Digital micro-services on an AI-based construction site simulation platform: Exploring service types and key challenges

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Abstract

A construction site typically encompasses various heavy-duty industrial electric and autonomous vehicles. As the construction industry embraces advanced digital and Industry 4.0 capabilities, it has begun exploring ways to enhance customer support for continuous site operations through diverse digital micro-services. These micro-services offer opportunities to improve operational efficiency, promote sustainability, and deliver tailored solutions. However, their specific types and implementation challenges remain insufficiently understood across different levels of construction site operations. To bridge this knowledge gap, this study aims to investigate the potential of digital micro-services on an Artificial Intelligence (AI)-based construction site simulation platform within the heavy-duty vehicle industry. By conducting a case study in a manufacturing company operating in the heavy-duty vehicle industry, this research identifies the key types of digital micro-services that the company can offer. It considers four levels of construction site operations: site-level, fleet-level, machine-level, and component-level. Furthermore, the study elucidates the primary challenges encountered during the development and delivery of digital micro-services on an AI-based site platform. Drawing upon the Technology-Organization-Environment (TOE) theory, the research systematically categorizes these challenges. Overall, this study contributes to the existing literature on digital servitization, data-driven services, and digital platforms by shedding light on the

significance of digital micro-services in the construction industry. Through the exploration of their types and challenges, it provides valuable insights for practitioners and researchers.

Keywords: Digital servitization, Data-driven services, Digital platforms, Industry 4.0.

Introduction

The construction industry is confronted with intricate challenges as it strives to embrace digitalization and achieve net-zero emission targets in site operations. To tackle these challenges, manufacturing companies, particularly Original Equipment Manufacturers (OEMs) in the construction sector, are actively developing advanced digital AI-based construction site simulation platforms. AI offers numerous benefits to the modeling and simulation of construction sites (Baduge, Thilakarathna, Perera, Arashpour, Sharafi, Teodosio et al., 2022). These platforms are intended to enhance operational efficiency, promote environmental sustainability, and provide tailored solutions through the provision of digital micro-services (Li, Xue, Li, Hong & Shen, 2018; Shumei, Xiaofei, Dewen, Qianfan & Liwei, 2011).

Despite the promising benefits associated with these platforms, there exists a significant gap in understanding the diversity of these services, the obstacles encountered during their development and delivery, and their effectiveness in meeting industry demands.

This study endeavors to navigate the intricate landscape of digital micro-services, aiming to unravel their inherent nature, the challenges they entail, and their untapped potential within the realm of AI-based construction site simulation platforms. By addressing this existing research gap, the study offers valuable insights and guidance for industry professionals, policymakers, and academics

who seek to harness the potential of these services for a wide range of purposes (Wan, Kumaraswamy & Liu, 2013).

Methodology

The research employed a case study approach (Yin, 2009) and utilized semi-structured interviews as the primary method of data collection. The study included a total of 12 participants who held various roles within an OEM and construction companies. These participants consisted of four individuals from management, four from information technology (IT), and four representing the construction site, including both managers and engineers involved in site operations. The interview questionnaires were thoughtfully designed and tailored to each participant, aiming to elicit rich and detailed data regarding their experiences with digital micro-services on an AI-based construction site simulation platform. The collected data was analyzed using a three-order thematic analysis approach (Braun & Clarke, 2006) to identify relevant themes and findings. Specifically, the key challenges were examined through the lens of the Technology-Organization-Environment (TOE) theory, which elucidates how a firm's technological, organizational, and environmental context influences the adoption and implementation of technological innovations (Tornatzky & Fleischer, 1990). This theory proves relevant and applicable to the study context.

Results

The study yielded comprehensive insights into the different service levels within construction sites, including site, fleet, machine, and component levels. These insights shed light on the key challenges encountered during the development and delivery of digital micro-services, as depicted in Figure 1.

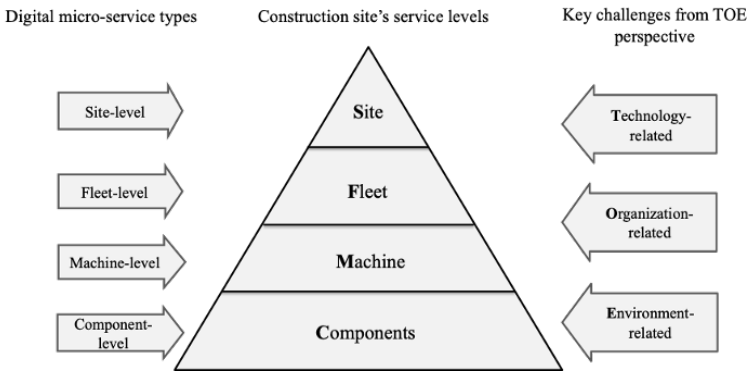

Figure 1. Mapping key types of digital micro-service and key challenges across the four levels construction site.

At the site level, the customer-centric approach emphasized by Interviewee1 calls for digital services to provide actionable, outcome-based information. This includes the integration of financial data into user interfaces and dashboards to provide a clearer understanding of operational implications. The importance of embracing innovation, digitalization, and connectivity to stay competitive is underscored, with a need for visionary leadership to drive change and adoption of service business models.

Moving to the fleet level, Interviewee2 highlighted the importance of differentiating between site data and machine data and determining data ownership. This differentiation is vital for managing construction equipment effectively. His emphasis on predictive maintenance and component monitoring as crucial aspects of equipment management resonates at the machine level, demonstrating the role of data-driven solutions in improving efficiency and sustainability.

At the component level, Interviewee3's insight reveals the role of microservices and new technologies in meeting the rising

sustainability expectations of customers. Manufacturers should be prepared to engage in deeper, strategic conversations with customers about sustainability, as it becomes an integral aspect of their decision-making process.

However, implementing micro-services comes with challenges that are technology-related, organization-related, and environment-related. Technology-related challenges are illuminated by Interviewee2's focus on streamlining operations through microservices and enabling continuous feedback loops between stakeholders. In contrast, organization-related challenges arise from SL's emphasis on the need to adjust KPIs, reporting, and compensation structures to encourage the adoption of service business models. Interviewee4 underscored environment-related challenges, including the necessity for understanding customers' needs, developing clear strategic visions, and fostering effective collaboration within teams.

To conclude, the suggested mapping will improve the understanding of key types of digital micro-services on AI-based platform and involve challenges in the site operations in the construction industry. The study has an important contribution to the theory of digital servitization, data-driven services, and digital platforms with a specific focus on digital micro-services in the construction industry.

References

Baduge, S. K., Thilakarathna, S., Perera, J. S., Arashpour, M., Sharafi, P., Teodosio, B. et al. (2022). Artificial intelligence and smart vision for building and construction 4.0: Machine and deep learning methods and applications. *Automation in Construction,* 141, 104440. https://doi.org/10.1016/j.autcon.2022.104440

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qual. Res. Psychol.,* 3(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Li, C. Z., Xue, F., Li, X., Hong, J., & Shen, G. Q. (2018). An Internet of Things-enabled BIM platform for on-site assembly services in prefabricated construction. *Automation in Construction*, 89, 146-161. https://doi.org/10.1016/j.autcon.2018.01.001

Shumei, C., Xiaofei, L., Dewen, T., Qianfan, Z., & Liwei, S. (2011). The construction and simulation of V2G system in micro-grid. *2011 International Conference on Electrical Machines and Systems,* 1-4. https://doi.org/10.1109/ICEMS.2011.6073378

Tornatzky, L.G., &Fleischer, M. (1990). *The Processes of Technological Innovation.* Lexington Books, Lexington, MA.

Yin, R.K. (2009). *Case Study Research: Design and Methods.* Sage Publications, Thousand Oaks, CA.

Wan, S. K. M., Kumaraswamy, M., & Liu, D. T. C. (2013). Dynamic modelling of building services projects: A simulation model for real-life projects in the Hong Kong construction industry. *Mathematical and Computer Modelling,* 57(9-10), 2054-2066. https://doi.org/10.1016/j.mcm.2011.06.070