Exploring effort estimation challenges in agile software development

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Abstract

In Agile Software Development (ASD), effort estimation is an activity that appears in the planning phase, and is impacted by a number of variables. Effort estimation in ASD is needed for efficient resource allocation, realistic scheduling, and improved predictability. Without it, teams risk mismanaging resources, missing deadlines, overcommitting, and disappointing customer and/or stakeholders. In this paper, through a semi-structured literature review, we identify and group twenty five major effort estimation challenges that occur in ASD into five categories. We give a summary of each challenge and examine how common it is in the found literature, emphasizing both commonly discussed and less well-known problems. We additionally identified mitigation propositions for the least frequently mentioned challenges found. Our findings show that while certain issues, such as the value of team experience and the influence of biases, are well known, others — including unclear information, responsibilities and lack of a formal estimation technique, remain under-explored, despite their potential impact. The results of our paper aim to guide practitioners in identifying and managing challenges within their specific contexts, while also highlighting existing gaps that need further investigation. Additionally, our findings contribute to the foundation for improving estimation procedures and informing future research in this domain.

Keywords

effort forecasting, effort prediction, scrum, software development, software engineering

1. Introduction

The Project Management Institute (PMI) defines the estimation objective as providing an approximation (estimate) of the amount of resources needed to complete project activities and deliver outputs – products or services – of specified functional and nonfunctional characteristics [1, 2]. Estimates for work effort, time, expenses, people, and/or physical resources are being developed during the planning stage of software development. A quantitative assessment of a variable's likely quantity or result, such as project costs, resources, effort, or duration, is called an estimate [1].

Effort estimation in Agile Software Development (ASD) appears in the planning phase of the Software Development Life Cycle (SDLC). When planning an iteration (e.g. a sprint in Scrum), an Agile software development team estimates the effort of a work item (a task or a user story).

SQAMIA 2025: Workshop on Software Quality, Analysis, Monitoring, Improvement, and Applications, September 10–12, 2025, Maribor, Slovenia

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The team then chooses a set of tasks to be completed during the sprint based on the estimated effort, making sure that the total effort of the chosen tasks does not exceed the sprint's capacity. The estimated effort of the delivered work items in previous sprints is used to determine the sprint capacity. This therefore means, that the product of the effort estimation activity is an estimate on how many functionalities (in a sprint) can be delivered, rather than predict time or costs [3]. Using these estimates as forecasts, all involved during Agile software development can make informed decisions on how much work can be finished in a limited amount of time.

Depending on the requirements, circumstances, and preferences, effort estimation activities can produce different estimations. For example, because of their ease of use and reliance on past experiences, certain development teams may choose relative estimating activities, such as comparing new tasks or user stories to ones that have already been finished. Others could use group estimating activities, which involve cooperative discussions to reach a consensus about the estimated effort. These preferences frequently show how comfortable and knowledgeable the team is with different estimation techniques.

In ASD, effort estimation is needed for efficient resource allocation and planning. Teams can better schedule and distribute the workload by using it to predict how much time and effort a job will demand [4]. It also helps in setting realistic expectations and improving project predictability. On the other hand, lack thereof might cause problems like resource mismanagement and missed deadlines. Inaccurate or non-existing estimates may also result in overcommitment, underdelivery, additional costs and stakeholder dissatisfaction [5].

The aim of this paper is to present a thorough investigation of the challenges associated with effort estimation in ASD. We can learn more about the elements that lead to them by examining their categorization and frequency of appearance in the literature. We further enrich our findings with mitigation propositions for the least mentioned challenges found in the set of literature. Understanding these challenges is essential for developing more reliable effort estimation approaches that not only align with the Agile principles, but also enhance the outcomes of software projects. In the end, resolving these challenges may result in better resource allocation, enhanced decision-making, and a more efficient development process.

The research question that will guide this paper is:

RQ1: What are the challenges within effort estimation in ASD?
RQ1.1: How can these challenges be classified?
RQ1.2: Which challenges occur the least?

The rest of the paper is structured as follows: We start with an overview of related works in this area, which are presented in Section 2. In Section 3 we present the chosen research methodology, whose findings we present in Section 4 of this paper. In subsections 4.1 and 4.2 respectively, we delve deeper into the categorization of the identified challenges and their frequency mapping. Section 5 provides the identified mitigation propositions and in Section 6 we conclude with our overall findings and suggestions for future work.

2. Related work

Because of it's inherent challenges and the requirement for precise forecasting in dynamic situations, effort estimation in ASD has been the focus of a great deal of research, including

systematic literature reviews [6, 7, 8, 9, 10, 11, 12] and mapping studies [13].

In order to classify various methods to increase estimation accuracy and find common causes of imprecise effort estimations, Pasuksmit et al. [6] carried out a systematic literature review. According to their findings, there are five primary categories of factors that contribute to inaccurate estimations: information quality, team, estimation practice, project management, and business influences. They also looked at approaches that were suggested to improve effort estimation. One important finding from their paper is that a significant contributing element to inaccurate estimations is low-quality information. They also stress how crucial it is for practitioners to possess adequate technical and domain expertise in order to increase estimation reliability.

Iqbal et al. [14] examine the difficulties of user story-based effort estimation in ASD, which also identifies important contributing reasons to inaccurate estimations. According to the paper, technological complexity and inconsistencies in user stories, as well as internal factors like communication, team composition, and competence, have a significant impact on estimating dependability.

Fernandez-Diego et al. [11] revised an existing Systematic Literature Review (SLR) by examining 73 new articles on effort estimation in ASD. In addition to mapping the use of different types of estimation methods (expert-based, data-based or hybrid) and most frequently used accuracy metrics, they also explored cost factors. Sinaga et al. [8] also conducted a SLR, which found 59 challenges regarding effort estimation. The results show that while dependence on expert opinion increases bias, team experience, domain expertise, task complexity, and lack of data are important factors that lead to inaccurate estimates.

Lastly, Piñeros Rodríguez et al. [13] conducted a systematic mapping study of effort estimation in ASD. One of the four research questions of their paper was the collection of the most relevant problems and their causes in effort estimation. They found that in Agile settings, the effort estimation mostly relies on expert judgment, and accuracy is greatly impacted by estimators' communication, expertise, and experience. Additionally, reliable estimation is further challenged by problems like dominance in Planning Poker and insufficient information consolidation.

As indicated by the existing body of literature, considerable effort has been dedicated to identify challenges associated with effort estimation in ASD. Numerous studies have explored various technical, organizational, and human-related factors that influence the estimation activity. However, what distinguishes this paper from prior work is it's approach to collecting and categorizing the identified challenges. In addition to the collection of well-known challenges, in this paper we also address the least frequently mentioned challenges—those that are often overlooked yet can significantly affect estimation outcomes. By collecting mitigation strategies for these less-known challenges, the paper and offers practical value for both researchers and practitioners seeking to improve effort estimation in ASD.

3. Research method

To effectively grasp the existing knowledge regarding effort estimation in agile settings, we conducted a semi-structured literature review, which aimed to provide answers for our set research question and it's according sub-questions presented in Section 1.

The literature review covered the following points:

- The pool of literature was limited to the results found in 3 academic digital libraries: IEEE Xplore, ACM and SpringerLink.
- The search string used for the literature search was the following:
  (("All Metadata":„effort estimation") AND ("All Metadata":„agile") AND ("All Metadata":„challeng*") OR ("All Metadata":„issue*"))
- The results were limited only to peer-reviewed literature.
- All relevant literature needed to be written in English.
- The literature that was not directly related to answering the proposed research questions was excluded.

After identifying the initial set of papers through the presented search strings, we reviewed their references to find additional relevant studies (snowballing). Additionally, we incorporated literature that we were aware of, but did not appear in the initial search results. By following this semi-structured method, this paper tries to synthesize key findings while staying adaptable to new viewpoints. The results of the conducted research method are presented in Section 4.

4. Effort estimation challenges

As mentioned in the Introduction, the focus of this Section is on presenting the challenges that were uncovered through the research methodology employed. In the following Sections 4.1 and 4.2, will look more closely at these challenges, which have emerged as significant findings. Previous research [6] in this area served as the major source of information for our classification of challenges. In addition to other literature, we changed and renamed certain challenge categories while still keeping their intended purpose. This was done in order to improve the readability and clarity of our results. An overview of the five identified challenge categories is presented in Figure 1.

4.1. Identified challenges

The challenges associated with effort estimation manifest at various stages of estimation —namely, before, during, and after the actual estimation. Some of them are complex and encompass many different aspects, each of which poses particular difficulties. In the following of this Section, we will examine and evaluate these challenges, shedding light on the complexities that arise regarding the activity of effort estimation. By doing this, we hope to offer a thorough overview of the variables affecting estimation as well as the challenges that arise during it. Note that all identified challenges are already present in the selected literature (see Table 1) and their categorization is done based on subjective assessment.

1. **Challenges related to the organization**
   Organizations frequently face a number of challenges throughout the effort estimation activity. Eight key challenges that obstruct efficient effort estimation were found and are discussed in the following.

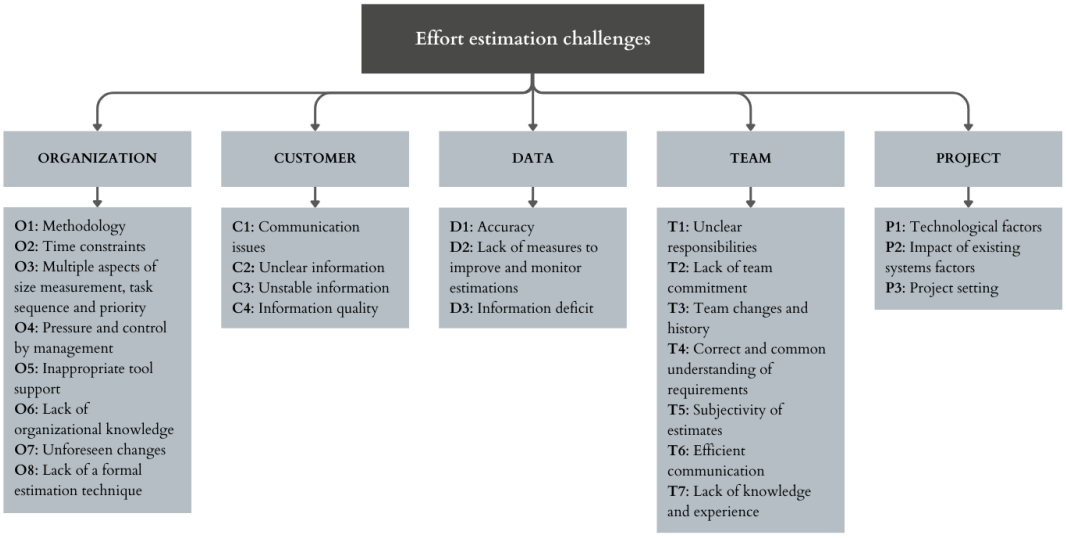

Figure 1: Categories of identified effort estimation challenges.

- **O1: Methodology/formalism** – Pertains to the lack of procedures and policies on how to deal with failures and avoid repeating mistakes by learning from past experiences.
- **O2: Time constraints** - There is a lack of time for estimating requirements, and the activity of estimating effort and identifying dependencies can be very time-consuming.
- **O3: Task details** - Multiple aspects of size measurement, their adjustment, task sequence and priority.
- **O4: Pressure and control by management** - A very common challenge resulting in inaccurate estimates to meet management expectations and feeling pressured to be faster than original estimates.
- **O5: Inappropriate tool support** - Complexity and inflexibility of the (estimation) tool, as well as the lack of features that could support the estimation activity.
- **O6: Lack of organizational knowledge** - Pertains to the lack of contacts (experts) required for the effort estimation activity, additional overhead such as meetings and explanations, neglection of relevant factors such as dependencies in initial estimates or non-functional requirements and resources in terms of people.
- **O7: Unforeseen changes** - In terms of system or process-related problems during implementation, ad-hoc requirements, changes in the timeline, or people leaving the project.
- **O8: Lack of a formal estimation technique** - In ASD, people and the interactions between them are valued more than processes and tools, but this doesn't mean that the estimation activity should be completely left behind. Other challenges include lack of information about the estimation activity itself.

2. **Challenges related to the customer**
   Accurately capturing customer requirements and expectations is a crucial challenge during the effort estimation activity. During our research, we identified four general challenges in this area.

   - **C1: Communication issues** – that pertain to customer irresponsiveness.
   - **C2: Unclear information** - information deficit regarding the requirements and unclear .
   - **C3: Unstable information** - uncertainty of requirements and frequent requirements changes, after the estimation is done.
   - **C4: Information quality** - the amount and characteristics of the information provided by the customer.

3. **Challenges related to data**
   The quality, availability, and interpretation of data are crucial components of effort estimation. As a result of our research, we found that this category presents three challenges.

   - **D1: Accuracy** – Pertains to the accuracy of the estimated value in relation to actual effort spent.
   - **D2: Lack of measures to improve and monitor estimations** – In addition to measures/metrics that measure planned and actual efforts.
   - **D3: Information deficit in the initial estimation of large, complex requirements** – lack of historical data (in regard to previous projects or completed requirements, as well as the data quality and dataset characteristics) and changing requirements (especially in the beginning) due to size, dependencies, and uncertainty.

4. **Challenges related to the team**
   Issues pertaining to the team itself present another challenge category during effort estimation. Estimates can be greatly impacted by factors like team composition, experience levels, and communication styles. We identified seven key challenges that belong in this category, which are more elaborated in the following.

   - **T1: Unclear responsibilities** - Lack of knowledge about the responsibility in terms of person, team, or workstream for certain requirements. Another sub-challenge is working on parallel projects, therefore producing the same outcome.
   - **T2: Lack of team commitment** - General resistance to the program's way of working and team members not participating in the estimation activities. In some cases, there also may be resistance of the estimation technique used, as well as ignorance of documentation.
   - **T3: Team changes and history** - Frequent team changes and a lack of previous work history may hinder the estimation activity.
   - **T4: Common understanding of requirements** - A correct and team-wise understanding of requirements may in some cases negatively affect the estimations produced.

- **T5: Subjectivity of estimates (biases)** - Estimates are based on subjective criteria such as the individual knowledge of the estimators. There are some different aspects to this challenge, namely:
  a) anchoring - the first numbers "played" or vocalized serve as an implicit starting point, influencing later estimates.
  b) groupthink - dominant personalities or the desire for quick consensus causes team members to converge on estimates without fully debating underlying uncertainties.
  c) Optimism & pessimism - voicing the very extreme estimates.
  d) Skill disparities - team members may not have the same experience as their more senior counterparts, affecting their judgement.
- **T6: Efficient communication** - Language barriers challenging the correct understanding of requirements, spatial distribution and difficulty to reach a consensus all lie within this category.
- **T7: Lack of knowledge and experience** - Teams often lack experience and knowledge regarding effort estimation.

5. **Challenges related to the project**
   The software project being developed plays a big role in the potential challenges that may arise during effort estimation. In this category, we identified three major challenges.

   - **P1: Technological factors** – The technological complexity of the project and lack of knowledge on the required technologies.
   - **P2: Impact of existing system factors** – The set of chosen factors, such as database used, development platform an programming language.
   - **P3: Project setting** - A fixed, large time frame requiring initial estimates and the tight tying of estimates to the budget limit the flexibility of estimations. Other issues that arise in this category are (too) big projects or backlogs, complexity of tasks and project environmental settings.

4.2. Challenge frequency mapping

Following the classification of the identified challenges in the previous subsection, we now turn to their frequency mapping. This step involved aggregating the frequency with which each challenge was mentioned in the literature. An overview of all references is given in Table 1, which links each of the challenges to the appropriate source from which it was found.

The presence of **T5: Subjectivity of estimates**, which was found in twelve distinct references, is an important finding from our research. This implies that a significant issue facing ASD is subjective biases in effort estimation. During effort estimation, expert judgment is often necessary, which, by it's nature, involves subjectivity. Furthermore, this challenge is often brought to light due to differences in experience, biases, and different perceptions of project needs. Similarly, **C1: Communication issues** with the customer were mentioned eleven times, making it another frequently mentioned challenge. This high number is explained by how important stakeholder engagement is to estimations. The importance of this challenge is further

Table 1
Mapping of challenges reported in the literature

Source	O1	O2	O3	O4	O5	O6	O7	O8	C1	C2	C3	C4	D1	D2	D3	T1	T2	T3	T4	T5	T6	T7	P1	P2	P3
Pasuksmit [6]						✓	✓		✓	✓	✓	✓								✓		✓			
Sinaga [8]	✓	✓	✓	✓		✓			✓	✓	✓		✓	✓	✓		✓			✓			✓	✓	✓
Alsaadi [9]			✓	✓																		✓			✓
Diego [11]													✓											✓	
Rodriguez [13]								✓												✓		✓			
Iqbal [14]	✓	✓	✓	✓		✓	✓		✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓
Popli [15]	✓			✓					✓				✓	✓					✓						✓
Schweighofer [16]													✓												
Moechtar [17]													✓												
Usman [5]	✓			✓		✓		✓	✓				✓		✓		✓	✓	✓	✓		✓			
Britto [18]													✓								✓		✓		
Weigelt [19]			✓	✓	✓	✓	✓		✓					✓	✓	✓	✓		✓	✓	✓	✓			✓
Mallidi [20]	✓			✓					✓						✓	✓	✓				✓	✓			✓
Hacaloglu [21]	✓		✓	✓					✓											✓					
Usman [22]				✓		✓			✓							✓		✓		✓			✓		✓
Siddique [23]		✓							✓									✓		✓					
Popli [24]							✓		✓																
Mahnič [25]																	✓			✓	✓				
Molloken [26]																				✓					
Jorgensen [27]																				✓					

highlighted by the fact that inconsistency in effort estimation is frequently caused by misaligned expectations, unclear requirements, and insufficient communication.

On the other hand, challenges including **O4: Pressure and control by management**, **D1: Accuracy**, **P3: Project setting**, and **T7: Lack of knowledge and experience** with the estimation activities received less references. Their specificity to certain organizational contexts, or their minor importance in relation to more dominant challenges (like subjectivity), may be the reasons for the smaller amount of attention they receive.

On the other end of the spectrum, the least mentioned challenges are mostly related to the customer (**C2: Unclear information, C3: Unstable information and C4: Information quality**) and **O5: Inappropriate tool support**. These challenges seem to be less present in the literature, as presented with less than three mentions. One possible explanation may be that organizations prioritize other challenges that can be solved in a known way. On the other hand, this finding may potentially reference a lesser know gap in the literature, that can be addressed in the future.

5. Mitigation propositions

To further enrich the insights from our research, we selected the least frequently discussed challenges in the set body of literature discussed in Section 3. This decision was motivated by the understanding that, despite their limited representation in the literature, these challenges may have important implications for both theory and practice. By highlighting them, we want

to consolidate potential solutions to address them, as well as encourage more research into these understudied but potentially significant areas.

To mitigate **O5 - Inappropriate tool support** organisations should utilize tool support to automate estimation using available and historical data, thereby reducing time and incomparability while enhancing transparency. In this case, it is recommended that such tools are user-friendly and capable of integrating relevant data [19]. The incorporation of analogies with similar projects and initial estimates can further improve estimation. Additionally, tools can be enhanced with features such as Post-its or Scrum Boards to support and visualize the estimation activities [19].

Given the similar nature and underlying causes of challenges **C2 - Unclear information, C3 - Unstable information** and **C4 - Information quality** a combined set of mitigation strategies is proposed to address them collectively. Common issues such as unclear, unstable, or inaccurate data, should be addressed particularly in user stories, acceptance criteria, and requirements. A proposed approach is through detailed analysis and stakeholder validation prior to estimation. Practitioners should apply structured approaches such as the INVEST criteria, estimation checklists, and developer stories, as well as explore techniques for identifying uncertainty, missing information, or relevant quality attributes. Team members should be equipped with adequate domain and technical knowledge [6]. Clear documentation standards are recommended to be established and validation procedures to be enforced during information gathering. An additional recommendation can be to implement version control and change management practices to ensure traceability of evolving information.

Another rarely mentioned challenge is **O8 - Lack of a formal estimation technique**. To mitigate this challenge, a structured process for developing and evolving estimation checklists tailored to agile teams can be adopted. Such checklists could support expert judgment by ensuring critical factors are considered consistently, thereby reducing the risk of underestimation and improving the reliability of effort estimates [22]. Training sessions and workshops can be implemented to enhance development team and stakeholders' understanding and application of estimation techniques, to promote consistency and overall understanding. This challenge can be improved with the integration of estimation tools (O5) to streamline adoption and ensure continuous usage.

Since challenges **P1: Technological factors** and **P2: Impact of existing system factors** share a similar underlying nature, their mitigation proposals will be discussed jointly. A potential solution lies in investing in continuous training and upskilling initiatives, that are tailored to the project's tools and platforms. Technical evaluations conducted early on can assist in identifying knowledge gaps and directing resource allocation appropriately. To further lower technical risk, criteria should be established for choosing technologies based on team knowledge, scalability, and project needs. Cooperation with external experts can offer additional assistance in handling challenging technology settings.

The mitigation propositions discussed above are specifically tailored to address the least frequently mentioned challenges identified in the reviewed literature. While these proposals offer potential solutions, it is important to acknowledge that their effectiveness may vary across different contexts, team structures, and software characteristics.

6. Conclusion and future work

In this paper, through a semi-structured literature review, we shed light on twenty five major challenges regarding effort estimation in ASD, along with explanations of their definitions. Additionally, we grouped them into five categories, each focusing on a distinct area. Furthermore, we examined how commonly they appear in the literature, emphasizing both the most and the least frequently discussed challenges. Our findings highlight that certain challenges, like the importance of team experience and the impact of biases, are well known, others, including information quality and tooling support, are not as well-discussed but nevertheless affect the estimation activities. Another significant contribution of our paper lies in the identification and formulation of mitigation propositions for the least frequently mentioned challenges in effort estimation in ASD. These challenges, while not widely discussed in the existing body of literature, can have a considerable impact on project outcomes if left unaddressed. The proposed mitigation strategies serve as potential solutions and are proposed based on findings from the reviewed literature.

Using the results of our paper, the proposed strategies are intended to guide practitioners in proactively identifying and managing these challenges within their own organizational and project-specific settings, as well as have a better understanding of existing gaps and areas that need more investigation.

Even though this paper provides a structured perspective on the challenges in effort estimation in ASD, there are still a number of future research directions that can be explored further. During our research, we noticed that there is a lack of empirical studies done in this area. Therefore, one potential research direction lies in the empirical validation of the impact and occurence of these challenges in actual agile projects. Further research into less-studied challenges, such as information quality, unclear and unstable information, may reveal some new viewpoints and solutions.

Future research can help develop more accurate and efficient methods for effort estimation by filling in these research gaps. This will, in turn ultimately help in the successful planning and implementation of agile software projects.

Acknowledgments

The authors acknowledge financial support from the Slovenian Research and Innovation Agency (Research Core Funding No. P2-0057).

Declaration on Generative AI

During the preparation of this work, the authors used QuillBot, Grammarly and Thesaurus in order to: Paraphrase and reword, check grammar, search for synonyms, analyze tone, and improve fluency. After using these tools and services, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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