Appendix - Embrace Ad-hoc Requirements - A characterization based on a multi-method industry (case) study

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Abstract

This online appendix contains additional data related to our paper. These data provide more transparency about our research setup, including the materials used. Due to data confidentiality constraints, we are unable to share the analyzed data. We provide this appendix to enable other researchers to replicate our study or specific parts of it. This data collection is specific for the paper Embrace Ad-hoc Requirements and contains data used in previous publications or appendix provided by us.

This document is not intended for top-down reading; the table of contents shall guide the interested reader to areas of interest.

Contents

1 Intralogistics

Disclaimer: *This text was first used in our online appendix about ad-hoc requirements at REFSQ'25.*

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 types of software, including Warehouse Management Systems (WMS), and mechanical control software.

2 LAS population

Disclaimer: *This text was first used in our online appendix about unequal pains submitted to REFSQ'26.*

We did not found reports, or publications on the global RE population at LAS providers. However, we believe that a reflection on this population is useful to understand what would be needed for representative samples.

We used an extrapolation from three perspectives: 1) Review and classification of exhibitor directories from international logistics fairs; 2) workforce analysis based on annual reports of the top-level LAS providers, and market

Company/Group	**Employees**
KION Group (incl. Dematic)	>42.000
Honeywell Intelligrated	>39.000
Jungheinrich	>21.000
Körber	>13.000
Daifuku	>11.000
Fives Intralogistics	>9.200
SSI Schäfer	>8.600
Beumer Group	>5.600
Murat Machinery	>8.500
KNAPP AG	>8.300
Toyota Industries Corporation (incl. Vanderlande)	>6.500
TGW Logistics Group	>4.500
Swisslog	>3.000
Kardex Group	>2.700
Sum all	>182.900
Estimate RE & Dev	>40.238

Table 1: Date included in the extrapolation of LAS RE & DEV population.

reports; and 3) the assumption that the formally assigned RE responsible and development employees will be $\geq 22\%$, which is the ratio from the case company Z.

Disclamer: Criteria 3 adds a bias. At this point in time it is the best information we have about the distribution.

We reviewed the exibitor lists from ProMAT USA'23, LogiMAT GER'24, MODEX USA'24, CEMAT GER'24, and CEMAT SEA'24. For the paper on *Unequal RE Pains* and we only focus on those global top LAS providers running projects at least in Germany, Austria, or Switzerland (DACH region), and having more than 2.000 employees. This leads to a conservative estimate of at least 40.238 RE and development employees as LAS RE population.

3 Survey B

Disclaimer: *This text was first used in our online appendix about unequal pains submitted to REFSQ'26.*

For survey B we used two versions: B_1 at company Z and B_2 for other LAS providers. As survey B_1 includes the name of the company we provide for confidentality reasons only a copy of survey B_2. The survey is also available as LimeSurvey template (temporary see https://www.andrea-wohlgemuth.de) in English, German, and French.

3.1 Sampling and invite for B_2

For survey B_2, we purposively selected events where a high number of LAS providers is expected and identified exhibition halls with the highest likelihood of meeting LAS providers with more than 2.000 employees and at least one project in the DACH region (LogiMAT GER'24, Zukunftskongress Logistik'23 and '24). Here, we provided a German and English survey invite to participants and to the booth staff and asked for internal sharing (snowball sampling). Additionally, we used professional LAS communities (Fraunhofer IML's Participants Meeting Warehouse Logsitics'23 and '24, working groups of the European material handling federation in 2024) and the personal network to share the same invite only with people from the LAS community. We used the personal conversation to advertise our broker approach.

70% of the survey participants provided in total 193 responses to the last open questions in the survey (B_1). Fig. 4 visualizes the feedback length measured in characters and shows that partially extensive feedback was provide. This feedback included challenges and context descriptions from which we code feedback related to the individual challenges.

3.2 Differences in the matrix question B_1 and B_2

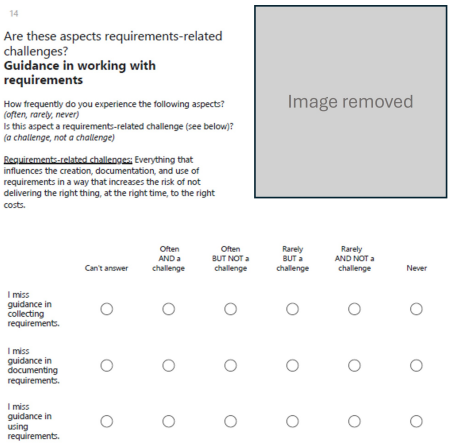

Figure 1: Excample from B_1 matrix question with combined answer options.

*

Guidance in working with requirements

Are these aspects requirements-related challenges?

Remarks:

- ***How frequently do you experience the following aspects? (often, rarely, never)***
- ***Is this aspect a requirements-related challenge (see below)? (a challenge, not a challenge)***

Requirements-related challenges: Everything that influences the creation, documentation, and use of requirements in a way that increases the risk of not delivering the right thing, at the right time, to the right costs.

	How frequently?			Requirements-related challenge?		
	Often	Rarely	Never	Challenge	Not a challenge	Can't answer
I miss guidance in collecting requirements.	○	○	○	○	○	○
I miss guidance in documenting requirements.	○	○	○	○	○	○
I miss guidance in using requirements.	○	○	○	○	○	○

Figure 2: Excample from B_2 dual matrix question.

We reported in the paper on differences in the representation between the answer options for frequency and if experienced as a challenge between B_1 and B_2. Fig 1 and Fig. 2 illustrate the differences by one example.

3.3 Broker approach for survey B_2

We introduced a broker approach to include other LAS providers. This was done based on the small structure of the LAS domain, where people strongly connect and to avoid that any conclusion on the participating companies was possible. We selected Fraunhofer IESE as trustworthy broker. The approach is illustrated in Fig. 3, this image was (beside small adjustments on the founder) shared during the invite for survey B_2 with potential participants.

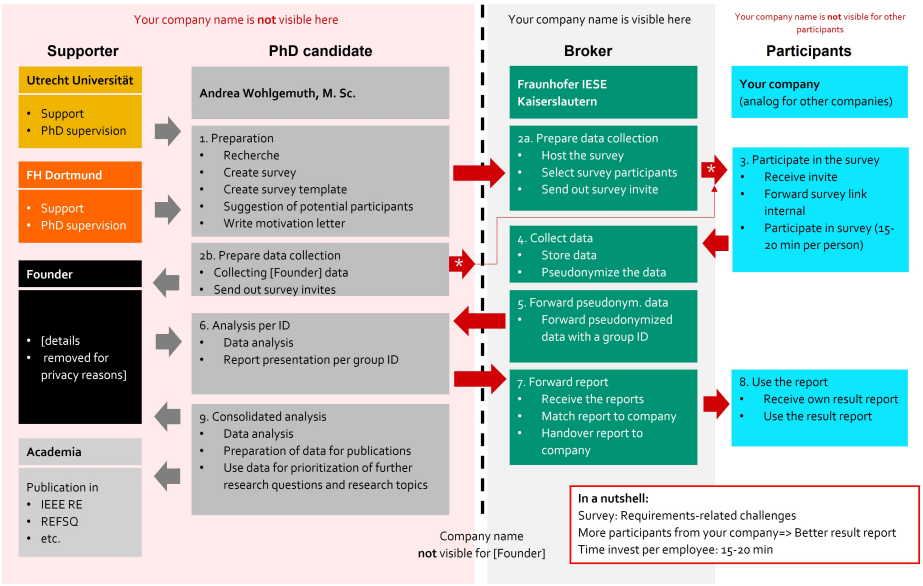

Figure 3: Concept of pseudonymity in our survey b_2 by a broker approach.

3.4 Feedback length in the survey B_2

The length of the free-text feedback provided in B_1 is presented in Fig. 4.

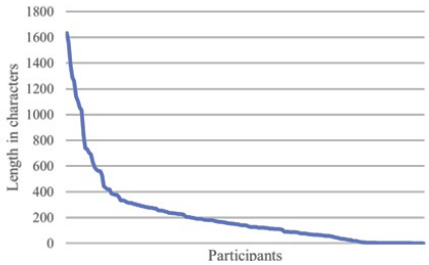

Figure 4: Survey feedback length in characters. A standard DINA4 page has 1800 charachters.

3.5 Questionaire B_2:

We list below the questionnaire without formatting. A LimeSurvey Template (temporary at https://www.andrea-wohlgemuth.de).

3.5.1 Survey - Definition of requirement

Definition of requirement - A requirement is something demanded, needed, or wanted.

Depending on your role in your company, you may hear or use words different from "requirement." You may use market demand or vision if your position is in strategy, portfolio, or product management. In product development or projects, you might call them specification, function, item, enhancement, change order, user story, or customer demand.

Requirements may be presented in different ways. A requirement can range from a full-page explanation to only a one-sentence statement. Requirements might focus on an entire solution, a single screw, or a single button in a graphical user interface. Although requirements vary, they define what your company shall deliver.

Which terms do you use for "requirements" not listed here?

[Free-text]

3.5.2 Survey - Demographic information - work-related data

Please provide some information about you and your work-related background.

What is the name of the company you currently work for?

Remarks: The company name is only visible for <BROKER NAME> as a broker.

In the scenario of multiple regional subsidiaries operating under the same label and interacting like one company, select the name that best represents the whole company. (e.g., A GmbH, A AG, A b.v. write A)

[Free-text]

How many employees are working in your company?

Remark:The overall number of employees is used in the case of multiple regional subsidiaries working under the same label and interacting like one company.

[Less than 50]

[50 to 399]

[400-999]

[1.000-5.000]

[More than 5.000]

What type of intralogistics company fits best to your company?

[Full solution provider (mechatronic + software like WCS, WMS, WES)]

[Storage and material flow equipment provider (mechatronic)]

[Storage and material flow equipment provider (mechatronic AND controls software)]

[Software provider]

[Not a company with an intralogistics focus]

In which continent are you located?

[Asia]

[Australia]

[Africa]

[Europe]

[North America]

[South America]

To which of the following organizational groups do you belong?

Remark: Select the most suitable group from the list based on your work experience, as organizational structures vary per company. Strategy, innovation, or portfolio management - You focus on future setups.

[Solution, product management, or Research and Development - You focus on the design of multicomponent]

[solutions (mechatronic and software)]

[Software products - You focus on the design and architecture of software products.]

[Controls products - You focus on the design and architecture of control software for mechatronic systems.]

[Sales (non-Software) - You focus on selling solutions mechatronic solutions and software as a total package.]

[Software project - You focus on refining and selling software details with the customer this might be done by supporting your non-software sales colleagues]

[Controls project - You focus on refining control details with the customer.]

[Project Manager - You focus on managing customer projects.]

[Software Developer - You focus on developing or customizing software.]

[Software Tester - You focus on testing software or software customization.]

[Software Support - You focus on support and maintenance for software and controls.]

How many years of work experience do you have in ...?

Logistics [none],[<1],[1-2],[3-5],[6-10],[11-15],[>15] years

Your company [none],[<1],[1-2],[3-5],[6-10],[11-15],[>15] years

Software [none],[<1],[1-2],[3-5],[6-10],[11-15],[>15] years

Mechatronic [none],[<1],[1-2],[3-5],[6-10],[11-15],[>15] years

Collect requirements [none],[<1],[1-2],[3-5],[6-10],[11-15],[>15] years

Document requirements [none],[<1],[1-2],[3-5],[6-10],[11-15],[>15] years

Review requirements [none],[<1],[1-2],[3-5],[6-10],[11-15],[>15] years

How confident do you feel about your knowledge to ...?

Collect requirements [0 Not at all],[1],[2],[3 Extremely],[Can't answer]

Document requirements [0 Not at all],[1],[2],[3 Extremely],[Can't answer]

Review requirements [0 Not at all],[1],[2],[3 Extremely],[Can't answer]

Use requirements (e.g. building, testing, updating) [0 Not at all],[1],[2],[3 Extremely],[Can't answer]

How frequently are you doing the following tasks?

Collect requirements [Daily], [Weekly], [Monthly], [Sometimes], [Never]

Document requirements [Daily], [Weekly], [Monthly], [Sometimes], [Never]

Review requirements [Daily], [Weekly], [Monthly], [Sometimes], [Never]

Use requirements (e.g. building, testing, updating) [Daily], [Weekly], [Monthly], [Sometimes], [Never]

3.5.3 Survey - Your rating about potential requirements-related challenges

We present lists of potential challenges that were evaluated in different companies. We want to explore if you have experienced these challenges and if you rate them as requirements-related challenges in your company.

Remarks: Requirements-related challenges: Everything that influences the creation, documentation, and use of requirements increases the risk of not delivering the right thing, at the right time, at the right cost. The following questions have two scales: answer about frequency (right) and challenge (left).

For these questions the matrix or dual matrix answer options were provided see (Fig.1 and Fig. 2). to support readability we do not display these answer options.

We also displayed the following hint multiple times, while we only state it only once here: Remarks: **How frequently do you experience the following aspects?** (often, rarely,never) **Is this aspect a requirements-related challenge?** (a challenge, not a challenge)

Requirements-related challenges: Everything that influences the creation, documentation, and use of requirements in a way that increases the risk of not delivering the right thing, at the right time, to the right costs.

Organizational aspects

- Teams organized as silos.
- Different employees document requirements than the ones involved in the collection or refinement.
- Employees use different tools to work with requirements. e.g., excel, word, polarion, doors, Jira
- Employees follow different work processes.

Collecting requirements

- Requirements are changing.
- I miss requirements from a higher level to refine relevant requirements for my context. (e.g., specification from solution for a product)

- Missing product features are forcing us to add individual customer requirements.

Documenting requirements

- I need to address different target audiences with the same requirement. (e.g.,customer and colleague)
- I miss seeing the relation between requirements on different detail levels (e.g., solution level to product level).
- Reuse of given text blocks in the documentation for projects. (e.g., default functional descriptions)
- Some requirements are only documented in meeting notes, mails, or presentations.
- Some requirements we agreed on in discussions are never documented.
- Documenting good requirements is too time-consuming.
- Non-functional requirements are not documented. (e.g., requirements related to legal aspects, performance, availability, hardware capability)

Using requirements

- Requirements are not testable.
- It is impossible to develop based on the given requirements.
- I need to search for similar requirements to avoid that I create an already existing requirement again.
- I have the impression that the requirements defined by me are not becoming part of the product.
- Some requirements appear unexpected in later development or test phases.
- I see deviations between what was required and what was delivered.
- I have difficulties identifying the start and end of a specific requirement in the documentation.
- I have the impression that we miss the big picture of how requirements fit together.

Communication and understanding

- I miss direct communication about requirements with customers and other stakeholders.
- I don't understand requirements due to language barriers.
- Requirements are changed without informing those that defined the prior requirements.

- I don't understand the terms used in requirements. (e.g., logistics or customer-specific terms)
- We use different terms for the same information. OR we use the same terms for different information.
- I need to work with requirements that are hard to understand or leave room for interpretation.

Delivering what is requested

- We lose requirements. (e.g.; requirements agreed with the customer are not transmitted to the developers)
- The project scope becomes unclear.
- I miss details in the requirements that I need for my work. (e.g., implicit information missing)
- I receive design information (how) and not requirements (what).

Guidance in working with requirements

- I miss guidance in collecting requirements.
- I miss guidance in documenting requirements.
- I miss guidance in using requirements.

3.5.4 Survey - Closing

Final statement and email address for report submission

Do you want to provide any other feedback? [Free-text]

Remark: To support pseudonymization, avoid using your company's name and use generic product terms instead of your company's products.

Please enter your email address to get your company's report. [Free-text]

Remark:Your email address is only visible for the <BROKER NAME> as a broker. A report will only be created and submitted if 20 or more employees from your company finish the survey.

4 Focus group interviews E

Disclaimer: *The explanation was adjusted based on the one shared in our Ad-hoc Requirements paper and the interview guide is the same as shared in the online appendix for our Ad-hoc requirements paper at REFSQ'25 and REFSQ'26.*

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 *Unequal RE Pains* 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 after the question was first places as written. 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 per process-level based on the survey (Sec. 3.5) feedback.

Research questions 8., 9., and 10. are not in focus of the *Unequal RE Pains* paper.

Beside two 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 adhoc 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. 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 Validation survey ad-hoc requirements H_2

Survey H was executed as H_1 and H_2. We present Survey H_2 here, as it is the extended version shared with a less controlled audience. It contains demographic questions to identify academic and consultancy participants, determine whether the participant also contributed to our other surveys (exclusion criteria), and ensure that feedback is provided based on knowledge of real industry requirements.

We present the survey here and provide a template.

5.1 Introduction - Experiences with informal requirements

In the context of a PhD project at Utrecht University we are exploring requirement phenomena in the context of system development. We focus on require-

ments for mechatronic and software products.

Our objectives:

- Explore less-addressed requirement phenomena
- Explore less formalized requirement variants
- Create optimization concepts for requirement tool and AI use cases
- PhD research

Time: 15 min

Data protection and privacy: The survey is anonymous and does not reveal private information about the individual participants or companies behind it. The data is stored and processed at Utrecht University and on my computer. The data is used for my PhD and related publications. The raw data are only accessible to the research core team of 3 people.

Focus: In this survey, we present a list of "ad-hoc requirements" and want to know if you have experienced them in your work context. Affiliation: Andrea Wohlgemuth is a PhD student at Utrecht University (NL) and FH Dortmund (GER).

I agree to the terms and want to participate in the survey. [Agree], [Do not agree]

5.2 Demographic data

Q2. Which business domain best describes your company?

- Intralogistics
- Logistics (not intralogistics)
- Robotic
- Production site provider
- Automotive
- Other <Freetext>

Q3 What kind of systems/products does your company offer?

- Software
  - Embedded software
  - Machine controlling software
  - Process automation software (e.g., ERP, WMS, WES, TMS)
  - Other software <Freetext>
- Mechatronics
  - Local industry robots
  - AMR/AGV (mobile robots)
  - Material flow equipment

  - Automated storage equipment
  - Production site equipment
  - Automobiles
  - Other mechatronic systems <Freetext>
- Neither software nor mechatronic products

Q23 How would you describe the geographical reach of your company's location?

- Global or regional?
  - Global setup on multiple continent
  - Multiple countries with focus on one continent
  - Focus on one country
- Countries
  - Germany
  - Switzerland
  - Austria
  - Netherlands
  - Other countries <Freetext>
- Continent
  - Africa
  - Asia
  - Australia
  - Europe
  - North America
  - South America

Q24 In which country is your main work location?

- Germany
- Switzerland
- Austria
- Netherlands
- Other countries <Freetext>

How many years of work experience do you have in ...?

- Your company's domain <Freetext>
- Requirements handling / Requirements management <Freetext>
- Other countries <Freetext>

In which process levels of a generic process do you work?

- Overall vision
  - Creation of company-wide strategy/portfolio aspects
  - Creation of system concepts (e.g., business case with intended mechatronics and software products)
- Product baseline design and development
  - Mechatronic product design (concept)
  - Mechatronic development (realization)
  - Mechatronic test and integration
  - Software product design
  - Software product development
  - Software product test
  - Other product process levels <Freetext>
- Customer project
  - Sales for overall system
  - Project management for customer projects
  - Mechatronics sales or requirements refinement
  - Software sales or requirements refinement
  - Other project process levels <Freetext>
- Customer service
  - Software customer service
  - Mechatronics customer service
  - Other customer service process levels <Freetext>

5.3 Definition of requirement:

A requirement is something demanded, needed, or wanted. You might use words other than 'requirement.' And its representation can vary from one sentence to a full page to address an entire system or a single aspect like a screw or button.

5.4 Storing requirements

Q11 Do you experience requirements being stored/documented in the following tools? Matrix questions.

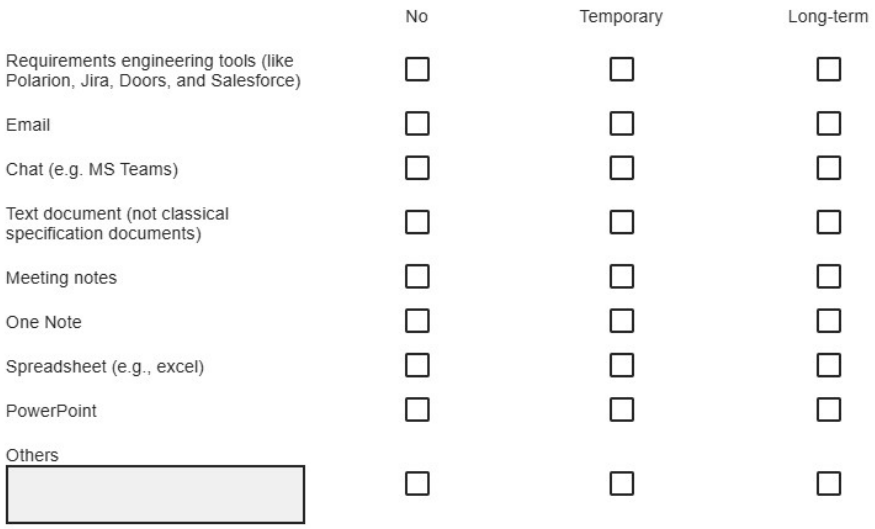

Figure 5: Question Q11 - Storing requirements.

Q12 Do you experience the following access permission aspects of requirements? In case of researcher/consultant: Do you have evidence of the following access permission issues when practitioners are handling requirements?

Dual Matrix question.

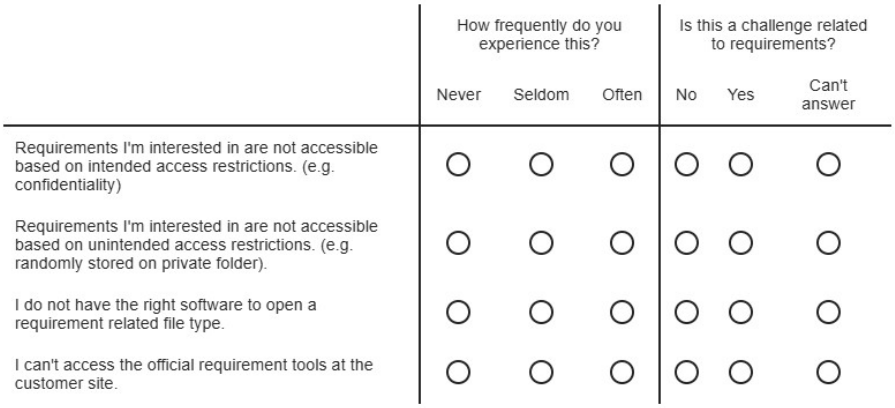

Figure 6: Question Q12 - Access permission.

5.5 Communication

Q13 Do you experience these requirement phenomena related to requirements communication? Dual Matrix question.

	How frequently do you experience this?			Is this a challenge related to requirements?		
	Never	Seldom	Often	No	Yes	Can't answer
Changing participants in a communication flow	○	○	○	○	○	○
Branching of communication flows (e.g. sharing a version with team A while still refining the requirements)	○	○	○	○	○	○
Merging of communication flows (e.g. consolidation and alignment after different groups worked independend on the requirements)	○	○	○	○	○	○
Sharing static requirement representation (e.g., file copy)	○	○	○	○	○	○
Sharing dynamic requirement presentation (e.g., link to shared document)	○	○	○	○	○	○
Communication about different products in one conversation	○	○	○	○	○	○
Communication about different projects/customers in one conversation	○	○	○	○	○	○

Figure 7: Question Q13 - Communication.

Q14 Do you experience these requirement phenomena related to requirements communication? Matrix questions.

	No	In chats	In emails	In Requirements Engineering tools (like Polarion, Jira, Salesforce)
Real-time written elicitation communication	☐	☐	☐	☐
Time-shifted written elicitation communication (asynchronous)	☐	☐	☐	☐
Real-time written refinement communication	☐	☐	☐	☐
Time-shifted written refinement communication (asynchronous)	☐	☐	☐	☐

Figure 8: Question Q14 - Communication.

Q15 Which maturity level of a requirement is provided to which group based on your experience? Matrix questions.

	A drafted version of a requirement candidate.	A formal version of a requirement candidate.	A drafted version of an agreed requirement.	A formal version of an agreed requirement.	A formal version af an agreed and reviewed requirement.
Company vision and portfolio team	☐	☐	☐	☐	☐
Overall system design team	☐	☐	☐	☐	☐
Product design team	☐	☐	☐	☐	☐
Product development team	☐	☐	☐	☐	☐
Project design team	☐	☐	☐	☐	☐
Project development team	☐	☐	☐	☐	☐
Customer service team	☐	☐	☐	☐	☐

Figure 9: Question Q15 - Maturity level of requirements provided to each group.

5.6 Writing

Q9 Do you experience these requirement phenomena related to writing and documenting? Dual matrix.

	How frequently do you experience this?			Is this a challenge related to requirements?		
	Never	Rarely	Often	No	Yes	Can't answer
Some requirements are only documented in meeting notes, emails, or presentations.	○	○	○	○	○	○
Some requirements we agreed on in discussions are never documented.	○	○	○	○	○	○
Some requirements are written as bullet points.	○	○	○	○	○	○
Some requirements are written as incomplete sentences.	○	○	○	○	○	○
Some requirements are written as natural text and do not follow phrasing guidelines.	○	○	○	○	○	○
Some requirements are written as site notes in documents or files.	○	○	○	○	○	○
Some requirements are embedded text in an image. (More like a comment.)	○	○	○	○	○	○
Models (UML, EPK, BPMN, ...) are used to document requirements.	○	○	○	○	○	○
Sometimes, a local language, not the company language, is used to write requirements.	○	○	○	○	○	○

Figure 10: Question Q9 - Writing ad documentation.

5.7 Closing

Q17 Please share your experience with requirement-related aspects as listed in this survey. Freetext answer.

Q18 Do you have any other comment? Freetext answer.

6 Code book

Disclaimer: *The original version of this text was first published in our online appendix about ad-hoc requirements at REFSQ'25.*

We created and refined the final code book in multiple phases. Started with (i) inductive coding, we (ii) conceptualized the findings and refined the code book, and (iii) 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. We used a total of 783 codes and sub-codes, not all relevant to answer RQ1–RQ4.

We present here an extract of the codes used to answer our research questions, based on the final code book. We present here a collection of codes, arranged for efficient space use, based on the code book in MAXQDA. Fig. 11 lists an export of codes from MAXQDA that are mainly used to answer RQ1. On the right side in Fig. 12 are codes used mainly for RQ2, and on the left side for RQ3.

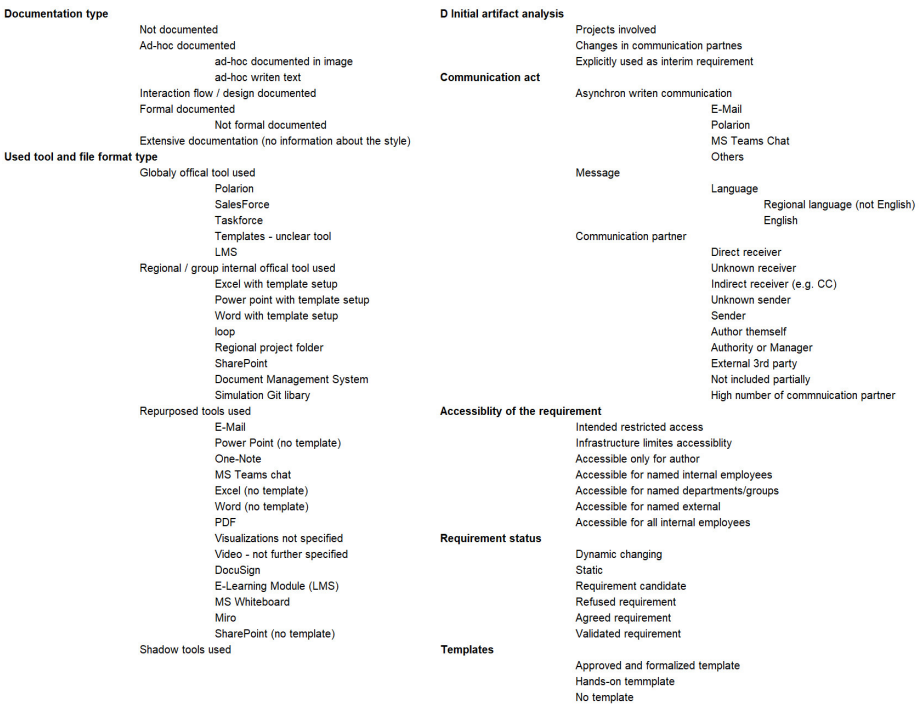

Figure 11: Codes used mainly for RQ1 - What are the characteristics of AhR?.

Figure 12: Codes used in multiple research questions.

7 Example of evidence

Disclaimer: *The original version of this text was first published in our online appendix about ad-hoc requirements at REFSQ'25.*

As we can't share the data or all coded segments, we provide a few examples in Tab. 2 and Tab. 3 as evidence for our findings.

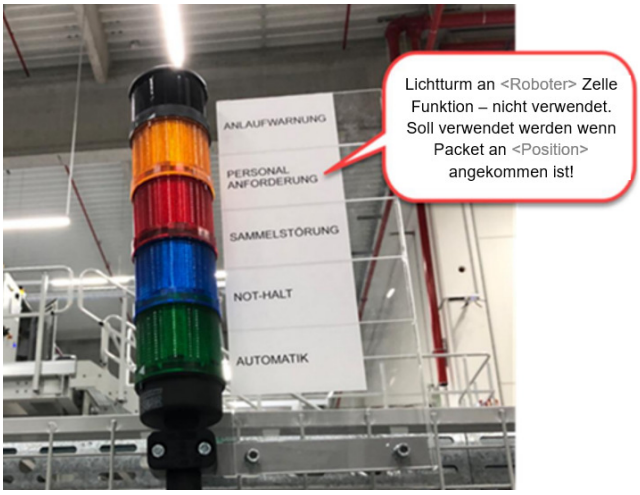

Figure 13: Text in image and non-default language used.

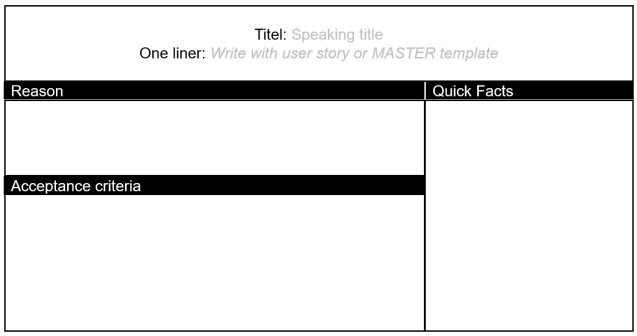

Figure 14: Pragmatic requirements template in PowerPoint.

8 Statistics for RQ4

For data collected with survey H (validation ad-hoc requirement), we tested based on 41 responses if there are statistically significant differences between experienced as a challenge and participants' business domain, process level, products, and years of experience, see Fig. 4 as an example.

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 attachments, 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 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. [. . .]"
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"

Table 2: Example 1: Evidence for ad-hoc requirement characteristics based on the artifact analysis.

Finding	Example of evidence
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." (Alignment 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 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 [. . .]."
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. See Fig. 14.
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." See Fig. 13.

Table 3: Example 2: Evidence for ad-hoc requirement characteristics based on the artifact analysis.

Question	OC	RC	ON	RN
In meeting notes, emails, or presentations	(22;25)	(15;15)	(32;40)	(23;22,5)
Not follow writing guidelines	(15;15)	(20;20)	(27,5;27,5)	(16,5;11)
Bullet point lists	(15;19)	(27,5;27,5)	(15;15)	(12,54;12,54)
Never documented	(12,5;12,5)	(15;15)	(33;40)	(17;16)
Incomplete sentences	(15;15)	(20;20)	(24;25)	(15;15)

Table 4: Median of years in the company and working in RE. Listing the company first and RE experience second.