness of the update. The concept presented by (Kääriäinen, Teppola, Vierimaa, & Välimäki, 2014), which visualized the relevant stakeholders and artifacts and their interactions in the process model, also informed the design.

The researcher dedicated one section of the A3PO to "*key textual information*" to remedy the lack of a text-based summary page. The goal of this section was to address the case company's knowledge management challenges. The A3PO author was expected to use this section to gather relevant information in one place. There was also a section for a diagram of the various relevant "*system stakeholders*" and how they relate to the process to facilitate stakeholder communication. The "*considerations and elaborations*" section was used to detail solutions, implementations, concerns, or other considerations relevant to planning an update for the system of interest in the specific project. The A3PO author was free to decide the best way of communicating this information; the section could be textual, visual, or a combination. The "*process overview*" section visualized the process model for the system of interest. For the L0 template, there was also a section dedicated to modeling the "*system overview*". This could be a physical view model, a topology model, or similar, whichever the A3PO author believed communicated the overall system overview best.

Case Study Findings

Gathering data

As part of the case study, a series of unstructured and open interviews was conducted to gather the necessary data. The first interview focused on identifying and classifying the different stakeholders, while the later interviews focused on gap analysis and root-cause analysis to identify and capture the requirements. A third round of interviews focused on capturing and documenting the current best practices. During that round, the participants were split into groups based on the type of knowledge to capture.

Id	Participant(s)	Combined experience	Objective
U.I.1	1 Principal Engineer 1 Senior Engineer	35 years of experience in the company combined. More than 40 years in the industry	Explore the problem and define the research questions. Identify relevant stakeholders and metrics.
U.I.2	1 Principal Engineer 1 Lead Engineer 2 Senior Engineers	Around 70 years of experience in the company combined.	Perform GAP analysis, root cause analysis, and identify stakeholder requirements.
U.I.3.1	1 Principal Engineer 1 Senior Engineer	Around 30 years of experience in the company combined.	Capture and document best practices of KCS updates
U.I.3.2	1 Lead Engineer 2 Senior Engineer	Around 47 years of experience in the company combined.	Capture and document best practices of real-time system upgrades (AIM + FW)

Table 1 - Research interviews

In addition to the scheduled interviews, feedback was also gathered through informal interviews, such as spontaneous meetings and discussions around the coffee machine.

Findings in interviews

Relevant Stakeholders. For the interview "U.I.1" (Table 1), the focus was on exploring the problem, identifying and analyzing the stakeholders, and identifying some metrics that could be used to measure the impact of the project. The result is mapped in a Power / Interest grid below in Figure 4.

Figure 4 - Stakeholder Power / Interest Grid

Root causes. The participants in interview "U.I.2" (Table 1) were selected based on their identification as stakeholders in interview "U.I.1" (Table 1). The interview focused on exploring the problem further through a gap analysis. The participants also performed a root cause analysis during the interview using the "Five whys" technique (Pojasek, 2000). "Appendix A – Root Cause Analysis" includes a table showing the root cause analysis and findings.

Requirements. Based on the interviews and the root cause analysis, a list of requirements could be formulated. The requirements are listed in Table 2.

Id	Requirement description	Objective
REQ1	The tool shall reduce the workload– and dependency on key personnel such as lead engineers.	Expert workload reduction of 30%. Henceforth referred to as REQ1 or the "*Workload reduction*" requirement.
REQ2	The tool shall be considered a "living artifact", meaning that it shall be always kept up to date, and as such it shall be easy to update.	Maintenance effort less than that of existing ways of working (scale 1-10). Henceforth referred to as the REQ 2 or "*Maintenance effort*" requirement
REQ3	The tool shall capture and display the necessary knowledge needed to plan and schedule software upgrades.	Reduce time spent looking for information by 50%. Henceforth referred to as REQ3 or the "*time reduction*" requirement.

Table 2 – Table of Requirements

Best practices. In interviews "U.I.3.1" and "U.I.3.2" (Table 1), the focus was on identifying and capturing best practices within the case company. The participants were selected based on their identification as expert engineers in interviews "U.I.1" and "U.I.2" (Table 1). The captured best practices were then applied to the conceptual solution to create the prototype.

Prototyping

Once the prototype was ready, the research entered the *application phase.* A series of semi-structured interviews was conducted to gather feedback and improvements for each prototype iteration. A final semi-structured interview was also conducted during the verification and validation phase to determine the success of the released prototype.

During the semi-structured interviews, participants were allowed to talk and discuss freely for the most part, but some pre-defined questions were asked to try to keep the discussions and feedback on relevant topics for the A3PO research. Later in the process, the researcher also added a question to measure the Net Promoter Score (NPS).

The following conditions were set for considering the prototype ready for release:

- The interviews yielded few or no tangible new suggestions for changes.
- The participants were confident that the prototype would meet the requirements, and the prototype scored a positive NPS.
- Or until the fourth iteration of the process is completed (due to time constraints).

Table 3 shows an overview of the interviews and the participants.

Id	Participant(s)	Combined experience	Objective
S.I.1	2 Principal Engineers 1 Lead Engineer 2 Senior Engineer	Around 95 years of experience in the company combined.	Familiarize the participants with the A3PO concept. Gather initial feedback and input on prototype 1.
S.I.2	1 Principal Engineers 1 Lead Engineer 1 Senior Engineer	Around 60 years of experience in the company combined.	Gather feedback and input on prototype 2.
S.I.3	2 Principal Engineers 1 Lead Engineer 2 Senior Engineer	Around 95 years of experience in the company combined.	Gather feedback and input on prototype 3.
S.I.V	1 Department Manager 2 Technical Manager 4 Lead Engineer 3 Principal Engineer 4 Senior Engineer	Around 263 years of combined experience in the company. Around 313 years of experience combined in the industry.	Conclusion, Verification & Validation of the release version of the tool.

Table 3 - Application and Validation Interviews

Three prototype iterations were created, in addition to the final release version. Each iteration incorporated several changes based on participant feedback, both in content and design. The participants in S.I.1 through S.I.3 consisted mostly of the same people. It was noteworthy how quickly they adapted to the A3PO format after the first interview. Feedback in the first interview focused mainly on the concept and its possible uses and therefore contained little constructive input to build on. In the following sessions, however, the participants were able to provide more concrete and constructive feedback. Table 4 lists the changes for each prototype iteration.

Prototype iteration	Proposed changes to be implemented for the next iteration
Prototype 1	• Add symbols to visualize the various artifacts, and where they are relevant. • Changes and input on content.
Prototype 2	• L1-level A3PO System-of-Systems impact overview (list impacts on and from other systems). • Feedback on content, especially content, and flow of process maps.
Prototype 3	• L0-level A3PO should have a pre-check, to quickly determine which subsystems will be affected by the scope of the update. • Minor changes to content.

Table 4 - Prototype iterations and changes

After the third iteration, the decision was made to stop iterating and release the tool. Feedback and proposed changes were becoming vague and less tangible, and the participants also responded that the prototype stood a fair chance of meeting the three requirements. The prototype scored an NPS of +80 from the participants (two participants gave a rating of 10, two gave a rating of 9, and one gave a rating of 8). Figure 5 shows the updated templates for the A3PO release version.

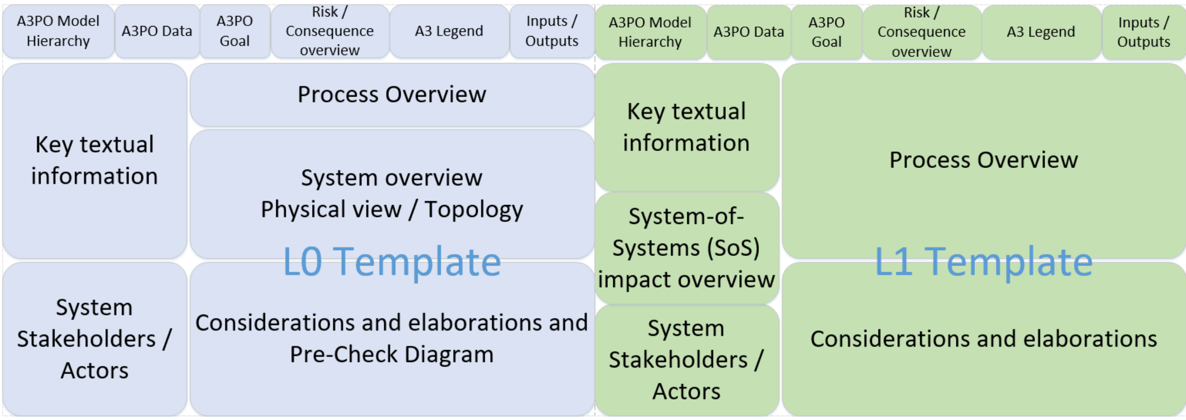

Figure 5 – A3PO Templates Release Version

In "Appendix C – A3PO Examples" there are examples of L0 and L1 A3POs that were created using the release version of the templates.

Validation and Verification

The release version of the A3PO was tested in a workshop ("S.I.V" Table 3). For most of the participants, this was the first time they were introduced to the A3PO tool, but a few were also part of earlier testing. A survey was prepared before the workshop where one part focused on the As-Is situation, while the other focused on the new situation after the implementation of the A3PO tool. The survey consisted of three topics: "Knowledge management", "The Process for Software Upgrade Projects", and "Working with the A3PO". There was also a section with questions to validate the requirements. "Appendix B – Survey results" shows the results and diagrams from the surveys and questionnaires.

Knowledge Management survey results. In many regards the A3PO scores considerably better than the As-Is situation, however, the current A3PO version does not seem to properly convey how updated the information on it is. It also falls short of making it easier to find relevant product documentation and making the user feel that all necessary project information is properly captured and documented.

Software upgrade process survey results. The results for the part of the survey focusing on the process itself indicate that the A3PO does offer a better alternative than the As-Is situation in most aspects. However, when it comes to gathering necessary artifacts like change notes and increasing the information to provide to the customer it falls somewhat short.

Working with A3POs survey results. The workshop participants were also surveyed about their experience of working with the A3POs themselves. The A3PO received a positive NPS on questions related to preference over textual documentation, discovering system aspects they would otherwise miss, facilitating discussions, and identifying information not stored elsewhere. However, it received a negative NPS on making the company less dependent on key personnel and on being easy to change and update. It received a neutral result (NPS 0) on being intuitive to read and understand.

Validating the requirements. The objective of REQ1 was to reduce the workload (concerning support of upgrade projects) of expert engineers by 30%. The participants were surveyed regarding their expectations of the impact of the A3PO release candidate and it scored a reduction of 34%, and as such the A3PO passes this requirement.

In the survey, the participants were also asked to score miscellaneous artifacts on their "Maintenance Effort Score" (MES). The results serve as a comparison basis for the maintenance effort level of the A3PO (REQ2). The requirement was to be better than existing ways of working. The A3PO passes the requirement with a score of 3.9, with the second-lowest scoring artifact being checklists with a score of 4.5.

The objective of REQ3 was to reduce time spent looking for information by 50%, the A3PO falls slightly short of REQ3 at a 47% reduction.

Overall Net Promoter Score. The workshop participants were also asked how likely they were to recommend the A3PO for other projects. Figure 6 shows the results. The A3PO scored an overall NPS of +43.

Topic	ID	Question	1	2	3	4	5	6	7	8	9	10	NA
NPS	S2.6.4	On a scale from 0 (not at all likely) to 10 (extremely likely), how likely are you to recommend using the A3PO tool in the project?					2	1		1	7	2	1
		Calculated Net Promoter Score (NPS):	**+43**										

Figure 6 - Overall Net Promoter Score (NPS)

Reflections

Limitations. It should be noted that the dataset (from interviews, surveys, and workshops) is limited. Two issues are especially important:

1. The low number of participants.
2. The lack of diversity among the participants. The dataset lacks input from less-experienced personnel.

Another concern is that some survey questions are somewhat ambiguous and, to some degree, open to interpretation. Some misunderstandings could be mitigated during the workshop, but in retrospect the survey needed refinement. The MES questionnaire section stands out in this regard.

A handful of participants were asked about their interpretation of some of the questions after the workshop, and their responses may indicate that this explains at least some of the "camel" responses. One lesson learned would be to present the questionnaire to a selection of people before the workshop and discuss their interpretation of it. It could also be wise to build a larger dataset for the questionnaire section only by separating it from the survey and sending it to a larger group of people.

Reflections on survey results and interviews

Knowledge Management. The survey results show that the A3PO shows potential as a way of introducing resources to new projects and can be used to motivate users to learn about the project from documentation and artifacts rather than consulting with their colleagues straight away. However, the A3PO still falls short of expressing whether or not the information on it is up to date. The A3PO tool still needs some work when it comes to capturing the necessary knowledge. One possible reason is the small dataset used in the prototyping phase of the A3PO. More stakeholders should have been surveyed and interviewed about what they considered necessary knowledge, but this could also be addressed in later iterations of the tool as it sees broader use and users become more familiar with the A3PO.

Process for Software upgrade projects. The A3PO tool succeeds at being a helpful tool for planning and preparing software upgrades. There are also indications that it builds confidence in the user that he has taken all necessary considerations in the process, identified risks and consequences, and increased the quality of the information regarding the impact on the SAS systems when using the tool. There is some indication that the participants believe the A3PO helps them become less dependent on key resources in the process.

The survey results indicate that the A3PO tool needs improvements when it comes to gathering product artifacts, such as change notes and procedures, and improving the quality of the information provided to customers based on such artifacts. Feedback from interviews and discussions reveals another problem with artifacts related to release and change notes. Even though the A3PO may help the user learn where the various release notes can be found, most of the release notes themselves are company internal, and as such they need to be manually processed before they can be released to customers and other external stakeholders. This task often requires the assistance of key personnel from the development environment.

Working with the A3POs. It is surprising that the A3PO scores a negative NPS in the survey when participants were asked whether the tool is easy to change and update, while it still achieves the MES requirement of being better than the existing ways of working. However, several participants commented that "*the A3PO feels overwhelming at first glance, but I'm quickly attuned to the format once I start reading it*". This also fits the observations made during the prototyping process: participants initially felt somewhat overwhelmed, but once they started reading, they quickly became more comfortable. In follow-up discussions and later prototype reviews, none of the returning participants raised this issue again.

It is interesting that the A3PO scored a *positive* NPS when participants were asked whether the tool helps them become less dependent on key resources in the software upgrade planning process, while it scored a *negative* NPS when they were asked whether the company as a whole would become less key-resource dependent. This may indicate that, even though the A3PO may fall short of making the company less dependent on key personnel overall, it is still successful in reducing the workload of such personnel.

The A3PO scored higher on preference over reading textual documentation, facilitating discussions, and helping the user discover system aspects and knowledge that they would otherwise miss. This supports claims that the A3 format is a strong tool for communication.

Validating the requirements. The tool passes the workload requirement (REQ1) and the Maintenance Effort Requirement (REQ2). The inconsistency in responses on the questionnaire used to score artifacts on maintenance effort could call into question whether this requirement has been sufficiently validated. However, after discussing the results with some of the participants after the workshop, the study suggests that some of the existing artifacts likely received lower scores than they should have, rather than the A3PO receiving an artificially low score due to misinterpretation of the questionnaire.

When looking at the survey results, the A3PO falls slightly short of REQ3 at 47%. However, as several participants pointed out during discussions and the workshop, the reduction would normally be smaller for more experienced engineers. The majority of participants in the validation workshop were lead or expert personnel with many years of experience. If the results are filtered to show the average for senior engineers, the outcome is well within the requirement, as shown in Figure 7. The study therefore concludes that the tool is close enough to its target but fails the requirement largely because the available dataset includes too few participants with less experience to support a dependable answer.

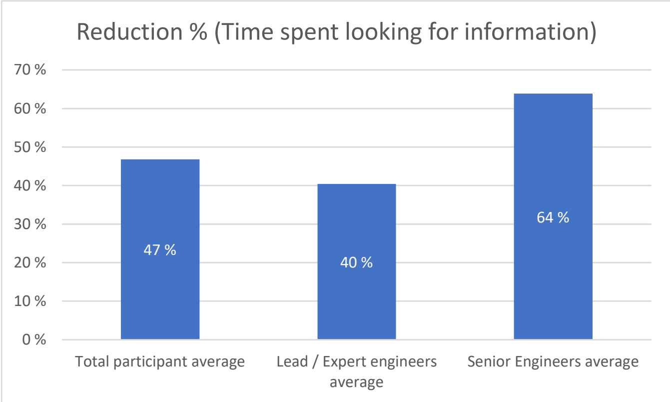

Figure 7 – Survey results "Reduction in time spent looking for information"

Conclusion

This study set out to answer two research questions. The first was "*What tool can we develop to help the company reduce the workload on key personnel when planning software upgrades?*". The findings show that the A3PO can serve as such a tool. By capturing and codifying best practices for software upgrade planning in the A3PO, stakeholders felt more confident in taking on such projects and were also less dependent on other key resources during the process.

The second question was "*How can the tool help address the cultural issues related to how employees seek knowledge?*". The A3PO addresses this by gathering and visualizing the needed information in one place. In turn, stakeholders felt more motivated to seek and find information from documents and other resources before consulting colleagues.

The research has shown that the A3PO is a strong tool to communicate knowledge and gather information. The tool improves several aspects of the software upgrade process, such as lowering the dependency and workload on key personnel during such projects, improving the quality of the early information regarding the impact on the SAS system so the customer can better plan and schedule the implementation, reducing the time spent searching for information and helping to identify risks and consequences of performing the updates.

Future research

An important addition for the next iteration of the tool is to integrate COTS components such as Operating Systems (i.e. Microsoft Windows) and network equipment in the process. Some COTS components serve core functions in the SAS system. COTS components are more exposed to threats such as cyberattacks than in-house developed systems since the market availability and exposure of these components are higher. The vendors define the lifecycle and servicing plans for COTS components, so it is important to include these in the upgrade planning process to ensure that the vendors still support the systems (Microsoft, 2016). It is also preferable to perform upgrades and maintenance on these systems during the same maintenance windows as updates for in-house components whenever possible to avoid unnecessary downtime and production loss.

The tool did not mature to a level where the case company ultimately embraced it. This may be partly due to focusing too much on designing and implementing the A3PO itself while overlooking some important questions, such as:

- What artifacts can the A3PO replace to avoid duplicate documentation.
- How is ownership of each of the A3POs decided.
- Where and how should the A3POs be stored and accessed.
- How can the user know whether this is the latest version of the A3PO?

As an extension of this, it would be beneficial to explore how working with the A3PO in a cloud environment would affect the ability to co-author and perform on-the-fly updates and changes. Could there be other benefits as well, such as greater interactivity and better facilitation of discussions and feedback through digital meeting arenas like Teams or Zoom?

During the feedback session for the third prototype, one participant commented that the artifact symbols were cluttering the A3PO. Future iterations should therefore explore whether links between artifacts, stakeholders, and process steps could be visualized in a less cluttered manner. Another point raised was that the condensed risk matrix could perhaps be integrated directly into the process map to show more clearly what would escalate the different risk levels.

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Appendix A – Root Cause Analysis

<table>
<tr><th>Problem</th><th>Category</th><th>Cause</th><th>Root cause</th></tr>
<tr><td rowspan="12">The company is dependent on a handful of key resources to plan and perform software upgrade projects on installations in operation.</td><td rowspan="3">Organization</td><td>Lack of qualified resources</td><td>No standardized or organized process plan. Just experience and knowledge-based.</td></tr>
<tr><td rowspan="2">Instead of seeking out information through documents, the employees confer with experienced resources.</td><td>There is little guidance in finding and locating documentation</td></tr>
<tr><td>The documents feel overwhelming and difficult to read.</td></tr>
<tr><td rowspan="6">Project</td><td>Sensitive information, such as credentials for various systems, etc is difficult to find.</td><td>No standard way of documenting this information.</td></tr>
<tr><td rowspan="2">Too many “project-specific” solutions and implementations</td><td>The engineering handbook is incomplete/insufficient.</td></tr>
<tr><td>The engineering handbook is simply not used.</td></tr>
<tr><td rowspan="3">Difficult and time-consuming for new resources to “get up to speed” in the project. The same goes for resources who have been out of the project for some time.</td><td>Not all relevant project knowledge is captured</td></tr>
<tr><td>The knowledge that is captured is spread over several sources</td></tr>
<tr><td rowspan="2">Some risks and consequences are project specific.</td></tr>
<tr><td rowspan="3">Product</td><td rowspan="2">Difficult to get an overview of the risks and consequences of the various upgrade operations</td></tr>
<tr><td>Existing guides and procedures are created for new projects, not maintaining or upgrading installations in operation.</td></tr>
<tr><td>Difficult to get an overview of change notes</td><td>Change notes for the various products are spread, and a lot of the change notes are classified as company internal.</td></tr>
<tr><td colspan="2" rowspan="2">LEGEND</td><td colspan="2">Root Causes considered out of the scope of CIP</td></tr>
<tr><td colspan="2">Root Cause considered as within the scope of CIP</td></tr>
</table>

Table 5 – Root Cause Analysis

Appendix B – Survey results

Knowledge Management survey results.

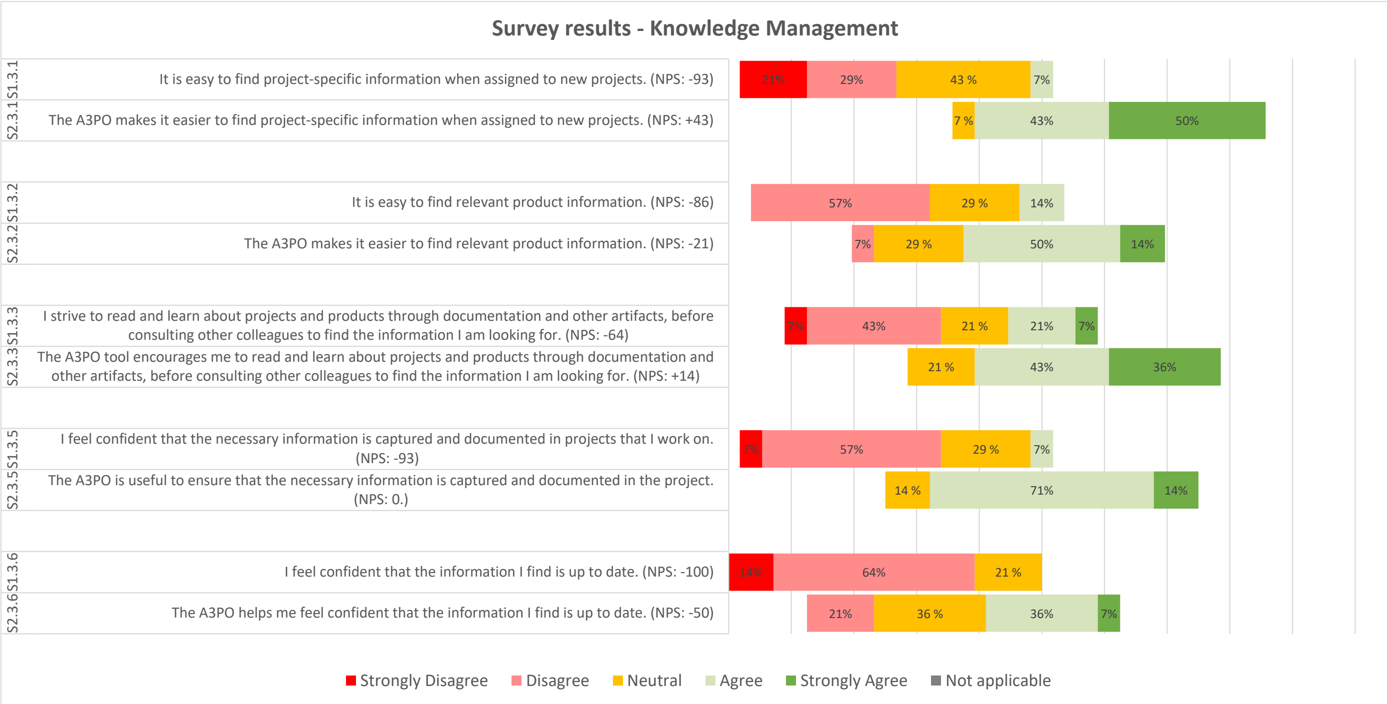


Figure 8 - Survey results “Knowledge Management” Part 1

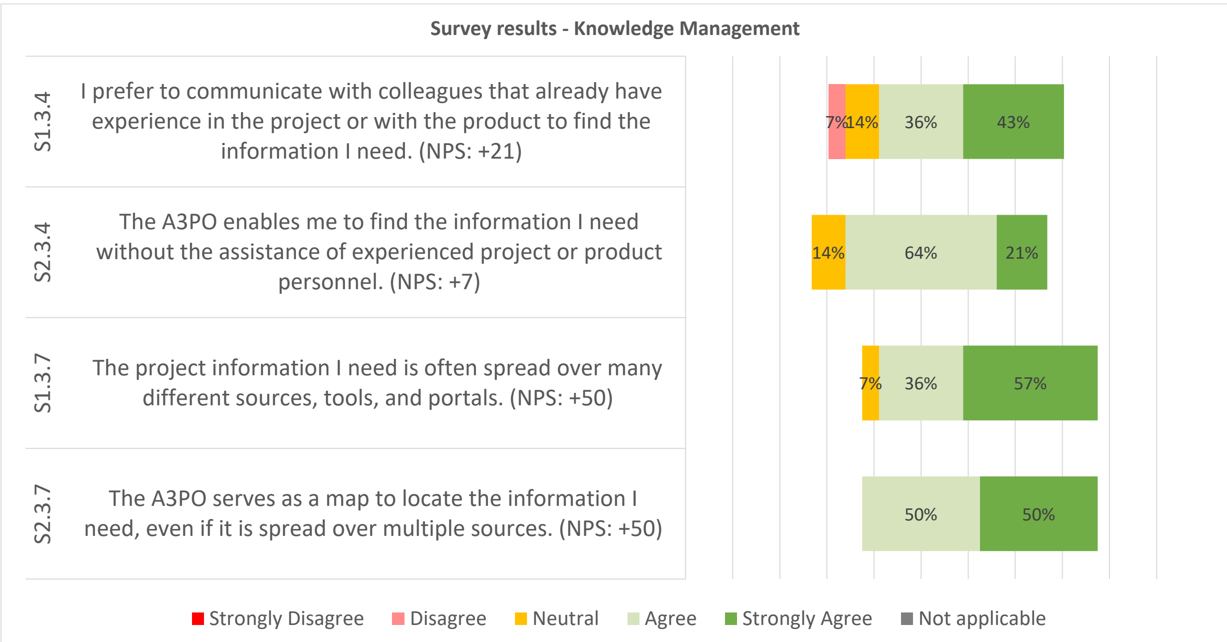


Figure 9 - Survey results “Knowledge Management” Part 2

Software upgrade process survey results.

Figure 10 - Survey Results "Process for Software Upgrade Projects"

Working with A3POs survey results.

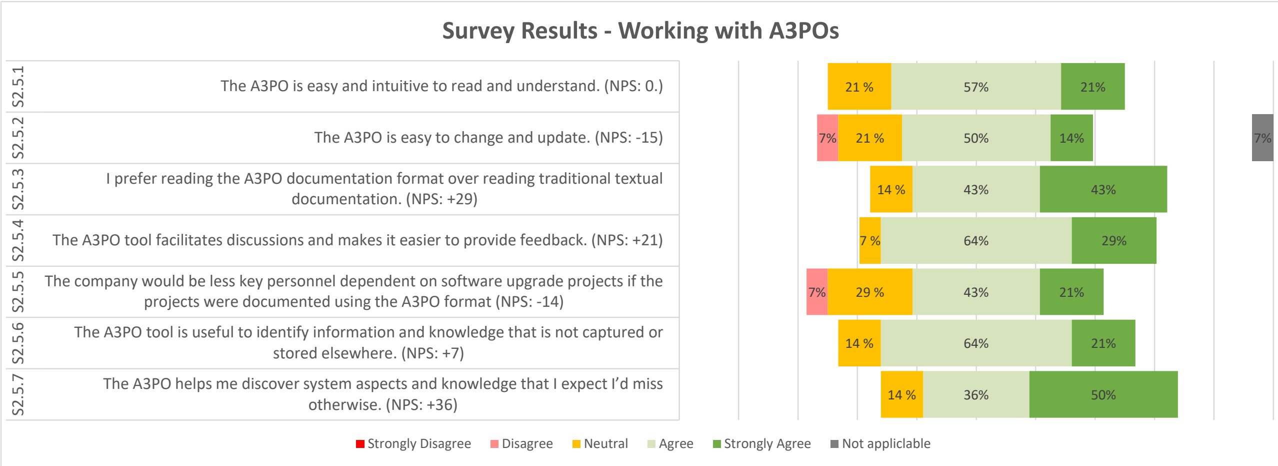


Figure 11 - Survey Results "Working with A3POs"

Validating the requirements.

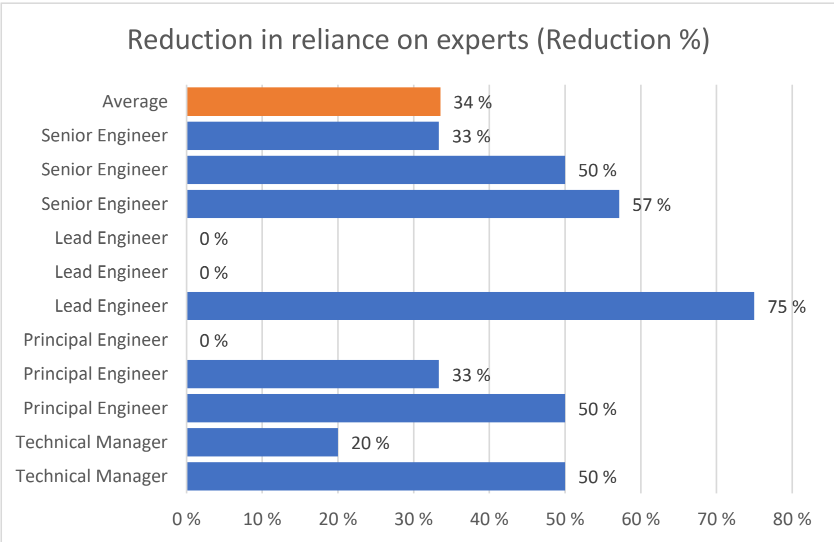


Figure 11 - Reduction in reliance on experts

Topic	ID	Question	1	2	3	4	5	6	7	8	9	10	NA
Artifact Maintenance Effort Score	S1.5.1	Please rate your experienced effort to revise or update a text document (procedure, function description etc).		3	6		1		2	2			
	S1.5.2	Please rate your experienced effort to revise or update a Check list.	1	2	3	2	2		2		1		1
	S1.5.3	Please rate your experienced effort to revise or update a web page.			1		2	2		2		3	4
	S1.5.6	Please rate your experienced effort to revise or update a drawing (i.e AutoCad / Engineering Base)	2				1	3	1	2		1	4
A3PO	S2.6.3	How would you rate the Maintenance effort of the A3PO tool?	1	2	4	4	2			1			

Figure 12 - Artifact Maintenance Effort Responses

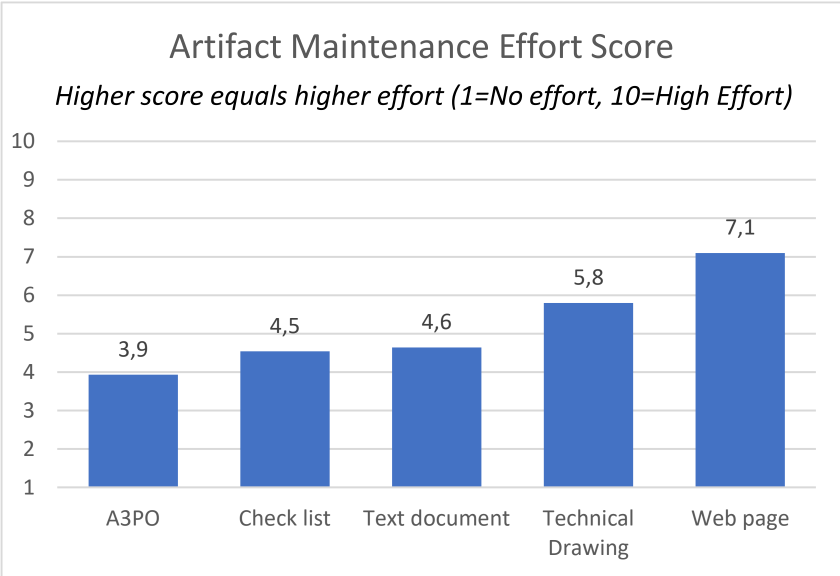


Figure 13 – Artifact Maintenance Effort Scores

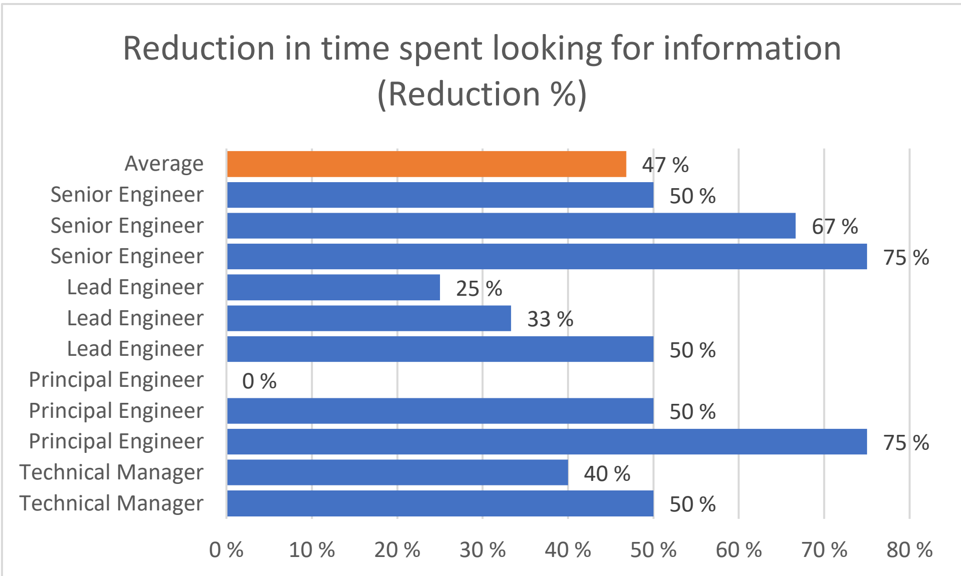
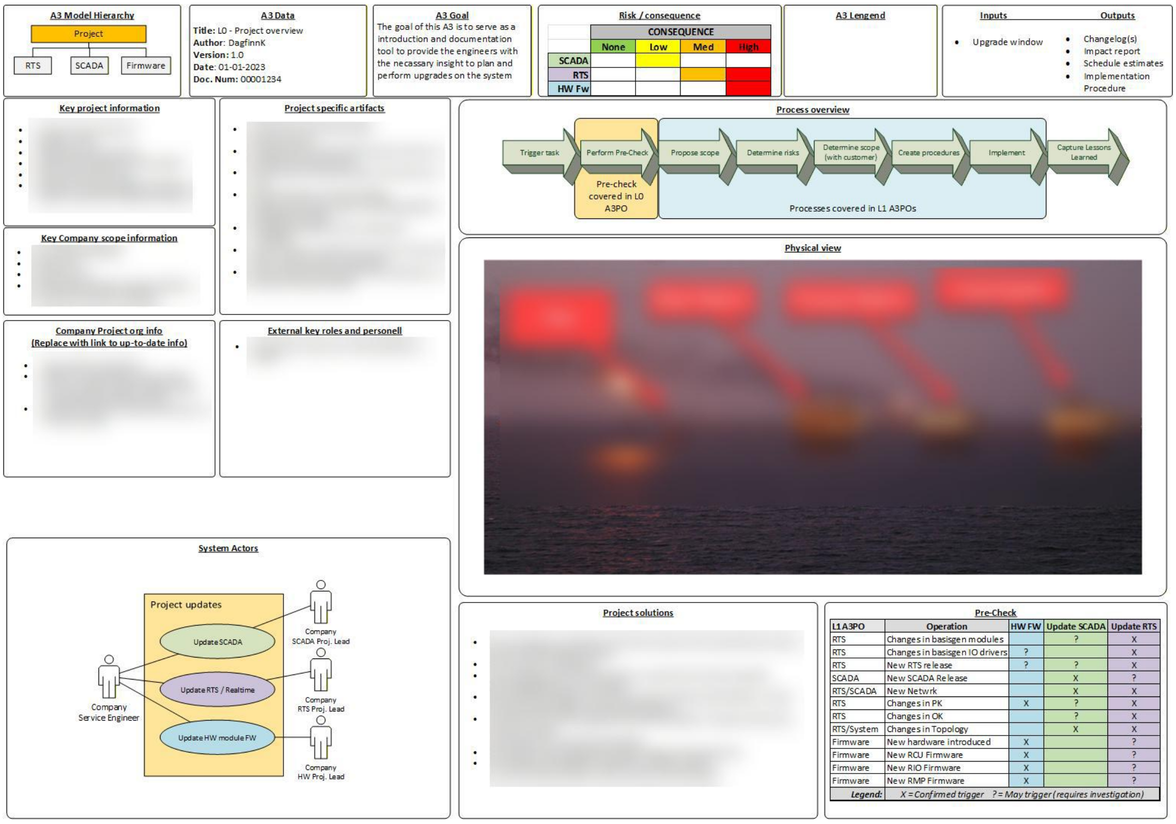


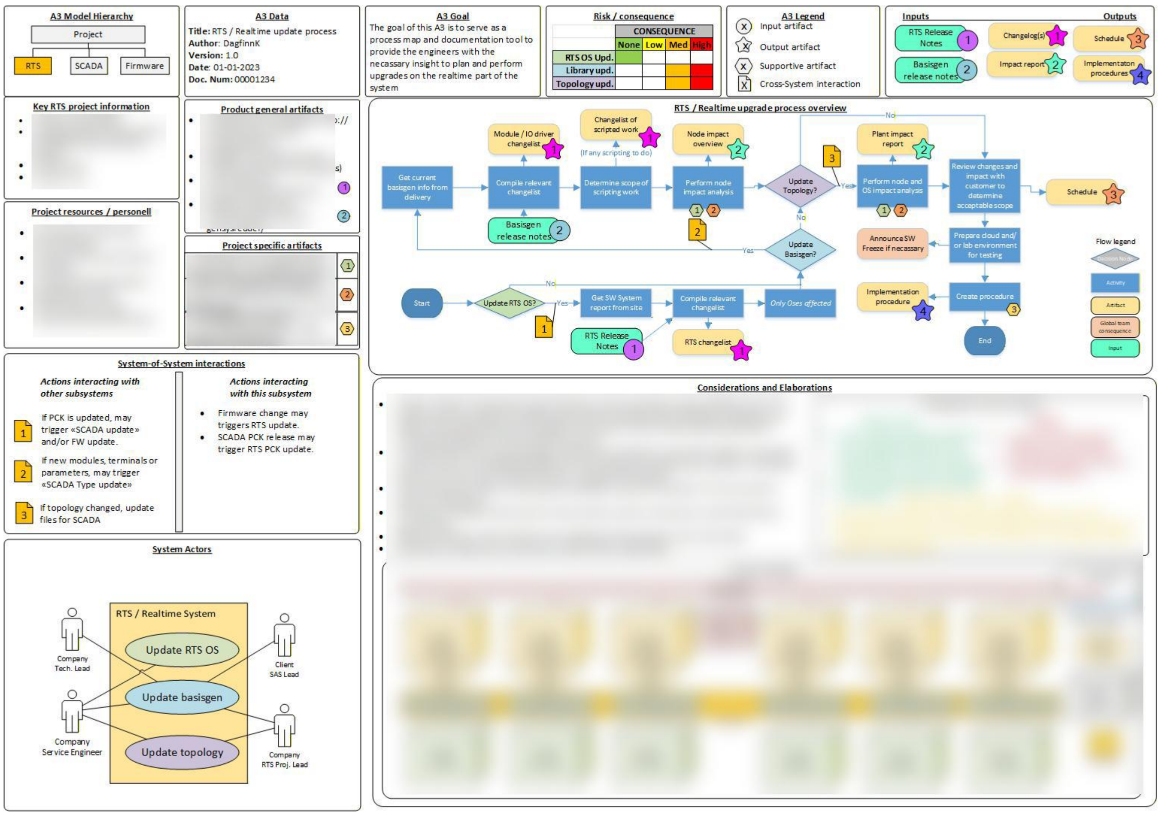
Figure 14 - Reduction in time spent looking for information

Appendix C – A3PO Examples

L0 A3PO example



L1 A3PO example 1



L1 A3PO example 2