Digital Twin-Driven, Human-Centric Ergonomic Risk Forecasting in Manufacturing Assembly: Collective Case Study

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Abstract. This study adopts a collective case study methodology to explore the application of digital twin (DT) technologies for human-centric ergonomic risk forecasting in manufacturing assembly environments. By analyzing three distinct automotive and industrial manufacturing companies with varying sizes, sectors, digital maturity levels, and workstation organizations, the research investigates how digital twins (DTs) and associated digital human models (DHMs) are utilized to anticipate, assess, and mitigate ergonomic risks on the assembly line. Through within-case and cross-case analyses, the research identifies key themes around ergonomic risk identification, DT deployment, and human–machine interaction strategies tailored to different operational contexts. The findings highlight the role of advanced digital tools, including sensor networks, biomechanical simulations, and real-time monitoring, in enabling proactive ergonomic interventions that align with Industry 5.0 principles. This comparative approach provides valuable insights into how digital transformation drives ergonomic improvements and worker well-being across diverse manufacturing settings.

Keywords: Ergonomic Risk Forecasting, Collective Case Study; Digital Twin; Human-Machine Collaboration; Manufacturing Assembly, Industry 5.0.