Online appendix

Exploring and characterizing Ad-hoc Requirements - A case study at a large-scale systems provider

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Introduction. This online appendix contains additional data related to our paper. These data shall provide more transparency about our research setup including used material. Based on data confidentiality we can't share the analyzed data. We provide this appendix to enable other researchers to replicate our study or parts of our research in a different setup.
This document is not intended for top-down reading and the table of content shall guide the interested reader to areas of interest.

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1 Intralogistics

1.1 Intralogistics introduction

Intralogistics is a sub-domain of logistics. Business processes, tasks, material flow and data flow in intralogistics focuses on what is happening within the boundaries of a warehouse. In some cases, aspects of adjacent contexts related to shipping, yard management or customs are covered as well.

Archetypal for intraLogistics Automation Solutions (LAS) is the high number of configurations and individualizations. This is caused by the diversity of the customer business segments, country specific regulations, articles, and surrounding Information Technology (IT) systems. The same system components can be orchestrated for warehouses in (1) business segments like grocery, food production, fashion, electronic spare parts, car production supply, and health care. They can be used for system setups (2) located worldwide where legal regulations vary, like those related to data privacy and work environments. These system setups (3) handle articles of different sizes, weights, and handling sensibility like egg stages, electronic resistors, furniture parts, water bottles, frozen pizza, and car tires, and (4) can be connected to different industry software systems, like Enterprise Resource Planning systems (ERP) to support data interchange and connected workflows along the supply chain.

LAS sub-systems are industry robots, storage and retrieval systems, transport systems, different type of software including Warehouse Management Systems (WMS), and mechanic control software.

1.2 Software tools used in RE in by WMS provider

We conducted in 2016 a survey study on RE at WMS providers with 18 participants from different companies. Beside pure software providers also 5 LAS providers participated in this survey. We identified a diverse landscape of Software tools used in RE (see Fig. 1), like the one we found in our case company during the AhR reserach. (See Master Thesis [2]).

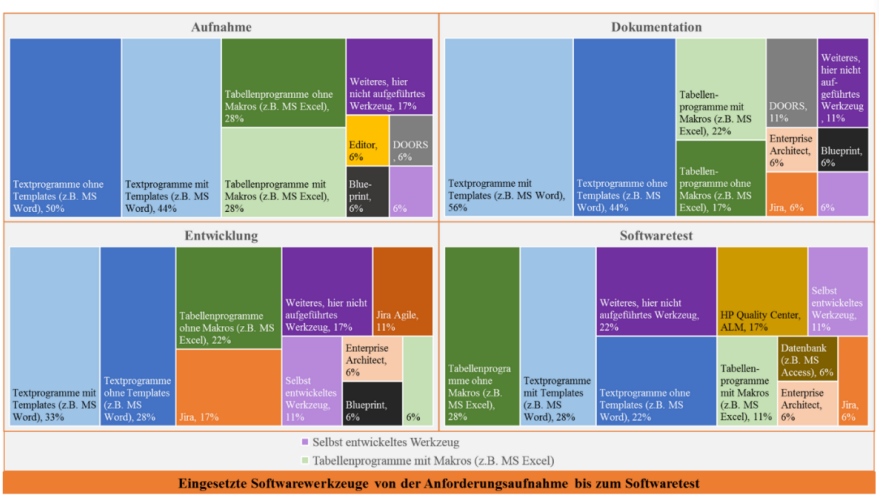


Fig. 1. Software tools used in RE (elicitation, documentation, development, and test) by WMS provider. Image is taken from our survey study [2].

2 Simplified RE process model and involved population groups.

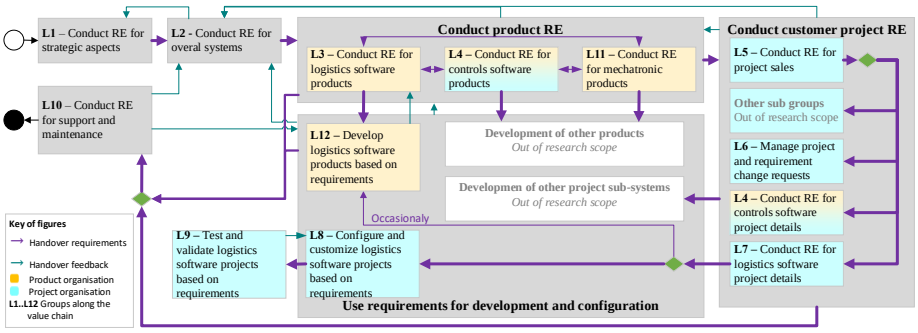


Fig. 2. Simplified RE process overview at the case company and typical for LAS provider.

We deducted from reviewed Requirements Engineering (RE) related processes 12 organizational levels along the value chain at the case company that also allow comparability with other LASs providers. Fig. 2 illustrates the simplified RE process, indicating the focus on RE or development related activities per level. The process in Fig. 2 illustrates a multistage requirement engineering process in a LAS system, sub-system context. With a current focus on software sub-systems, we excluded detail process information related to non-software sub-system requirements handling to reduce complexity. Anyhow sub-system alignment and dependencies can be addressed on a high level with this simplified process model.

3 Population

Presuming that there might be (i) level related deviations and (ii) dependencies between requirements on different levels (see Fig. 2) we wanted to ensure that a split of research data and results per level is possible.

Each group L1-L12 is a consolidation of employees with similar responsibility related to RE and development activities. The members of each group can hold different roles and can be assigned to different departments. This is a simplified model providing an overview, it is not intended to fully illustrate the case company roles. Table 1 provides RE related details per group.

Table 1. Simplified overview of assigned or perceived RE responsible groups.

Group	Focus
L1- Strategy	Involved in definition of strategic direction and strategic requirements. Requirements can be related to market demands and future trends.
L2- System	Involved in requirements refinement, breakdown, and definition for overall LAS concepts. Requirements can be related to overall LAS concepts and first sub-system requirements.
L3 - SW product RE	Responsible to refine, breakdown, or define requirements for the logistics software product including WMS functionality. Requirements define the WMS product base line. They include functional and quality requirements as well as constraints. Like interface, configuration, cyber security, and logistics process requirements.
L4 - Controls	Responsible to refine, breakdown, or define requirements for mechatronic controlling software. Requirements address control software for all mechatronic systems. They include functional and quality requirements as well as constraints. Like safety, interface, configuration, cyber security, and material flow requirements.
L5 - Sales	Involved in the overall sales process of LAS. Requirements address LAS requirements from the perspective of individual customer projects. They include functional and quality requirements as well as constraints. Like logistics process, material flow, sub-system selection, surrounding IT-ecosystem and mechatronic ecosystem. The RE process here included COTS-RE.
L6 - Project management	Involved in different project management tasks and primary contact for customers in sold projects. RE is here mainly related to change requests RE processes of different detail level addressing logistics process, material flow, mechatronic sub-system, WMS, and controls software requirements.
L7- SW projects RE	Responsible for WMS software requirement refinement, breakdown, and definition in projects and partially involved as sales support. Requirements provided are related to the WMS software and address functional and quality requirements, as well as constraints. Like logistics process, user, interface, configuration, cyber security, configuration, and customization requirements. The RE process here included COTS-RE.
S8- Project SW Developer	Responsible for software design, architecture, and software development tasks. This group is responsible to orchestrate the WMS as a project sub-system setup based on provided requirements.
S9- Project SW Tester	Responsible for software test and other quality assurance tasks. This group is responsible to setup and conduct tests based on provided requirements and software from project.
S10 -	Responsible for (software) support and maintenance tasks. Requirements provided and used by this group are mainly related to issue fixing, updates, and

Support and maintenance	system migration. Within this context they address functional and quality requirements, as well as constraints. Like logistics process, user, interface, cyber security, system migration, and customization requirements.
S11- Mechanical Engineering	Responsible for mechatronic engineering tasks. This group refines, breakdown, and defines mechatronic requirements and is involved in development of mechatronic sub-systems. *A further split of this group in RE and development is possible in the future.*
S12- Product SW development	Responsible for software design, architecture, and software development tasks. This group is responsible to develop and maintain the WMS software baseline by using provided requirements.

Fig. 3 represents the RE population and the split to the different samples and involved employees per research phase.

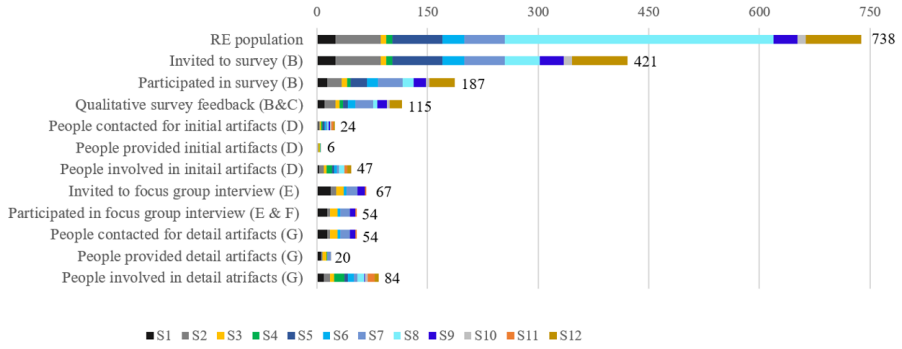


Fig. 3. Population, sample and involved employees per research phase.

4 Survey questionnaire and focus group interview guideline

4.1 **Survey questionnaire extract** (Research phase B and C)

The survey is used to empirically research challenges in requirements engineering. We carefully checked the NaPiRE [1] survey for reuse in our context with the intention to cross-reference between results. Finally, we identified the need for deviating categories, questions, and answers. This was based on our intention to use (i) terminology adaptation to non-software communities, and (ii) to include potential issues as named in the LAS and WMS community, and (iii) to have a stronger differentiation between *experienced* and *experienced as challenge*.

Survey parts used in the AhR-paper are those related to the questions 10.4 in Fig. 4, 8.2 in Fig. 5, and 15 and 16 in Fig. 6.

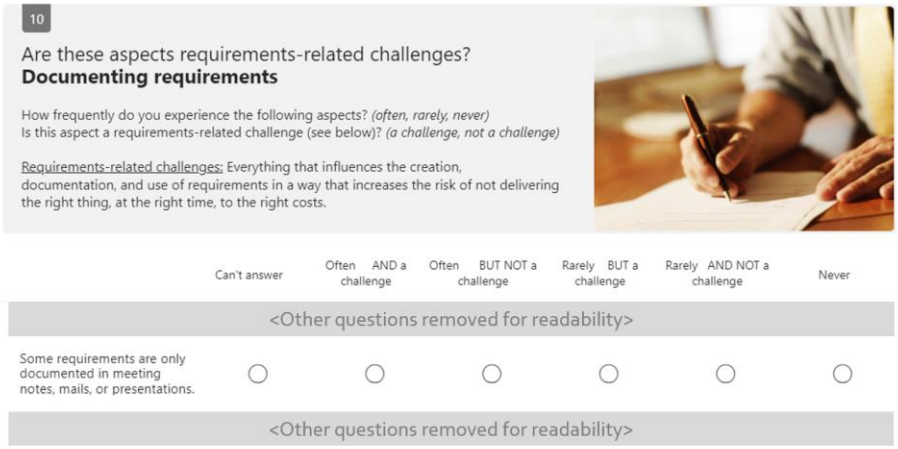


Fig. 4. Question 10.4 from our survey in research phase B (we removed the other questions)

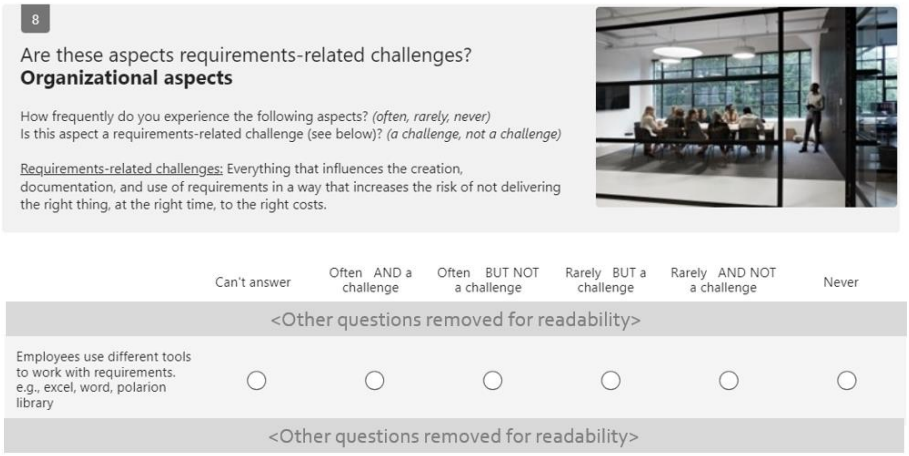


Fig. 5. Question 8.2 from our survey in research phase B (we removed the other questions)

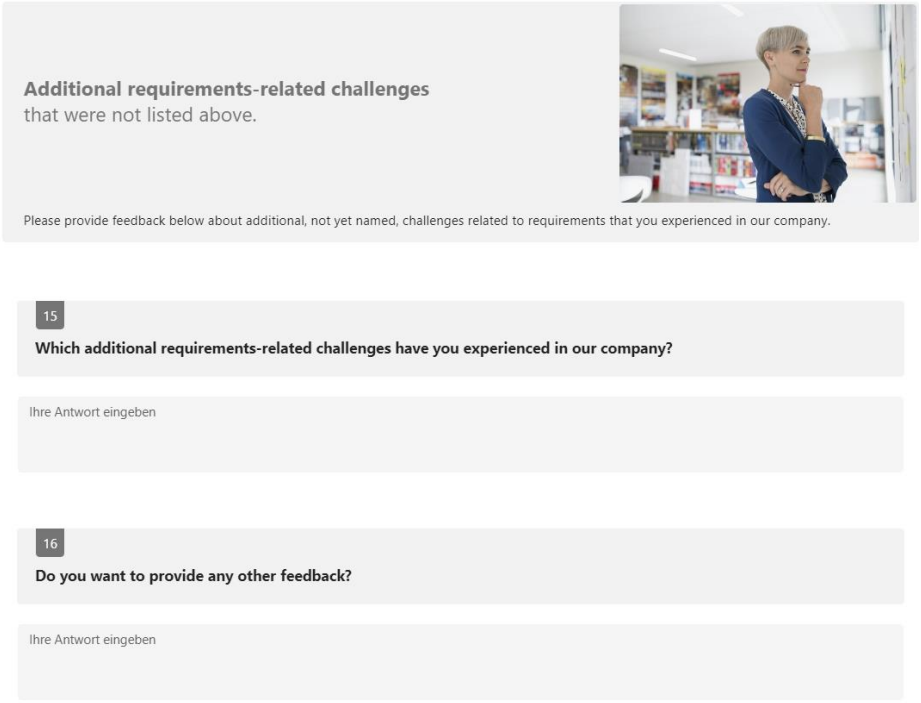


Fig. 6. Questions 15 and 16 from our survey in research phase B and used in research phase C – The work instruction adjust to the users' language setup.

4.2 **Focus group interview guide** (Research phase E and F)

The focus group interviews were used to (1) validate findings from the survey research and to (2) explore ad-hoc requirements in more detail. We provide here the full interview guide even though only selected aspects are used in the AhR paper.
As participants from L1-L12 were invited to the interviews small deviations in terminology as related to domain knowledge were considered. We decided on a semi-structured interview guide, to leave freedom for small adaptations like talking about either "software requirements" or "system requirements", as well as by rephrasing the questions if needed to support understandability. The language and terminology are adjusted to industry participants.
We used time markers (visible in blue) in the interview guide as orientation for timeboxes and to ensure that all questions could be addressed in the interview time of 2 hours. Annotation in grey were used as help for the interviewer and the note taker, the impulses were used in case the participants required support to answer.

For question 6 we showed during the interview a list of top challenges based on the survey (Sect. 4.1) feedback.

The example for AhR shared in question 8 were based on the initial provided artifacts in research phase D.

Beside 2 interviews all interviews were done remote, the face-to-face interviews used a video conference room setup that supported recording.

Focus group interview – Requirements related challenges.

Date:
Reference group:
Participants:
-
-
Start: 13:30
----------Interview questions----------
Introduction
Start recording

1. We understand a requirement as something demanded, needed, or wanted. Is there anything in your daily job that fits as a requirement?
   (max. 10 min – 13:40)
   Intention: Clarify understanding
   Add your notes here:

Process

2. Could you share your typical activities at <company name> for identifying and handling requirements?
   (max. 20 min – 14:00)
   Impulses: Tasks, communication, and handover
   Protocol: In text or as short activity diagram
   Protocol: Possible that question 3 and 4 are answered
   Add your notes here:
3. Which sources do you have as input for requirements?
   (max. 8 min – 14:08)
   Impulses: Creating, people, documents, videos, market analysis, etc.
   Protocol: Bullet points; Visualization
   Add your notes here:
4. Who comes to your mind, thinking of groups and people using or relying on requirements provided by you?
   (max. 8 min – 14:16)
   Protocol: Bullet points; Visualization
   Add your notes here:
5. How do you handover requirements related information to others?
   (max. 10 min – 14:26)
   Impulses: Text, conversation, image, tool, structure, meeting notes, …
   Protocol: Bullet points
   Add your notes here:

Challenges

6. We collected requirements related challenges at <company>. Have a look to the following challenges. Choose 1 to 2 challenges that resonates with you the most and share your personal experiences linked to it.

(max. 14 min – 14:40)
Protocol: List the selected topic and document in bullet points.
Preparation: Prepare slide with top RE challenges of the related group based on the survey data.
Add your notes here:

7. (Optional) Are there any topics in the list, that you rate as not relevant or critical related to requirements?
(if time – 14:40)
Protocol: Document in bullet points
Add your notes here:

Ah-hoc requirements

8. "Ad-hoc" requirements might be notion of requirements as in meeting notes, emails, or power point presentation. Could you share your experiences with ad-hoc requirements?
(max. 20 min – 15:00)
Show a few example (example: side note in PowerPoint, meeting note, requirement refinement)
Protocol: Bullet points
Protocol: Possible that 9 and 10 are answered
9. Could you share examples of tool and document types where you saw or used ad-hoc requirements?
(max. 10 min – 15:10)
Impulses: e-mails, Power Point, Teams, …
Protocol: Bullet points
10. 10. What are your reasons for "ad-hoc" documentation of requirements?
(max. 15 min – 15:25)
Protocol: Bullet points

Closing

(max. 5 min – 15:30)
Thank you!
Request to send ad-hoc requirement examples from their daily work.

5 Coode book

We created and refined in multiple phases the finally used code book. Started with (i) inductive coding, we (ii) conceptualized the findings and refined the code book, and (ii) used hybrid coding for the extended analysis in research phase G, we carefully checked if additional codes were really needed before adding them in the last phase.

Find below the finally used code book and its linking to our research questions. We present here collection of code as arranged images for reasonable space use, based on the code book in MAXQDA. Fig. 7 , Fig. 8, and Fig. 10 illustrate codes that were used to answer RQ1 and to address the characteristics of AhR.

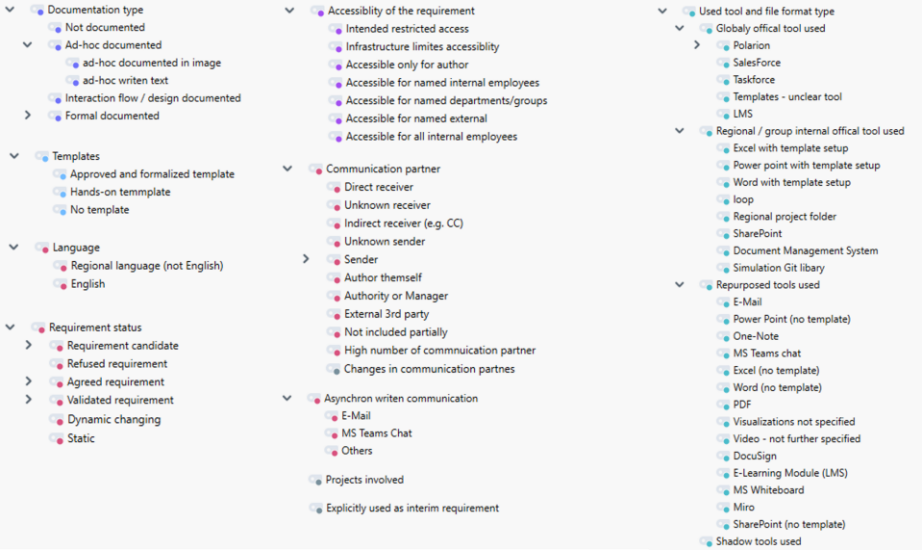


Fig. 7. Codes used mainly for RQ1 – What are the characteristics of AhR?

For research RQ2 reasons for AhR we used the code group on the right in Fig. 8.

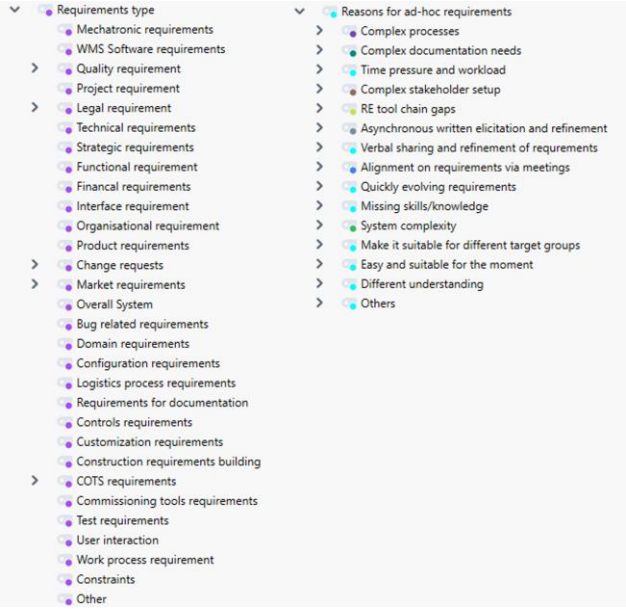


Fig. 8. Codes used in multiple research questions.

For RQ3 information covered in AhR we used codes and information as requirements types in Fig. 8, included sub-artifacts as in used file formats Fig. 7 and in Fig.

10, and for the identification of multiple projects we used the code about involved projects in Fig. 7.

6 Data and artifacts

Based on confidentiality reasons we can't share the data and artifacts used in this research. Anyhow we will provide additional information including examples and structural overviews created during the analysis. All data and artifacts were shared voluntary.

6.1 Survey feedback

We started exploring the context based on the quantitative data provided in the survey (research phase C). Answers to the question #15 and #16 (see 4.1) were coded with a fully manual, hybrid, iterative approach. 70% of the survey participants provided in total 193 responses. Fig. 9 visualizes the feedback length measured in characters and shows that partially extensive feedback was provide. This feedback included challenges and context descriptions from which 30 segments from 29 participants were coded to one of the AhR related codes.

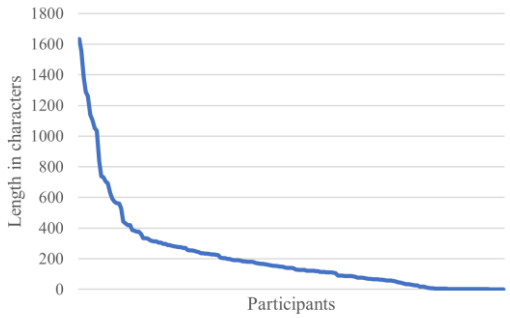


Fig. 9. Survey feedback length in characters. A standard DINA4 page has 1800 characters.

6.2 Artifacts

Fig. 10 illustrates an overview of the provided and analyzed artifacts. As the figures in the paper indicate, not all artifacts included AhR or even requirements. We analyzed in total 99 artifacts with 631 included or linked sub-artifacts. The involved parties were allowed to anonymize or remove (with indication) information in the artifacts before sharing, this provided confidence in sharing private notes for the analysis.

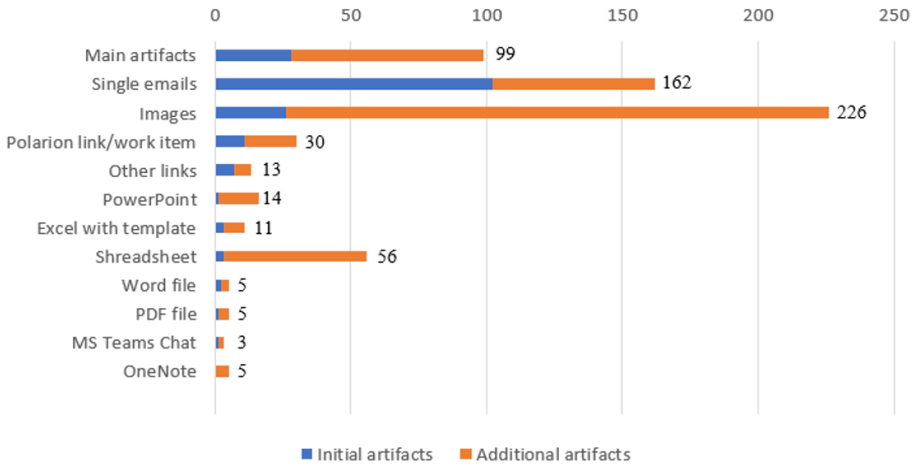


Fig. 10. Overview of provided artifacts used in research phase D (initial) and G (all).

6.3 Communication partner

Fig. 11 illustrates the number of communication partner per group involved in the artifacts. In most of the cases a bidirectional communication was used in e-mail or Polarion as illustrated by an extract from a communication diagram based on an e-mail requirements refinement process in Fig. 12. Sie communication and branching of communication tool also place in the example but is not presented in the extract.

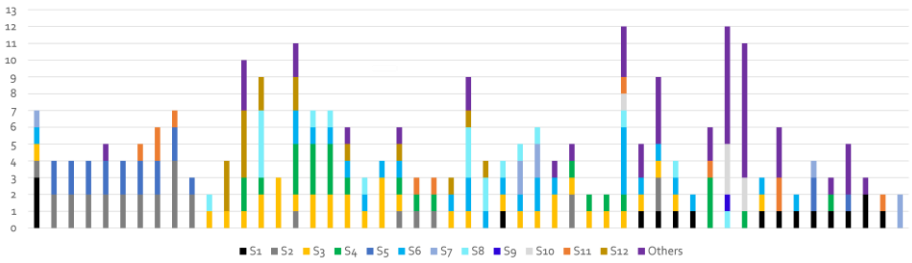


Fig. 11. Communication partner involved in artifacts (only if more than 1 was named)

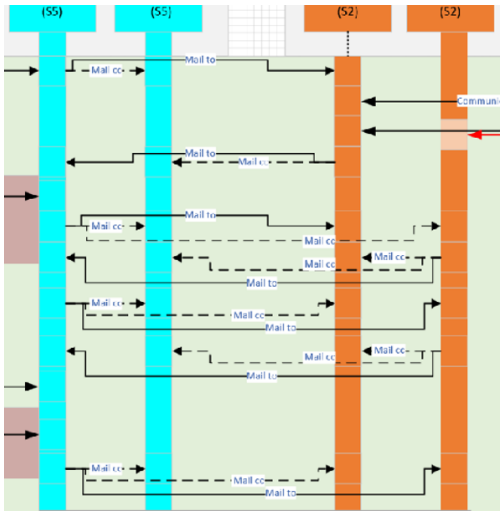


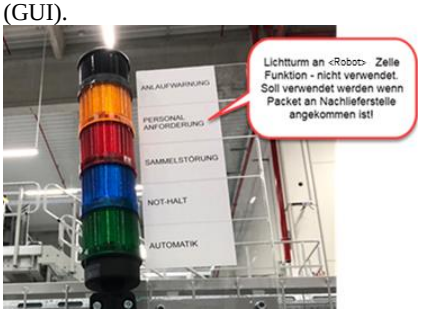
Fig. 12. Extract from a communication flow based on RE refinement via e-mail (each line in blue / orange represents one employee).

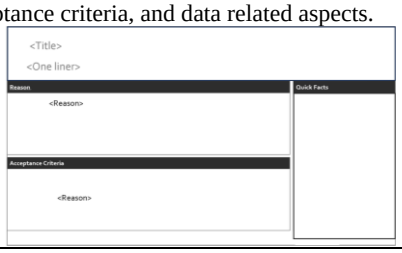
7 Example of evidence

As we can't share the data and all coded segments, we provide a few example in Table 2 that we used as evidence for our findings.

Table 2. Example of evidence based on the artifact analysis

Finding	Example of evidence
Sometimes emails are used to store requirements.	Examples from different emails: "[…] the other 5 cells will require that conveyor loop for presetting empty target bins and take away the fulfilled order bins." "After the workstation enabled the TuType, it can work on orders of that TuType."
Sometimes emails are used to communicate requirements.	Emails containing requirements in the body or as attachment including (inline images). "Enclosed the specification: <Polarion ID>" "[…] we would need an additional button on the <GUI> requesting the <equipment> to move to the service position after <event>."
Sometimes participants change in written requirement related communication.	The identified changes are related to: (1) Adding participants, (2) removing participants, (3) branch communication for side discussions, and (4) changes between direct and secondary recipients. "I added <name> to this."
Sometimes emails are used to elicit or refine	Example from one long-time email conversation between participants from different continents.

requirements in an asynchronous dialog.	"I would like to confirm that the TU size is <l,w,h> mm at the picking station. The cartons will be cut down to size (<l,w,h> mm) automatically at the carton closing machine. We need to check that. Do we have fragile items. With pick and drop we also let the items drop around <x> mm."
Sometimes ideation and discussion take place on design information and not on requirements in the written communication.	"We need to understand the layout by your explanation. I assume that the carton presentations are bi-directional? […] I'd like to confirm that for both sites the conveyors are bi-direction, […]"
Sometimes work in progress requirements are shared with other groups in static deliverables.	"[…] here the specification for the new concept of the <topic>. In the attachment you will find a PDF-Version […] [the] document is a living document […]."
Some natural language requirements are written in an ad-hoc manner.	"Is it required that an operator is logged in at the workstation before work can be assigned to a workstation?" "- QR Codes - Damaged item handling" "improve <warehouse area> picking speed → this topic can't be completely fixed on software side. […]"
Ad-hoc phrased natural language requirements are sometimes embedded in images.	Images like layout, mechatronic, or graphical user interfaces (GUI).  [Translation: "Light tower at <Robot> cell function – not used. Shall be used if package arrived at replenishment."]
Sometimes work in progress requirements are shared with other groups in dynamic deliverables.	"I will send you […] the link to the live document in <Polarion ID>. For the <group> topics the live document […] will not stay the same and might change."
Requirements are sometimes stored in repurposed tools and file formats.	The artifacts contained e-mails, the artifacts, Excel, PowerPoint, MS Teams, Word, and other example. Translation: "Ideation collection from Teams Chat"
Local non-English languages are sometimes used for written requirements and requirements discussions.	„I switch to English as I added <name> to this." "Vi måste hitta ett sätt att kalla samma element med samma namn." (Alignement of element naming). „Sequenzierung gemäß Gruppe" (group sequencing).

Sometimes emails are used to store requirements interim.	We only coded examples that made the interim state explicit or indicated a transition. “I’ve moved the long email threads into this work item <Polarion ID> […].”
Requirements and requirements artifacts are sometimes not fully accessible.	“unfortunaly we do not have any software that we can use to export <file type>” “the files are to big to open”
Sometimes best-practice requirements templates are provided and used in office tools.	Requirement templates in Excel used. Requirement template in power point addressing reason, acceptance criteria, and data related aspects. 
Sometimes requirements for different projects are discussed in the same written communication flow.	“For the files, I have now saved [...] for both <project A> and <project B> […]”
MS Teams Chats are used to elicit or refine requirements in an asynchronous dialog.	Translation of a non-English example in a local langue related to a monitoring GUI. „maybe it must be stored in the equipment table to which category and origin they belong? Without this entry there will be no […].”

Literatur

1. Mendez D, Wagner S, Kallinowski M, Felderer M, et al. (2018) NaPiRE. Naming the Pain in Requirements Engineering
2. Wohlgemuth A (2017) Optimierungspotentiale des Requirements Engineerings für Anbieter von Warehouse Management Systemen. Eine qualitative und quantitative Untersuchung der Aufnahme und Dokumentation von Anforderungen an Warehouse Management Systeme; Master Thesis; accessible at www.re.andrea-wohlgemuth.de