Assessing Usability Attributes and Metrics: Causes and Causalities in SCADA Systems for the Forestry Industry

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- University of Turku is located in Turku in southwestern Finland
- Approximately 22,000 degree students
  - Bachelor’s, master’s and doctoral degrees are offered both in Finnish and in English.
- The third largest university in the country as measured by student enrollment
- The largest faculties are the Faculty of Humanities and the Faculty of Science and ***the Faculty of Technology*.**
- Department of Computing
  - Software Engineering
  - Cyber Security
  - Data Analytics
  - Robotics and Autonomous Systems
  - Health Technology

Background

- Organizations invest significant resources to enhance usability, yet identifying context-dependent root causes remains challenging.
- This paper describes a usability study conducted by a Finnish forestry company on a Supervisory Control And Data Acquisition (SCADA) control system.
- The study utilized academic research to identify key usability attributes and metrics, which formed the basis of a comprehensive usability questionnaire.
- Analysis of survey responses underscores the importance of situational analysis and identifying cumulative and causal influences on end-user perceptions of usability.

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Research question and methods:

- **Research target**: to evaluate the usability of the SCADA system and identify areas for improvement through an understanding of the root causes of usability issues.
- **Research question**: How to measure SCADA system usability to better understand underlying usability challenges and enhance system usability development?
- **Research approach:**
  - Phase 1: identifying usability attributes based on academic research and standards.
  - Phase 2: defining a usability survey based on these attributes.
  - Phase 3: conducting the survey within the forestry company.
  - Phase 4: analyzing the survey results.

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SCADA control system

- SCADA is a system used to control and monitor industrial applications.
  - Key features of SCADA systems are to visualize physical production processes through the system, communicate information related to the production process, and remote-control equipment related to the production process.
  - SCADA systems connect physical devices, machines, and IT systems related to the production process into a coherent entity via a data network providing real-time production data acquisition, data processing and transmission, and process management through a single interface.
- In the context of this paper, the SCADA system at a forestry company's production plant is responsible for controlling almost the entire production process of the plant.
  - The forest company's production facility is divided into five departments and each department has a unique SCADA view(s).

Phase 1: Identifying key usability attributes and metrics based on academic research

- The first and most critical step was to compile the usability attributes to be evaluated during the study.
- The study identified the following usability attributes to be used to evaluate the SCADA system (Table 1):

TABLE I
USABILITY ATTRIBUTES AND METRICS IDENTIFIED TO EVALUATE THE USABILITY OF THE SCADA SYSTEM

	Attribute/metric	Description	Reference
1.	Effectiviness (ISO)	Achieved targets, performed tasks, errors in task performance, intensity of errors	[24], [27]
2.	Efficiency (ISO and Nielsen)	Time spent on the task, time efficiency, redundant activities	[24], [26] [6] [27]
3.	Satisfaction (ISO and Nielsen)	Overall satisfaction, satisfaction with features, use of features, user confidence, perceived comfort and convenience	[24], [26] [6], [27]
4.	Learnability (ISO ja Nielsen)	Simplicity of the system, time, completeness of instructions, default values for input fields, understandability of error messages, understandability of user interface	[24], [26]
5.	Memorability (Nielsen)	Ease of use, memorability after a break in use	[24], [26]
6.	Errors/User error protection (ISO and Nielsen)	Number of errors, recovery from errors, impact of errors	[24], [26] [19]
7.	Appropriateness recognisability (ISO)	Fitness for purpose	[19]
8.	Operability (ISO)	Consistency of functionality and layout, clarity of messages, customisability of functionalities and user interface, auditability, cancellation of actions, understandable categorisation of information	[19]
9.	User interface aesthetics (ISO)	Aesthetic satisfaction	[19]
10.	Accessability (ISO)	Accessibility for disabled users, supported languages	[19]
11.	Up-to-date information (Industry 4.0 user inferfaces)	Up-to-date representation of the process status	[2]
12.	Supporting the user in decision making (Industry 4.0 user interfaces)	Providing the necessary information to support the user's decision making	[2]
13.	Intuitivity	Intuitive to use	[26]

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Phase 2: defining the usability survey

- Based on the defined usability attributes and metrics (Table 1), the survey was designed to ensure each question corresponded to a specific usability attribute.
- The survey included 13 statements, closed-ended, 7-point yes/no Likert scale questions.
  - Open-ended questions at the end of the survey enabled participants to clarify their answers and provide additional comments on SCADA usability.

Phase 3: conducting the survey within the forestry company

- The survey was sent out to a limited number of operators by the forestry company.
  - This limited the number of potential respondents, but also improved the value and quality of the received responses.
  - Participation to the survey was voluntary.
- The data collection process for the SCADA usability case study was conducted as an electronic Webropol-survey between 14.2.2023-11.1.2024.

Phase 4: analyzing the survey results 1/2

- A total of 19 responses to the survey question, 13 responses to the open-ended comment field.
- High degree of subjectivity in user experience, individual answers vary between both extremes.
  - The results show that the average dispersion is weighted well below the neutral average, suggesting there is room for improvement in SCADA usability.
  - The responses to many of the statements vary widely between the two extremes.

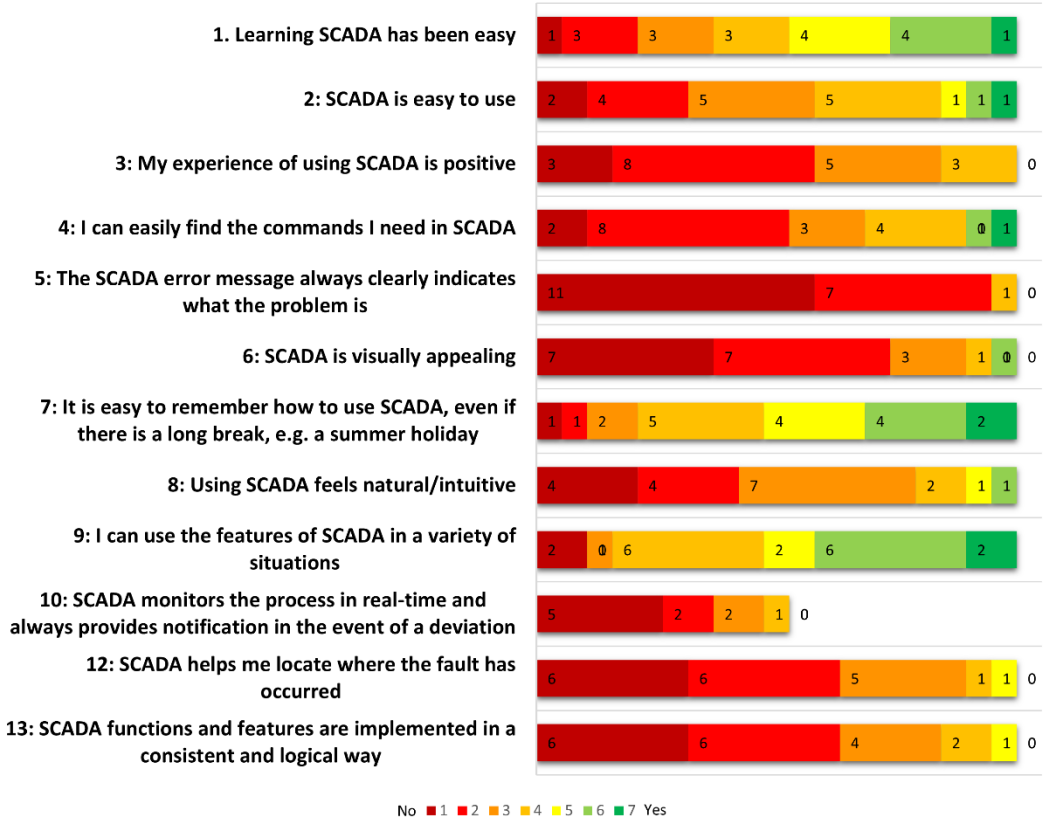

Figure 2: Surveys results

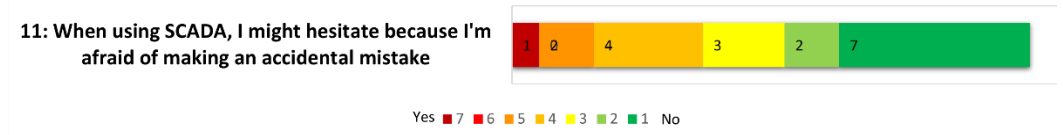

Figure 3: Inversed Likert Scale

Phase 4: analyzing the survey results 2/2

- Based on Table 2:
  - Achieved usability: 4/13
  - Usability Improvements: 9/13
- The identified usability improvement areas must be viewed in the context of the SCADA being a complete control system in operation and meeting its operational objectives.

Table 2: SCADA usability findings and the operators' comments

	Average	Question	Used attribute/metric (Table 1)	Observations	Usability findings from operators
Usability achieved	5.21	11	Errors/User error protection (attribute 6)		1. Slowness, stuttering, navigation is sometimes confusing and difficult
	4.68	9	Effectiveness (attribute 1)		2. SCADA also has a lot of good things
	4.58	7	Memorability (attribute 5)		3. Slowness of user interface in case of failures e.g. when moving from one page to another, you get used to using SCADA when using the system, it is easy to find the causes of failures
	4.16	1	Learnability (attribute 4)		4. Requires learning by heart, no information is available when looking for a new thing and you have to rely on other operators
Identified areas for usability development	3.32	2	Operability (attribute 8)	1,3, 6, 7, 8, 10, 12	5. Needs further development
	2.94	4	Efficiency (attribute 2)	1, 4, 8, 11	6. The system is confusing
	2.74	8	Intuitivity (attribute 13)	4	7. Slow, illogical, production lines poorly outlined
	2.42	3	Satisfaction (attribute 3)	2, 8, 10, 12	8. System is confusing, difficult to find information, not enough information, several buttons not working or missing, slow to move from one page to another
	2.26	13	Operability (attribute 8)	6, 7, 8, 12	9. Operators are not consulted enough and requested changes are not implemented, fault locations are not clearly and accurately displayed
	2.21	12	Supporting the user in decision making (attribute 12)	3, 9, 10, 12, 13	10. Poor visual appearance, poor navigation, poor alarm indication, some buttons missing, some buttons not working
	2.11	6	User interface aesthetics (attribute 9)	10	11. Too much time spent moving from one page to another to access information and functions
	1.9	10	Up-to-date information (attribute 11)	3, 9, 10, 12, 13	12. Alarms poorly targeted, alarms can only be displayed on certain pages, alarm indication in main view should be better, not all information is accessible, SCADA implementations differ in views and functionalities
	1.53	5	Supporting the user in decision making (attribute 12)	3, 9, 10, 12, 13	13. Operators have not been consulted enough and requested changes have not been implemented, and fault locations are not displayed clearly and accurately enough

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The importance of understanding context, root-causes and causality

- Most of the identified usability improvements are related to deviations in the production process, which may require operator intervention via SCADA.
- In this situation, the operator is under urgent problem-solving and time pressure, which increases the overall negative impact and experience on usability (Figure 3).
- SCADA usability improvements closely follow the regular workflow of the problem-solving process.
- By understanding the contextual workflow, the survey results show that usability challenges can be examined from a root-cause and cumulative effect perspective.

Root cause analysis of the cumulative effect resulting from process deviation

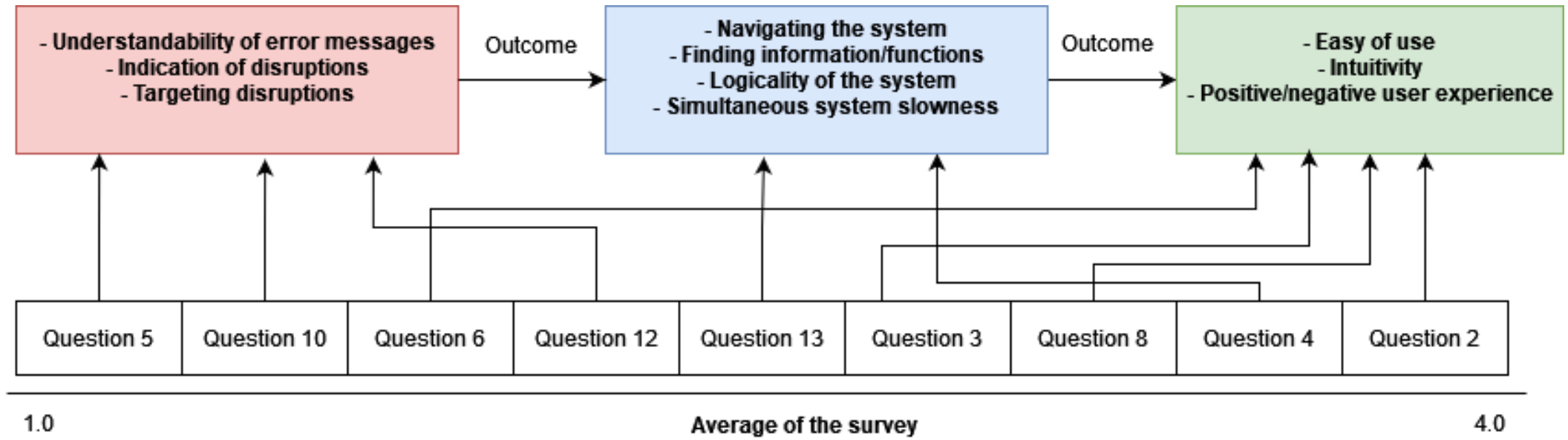

Figure 3: Root-cause analysis of the cumulative effect resulting from process deviation

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Analyzing the results based on the industry insight

- It was found that the primary usability challenges can be root causes that have a cumulative and cascading effect on other aspects of the user's experience with the system (RQ).
  - Problems with these primary usability challenges, if not mitigated, lead to secondary challenges, which in this case are system navigability, ability to find information, system slowness, and perceived sense of system logic and understandability.
- Understanding the context of use is critical to making accurate observations and drawing valid conclusions.
  - By analyzing the results with industry insights, it is possible to identify root causes and causal relationships, enabling targeted development activities to improve usability and address gaps more efficiently.
- The cumulative effect and root cause hypothesis provides a valuable perspective for usability analysis. This approach shifts the focus from simply interpreting usability metrics to understanding causality.

Conclusion

- This paper presents the results of a SCADA usability study conducted in the Finnish forestry company, highlighting the challenges of achieving optimal usability.
- Despite the achievement of system goals and the successful implementation of the system, there can be a significant gap between the actual usability experienced by the end user and the way the system performs.
- Understanding the contextual aspects of the user experience proved to be critical.
- While the attributes and measures used in the study generally capture various aspects of usability effectively, the findings highlight the importance of a thorough understanding of the operating environment and workflow to accurately identify and address usability issues.

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Thank you!