Employee Engagement in Smart Factories: Research Gaps and a Nomological Framework for the Sri Lankan Apparel Sector

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ABSTRACT

The main objectives of this article are to identify research gaps on Smart Factory context and employee engagement in apparel manufacturing and to develop an integrated nomological framework. A systematic literature review (SLR) strategy was used to achieve these objectives. The literature survey was conducted using databases including Scopus, Taylor & Francis, Web of Science, Emerald Insight, Google Scholar, JSTOR, Oxford, Sage and Wiley Online Library, covering the period from 1990 to 2024. More than 350 articles were reviewed, of which 91 met the inclusion criteria for relevance, full-text availability, and scientific rigor. Through the SLR four key research gaps, were identified: Empirical Gap, Knowledge Gap, Methodological Gap and Theoretical Gap. Based on the identified gaps, an integrated framework was developed for further empirical studies. This study is limited to nomological framework development; it sheds new light on the human-centered dimensions of Smart Factory Context by injecting theoretical perspectives such as the Technology Acceptance Model, Job Demands–Resources model, Social Exchange Theory and the Resource-Based View. This study contributes to the literature on Smart Factories and employee engagement, as it addresses previously unexplored relationships among training, workplace support and operational efficiency. Further, it offers valuable insights to managers and policymakers in the apparel industry, aligning Smart Factory practices with employee engagement to ensure sustainable competitiveness.

Keywords - Apparel Industry, Employee Engagement, Nomological Framework, Smart Factory Context

INTRODUCTION

The advancement of Industry 4.0 has introduced a new era of digital revolution in manufacturing, where Smart Factory technologies such as automation, cyber physical systems (CPS), artificial intelligence (AI) and the Internet of Things (IoT) are reshaping production systems (Lasi et al., 2014; Kang et al., 2016). These technologies have enabled firms to achieve greater productivity, operational efficiency and accuracy of decision making, thereby enhancing competitiveness in global markets (Xu, Xu & Li, 2018; Sony & Naik, 2020). While the technical and economic benefits of these innovations are well acknowledged, the implications for human aspects, particularly employee engagement, remain less explored in academic discourse.

The Sri Lankan apparel manufacturing sector, as one of the largest contributors to the national economy and a major employment generator, is progressively adopting Smart Factory practices to meet global standards of agility, quality and sustainability (Perera et al., 2023). However, this transformation is accompanied by unique challenges due to its labor-intensive nature and the key role played by frontline employees such as machine operators. Although prior studies emphasize the operational and technological outcomes of Smart Factory transformation (Zhong et al., 2017; Wang et al., 2021), they often overlook the socio-psychological dimensions of this shift, particularly how digital integration impacts worker motivation, adaptability and engagement (Jabbour et al., 2018; Riemer & Peter, 2021).

Employee engagement is widely recognized as a cornerstone of organizational performance, innovation and retention, especially in periods of technological evolution (Kahn, 1990; Saks, 2006). Within the Smart Factory

context, where employees must continuously adapt to new systems and workflows, engagement becomes even more critical. However, the existing body of knowledge provides limited empirical and theoretical insights into how factors such as training, workplace support and operational efficiency influence engagement in developing country contexts such as Sri Lanka's apparel industry (Senanayake & Abeykoon, 2019; Fernando, Gunasekara & Wijesinghe, 2021).

Thus, this study aims to address these gaps by systematically reviewing the literature to identify key knowledge, empirical, methodological and theoretical gaps that hinder a holistic understanding of Smart Factory context and their effects on employee engagement.

The findings of this review are expected to contribute significantly in two ways. Theoretically, it enriches the current discourse by positioning human-centered dimensions within the Smart Factory context and expanding the application of established theories. Practically, it provides insights for policymakers and industry leaders on aligning digital transformation initiatives with human capital strategies, ensuring that technological growth enhances not diminishes the engagement of machine operators who remain central to the apparel industry's success.

Objectives Of the Study

This paper is guided by the following objectives:

1. To identify the literature on Smart Factory Context and employee engagement in the apparel industry.
2. To review the relationship between Smart Factory Context and employee engagement.
3. To identify research gaps in Smart Factory Context and employee engagement literature.
4. To develop a nomological framework that illustrates the relationship between Smart Factory Context and employee engagement.

METHOD

The desk research strategy was employed in this study as it is the most appropriate approach to achieving the objectives mentioned. An extensive literature survey was conducted to address the first, second and third objectives of the study. A literature review provides the strongest foundation for scholarly research, enabling the researcher to critically understand the domain and identify gaps in existing studies (Callahan, 2014).

This review was carried out through a three-step process: (1) planning the review, (2) establishing screening criteria and (3) extracting and analyzing data. In the first step, research articles were collected using search strings such as "Smart Factory," "Industry 4.0," "employee engagement," "training," "workplace support," and "operational efficiency" in article titles and keywords. Based on these terms, articles published between 1990 an d 2024 were retrieved. The publication types included peer-reviewed journal articles, conference proceedings and book chapters. The databases accessed included Emerald Insight, Google Scholar, JSTOR, Oxford, Sage, and Wiley Online Library, through which more than 350 papers were reviewed

In the second step, inclusion and exclusion criteria were applied to screen the articles. The inclusion criteria specified that: (A) articles should have been published between 1990 and 2024, (B) articles in the English language, and (C) articles primarily focus on Smart Factory practices, employee engagement or related dimensions such as training, workplace support and operational efficiency.

In the final step, irrelevant articles were excluded on the basis that they (i) were not directly related to Smart Factories or employee engagement, (ii) lacked full-text availability, or (iii) were not scholarly or peer-reviewed. After careful screening, a total of 91 articles were selected as the final sample for the study.

LITERATURE REVIEW

First, review the concepts of smart factory context and employee engagement in this section.

Definition of Smart Factory Context

By incorporating advanced technologies, the Smart Factory setting 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 context, offering various perspectives on its role and impact in modern manufacturing.

Table 1 presents key definitions of the Smart Factory concept, showcasing its progression and the technological advancements that have shaped its growth. 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 factories in Sri Lanka.

Table 1: Definition of Smart Factory Context and Characteristics

Author & Citation	Definition	Characteristics
Kagermann et al. (2013)	As a production environment capable of self-organization, where physical and virtual systems integrate to enable intelligent decision making and autonomous control.	Self-Organization, integration of physical and virtual systems, intelligent decision making, autonomous control, decentralization
Lee et al. (2015)	An advanced manufacturing ecosystem that leverages predictive analytics, real time data and machine learning to achieve self-diagnosis, optimization and continuous improvement.	Predictive analytics, real time data and machine learning for self-diagnosis and optimization.
Kusiak (2018)	A data driven environment where big data analytics and AI drive predictive and prescriptive decision-making across operations.	Big data analytics, AI driven decisions, predictive maintenance, automation.
Hofmann & Rusch (2017)	The integration of Industry 4.0 technologies in manufacturing, where machines and systems communicate autonomously to improve productivity, flexibility and adaptability.	Flexibility, real time data usage, digital manufacturing, adaptive systems.
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.	CPS integration, optimization of production systems, reduction of waste and mass customization.
Kang et al. (2016)	A smart factory is an intelligent production environment where advanced ICT enables customized and flexible manufacturing.	ICT integration, customization, flexibility and intelligent networks.
Sony & Naik (2019)	Smart factories as fully digitized manufacturing ecosystems where intelligent assets communicate, analyze and optimize processes independently.	Intelligent assets, autonomy, data exchange, ecosystem integration.
Oztemel & Gursev (2020)	A smart factory is characterized by its adaptability, resource efficiency and seamless integration of digital technologies across processes.	Adaptability, sustainability, resource efficiency and digital integration.

Ghobakhloo (2020)	A smart factory is a sociotechnical system combining advanced technologies and human capabilities to achieve operational excellence.	Human-technology integration, operational excellence, sociotechnical systems.
Stock & Seliger (2016)	A smart factory is defined as an environment that achieves sustainable and resource efficient production by leveraging smart technologies.	Sustainability, resource efficiency, smart technologies, green manufacturing.
Lu (2017)	Smart factory refers to the full integration of IoT, cloud computing and analytics to create intelligent production environments.	IoT, cloud computing, data analytics and intelligent environment.
Xu et al. (2018)	A smart factory is a CPS based factory that adapts and reconfigures itself based on demand and environmental conditions.	CPS, adaptability, reconfiguration, demand-responsiveness.
Liao et al. (2017)	A vision of digitalized production enabling mass customization and real time optimization through Industry 4.0.	Mass customization, real-time optimization and Industry 4.0 integration.

Source: (Compilation from literature, 2025)

The concept of the smart factory, as reflected across multiple scholarly definitions, consistently emphasizes the integration of advanced digital technologies such as IoT, AI, robotics and big data analytics into manufacturing processes (Kusiak, 2018; Lee et al., 2015). These technologies enable a cyber physical production environment that is adaptive, self-organizing and capable of real time decision making (Kang et al., 2016; Hofmann & Rusch, 2017). Unlike traditional factories, smart factories are characterized by their ability to optimize resources, reduce waste and improve efficiency through data driven insights (Zhong et al., 2017; Xu et al., 2018). Moreover, the literature underscores the importance of connectivity and interoperability across machines, humans and systems, ensuring seamless integration and collaboration within the value chain (Lasi et al., 2014; Oztemel & Gursev, 2020). As per the above definitions, research identified the following important aspects in the definitions.

1. Digital Integration & Automation – Use of IoT, AI, robotics, and big data to enable intelligent, automated operations.
2. Real Time Data & Decision Making – Reliance on data analytics for predictive, adaptive and self-correcting processes.
3. Cyber Physical Systems (CPS) – Interconnection of digital and physical assets for adaptive, smart production.
4. Connectivity & Interoperability – Seamless communication between machines, systems, and humans across the value chain.

Definition of Employee Engagement

Table 2 provides a summary of key definitions of employee engagement, highlighting its theoretical evolution and the different perspectives adopted by scholars.

Table 2: Definition of Smart Factory Context and Characteristics

Author & Citation	Definition	Characteristics
Kahn (1990)	The harnessing of organizational members' selves to their work roles, whereby people employ and express themselves physically, cognitively and emotionally during role performances.	Cognitive, emotional and physical dimensions - employees' psychological presence in role performance.

Schaufeli et al. (2002)	A positive, fulfilling, work related state of mind characterized by vigor, dedication and absorption.	Vigor (energy, resilience), Dedication (involvement, enthusiasm), Absorption (full concentration, being engrossed in work).
Harter et al. (2002)	The individual's involvement and satisfaction with as well as enthusiasm for work.	Focus on satisfaction, enthusiasm and active involvement in work.
Saks (2006)	A distinct and unique construct that consists of cognitive, emotional and behavioral components associated with individual role performance.	Cognitive engagement (focus), emotional engagement (commitment), behavioral engagement (extra-role effort).
Bakker & Demerouti (2008)	A positive, fulfilling, work related state that enhances performance and wellbeing through job resources and personal resources.	Driven by job resources (support, autonomy) and personal resources (self-efficacy, resilience).
Macey & Schneider (2008)	A desirable condition with an organizational purpose, referring to the willingness of employees to invest discretionary effort at work.	Organizationally Aligned, Discretionary Effort, Willingness and Commitment, Emotional and Cognitive Involvement
Albrecht et al. (2015)	A positive work-related psychological state that drives motivation, innovation and competitive advantage.	Linked with innovation, performance and strategic HR practices.
Anitha (2014)	The level of commitment and involvement an employee has towards their organization and its values.	Strongly tied to commitment, performance and organizational support factors.

Source: (Compilation from literature, 2025)

Empirical Background: Smart Factory Context and Employee Engagement

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

Global Empirical Insights

The smart factory context has transformed manufacturing sectors worldwide by integrating advanced technologies such as the IoT, 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 factory technologies not only enhance productivity but also transform the workplace environment, demanding a skilled workforce capable of leveraging these advanced technologies (Lee et al., 2015).

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 adoptions, 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 environment significantly impacts employee performance. Also, a conducive environment increases employee commitment and achievement striving ability, leading to improved performance (Khan et al., 2022). Proper training is also crucial to ensure employees are equipped to handle technological advancements in smart factories. Investing in comprehensive training programs improves employees' skills and demonstrates

the organization's commitment to their professional development, thereby increasing engagement (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 technologies. In these contexts, employee engagement strategies are vital in managing the transition to automation and advanced manufacturing systems, ensuring workforce adaptability and job satisfaction (Hofmann & Ruch, 2017).

In the apparel industry, 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).

Sri Lankan Empirical Insights

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 an essential role in ensuring smooth adaptation and sustained performance (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 identified as critical factors in nurturing employee engagement in 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, a key factor, strengthens the relationship between smart factory transformation and employee engagement, as efficiency gains reinforce the perceived value of these technological enhancements (Jayasinghe & Thavakumar, 2020).

GAP IDENTIFICATION

The evolution of Smart Factory technologies in global manufacturing has received significant attention in recent years, with much of the existing literature focusing on technical advancements, automation and efficiency gains. However, in the setting of labour-intensive sectors such as apparel manufacturing in developing economies like Sri Lanka, the human dimension, particularly employee engagement remains significantly under researched. A thorough review of current literature discloses a lack of holistic inquiry into how smart factory implementation affects the engagement levels of frontline workers, such as machine operators. Moreover, there is limited empirical exploration of mediating and moderating variables. This review identifies and categorizes key gaps in the existing body of knowledge to notify future research directions and ensure more inclusive, human-centered digital transformations in the apparel industry.

The Empirical Gap, Knowledge Gap, Theoretical Gap and Methodological Gap are critically reviewed in this study to provide a comprehensive understanding of the underexplored scopes related to smart factory implementation and employee engagement in the apparel manufacturing context.

Gap 1 - Empirical Gap

An important empirical gap exists in smart factory context, where most studies have concentrated on technical innovation, automation and operational improvements (Lasi et al., 2014; Xu et al., 2018; Wang et al., 2021), with

limited focus on employee centric outcomes such as engagement, particularly in developing economies like Sri Lanka's apparel industry. While global literature reports successful smart factory adoptions (Kaur, Singh & Kumar, 2021), these findings are largely derived from advanced economies and do not adequately reflect South Asian or apparel-specific contexts. Accordingly, little empirical evidence exists on how machine operators experience and respond to technological transitions in terms of engagement, motivation and workplace support. Moreover, although operational efficiency is recognized as a critical metric in the smart manufacturing context, its moderating role in shaping the relationship between smart factory adoption and employee engagement remains underexplored, especially in Sri Lanka (Chandrasekara & Jayasekara, 2023). This review addresses the gap by empirically examining how smart factory transformation interacts with employee engagement, training, workplace support and operational efficiency, thereby contributing new insights at the intersection of technology transformation and workforce experience in large-scale apparel firms.

Gap 2 - Knowledge Gap

The integration of Smart Factory principles under Industry 4.0 has advanced global manufacturing through cyber-physical systems, automation and real time data analytics (Kang et al., 2016), yet research has largely prioritized technological and economic outcomes over human centered aspects such as employee engagement (Liao et al., 2017; Zheng et al., 2021). Evidence is predominantly from developed economies, leaving limited insight into developing contexts like Sri Lanka, where the apparel sector is both economically crucial and in the early stages of adopting smart technologies (Eshun & Boateng, 2021). Notably, little is known about the experiences of frontline employees, particularly machine operators, whose engagement, motivation and satisfaction are directly influenced by automation and digital workflows (Riemer & Peter, 2021). Moreover, while training and workplace support are recognized as essential to digital transformation, their mediating effects on employee engagement remain underexplored (Zhang et al., 2020), as does the moderating role of operational efficiency in shaping these relationships. To address these gaps, this study systematically examines how Smart Factory context influences employee engagement among machine operators in large scale apparel firms in Sri Lanka, with particular focus on the mediating roles of training and workplace support and the moderating role of operational efficiency, thereby advancing a more human centric understanding of smart manufacturing transitions in developing economies.

Gap 3 - Methodology Gap

A clear methodological gap exists in smart apparel factory context, where prior studies have primarily relied on qualitative approaches or isolated case studies that, while descriptive, fail to capture the complex, multidimensional relationships between Smart Factory Technologies and employee engagement (Sony & Naik, 2020; Kagermann et al., 2013). Empirical studies employing advanced quantitative techniques such as Structural Equation Modeling (SEM) remain scarce, particularly in developing contexts like Sri Lanka, where mediating and moderating factors such as training, workplace support and operational efficiency are underexplored (Safavi & Tareq, 2023). Existing research tends to prioritize operational and economic outcomes (Lasi et al., 2014; Chien & Chen, 2018), overlooking workers' behavioral and emotional responses to automation and digitalization. Scholars such as Jung and Shin (2021) call for holistic mixed-method designs that integrate qualitative insights with quantitative rigor, yet such approaches are seldom applied, resulting in fragmented knowledge. To address this gap, the present review proposes an integrated framework using SEM to empirically test these relationships, while also triangulating with qualitative insights, thereby offering a comprehensive methodology to investigate employee engagement within smart apparel factories in Sri Lanka.

Gap 4 - Theoretical Gap

A theoretical gap exists in smart factory research, where frameworks such as the Technology Acceptance Model (TAM), Job Demands-Resources (JD-R) model, Resource-Based View (RBV) and Social Exchange Theory (SET) have been applied to study technological transformation but inadequately explain human-centered outcomes like employee engagement. While TAM effectively assesses technology adoption (Kumar & Sharma, 2020), it overlooks organizational and psychological factors such as workplace support, training and operational efficiency. The JD-R model, though relevant to Industry 4.0, has seldom been used to study how to train and support shape engagement in apparel factories (Goh et al., 2022). Also, RBV emphasizes technological assets

(Barney, 1991; Grant, 1996), neglecting intangible resources vital for sustaining engagement. SET (Blau, 1964), despite its potential to describe how organizational investments foster reciprocal employee engagement, remains underutilized. To address this gap, the present study integrates TAM, JD-R, RBV, and SET to examine how smart factory practices, supported by training, workplace support and operational efficiency, influence machine operators' engagement in Sri Lanka's apparel industry, thereby advancing a human-centered, theory-driven perspective.

Research Gaps in Smart Factory Context and Engagement are explained in Figure 1.

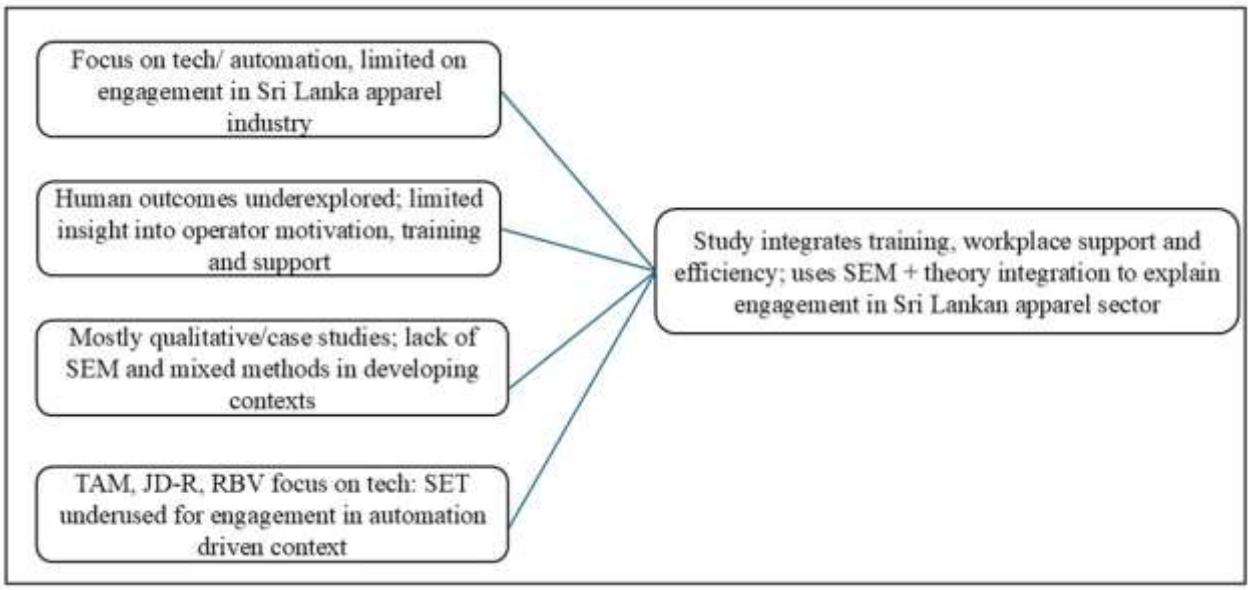

Figure 1: Research Gaps: Smart Factory Context and Engagement

Source:(Authors Compilation,2025)

Nomological Network of Variables

The nomological network of this study positions the Smart Factory Context as the independent variable that influences Employee Engagement, the dependent variable, the mediating roles of Training and Workplace Support and Operational Efficiency as a moderating variable (refer Figure 2)

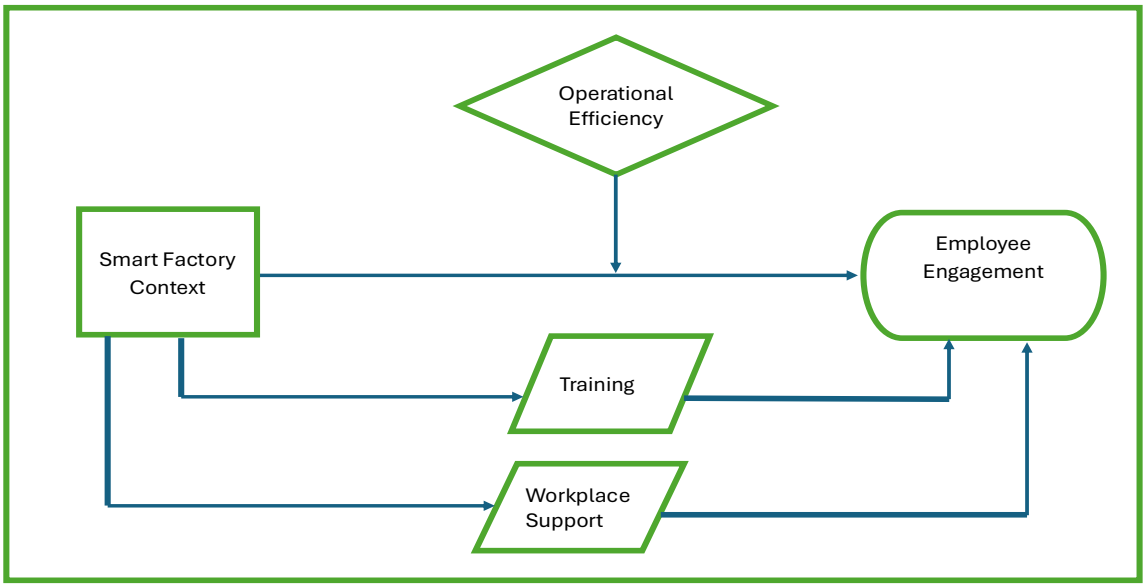

Figure 2 - Nomological Network

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should empirically test the proposed framework through a multi-stage design. This contains conducting quantitative surveys with Sri Lankan apparel machine operators to measure smart factory practices and engagement, analyzed using Structural Equation Modeling (SEM) (Weerasinghe et al., 2023). Qualitative methods such as interviews or focus groups should complement the survey to identify contextual insights and lived experiences (Susitha, 2021). A longitudinal approach, where feasible, can track pre and post implementation changes to study causality and sustainability (Zhang et al., 2020).

Practically, the challenges identified such as skill gaps, resistance to change, and the need for supportive workplace climates are common across developing economies (Silva & Wanninayake, 2021). Findings can guide policymakers and managers in countries like Bangladesh, Vietnam, and Ethiopia, where apparel industries are labour-intensive and undergoing Smart Factory transitions (Eshun & Boateng, 2021). Future studies should also assess interventions such as scalable training programs, participatory automation design and engagement monitoring systems. These insights may further support international development agencies in shaping human-centred smart factory strategies that balance technological progress with workforce wellbeing (Weerasinghe et al., 2023).

CONCLUSION

This review highlights that while Smart Factory technologies enhance operational efficiency and automation, research on their human centered impacts, particularly on frontline machine operators in Sri Lanka's apparel sector, is limited. Existing studies focus on economic and technical outcomes, overlooking employee engagement, motivation, adaptability and psychological readiness. Gaps exist across evidence, theory, methodology and context, with insufficient exploration of training and workplace support as mediators and operational efficiency as a moderator in shaping engagement. The review advocates a human centered approach, proposing a nomological framework where Smart Factory Context influences Employee Engagement, mediated by Training and Workplace Support and moderated by Operational Efficiency, emphasizing strategies to align technological innovation with workforce adaptability and resilience.

REFERENCES

1. Ahmad, I., Donia, M.B.L., Khan, A. & Waris, M. (2022). 'Do as I say and do as I do? The mediating role of psychological contract fulfillment in the relationship between ethical leadership and employee engagement', Journal of Business Ethics, 176(3), pp. 703–718.
2. Albrecht, S.L., Bakker, A.B., Gruman, J.A., Macey, W.H. & Saks, A.M. (2015). 'Employee engagement, human resource management practices and competitive advantage: An integrated approach', Journal of Organizational Effectiveness: People and Performance, 2(1), pp. 7–35.
3. Anitha, J. (2014). 'Determinants of employee engagement and their impact on employee performance', International Journal of Productivity and Performance Management, 63(3), pp. 308–323.
4. Bain & Company (2021). 'The future of the apparel industry: How to navigate the digital and sustainability transformation', Bain & Company Insights.
5. Bakker, A.B. & Demerouti, E. (2008). 'Towards a model of work engagement', Career Development International, 13(3), pp. 209–223.
6. Barney, J.B. (1991). 'Firm resources and sustained competitive advantage', Journal of Management, 17(1), pp. 99–120.
7. Blau, P.M. (1964). Exchange and Power in Social Life, New York: Wiley.
8. Callahan, C. (2014). Writing literature reviews: A guide for students of the social and behavioral sciences. 6th edition. Glendale, CA: Pyrczak Publishing.
9. Chandrasekara, A. & Jayasekara, P. (2023). 'Operational efficiency and technology adaptation in Sri Lanka's apparel industry: Human impact perspectives', Sri Lanka Journal of Management Studies, 4(1), pp. 45–59.
10. Chien, C.F. & Chen, Y.J. (2018). 'Data-driven innovation for smart manufacturing in the era of Industry 4.0', International Journal of Production Economics, 204, pp. 282–294.

11. CPS HR (2023). 'The importance of employee training and development in the workplace', CPS HR Consulting. Available at: https://www.cpshr.us (Accessed: 23 August 2025).
12. Eshun, P.A. & Boateng, P.A. (2021). 'Smart factories and the transformation of developing economies: A critical review', International Journal of Production Research, 59(6), pp. 1784–1802.
13. Fernando, Y., Gunasekara, L. & Wijesinghe, S. (2021). 'Adoption challenges of smart manufacturing in the Sri Lankan apparel industry', Journal of Manufacturing Technology Management, 32(8), pp. 1725–1741.
14. Ghobakhloo, M. (2020). 'Industry 4.0, digitization, and opportunities for sustainability', Journal of Manufacturing Technology Management, 31(1), pp. 1–30.
15. Goh, P., Ng, Y.T., Wong, L.T. & Ahmad, R. (2022). 'The application of JD-R theory in Industry 4.0 workforce transitions: A review', International Journal of Human Resource Management, 33(5), pp. 845–862.
16. Grant, R.M. (1996). 'Toward a knowledge-based theory of the firm', Strategic Management Journal, 17(S2), pp. 109–122.
17. Harter, J.K., Schmidt, F.L. & Hayes, T.L. (2002). 'Business-unit-level relationship between employee satisfaction, employee engagement, and business outcomes: A meta-analysis', Journal of Applied Psychology, 87(2), pp. 268–279.
18. Hofmann, E. & Rusch, M. (2017). 'Industry 4.0 and the current status as well as future prospects on logistics', Computers in Industry, 89, pp. 23–34.
19. Jabbour, C.J.C., de Sousa Jabbour, A.B.L., Foropon, C. & Godinho Filho, M. (2018). 'When titans meet–Can industry 4.0 revolutionise the environmentally-sustainable manufacturing wave? The role of critical success factors', Technological Forecasting and Social Change, 132, pp. 18–25.
20. Jayasinghe, L. & Thavakumar, D. (2020). 'Operational efficiency and its impact on employee engagement: Evidence from apparel sector in Sri Lanka', Sri Lanka Journal of Human Resource Management, 10(2), pp. 45–60.
21. Jayawardana, A. & Weerasinghe, D. (2021). 'Smart manufacturing adoption in Sri Lanka: Opportunities and challenges', Journal of Manufacturing and Service Operations, 3(1), pp. 27–39.
22. Jung, K. & Shin, D. (2021). 'A framework for evaluating Industry 4.0 training programs: A qualitative perspective', Journal of Manufacturing Technology Management, 32(5), pp. 1013–1028.
23. Kahn, W.A. (1990). 'Psychological conditions of personal engagement and disengagement at work', Academy of Management Journal, 33(4), pp. 692–724.
24. Khan, M.A., Ismail, H.N., Hussain, D. and Alghazali, B. (2022). 'The impact of workplace environment on employee performance: Mediating role of employee commitment and achievement striving', Cogent Business & Management, 9(1), 2102139.
25. Kagermann, H., Wahlster, W. & Helbig, J. (2013). 'Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final Report of the Industrie 4.0 Working Group', Frankfurt: Acatech.
26. Kang, H.S., Lee, J.Y., Choi, S., Kim, H., Park, J.H., Son, J.Y., Kim, B.H. & Noh, S.D. (2016). 'Smart manufacturing: Past research, present findings, and future directions', International Journal of Precision Engineering and Manufacturing-Green Technology, 3(1), pp. 111–128.
27. Kaur, G., Singh, J. & Kumar, R. (2021). 'Smart factory implementation: A review of enablers and barriers from a global perspective', Journal of Manufacturing Technology Management, 32(3), pp. 612–633.
28. Kusiak, A. (2018). 'Smart manufacturing', International Journal of Production Research, 56(1–2), pp. 508–517.
29. Kumar, N. & Sharma, R. (2020). 'Understanding technology adoption in manufacturing: An extension of the TAM model with job relevance and perceived risk', Journal of Manufacturing Technology Management, 31(6), pp. 1225–1244.
30. Lasi, H., Fettke, P., Kemper, H.G., Feld, T. & Hoffmann, M. (2014). 'Industry 4.0', Business & Information Systems Engineering, 6(4), pp. 239–242.
31. Lee, J., Bagheri, B. & Kao, H.A. (2015). 'A cyber-physical systems architecture for industry 4.0-based manufacturing systems', Computers & Industrial Engineering, 81, pp. 18–26.
32. Liao, Y., Deschamps, F., Loures, E. de F.R. & Ramos, L.F.P. (2017). 'Past, present and future of Industry 4.0 – a systematic literature review and research agenda proposal', International Journal of Production Research, 55(12), pp. 3609–3629.

33. Lu, Y. (2017). 'Industry 4.0: A survey on technologies, applications and open research issues', Computers in Industry, 82, pp. 40–55.
34. Macey, W.H. & Schneider, B. (2008). 'The meaning of employee engagement', Industrial and Organizational Psychology, 1(1), pp. 3–30.
35. Oztemel, E. & Gursev, S. (2020). 'Literature review of Industry 4.0 and related technologies', Journal of Intelligent Manufacturing, 31(1), pp. 127–182.
36. Perera, D., Ranasinghe, A. & Jayasuriya, L. (2023). 'Smart factory transformation in Sri Lankan apparel manufacturing: Pathways, challenges and opportunities', Journal of Manufacturing Technology Management, 34(7), pp. 102–118.
37. Perera, H. & Jayasinghe, P. (2021). 'Employee engagement in the era of automation: Evidence from Sri Lanka's apparel industry', Journal of Management and Development Studies, 30(2), pp. 66–80.
38. PM World Journal (2023). 'Employee engagement in the era of Industry 4.0', PM World Journal, 12(7), pp. 1–8.
39. Riemer, K. & Peter, S. (2021). 'The human side of digital transformation: Workplace changes and employee engagement', Journal of Organizational Computing and Electronic Commerce, 31(4), pp. 275–297.
40. Safavi, H.R. & Tareq, M.A. (2023). 'Evaluating human factor integration in Industry 4.0: A quantitative synthesis of employee outcomes', Journal of Industrial and Business Management, 15(1), pp. 1–15.
41. Saks, A.M. (2006). 'Antecedents and consequences of employee engagement', Journal of Managerial Psychology, 21(7), pp. 600–619.
42. Schaufeli, W.B., Salanova, M., Gonzalez-Roma, V. & Bakker, A.B. (2002). 'The measurement of engagement and burnout: A two-sample confirmatory factor analytic approach', Journal of Happiness Studies, 3(1), pp. 71–92.
43. Senanayake, N. & Abeykoon, C. (2019). 'Industry 4.0 in Sri Lanka: Readiness of apparel sector employees for digital transformation', South Asian Journal of Human Resources Management, 6(2), pp. 220–240.
44. Silva, D. & Wanninayake, W.M.C.B. (2021). 'The impact of employee engagement on sewing automation success in apparel manufacturing in Sri Lanka', Sri Lanka Journal of Management Studies, 3(1), pp. 25–42.
45. Sony, M. & Naik, S. (2019). 'Key ingredients for evaluating Industry 4.0 readiness for organizations: A literature review', Journal of Manufacturing Systems, 54, pp. 282–290.
46. Sony, M. & Naik, S. (2020). 'Industry 4.0 integration with socio-technical systems theory: A systematic review and proposed theoretical framework', Technological Forecasting and Social Change, 161, p. 120326.
47. Stock, T. & Seliger, G. (2016). 'Opportunities of sustainable manufacturing in Industry 4.0', Procedia CIRP, 40, pp. 536–541.
48. Susitha, S.D.E. (2021). 'Influencing factors of employee readiness to adopt advanced manufacturing technology (AMT) on apparel shop floor in Sri Lanka'. International Journal of Multidisciplinary Studies, 8(3), pp.1–32.
49. Wang, J., Xu, C., Zhang, J. & Zhong, R.Y. (2021). 'Big data analytics for intelligent manufacturing systems: A review', Journal of Manufacturing Systems, 62, pp. 738–752.
50. Weerasinghe, N., Weerasinghe, A., Perera, Y., Tennakoon, S., Rathnayake, N. & Jayasinghe, P. (2023). 'Sustainability practices and organizational performance during the COVID-19 pandemic and economic crisis: A case of apparel and textile industry in Sri Lanka', *PLOS ONE*, 18(7), p.e0288179.
51. Wickramasinghe, V. & Perera, G. (2021). 'Industry 4.0 technologies in apparel manufacturing: Prospects for Sri Lanka', South Asian Journal of Human Resources Management, 8(2), pp. 220–239.
52. Wijethunga, K., Dickson, S., Weerathunga, N., Senevirathne, S., Samarakkody, T. & Thelijjagoda, S. (2023) 'Impact of Industry 4.0 on organizational performance in Sri Lankan apparel industry', Proceedings of the 2023 5th International Conference on Advancements in Computing (ICAC 2023).
53. Wijewardena, N. & Siriwardana, S. (2020). 'Human resource challenges in the age of Industry 4.0: Evidence from Sri Lankan apparel sector', Colombo Business Journal, 11(1), pp. 89–108.
54. Xu, L.D., Xu, E.L. & Li, L. (2018). 'Industry 4.0: State of the art and future trends', International Journal of Production Research, 56(8), pp. 2941–2962.

55. Xu, X., Xu, L.D. & Li, L. (2018). 'Industry 4.0: State of the art and future trends', Robotics and Computer-Integrated Manufacturing, 59, pp. 82–94.
56. Zhang, Y., Ren, S., Liu, Y. & Si, S. (2020). 'A big data analytics architecture for cleaner manufacturing and maintenance processes of complex products', *Journal of Cleaner Production*, 265, p.121383.
57. Zhang, Y., Zhang, G., Zhang, X., Hu, D. & Zhang, D. (2020). 'How do training and organizational support affect employee readiness for digital transformation?', Sustainability, 12(8), p.3122.
58. Zheng, P., Lin, T.J., Chen, C.H. & Xu, X. (2021). 'Smart manufacturing systems for Industry 4.0: Conceptual framework, scenarios, and future perspectives', Frontiers of Mechanical Engineering, 16(1), pp. 1–14.
59. Zhong, R.Y., Xu, X., Klotz, E. & Newman, S.T. (2017). 'Intelligent manufacturing in the context of Industry 4.0: A review', International Journal of Production Research, 3(5), pp. 616–630.