Proceedings of the 2025 Winter Simulation Conference
E. Azar, A. Djanatliev, A. Harper, C. Kogler, V. Ramamohan, A. Anagnostou, and S. J. E. Taylor, eds.

THE HUMAN GEAR: ENABLING RELIABLE SMART SIMULATION THROUGH EXPERT INTERACTION

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ABSTRACT

Organizations face increasing pressure to optimize processes, control costs, and comply with changing regulations. Business Process Simulation (BPS) offers a way to test process changes in a controlled environment before implementation, providing insights that support strategic decision-making. Yet, despite its proven potential, BPS remains underutilized in practice. Even with recent advances in automated simulation based on event logs, real-world adoption is hindered by persistent challenges such as poor data quality, lack of contextual understanding, and insufficient trust in black-box models. This PhD project tackles these barriers by proposing a novel, Human-In-The-Loop (HITL) simulation framework that dynamically balances automation with expert involvement. By embedding human judgment at key stages, this research aims to deliver more accurate, explainable, and practically usable simulations. The outcome is a scalable approach that bridges the gap between simulation theory and industry reality.

RESEARCH PROBLEM AND MOTIVIATION

Despite its potential to support evidence-based decision-making, BPS remains significantly underutilized in real-world organizational environments. Our previous work (Khraiwesh and Pufahl 2025b) has shown that BPS has largely concentrated on three methodological trends: (1) enhancing or introducing new model components, (2) exploring alternative modeling perspectives beyond traditional approaches, and (3) applying advanced techniques such as process mining and machine learning to support model construction. While these trends advance automation of building BPS models, they often neglect the real-world factors that limit BPS adoption in practice, such as poor data quality, socio-technical challenges, and the scarcity of skilled experts. Furthermore, we have shown that no existing work specifically targets or addresses data quality issues in BPS, and that only very few studies propose methods to both detect and resolve such issues from a process mining perspective (Khraiwesh et al. 2025). Addressing these gaps is key to making BPS a reliable tool for organizations. This PhD project proposes a HITL simulation framework that integrates human expertise at critical stages of BPS. The aim is to achieve an optimal balance between automation and manual involvement in both data quality filtering and BPS model construction, resulting in simulations that are more accurate, trustworthy, and applicable to real-world contexts. To address this aim, the research investigates the following questions:

1. Which stages of building the BPS model most critically require human involvement to ensure reliable and effective model construction?
2. What factors determine the necessity of human involvement in building the BPS model?
3. How can the optimal balance between human experts and automated systems be achieved to maximize efficiency and minimize bias?

RESEARCH APPROACH

This research follows the Design Science Research (DSR) methodology (Peffers et al. 2007), suitable for developing innovative solutions. The artifact of this research is a HITL simulation framework, which will be developed conceptually and implemented in a prototype. The design problem addressed in this research is how to construct reliable and trustworthy BPS models in contexts where event log data is incomplete or of low quality, while balancing automation with expert involvement. As outlined earlier, the research problem, motivation, and objectives were defined, and the requirements in (Khraiwesh and Pufahl 2025a) were derived from a Systematic Literature Review (SLR) and expert interviews on the HITL concept in BPS. Following the DSR methodology, the identified problem and objectives inform the design of a HITL simulation framework. The four work packages represent the design and development phase of this artifact, while subsequent evaluations will demonstrate its utility and effectiveness. Based on our requirements, we are currently working in parallel on four work packages:

(1) DATA VALIDATION FOR BPS This work package addresses the limitations caused by data quality issues and aims to increase the reliability of the inputs used to build BPS models. It focuses on BPS-specific data quality issues that have not yet been addressed in the research. Our approach involves, first, using Large Language Models (LLMs) to detect errors or quality issues, and second, integrating human expertise to validate or correct these errors.

(2) MOVING FROM SIMULATION OBJECTIVES TO SIMULATION PARAMETERS This work package addresses the limitation caused by the small number of available experts, enabling a link between stakeholders with higher-level knowledge—such as managers and decision-makers—and technical information (simulation parameters). It uses LLMs to support and translate simulation objectives into parameters, with explanations clarifying the reasoning behind the suggested parameters. These parameters will be generated within specific constraints provided as input to the LLMs by humans.

(3) SENSITIVITY ANALYSIS FOR SIMULATION PARAMETERS This work package addresses The limitation of finding the optimal balance between human involvement and automation by identifying the simulation parameters that largely affect the simulation output. This helps define the parameters that have the most significant impact on the outcome to be validated and provided by humans, while leaving those with minimal impact to be handled by automation techniques.

(4) HUMAN INVOLVEMENT IN CONTROL FLOW Automated control-flow discovery typically treats event logs as the single source of truth, which can lead to noisy or incomplete models that are difficult to trust for simulation. To address this limitation, we are working on augmenting automated discovery with human validation at key points, ensuring that contextual knowledge missing from logs is incorporated. Our contribution embeds human validation into a broader HITL simulation framework, explicitly linking it to data quality and trust challenges in BPS. Together, these work packages contribute to the development and evaluation of HITL framework as the central artifact of this research, consistent with the DSR approach.

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