

Supplementary Material: Interview Guide and Online Questionnaire

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The interview guide and online questionnaire were used in an exploratory sequential mixed-methods design. The aim of the study was to investigate the cost estimation of products in the early phases of product development in mechanical engineering, as well as practitioners' expectations of cost estimation assisted by artificial intelligence (AI). The study was conducted in compliance with applicable data protection regulations. Participation in the interviews and the online questionnaire was voluntary and could be terminated at any time without giving reasons. All participants were informed about the purpose of the study and the scientific use of the data. Participation was based on informed consent. In the interviews, participants were additionally informed about the audio recording and were asked for their consent. The collected data were stored and analyzed in anonymized form.

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1 Interview Guide

The following section describes the interview guide for the qualitative interviews. It was used for semi-structured interviews with cost engineers and served to structure the interviews. The order of the questions could vary depending on the course of the interview. In-depth as well as spontaneous follow-up questions were explicitly intended.

Topic Area A. General.

- **A1:** In which industry does the company you currently work for operate?
- **A2:** How large is the company you currently work for?
- **A3:** What position do you hold in this company?
- **A4:** How many years of professional experience do you have in cost estimation?

Topic Area B. Significance.

- **B1:** From your perspective, what role does cost estimation have in the early phases of product development?
- **B2:** For what reasons is cost estimation conducted in the early phases of product development?
- **B3:** Based on your experience, what effects does early cost estimation have on technical or economic decision-making?
- **B4:** Based on your experience, which groups of people are involved in the cost estimation process?

Topic Area C. Approach, Challenges, and Experiences.

- **C1:** Can you describe how you typically approach cost estimation in the early phases of product development?
- **C2:** At which level do you estimate product costs in the early phases of product development?
- **C3:** Which tools or software do you use for cost estimation in the early phases of product development?
- **C4:** Based on your experience, which knowledge or competencies are relevant for cost estimation in the early phases of product development?
- **C5:** In your opinion, what role does experience have in cost estimation in the early phases of product development?
- **C6:** From your perspective, are there particular challenges associated with cost estimation in the early phases of product development?

Topic Area D. Data Availability and Sources.

- **D1:** From your perspective, which specific data are relevant for cost estimation in the early phases of product development?
- **D2:** From which sources do you obtain the data used for cost estimation in the early phases of product development?
- **D3:** In what form or structure are the data available that you use for cost estimation in the early phases of product development?
- **D4:** At which levels are the available data provided in the early phases of product development?
- **D5:** How do you proceed when only limited data are available for cost estimation in the early phases of product development?
- **D6:** How do you deal with situations in which data required for cost estimation in the early phases of product development are missing?

Topic Area E. Accuracy.

- **E1:** From your perspective, which deviations between estimated and actual product costs are acceptable in the early phases of product development?
- **E2:** How would you describe the accuracy of your cost estimation in the early phases of product development? If possible, please indicate this as a percentage.
- **E3:** Do you recall a specific example in which your cost estimation deviated significantly from the actual value? If so, which component was involved, how large was the deviation, and what caused it?
- **E4:** How do you deal with uncertainties in cost estimation in the early phases of product development?
- **E5:** From your perspective, what role does the accuracy of cost estimation have overall in the early phases of product development?

Topic Area F. Duration and Efficiency.

- **F1:** How do you assess the time effort required for cost estimation in the early phases of product development?
- **F2:** In your opinion, which factors significantly influence the duration of cost estimation in the early phases of product development?
- **F3:** Which steps in cost estimation in the early phases of product development do you perceive as particularly time-consuming?

Topic Area G. Transparency, Traceability, and Explainability.

- **G1:** From your perspective, what role does transparency have in the presentation of cost estimation, for example with regard to the underlying calculation?
- **G2:** From your perspective, how important is it that design engineers can understand which factors influence product costs?
- **G3:** From your perspective, how important is the ability to provide a coherent explanation of cost estimation after it has been carried out?

Topic Area H. Artificial Intelligence.

- **H1:** Have you already used AI for cost estimation in the early phases of product development? If so, in what form?
- **H2:** Under what conditions would you use AI for cost estimation in the early phases of product development?
- **H3:** What challenges do you perceive in the use of AI for cost estimation in the early phases of product development?
- **H4:** What would need to be in place for you to trust an AI-assisted cost estimation?
- **H5:** Which functions or characteristics would you expect from an AI-assisted tool for cost estimation?
- **H6:** In your opinion, how should AI-assisted methods for cost estimation be designed in order to be successfully applied in practice?

Topic Area I. Comments and Suggestions.

- **I1:** Do you have any additional comments or suggestions regarding cost estimation in the early phases of product development?

2 Online Questionnaire

This section describes the online questionnaire used in the second part of the study. It was addressed to individuals who work professionally with cost estimation and served to quantitatively verify and generalize the key findings from the interviews.

Question 1. In which industry does the company you currently work for operate? (Single choice)

- Machine tool manufacturing and plant engineering
- Agricultural machinery

- Construction and building materials equipment
- Automotive engineering
- Aerospace
- Other (please specify)

Question 2. How large is the company you currently work for? (Single choice)

- Fewer than 250 employees
- 250 to 999 employees
- 1,000 to 4,999 employees
- 5,000 employees or more

Question 3. Which functional area do you work in? (Single choice)

- Product development
- Product costing / Cost management
- Project management / General management
- Purchasing / Supply chain management
- Manufacturing / Production
- Sales / Marketing
- Other (please specify)

Question 4. In what way are you involved in cost estimation? (Multiple choice)

- I personally carry out cost estimation.
- I provide input for cost estimation (e.g., technical data, experience-based knowledge, bills of materials).
- I use the results of cost estimation for decision-making.
- I am not directly involved.

Question 5. How many years of professional experience do you have in your current field of expertise? (Single choice)

- Less than 3 years
- 3 to less than 6 years
- 6 to 10 years
- More than 10 years

Question 6. Please rate each of the following 22 statements on a 4-point Likert scale.

- **Statement 1:** Cost estimation is essential in the early phases of product development.
- **Statement 2:** Cost estimation is important for supporting technical and economic decision-making and for justifying these decisions to third parties.
- **Statement 3:** In the early phases of product development, speed is often more important than accuracy in cost estimation in order to advance development efficiently.
- **Statement 4:** Cost estimation in the early phases of product development has a significant influence on design decisions, even if its accuracy is still low.
- **Statement 5:** In practice, cost overestimation is more tolerated than underestimation.
- **Statement 6:** A strong cost focus can restrict design freedom.
- **Statement 7:** Cost estimation initially requires additional personnel and time resources but can lead to cost savings for the company in the long term.
- **Statement 8:** Cost estimation is gradually refined along the development process.
- **Statement 9:** In the early phases of product development, the reliability of cost estimation depends primarily on experience and implicit knowledge, while available data have a supporting role.
- **Statement 10:** Cost estimation is based on input from various departments.
- **Statement 11:** In the early phases of product development, cost estimation is mainly performed using spreadsheet tools.
- **Statement 12:** Cost estimation is increasingly function-oriented rather than component-based.
- **Statement 13:** Poor data quality significantly hinders the performance of cost estimation and reduces its accuracy.

- **Statement 14:** Uncertainties such as concept changes, fluctuating production volumes, or material prices reduce the reliability of cost estimation and may lead to suboptimal decisions.
- **Statement 15:** Unclear roles, responsibilities, and communication channels weaken the reliability of cost estimation.
- **Statement 16:** Time pressure and extensive documentation effort reduce the quality of cost estimation.
- **Statement 17:** AI-assisted methods should be at least as accurate as traditional methods.
- **Statement 18:** AI-assisted methods should provide explainable cost estimates so that it is possible to understand how the result was obtained.
- **Statement 19:** AI-assisted methods should be traceable and allow users to influence parameters.
- **Statement 20:** AI-assisted methods should deliver fast, simple, and visual results.
- **Statement 21:** AI-assisted methods should identify the cost drivers.
- **Statement 22:** AI-assisted methods should be able to integrate into existing systems.

Question 7. Is AI used for cost estimation in your company? (Single choice)

- Yes
- No
- I do not know

Question 8. Where is AI used for cost estimation in your company, and which software do you use for this purpose? (Free text; the question was only shown if Question 7 was answered with “Yes”)