

EPOC 2026

Extended Abstract

Theme: Digital transformation in engineering or construction—where and how can we identify or build expertise and talent to fill the need to move forward

Title: Developing and Validating Sociotechnical Principles for Human-Robot Teaming Systems in an Australian Research Council (ARC) funded Research Hub in Australia

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Research Problem: The advancement of Artificial Intelligence (AI) and robotics has introduced new complexities to sociotechnical system design in the context of humans and robots working together.

The research problem addressed is: How do we develop suitable Sociotechnical Systems (STS) principles for use by research teams who are developing and implementing solutions for human-robot teams in the construction sector from an ARC funded Research Hub in Australia.

Background: The Robotics Institute at the Faculty of Engineering and Information Technology at the University of Technology Sydney was awarded an Industry Transformation Research Grant by the Australian Research Council, funded in 2025, to develop Human-Robot Teaming Solutions to improve productivity and enhance well-being in the construction sector. The authors of the paper, who are investigators of the research hub (HARTCon - <https://www.hartcon.org/>), were asked to develop sociotechnical systems principles that can be used by design teams to develop solutions at the hub, taking ergonomic or human-centric aspects of the design into consideration. After reviewing current sociotechnical design principles from the literature, the investigators decided that as humans and robots can now learn from each other, the existing sociotechnical principles had to be revisited to suit the work to be performed by research teams at the hub. Thus, an investigation to identify STS principles that could be used was carried out.

Methodology:

The project was carried out in two phases:

Phase 1: Identifying STS principles to be applied for human-robot teaming systems (HRT) - This phase has been completed.

The research questions addressed in this phase were:

RQ 1. How well do the current STS principles fit with the design and development of human-robot teams?

RQ 2. What modifications or additions do we need (if any) for STS principles to fit in the context of HRT design and development?

The investigators used a multimethod approach employing two qualitative methods within an interpretivist paradigm to review existing principles as well as propose new principles that are relevant in the HRT context. The research team included two STS experts in system design and HRT robotics experts with over 20 years of experience, as well as system designers who had developed robotics solutions for over 10 years.

The steps taken included:

1. A systematic literature review of existing STS principles.
2. Expert assessment of the applicability of existing principles to the HRT context.
3. Collaborative face-to-face discussions to discuss, debate, and justify the relevance of existing principles.
4. Iterative refinement through multiple validation sessions.

Through this process, 26 principles were identified from more than 150 existing principles from a review of the literature as still applicable in the HRT context. During the process, eight new principles were also introduced based on the experience of the robotics experts that have not been proposed before by STS scholars. The 34 principles were then grouped into seven themes relevant to the design and development of HRTs. The themes that resulted from the analysis are:

1. Systems Design and Adaptation
2. Human-Centered Approach
3. Integration and Optimization
4. Collaboration and Participation
5. Information and Communication
6. Organizational Alignment and Process Management
7. Trust and Reliability

The findings from Phase 1 have been published in *Applied Ergonomics* (Ang, Sankaran & Liu, 2025). These will be briefly reported at the conference.

Phase 2: Validating the STS principles developed for HRT systems design and development (in progress)

The investigators, who are also authors of the paper, reviewed existing STS principles and the ways in which they had been validated and found that no adoptable validation method had been used before. They found that while most of the existing principles had been proposed based on actual experience dealing with issues faced in sociotechnical contexts, except in one instance, where an action research process was applied through case studies.

Two of the investigators, who are systems thinkers, decided to use the twelve questions suggested in Critical Systems Heuristics (CSH) (Ulrich & Reynolds, 2020) and adapt them to interview different stakeholders involved in conducting research to develop HRT solutions from the HARTCon hub. CSH provides a framework of questions for carrying out interventions or evaluating a program where multiple stakeholders may have different views to ensure that they will be considered in delivering outcomes from the intervention. The investigators felt that the CSH framework could help examine the value judgments made by experts about which STS principles are to be used in HRT by considering the concerns of those affected by the implementation of the HRT systems. Ulrich & Reynolds (2020) point out that when we apply scientific knowledge in the real world, we often draw boundaries around the part of that world that we acknowledge as being affected when focusing on the part of the system under consideration. However, drawing such boundaries could impact the use of knowledge that has been developed. It was decided that using the twelve questions suggested by Ulrich & Reynolds (2020) could provide a better understanding of the implications of applying STS principles in the HRT context from different points of view.

Three reasons why we decided to use CSH are:

1. Making sense of situations: understanding assumptions and appreciating the bigger picture.
2. Unfolding multiple perspectives: promoting mutual understanding.
3. Promoting reflective practice: analyzing situations and changing them.

Using the questions derived from CSH and adapting them to the newly proposed STS principles, interviews have already been conducted with three sets of stakeholders: a human-robot design team, managers of the team, and representatives from the construction sector.

The data collected from these interviews is being thematically analyzed (King & Brown, 2018) by the authors, and the findings will be presented at EPOC 2026. The investigators plan to use Microsoft Copilot but building on prompts developed for thematic analysis using Chat GPT (Nguyen-Trung, 2025) and NVivo software (Jackson & Bazeley, 2019) to analyze the data using two methods, and the findings and plan to present it at EPOC 2026. Microsoft Copilot was used as it is the only authorized Gen AI software that is permitted at our university to use for our research. The authors will also reflect on the use of AI tools for qualitative data analysis.

Note: The authors acknowledge that Microsoft Copilot will be used to report on the use of AI for thematic analysis when this paper is presented at EPOC 2026.

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