Chapter 11
A Comprehensive Review and SWOT Analysis of Lean Six Sigma Integration With Industry 4.0 and 5.0 for Sustainable Transformation

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ABSTRACT

The advent of Quality 5.0, characterized by human-centricity, sustainability, and

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resilience, necessitates a reimagining of traditional Lean Six Sigma (LSS) methodologies. This paper synthesizes 150 seminal works to propose a transformative framework integrating LSS with emerging technologies (AI, IoT, digital twins) and socio-technical systems. A systematic literature review and conceptual analysis identifies ten key techniques that align LSS with Quality 5.0, emphasizing collaborative human-AI workflows, real-time analytics, and sustainable value streams. Case studies from manufacturing, healthcare, and services illustrate the framework's efficacy, while challenges like data security and workforce upskilling are critically examined. The study contributes a roadmap for organizations to navigate the Quality 5.0 transition, balancing technological agility with human empowerment.

1.0 INTRODUCTION

Lean Six Sigma (LSS) has become a strategic imperative in the dynamic landscape of industrial transformation. Lean and Six Sigma were first developed to enhance efficiency, minimize waste, and elevate quality. Since that time, they have broadened their emphasis to encompass initiatives for social and environmental sustainability (Garza-Reyes, 2015). As organizations transition from the automation-centric objectives of Industry 4.0 (I4.0) to the human-centric, resilient, and sustainable aspirations of Industry 5.0 (I5.0), redefining metrics is increasingly imperative (European Commission, 2022). This modification necessitates a comprehensive evaluation strategy that integrates process enhancement with long-term sustainability objectives. This plan must have measures for economic, environmental, and social performance. To achieve operational excellence, organizational accountability, and societal impact, it is essential to develop and implement comprehensive sustainability indicators tailored for LSS within the I5.0 framework (Kaswan et al., 2023). Lean is a philosophy derived from the Toyota Production System (TPS) in the mid-20th century. The objective is to enhance operations by eliminating various forms of waste, including overproduction, delays, and defects (Womack et al., 1990). Taiichi Ohno developed Lean, which emphasizes delivering value to the client via just-in-time production, continuous improvement (kaizen), and respectful treatment of individuals (Ohno, 2019). The significant increase in the 1990s, attributed to the global triumph of Japanese automakers, established lean as a universal paradigm that transcended manufacturing to encompass healthcare, production, and the public sector (Hines et al., 2004). Lean's principle of maximising efficiency with minimal