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Smart Factory Context and Employee Engagement in the Apparel Industry: A Systematic Literature Review

Yapa SG[1*], Perera GDN[2], Jayasekara P[3]

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[1*] S G Yapa, PhD Student, Faculty of Graduate Studies, University of Sri Jayewardenepura, Sri Lanka.

[2] G D N Perera, Professor, Department of Human Resource Management, University of Sri Jayewardenepura, Sri Lanka.

[3] P Jayasekara, Professor, Department of Human Resource Management, University of Sri Jayewardenepura, Sri Lanka.

This study presents a systematic literature review on the correlation between the Smart Factory context and employee engagement in the apparel industry. Drawing on peer-reviewed journal articles, conference papers, and industry reports published from 1980 to 2024, the review synthesizes theoretical and empirical evidence from global and Sri Lankan manufacturing contexts, especially apparel industry. The findings indicate that while smart factory technologies such as automation, IoT, real-time data analytics, and system integration significantly enhance operational performance, their impact on employee engagement is largely contingent upon human-centric aspects. Adequate training and supportive work environments enable machine operators to adapt to technological change, thereby fostering emotional, cognitive, behavioral, and social engagement. The review further highlights that operational efficiency strengthens this relationship by reinforcing positive perceptions of technology adoption. The study contributes by integrating technological and human perspectives within the Smart Factory literature and by identifying critical pathways through which digital transformation influences employee engagement in the apparel industry.

Keywords: apparel industry, employee engagement, literature review, smart factory context

Corresponding Author

S G Yapa, PhD Student, Faculty of Graduate Studies, University of Sri Jayewardenepura, Sri Lanka.
Email: savindikayapa@gmail.com

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1. Introduction

The rapid improvement of Industry 4.0 has fundamentally transformed manufacturing systems through the adoption of smart factory technologies such as automation, the Internet of Things (IoT), real-time data analytics, artificial intelligence, and cyber physical systems (Zhong et al., 2017; Ghobakhloo, 2018). These technologies aim to improve productivity, flexibility, and operational efficiency while enabling organizations to remain competitive in increasingly dynamic global markets. As manufacturing systems become more digitally integrated and autonomous, the smart factory context has emerged as a dominant paradigm shaping contemporary industrial practices, particularly within labour-intensive sectors such as apparel manufacturing (Sony & Naik, 2020; Wijayasiri & Dissanayake, 2022).

While the operational and technological benefits of smart factories are well documented, their implications for the human dimension of work remain comparatively underexplored, especially in developing countries' contexts. Employee engagement defined as the emotional, cognitive, and behavioral investment of employees in their work has been widely recognized as a critical driver of productivity, quality, innovation, and workforce sustainability (Kahn, 1990; Saks, 2006). In smart factory settings, where machine operators are required to interact with advanced technologies and adapt to continuously evolving workflows, employee engagement becomes both more challenging and more essential (Yapa et al., 2025).

Existing literature suggests that the relationship between the smart factory context and employee engagement is not direct but shaped by key organizational mechanisms (Wang et al., 2021). Training plays a critical role in equipping employees with the skills and confidence required to operate advanced technologies, while workplace support through managerial guidance, peer collaboration, and access to resources helps mitigate stress and resistance associated with technological change. Also, operational efficiency may strengthen this relationship by reinforcing employees' perceptions of the value and effectiveness of smart factory initiatives, thereby enhancing acceptance and engagement (Yapa et al., 2025).

Despite the growing body of research on smart factory context and employee engagement, empirical evidence remains fragmented, with limited focus on machine operators in the apparel industry and scarce insights from Sri Lanka and similar developing economies. Addressing this gap, the present study undertakes a systematic literature review to synthesize global and local evidence on the smart factory employee engagement nexus. By integrating technological and human centric perspectives, this review aims to provide a comprehensive theoretical foundation and identify critical research gaps to guide future empirical investigations and managerial practice.

2. Objectives of the Study

1. To examine the theoretical foundations and empirical evidence related to the Smart Factory context and employee engagement in apparel industry.
2. To identify and analyze the key dimensions of the Smart Factory context, including automation, real-time data, Internet of Things (IoT), and data integration, as discussed in prior studies.
3. To review the conceptualization and dimensions of employee engagement, with emphasis on emotional, cognitive, behavioural, and social aspects.
4. To compare global and Sri Lankan empirical evidence on smart factory adoption and employee engagement, with a specific focus on the apparel industry.

3. Method

This study adopts a systematic literature review (SLR) methodology to examine the relationship between the Smart Factory context and employee engagement. A systematic approach was selected to ensure transparency, rigor, and replicability in identifying, evaluating, and synthesizing relevant scholarly evidence (Tranfield, Denyer & Smart, 2003).

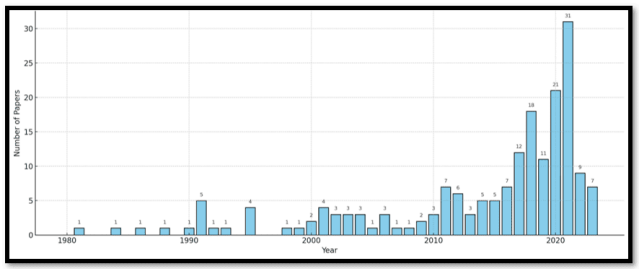
The review process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to structure the identification, screening, eligibility, and inclusion of studies. This approach minimizes selection bias and enhances the reliability of findings by applying consistent inclusion and exclusion criteria throughout the review process (Moher et al., 2009).

Secondary data was collected from peer-reviewed journal articles, conference proceedings, book chapters, working papers, and selected industry reports published between 1980 and 2024. The selected time horizon captures both early conceptual foundations of employee engagement and the emergence of Industry 4.0 and smart factory literature. Key academic databases including Scopus, Web of Science, Emerald Insight, Taylor & Francis, JSTOR, Oxford, Sage, Wiley Online Library, and Google Scholar were systematically searched to ensure comprehensive coverage. Industry reports and relevant publications from ResearchGate were used to supplement academic sources and capture recent developments.

The 292 scholarly articles and reports were retained for final analysis. The selected studies were systematically analyzed using thematic synthesis, enabling the identification of dominant themes, theoretical perspectives (Resource Based View, Job Demand - Resources, Social Exchange Theory, and Technical Acceptance Model), empirical trends, and research gaps. This methodological approach ensures a robust theoretical basis for examining the Smart Factory Employee Engagement relationship, particularly within large-scale apparel firms in Sri Lanka, while contributing to the broader Industry 4.0 and human-centric manufacturing literature.

Figure 1 clarifies the annual distribution of published research articles related to the Smart Factory context and employee engagement within the global apparel or manufacturing sector from 1980 to 2024. The trend shows a notable increase in scholarly attention from around 2010 onwards, which aligns with the global adoption of Industry 4.0 technologies and digital transformation in manufacturing. While there were very few relevant publications in the earlier decades (1980s to early 2000s), the number of articles began to rise steadily after 2010, with a sharp increase observed between 2015 and 2024. This reflects the growing interest among researchers and practitioners in understanding how smart technologies impact workforce dynamics, particularly in emerging economies such as Sri Lanka. The figure explains the emerging nature of the topic, indicating both its relevance and the research gap in the context of apparel industries in developing countries.

Figure 1: Number of papers published per year



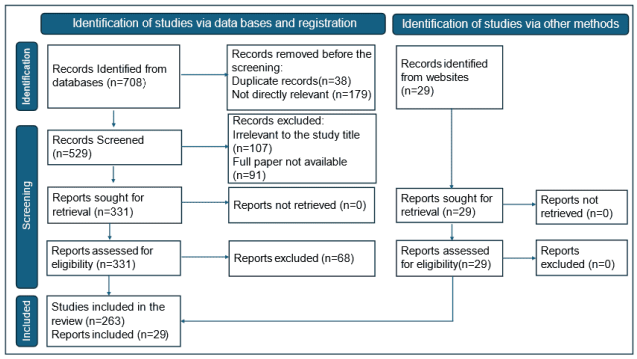
Source: (Created by Author, 2025)

3.1 Prisma Flow Chart

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) flowchart visually represents the systematic process of identifying, screening and selecting relevant studies for this systematic review, as presented in Figure 2. The process includes three main stages: identification, screening and inclusion. The key search terms used for this study involved "smart factory," "Industry 4.0," "intelligent manufacturing," "digital transformation in factories," "employee engagement," "workforce engagement," "training," "skill development," "workplace support," "organizational support" and "operational efficiency" in the titles, abstracts and keywords of the articles. The types of publications comprised peer reviewed journals, conference proceedings, working papers and book chapters.

Primarily, 708 articles were identified from databases such as Scopus, Taylor and Francis, Web of Science, Emerald Insight, Google Scholar, JSTOR, Oxford Library, Sage and Wiley, in addition to 29 relevant web reports. In the identification stage, 38 duplicate and 179 not directly relevant records were removed. In the next screening stage, 529 records continued. Out of those, 107 articles were removed due to being irrelevant to the study heading and 91 articles were removed due to the unavailability of a full paper. The remaining 331 articles along with 29 web reports were considered for the eligibility check. Here, 68 articles were found irrelevant to the study due to a lack of clarity. Finally, a total of 292 articles and reports were considered in the study's review.

Figure 2: PRISMA Flow Diagram



Source: (Created by Authors, 2025)

4. Literature Review

The smart factory context, driven by Industry 4.0 technologies such as automation, IoT, and real-time data analytics, has transformed manufacturing operations while reshaping workforce roles and expectations (Zhong et al., 2017; Ghobakhloo, 2018). Although existing literature extensively documents operational and efficiency gains, limited attention has been paid to employee engagement, particularly in labour-intensive industries such as apparel manufacturing (Sony & Naik, 2020). Employee engagement, defined as employees' emotional, cognitive, and behavioral investment in their work, becomes increasingly critical as machine operators adapt to digitally integrated and automated environments (Kahn, 1990; Saks, 2006). Prior studies suggest that training, workplace support, and operational efficiency play key roles in translating smart factory adoption into positive engagement outcomes, highlighting the need for a systematic synthesis of evidence, especially within developing-country contexts such as Sri Lanka (Wang et al., 2021; Wijayasiri & Dissanayake, 2022).

4.1 Smart Factory Context

The smart factory is a key element of Industry 4.0, emphasizing digital integration, automation and real time data analytics to transform manufacturing processes. It includes technologies such as IoT, AI, big data analytics and robotics to create a highly efficient, adaptive and interconnected production environment (Kusiak, 2018). Unlike traditional factories, smart factories operate with minimal human intervention, optimizing operations through self-correcting and self-organizing systems (Lee et al., 2015).

Globally, the smart factory context is redefining production across many industries, particularly in manufacturing. Germany's "Industry 4.0" initiative has been pivotal in advancing smart factory adoption by integrating digital technologies to enhance productivity and efficiency (Hofmann & Rusch, 2017). Similarly, Japan has incorporated smart factory principles into its renowned Kaizen practices, focusing on continuous improvement and employee participation within automated systems (Lee et al., 2015).

In Sri Lanka's apparel sector, the smart factory context is gradually gaining traction. As a labor-intensive industry, the transition to smart manufacturing aims to address challenges such as skill shortages, cost efficiency and global competitiveness (Jayatilake & Withanaarachchi, 2021). The incorporation of advanced technologies, such as the IoT, AI, robotics and big data analytics, can streamline processes from fabric cutting to packaging, improving accuracy and reducing waste (Maddugoda, 2021; Bain & Company, 2023). However, the success of smart factory implementation in Sri Lanka depends on factors like workforce readiness, investment in technology and organizational culture (Jayatilake & Rupasinghe, 2016; Bandara et al., 2023).

A critical aspect of smart factory adoption is its impact on the workforce. While automation reduces manual tasks, it demands a highly skilled and adaptable workforce capable of managing and maintaining advanced systems (Bessen, 2019; Acemoglu & Restrepo, 2020). Thus, the alignment of training and workplace support with technological advancements becomes crucial to ensuring a seamless transition and fostering employee engagement within smart factory environments (Ghobakhloo, 2020).

4.2 Definition of Smart Factory Context

By incorporating advanced technologies, the Smart Factory not only enhances operational efficiency but also fosters innovation, flexibility and sustainability in manufacturing processes. This evolution reflects the growing need for manufacturers to remain competitive in an era of digital revolution and global supply chain complexities. The definitions provided by various scholars and industry experts highlight the multifaceted nature of the Smart Factory, offering various perspectives on its role and impact in modern manufacturing.

The table below presents key definitions of the Smart Factory concept, showcasing its progression and the technological advancements that have shaped its development. These definitions provide a comprehensive understanding of the context, serving as a foundation for exploring its implications for employee engagement and operational efficiency in large scale apparel firms in Sri Lanka. Table 1 presents the definitions of the smart factory context.

Table 1: Definition of Smart Factory Context

Authors	Year	Definitions
Kagermann	2011	A Smart Factory integrates cyber physical systems and the Internet of Things to create autonomous and flexible production networks, providing significant improvements in efficiency and decision making.
Kagermann, Wahlster, & Helbig	2013	As a production environment capable of self-organization, where physical and virtual systems integrate to enable intelligent decision making and autonomous control.
Lee, Bagheri, & Kao	2015	An advanced manufacturing ecosystem that leverages predictive analytics, real time data and machine learning to achieve self-diagnosis, optimization and continuous improvement.
Schumacher, Erol, & Sihn,	2016	A factory characterized by interconnected processes and systems, enabling real time data exchange and adaptive manufacturing to respond dynamically to changing demands.
Zhong, et al.,	2017	A paradigm that integrates cyber physical systems and intelligent technologies, aiming to optimize production systems, reduce waste and enable mass customization.
Hofmann, & Rusch	2017	The integration of Industry 4.0 technologies in manufacturing, where machines and systems communicate autonomously to improve productivity, flexibility and adaptability.
Raj & Kulkarni	2020	The Smart Factory is a digitally enabled facility where interconnected devices, machines and systems work collaboratively, supported by artificial intelligence and advanced automation technologies.
Wang, et al.,	2021	A Smart Factory is a manufacturing system utilizing advanced technologies such as IoT, big data analytics, robotics and automation to enhance operational efficiency, flexibility and customization.

Source: (Compilation from literature, 2025)

4.3 Dimensions of the Smart Factory Context

The Smart Factory context, rooted in Industry 4.0, emphasizes the integration of advanced technologies, such as cyber physical systems (CPS), IoT, big data analytics, robotics and AI, to create autonomous, intelligent and interconnected manufacturing environments (Kagermann et al., 2013; Xu et al., 2018). These dimensions not only enhance operational efficiency but also support flexibility, customization and adaptive decision making in production systems. From the early definitions that introduced the idea of automation and digitalization to more contemporary studies concentrating on predictive analytics and real time data exchange, the dimensions of the Smart Factory have evolved significantly. Table 2 is a summary of key studies on the dimensions of the Smart Factory context.

Table 2: Dimensions of the Smart Factory Context

Authors	Year	Research Topic	Dimensions of the Smart Factory Context
Kagermann, Wahlster & Helbig	2013	Recommendations for Implementing the Strategic Initiative Industry 4.0: Securing the Future of the German Manufacturing Industry	Self-organizing systems, integration of physical and virtual systems for intelligent decision making and control.
Lee, Bagheri, & Kao	2015	A cyber physical systems architecture for Industry 4.0-based manufacturing systems	Predictive analytics, real time data and machine learning for self-diagnosis and optimization.
Schumacher, Erol, & Sihn,	2016	A maturity model for assessing Industry 4.0 readiness and the maturity of manufacturing enterprises	Interconnected processes, real-time data exchange and adaptive manufacturing to respond dynamically to market demands.
Zhong, et al.,	2017	Intelligent manufacturing in the context of Industry 4.0	CPS integration, optimization of production systems, reduction of waste and mass customization.
Hofmann, & Rusch	2017	Industry 4.0 and the Current Status as well as Future Prospects on Logistics	Autonomous systems, digital integration and enhanced productivity, flexibility and adaptability.
Raj & Kulkarni	2020	Enabling smart factories through IoT and AI technologies: A review	AI-driven collaborative devices, advanced automation technologies and enhanced operational efficiency.
Wang, et al.,	2021	Big data analytics for intelligent manufacturing systems: A review	Utilization of IoT, robotics, big data and automation to enhance flexibility, operational efficiency and customization.

Source: (Compilation from literature, 2025)

4.4 Employee Engagement

Employee engagement has emerged as a crucial factor in organizational performance and workforce sustainability. Defined as the emotional and intellectual commitment of employees to their organization, it is characterized by enthusiasm, dedication and absorption in work (Schaufeli et al., 2002). Engaged employees are more likely to contribute to organizational success through increased productivity, enhanced innovation and improved retention rates (Harter et al., 2002).

The apparel manufacturing industry, particularly in developing countries like Sri Lanka, heavily relies on the engagement of machine operators to meet production demands and maintain quality standards (Joarder et al., 2017; Kelegama, 2009). In this labour intensive industry, factors such as supportive work environments, clear communication and recognition play pivotal roles in fostering employee engagement (Anitha, 2014).

Providing opportunities for skill development not only enhances employees' ability to adapt to technological advancements but also strengthens their confidence and commitment to their roles (Albrecht et al., 2015). Workplace support, including managerial feedback and collaborative environments, fosters a sense of belonging and empowerment among employees (Kahn, 1990).

In the context of smart factories, employee engagement becomes even more vital. The integration of advanced technologies demands that machine operators acquire new skills and adapt to dynamic workflows. Without adequate engagement, employees may resist these changes, leading to inefficiencies and reduced productivity (Robinson et al., 2004). Organizations adopting smart factory models must therefore align strategies to engage their workforce, ensuring alignment with technological advancements and organizational goals.

4.5 Definition of Employee Engagement

Employee engagement has evolved significantly over the years, reflecting various perspectives on its role and impact within organizations. Originally conceptualized as a psychological state, it now encompasses emotional, cognitive and behavioral dimensions that contribute to organizational success. Table 3 summarizes the key definitions of employee engagement.

Table 3: Definitions of Employee Engagement

Authors	Year	Definition
Kahn	1990	The harnessing of organizational members' selves to their work roles, where they express themselves physically, cognitively and emotionally.
Harter, Schmidt & Hayes	2002	The individual's involvement and enthusiasm for work lead to improved performance and productivity.
Schaufeli & Bakker	2004	A positive, fulfilling, work-related state of mind characterized by vigor, dedication and absorption.
Saks	2006	The extent to which employees are emotionally and cognitively attached to their work and organization.
Macey & Schneider	2008	A desirable condition with an organizational purpose, referring to the willingness of employees to invest discretionary effort at work.
Rich, Lepine & Crawford	2010	The investment of an employee's self into their work roles, which includes physical, emotional and cognitive engagement.
Shuck	2011	A multi-dimensional construct comprising emotional, cognitive and behavioral states that drive employee performance and satisfaction.
Bailey, et al.,	2017	A workplace approach results in the right conditions for all members of an organization to give their best each day.
Crawford, et al.,	2019	A construct that connects individual passion and purpose with the organization's goals and strategies.
Robertson, & Cooper	2021	Psychological well-being and involvement directly influence organizational effectiveness.

Source: (Compilation from literature, 2025)

4.6 Dimension of Employee Engagement

Employee engagement has been extensively studied across different dimensions to understand its drivers and outcomes in varying organizational contexts. The dimensions of employee engagement typically include cognitive, emotional and behavioral aspects, as well as the factors that enhance or inhibit engagement. Below is a summary of studies, highlighting the dimensions of employee engagement, with a focus on their relevance to organizational success and employee well-being. Table 4 explains the dimensions of Employee Engagement.

Table 4: Dimensions of Employee Engagement

Authors	Year	Research Topic	Dimensions of Employee Engagement
Kahn	1990	Psychological Conditions of Personal Engagement and Disengagement at Work	Cognitive, emotional and physical dimensions - employees' psychological presence in role performance.
Harter, Schmidt & Hayes	2002	Business Unit Level Relationship Between Employee Satisfaction, Engagement and Business Outcomes	Behavioral engagement is characterized by discretionary effort and enthusiasm for work.
Schaufeli & Bakker	2004	Job Demands, Job Resources and Their Relationship with Burnout and Engagement	Vigor, dedication and absorption as key dimensions of work engagement.
Saks	2006	Antecedents and Consequences of Employee Engagement	Job and organizational engagement, focusing on emotional and cognitive aspects linked to organizational outcomes.
Rich, Lepine, & Crawford	2010	Job Engagement: Antecedents and Effects on Job Performance	Physical, emotional and cognitive dimensions of engagement influencing job performance.
Shuck & Wollard	2010	Integrative Review of Employee Engagement: A Multidimensional Perspective	Emotional and psychological dimensions, including satisfaction, commitment and alignment with organizational goals.
Albrecht	2012	Work Engagement and the Positive Power of Meaningful Work	Meaning, purpose and alignment of individual and organizational values as engagement dimensions.
Bailey,et al.,	2017	The Meaning, Antecedents and Outcomes of Employee Engagement	Psychological safety, meaningful work and supportive relationships as critical dimensions of engagement.
Crawford, et al.,	2019	The Antecedents and Drivers of Employee Engagement	Engagement dimensions tied to passion, purpose and adaptive behaviors in the workplace.
Robertson & Cooper	2021	Wellbeing: Productivity and Happiness at Work	Wellbeing, resilience and involvement dimensions contributing to sustainable employee engagement.

Source: (Compilation from literature, 2025)

5. Global and Sri Lankan Context of Smart Factory Context and Employee Engagement

This section describes the global background as well as the Sri Lankan context of the smart factory and employee engagement.

5.1 Global Context

The smart factory context has transformed manufacturing industries worldwide by integrating advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), robotics and big data analytics into production processes (Kusiak, 2018; Wang et al., 2021; Xu et al., 2018). This approach enables real time data analysis, predictive maintenance and increased operational efficiency, contributing to competitive advantages in a rapidly evolving market (Kusiak, 2018). Smart factories not only enhance productivity but also transform the workplace environment, demanding a skilled workforce capable of leveraging these advanced technologies (Lee et al., 2015, Yapa et al., 2025).

Employee engagement, a crucial factor in organizational success, becomes even more significant in the context of smart factories. Engaged employees are more likely to embrace technological changes, contribute to innovative processes and align with organizational goals (PM World Journal, 2023). Studies highlight that supportive workplace environments, proper training and enhanced autonomy foster higher employee engagement, especially in technology driven industries (Ahmad et al., 2022

A positive workplace setting significantly impacts employee performance. Also, a conducive environment enhances employee commitment and achievement striving ability, leading to improved performance (Khan et al., 2022). Proper training is also a vital factor in ensuring employees are equipped to handle technological advancements in smart factories. Investing in comprehensive training programs enhances employees' skills and demonstrates the organization's commitment to their professional development, thereby increasing engagement (Yapa et al., 2025, CPS HR, 2023).

Globally, countries such as Germany, the United States and Japan have embraced the Industry 4.0 framework, emphasizing the integration of smart factory context. In these contexts, employee engagement strategies are crucial in managing the transition to automation and advanced manufacturing systems, ensuring workforce adaptability and job satisfaction (Hofmann & Ruch, 2017).

In the apparel sector, where operational efficiency and quick response to market demands are crucial, smart factory adoption has the potential to revolutionize production while requiring a focus on employee engagement to address challenges such as skill gaps and resistance to change (Bain et al., 2021).

5.2 Sri Lankan Context

The transformation of the smart factory concept in Sri Lanka's apparel industry has gained traction in recent years, driven by global competition and the need for enhanced operational efficiency (Wijethunga et al., 2023). The integration of technologies such as automation, IoT and advanced data analytics has enabled large scale apparel firms to streamline their operations, reduce production lead times and maintain quality standards (Wickramasinghe & Perera, 2021; Jayawardana & Weerasinghe, 2021). However, the human element remains critical to the success of these transformations, as employee engagement plays a pivotal role in ensuring smooth adaptation and sustained performance (Yapa et al., 2025, Wijewardena & Siriwardana, 2020).

Sri Lanka's apparel industry, a key contributor to the national economy, employs a significant portion of the labor force, with machine operators forming the backbone of production. The introduction of smart factory principles has posed challenges, including skill gaps and resistance to change, necessitating strategic interventions to enhance employee engagement (Perera & Jayasinghe, 2021). Engaged employees are more likely to embrace technological progressions, contribute to problem solving and align with the organization's strategic objectives.

Training and workplace support are nurturing employee engagement in the smart factory context. Providing targeted training programs ensures that operators can effectively use new technologies, while workplace support systems enhance job satisfaction and reduce turnover intentions (Silva & Wanninayake, 2021). Additionally, operational efficiency strengthens the relationship between smart factory adoption and employee engagement, as efficiency gains reinforce the perceived value of these technological enhancements (Jayasinghe & Thavakumar, 2020).

6. Conclusion

This systematic literature review demonstrates that while the Smart Factory context characterized by automation, IoT, real-time data analytics and system integration significantly enhances operational performance, its influence on employee engagement is fundamentally dependent on human-centric organizational factors. The review reveals that training and workplace support play critical roles by enabling machine operators to develop the skills, confidence and psychological readiness required to adapt to technologically advanced work environments, thereby fostering emotional, cognitive and behavioral engagement. Furthermore, operational efficiency strengthens this relationship by reinforcing employees' positive perceptions of technology usefulness and organizational effectiveness. Importantly, the findings highlight a substantial research gap in developing-country contexts, particularly within the Sri Lankan apparel industry, where smart factory adoption often prioritizes technological outcomes over workforce engagement. Overall, the review underscores the necessity of integrating technological advancements with strategic human resource practices to ensure sustainable smart factory implementation and long-term employee engagement.

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