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IDENTIFYING MAINTENANCE TRAINING NEEDS IN SRI LANKA'S APPAREL INDUSTRY AND AUGMENTED REALITY AS A STRATEGIC SOLUTION

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ABSTRACT

Maintenance training in Sri Lanka's apparel industry remains largely informal and reactive, despite the sector's significant contribution to the national economy. This paper examines current maintenance training practices and needs within the industry and explores the potential of Augmented Reality (AR) as a strategic training solution. To achieve this, a qualitative research approach was adopted, using structured expert interviews with five professionals from the maintenance domain of the apparel industry. Purposive sampling ensured the inclusion of experts with substantial experience in Sri Lanka's apparel sector. Thematic analysis was conducted using NVivo software. Findings were discussed under three main topics: current training practices, training needs at different organisational levels, and the integration of AR into maintenance training. It was revealed that current practices are largely informal, reactive, and lack structure. Training needs were identified at three levels, operational, supervisory, and managerial, with skill requirements ranging from procedural knowledge to strategic decision-making. The integration of AR was found to be highly promising, with experts endorsing it as a viable solution. AR's ability to provide real-time, interactive simulations and task-specific guidance was highlighted as a major strength, improving engagement, accessibility, and adaptability. The study concludes that adopting a structured, hybrid training model incorporating AR can address skill gaps, enhance training efficiency, and better prepare maintenance personnel for evolving technological demands. These findings provide practical insights for stakeholders seeking to modernise training practices and align with global maintenance standards.

Keywords: *Apparel Industry; Augmented Reality; Maintenance Needs; Maintenance Training.*

1. INTRODUCTION

Maintenance is a critical function across industrial sectors, directly influencing operational efficiency, product quality, and cost-effectiveness. It accounts for approximately 60% to 70% of total production costs in many industries, including

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manufacturing (Mourtzis et al., 2016). Inadequate maintenance practices can lead to equipment failures, increased downtime, and safety risks (Abbasi, 2023), whereas intelligent and proactive maintenance strategies contribute to extended equipment life, reduced operational interruptions, and improved productivity (Fulcher et al., 2022). However, Li (2022), argued that the shift toward digitalized industrial systems presents challenges in upskilling maintenance personnel, particularly in adopting emerging technologies. Globally, the apparel industry is valued at over USD 1.7 trillion and employs more than 75 million people, making it a significant contributor to global manufacturing (Saxena & Khare, 2024). Sri Lanka's apparel sector alone contributes nearly 6% of GDP and accounts for over 40% of total exports, employing around 350,000 workers, with a large share engaged in production and facility operations (Vidanage et al., 2024). Despite its economic significance, maintenance training within this sector remains traditional, fragmented, and reactive, often resulting in skill gaps, inefficiencies, and delays in fault resolution (Wijesinghe, 2024). AR has emerged globally as a powerful tool for maintenance training, offering real-time, immersive guidance and reducing dependence on paper-based manuals and static procedures (Suhashi et al., 2024). Within the frameworks of Industry 4.0 and Industry 5.0, AR facilitates smarter, more human-centric maintenance practices, allowing technicians to visualize equipment, receive expert assistance remotely, and carry out tasks with higher accuracy (Runji et al., 2022). While AR applications in Sri Lanka have gained traction in education and retail, their adoption in industrial maintenance, particularly in apparel manufacturing, remains minimal and underexplored (Rajapaksha et al., 2021). Given the sector's role in Sri Lanka's national economic development and aspirations to attract foreign investment, integrating AR into maintenance training presents a timely and strategic opportunity. Therefore, this study aims to identify current maintenance training practices and needs in Sri Lanka's apparel industry and explore how AR can serve as an innovative solution to bridge skill gaps and enhance training efficiency. Accordingly, the research question is formulated as, "How can Augmented Reality be strategically utilised to address the maintenance training needs in Sri Lanka's apparel industry?"

2. LITERATURE REVIEW

2.1 AUGMENTED REALITY (AR) AND MAINTENANCE TRAINING

In the 1990s, augmented reality was defined and used to characterise specific tasks and applications (Rauschnabel et al., 2022). According to Harborth and Pape (2021), the concept of AR rapidly expanded as a scholarly community interested in the technology began engaging through conferences and workshops. With advancements in smartphone technology, it became technically feasible to apply virtual visuals onto the physical environment using mobile devices (Dargan et al., 2023). AR is increasingly utilised in technical training and maintenance as a replacement for traditional paper-based methods (PBM), enhancing operational efficiency and user-friendliness (Syed et al., 2022). In training contexts, AR enables workers to interact with both real and virtual environments simultaneously, displaying crucial information such as task progress and notifications (Yazdi, 2024). This interaction improves attention to operational conditions and speeds up information acquisition. However, Alimamy and Jung (2024), argued that the development of AR platforms remains resource-intensive and is often not fully adapted to the specific needs of users. AR remains a largely unexplored area in terms of its application for maintenance training. The integration of AR into Maintenance training

programs in apparel manufacturing has the potential to address several challenges faced by workers, such as the complexity of machinery maintenance, a lack of hands-on experience, and inefficiencies in traditional training methods (De Silva et al., 2018). While research on AR in industrial settings has demonstrated its effectiveness in enhancing worker performance, improving safety training, and reducing operational errors (Sorko & Brunnhofer, 2019), its implementation in the apparel industry remains limited in Sri Lanka. The complexity of apparel manufacturing processes, coupled with the rapid evolution of technology, highlights the need for a tailored AR training solution that can effectively address the unique needs and operational demands of the maintenance sector.

2.2 CURRENT MAINTENANCE TRAINING PRACTICES IN SRI LANKA'S APPAREL INDUSTRY

In Sri Lanka's apparel sector, maintenance operations are essential for ensuring the longevity and efficiency of production machinery(Wijesinghe & Mallawarachchi, 2019). However, training approaches within the facilities management (FM) and maintenance domains are still primarily based on traditional models such as classroom-based sessions, on-the-job training (OJT), and occasional workshops (Abdeen et al., 2019). These practices focus heavily on reactive problem-solving and are often informal, lacking standardised programs or structured evaluation methods. As a result, while they may suffice for basic skill transfer, they fall short in addressing the dynamic technical needs of modern manufacturing environments (Perera & De Silva, 2021). OJT is the most adopted strategy, wherein experienced workers mentor junior technicians by exposing them to real-time issues and practical fixes (Rathnaweera & Fernando, 2019). Though this promotes experiential learning, studies have criticised it for its inconsistency, dependency on mentor availability, and inability to cover complex or rare equipment breakdowns (Wijesinghe & Mallawarachchi, 2019b). Furthermore, paper-based manuals and verbal instructions still dominate, limiting knowledge retention and engagement among younger, tech-savvy employees (Perera & De Silva, 2021). Classroom-based training and specialised workshops are still integral components of the current training landscape in the Sri Lankan apparel maintenance sector (Jayarathne et al., 2021). These sessions often serve as introductory platforms for newly recruited technical staff or as occasional upskilling programs when new machinery is introduced (Abdeen et al., 2019). Similarly, specialised workshops tend to be conducted on an ad-hoc basis, with limited follow-up or assessment mechanisms to evaluate skill development and application in real workplace settings (Jayarathne et al., 2021). This disconnection between training content and real-world maintenance challenges contributes to skill gaps, especially in handling advanced machinery and automated systems. Moreover, the absence of well-defined and standardised training programs further challenges the effectiveness of capacity-building efforts in the maintenance sector of Sri Lanka's apparel industry. Training initiatives are often reactive, with little alignment to a broader workforce development strategy or competency framework (Wijesinghe & Mallawarachchi, 2019). This leads to inconsistencies in technical proficiency, reduced operational efficiency, and an overall vulnerability in the sector's ability to adopt emerging technologies and maintenance practices.

2.3 CURRENT TRAINING NEEDS OF THE MAINTENANCE SECTOR

The maintenance training needs within the apparel industry are diverse and vary significantly across different organisational levels. These needs are shaped by the nature of responsibilities, exposure to technology, and decision-making roles. According to Thenuwara and Sandanayake (2018), training can be effectively classified into three levels, namely, operational, supervisory, and managerial. This categorisation helps tailor training interventions to suit the specific functions and challenges at each level. At the operational level, technicians are responsible for hands-on equipment maintenance and troubleshooting. However, training is often limited to repetitive tasks, lacking depth in system-wide understanding (Abdeen et al., 2019). As a result, many workers struggle with preventive strategies or adapting to modern equipment, highlighting the need for broader, experience-based learning approaches (Wickramasinghe & Perera, 2022). Supervisory staff, such as engineers and maintenance supervisors, require a combination of technical and leadership skills. Literature emphasises the importance of training in areas like CMMS, predictive maintenance tools, and soft skills, including communication and planning (Jana & Tiwari, 2017). However, for managerial personnel, training must be aligned with organisational goals and long-term strategy. Managers should be equipped to lead digital transformation and implement initiatives like Total Productive Maintenance (TPM) and Industry 4.0 technologies (Anthonypillailionel & Oruthotaarachchi, 2025). According to Shamsuzzaman et al. (2023), strategic training helps managers shift from reactive approaches to data-driven, proactive maintenance planning.

2.4 INTEGRATING AR AS A STRATEGIC TRAINING SOLUTION

As global industries shift towards digitised and smart maintenance practices, the Sri Lankan apparel sector must modernise its training approaches to remain competitive (Wijesinghe & Mallawarachchi, 2019). One significant shortcoming in current methods is the continued reliance on paper-based procedures (PBP), which are time-consuming, inefficient, and often hinder effective knowledge transfer (Majumdar et al., 2021). In this context, Augmented Reality (AR) has emerged as a particularly promising tool for maintenance training. AR enables interactive, real-time learning by overlaying digital instructions onto physical equipment, thus enhancing comprehension and retention (Mourtzis et al., 2020). Integrating AR into facilities management (FM) training programs within the apparel sector could bridge existing skill gaps, promote a proactive maintenance culture, and align local practices with global digital trends.

3. METHODOLOGY

Research methodology outlines the strategic framework for conducting a study, encompassing the philosophical assumptions, data collection methods, and analytical techniques used to address the research objectives. As suggested by Abutabenjeh and Jaradat (2018), the methodology defines how research questions are addressed systematically from conception to interpretation. In line with this, the present study adopts a qualitative research approach, which is most appropriate for exploring the different experiences, perspectives, and contextual factors surrounding maintenance training practices in Sri Lanka's apparel industry. This approach was chosen for this study, as it allows for an in-depth understanding of the underlying factors influencing maintenance practices, training needs, and perceptions about the adoption of AR as a

strategic solution. Unlike quantitative methods that seek generalisability through numerical data, qualitative research is suited for exploring complex, context-specific phenomena that require rich, detailed narratives. This is particularly relevant in industrial environments as apparel manufacturing, where human factors, organisational culture, and technological adaptability play a critical role. To capture expert insights, the study employed structured expert interviews to ensure consistency across all participants while maintaining the depth of qualitative inquiry. Experts selected for the study include facility engineers & maintenance engineers connected to Sri Lanka's apparel sector. These individuals were chosen based on their direct experience and decision-making roles. This method is justified because it allows the researcher to explore current maintenance practices, identify specific training gaps, and assess expert opinions on the feasibility and strategic potential of AR in maintenance training. Structured interviews also reduce interviewer bias and enable the systematic comparison of responses across different stakeholder groups. Data were collected through structured interviews using a standardised questionnaire developed based on themes identified in existing literature. The questionnaire consisted of open-ended questions categorised under three themes: (1) current maintenance training practices, (2) current maintenance training needs, and (3) potential applications of AR technologies in training for the apparel industry in Sri Lanka. Purposive sampling was employed to select five experts with demonstrated expertise in maintenance practices, training methods, and augmented reality technologies. This approach aligns with the qualitative research emphasis on depth of insight rather than numerical generalisability. Each participant was chosen based on their strategic role and specialised experience in the apparel sector, ensuring a well-rounded understanding across both operational and technological dimensions. In line with qualitative standards, particularly in expert-driven studies, rich and meaningful data can be obtained from a limited number of interviews (Etikan, 2017). The small number of experts was also a consequence of availability and accessibility constraints since the roles were specialized, and the case involved a single facility. The approach applied ensures that the information obtained is highly specific and reflects the actual industry scenario, providing depth rather than breadth. The summary of the profile of the respondents is presented in Table 1 below.

Table 1: Profile of the respondents

Expert	Designation	Area of expertise	Work experience (Years)
E1	Maintenance Executive	Building Services	07
E2	Engineer	Building services and Total Productive Management (TPM)	20
E3	Facilities engineer	Building Services, Lean Management & OSH	10
E4	Automation engineer	Building Services, Machine Engineering and Automation	06
E5	Maintenance manager	Building Services and Machine Engineering	10

The qualitative data collected through interviews were analysed using thematic analysis, which is well-suited for identifying patterns and insights from textual data. For this study, the content analysis method was conducted using the NVivo software (2010) manufactured by Qualitative Solutions and Research (QSR) International (Pvt) Ltd.

4. FINDINGS AND ANALYSIS

Every respondent offered perceptions based on their experience in maintenance training within the apparel industry, and the research findings are comprehensively described under three topics hereafter.

4.1 CURRENT MAINTENANCE TRAINING PRACTICES IN SRI LANKA'S APPAREL INDUSTRY

The findings revealed that training practices for maintenance in the apparel industry are highly varied, disconnected, and largely non-standardised. The most frequently mentioned technique is on-the-job learning. All experts agreed that this method is widely applied, as it provides immediate, experiential exposure in real working conditions. It allows maintenance staff to self-learn practical skills and gain direct access to equipment and systems. However, experts noted that while effective for acquiring procedural knowledge of specific tasks, it often lacks theoretical depth and results in knowledge gaps related to broader system understanding and strategic insights. According to E3, "On-the-job learning is practical and widely used, but it does not equip technicians with a comprehensive understanding necessary for evolving maintenance challenges". Furthermore, to address these theoretical gaps, experts mentioned that classroom sessions and customised workshops are occasionally used. These interventions aim to teach foundational maintenance skills, safety procedures, and technical details related to facility management functions. However, experts highlighted that such sessions are intermittent and insufficiently integrated with practice-based learning, leading to a disconnection between theoretical knowledge and real-world application. As E2 noted, "Most training efforts are reactive and do not follow a structured curriculum aligned with business strategies". The use of ad-hoc workshops and collaboration with equipment manufacturers or service agents reinforces the reactive nature of current maintenance training practices. As many experts mentioned, although training provided by external sources is valuable for specialised knowledge, it is often dependent and uncertain, particularly when such external support is not consistently available. Another major inadequacy that was highlighted is the prevalence of poorly structured training programs. Experts noted that many organisations depend on training initiatives that lack clear learning objectives, are misaligned with operational goals, and result in weak skill development. This has been strengthened by E4 as "training initiatives are fragmented and poorly aligned with strategic goals, leading to inconsistent skill acquisition". Experts further highlighted the use of WhatsApp loop communication as an improvised training medium, demonstrating how maintenance teams have adapted to overcome communication and knowledge-sharing gaps. While such instant messaging platforms enable real-time collaboration and quicker troubleshooting, experts emphasised that they cannot replace structured learning methods. Informally communicated knowledge, they noted, is often fragmented, unverified, and lacks systematic control, which can compromise the consistency and reliability of maintenance practices. Table 2 below

summarises the experts' responses regarding the usage of current maintenance practices in the apparel industry.

Table 2: Current maintenance training practices

	Current maintenance training practices in industry	Experts				
		E1	E2	E3	E4	E5
1	On-the-job learning	✓	✓			✓
2	Occasional classroom sessions	✓				
3	Specialized workshops	✓				
4	Specific events like new equipment installation or safety updates	✓				
5	Ad-hoc workshops		✓	✓		
6	Engaging with manufacturers or agents		✓	✓		
7	Conducting poorly defined training programs			✓	✓	
8	WhatsApp loop communication			✓		

4.2 CURRENT MAINTENANCE TRAINING NEEDS IN SRI LANKA'S APPAREL INDUSTRY

Findings from expert interviews indicate that training requirements differ significantly across operational, supervisory, and management levels. At the operational level, technicians form the core of maintenance operations, performing hands-on tasks, troubleshooting equipment, and ensuring uninterrupted system functionality. However, experts mentioned that training provided to this group is often fragmented and narrowly task specific. Many technicians possess procedural knowledge but lack a comprehensive understanding of the overall maintenance process. Experts emphasised the importance of tailoring training programs to match the varying skill levels among technicians, promoting a more holistic maintenance capability. According to E2, "technicians need more than task specific training: A broader understanding is essential to improve overall maintenance effectiveness". Furthermore, they highlighted the practical challenge of organising training without disrupting ongoing operations, recommending that programs be modular, flexible, and seamlessly integrated into daily routines.

At the supervisory level, which includes supervisors, engineers, and maintenance professionals, the training needs extend beyond technical skills to encompass leadership development, strategy implementation, and the adoption of emerging technologies. Experts expressed the need for upskilling in areas such as maintenance management software, predictive technologies, and data-driven systems, which are lacking currently in Sri Lanka. Given the diverse competence levels within maintenance teams, training must be adaptable to suit different learner profiles. Here, experts E3 and E4 pointed out the preference of the supervisors for hybrid training approaches, combining traditional hands-on methods with advanced tools such as simulations and augmented reality. In addition to that, E4 emphasized that, "supervisors prefer training that blends traditional and innovative methods to prepare for future technological demands". For management-level personnel and decision-makers, training is closely tied to strategic organisational objectives. Experts stated that training programs for managers must be purposefully

designed to align with business goals, enabling them to move from reactive repair approaches to proactive maintenance strategies. Experts further opinionated that managers should be equipped not only to adopt new technologies but also to lead organisational change by overseeing the implementation of smarter, data-driven maintenance systems.

4.3 INTEGRATING AR AS A STRATEGIC TRAINING SOLUTION IN THE APPAREL INDUSTRY

Expert interviews revealed several critical limitations in the current maintenance training practices within Sri Lanka's apparel industry's Maintenance sector. While traditional methods such as on-the-job learning, classroom sessions, and workshops remain widely adopted, experts E1, E2, and E5 emphasised that these approaches have not evolved in line with the increasing complexity of maintenance systems, equipment, and digital technologies. All experts agreed that conventional training often lacks interactivity, real-time relevance, and adaptability to the dynamic operational environments now prevalent in this sector. Specifically, E3 highlighted that recent reliance on paper-based training has proven inadequate in equipping staff with the technical competencies required for today's maintenance demands. To address these shortcomings, all interviewed experts unanimously recommended adopting hybrid training models that combine traditional methods with advanced technologies. Among these, Augmented Reality (AR) emerged as a particularly promising tool for maintenance training. As E1 noted, "Technology like AR can be a game-changer in maintenance training," while E5 reinforced that by stating, "AR-based training can significantly enhance learning, especially for maintenance staff in the apparel industry." AR offers a range of strategic advantages aligned with both functional and non-functional training requirements. Experts E2 and E4 stressed the need for training systems that are intuitive, accessible, and adaptable, especially for junior or novice technicians. AR responds to this need with user-friendly interfaces, compatibility with mobile and wearable devices, and the capacity to deliver context-specific training directly at the point of task execution.

5. DISCUSSION

The study revealed a significant mismatch between existing maintenance training practices in Sri Lanka's apparel industry and the evolving demands of modern maintenance functions. Literature highlighted traditional methods such as on-the-job training (OJT), classroom-based sessions, and occasional specialised workshops. However, both the literature and research findings confirmed that these methods often lack standardisation, consistency, and long-term planning. This aligns with findings by Al-Najjar and Algabroun (2017) and Priyantha (2021), who recorded similar inadequacies in maintenance training approaches and the absence of a rich maintenance culture in apparel sector of Sri Lanka. Insights from expert interviews further uncovered additional practices currently in use in the apparel industry in Sri Lanka as training prompted by specific events like new equipment installations, demonstrations led by manufacturers or agents, and informal knowledge-sharing through WhatsApp loops. These findings suggest that current training is often reactive, fragmented, and situational rather than structured and strategic. The adaptive but unstructured learning environments reported in previous investigation in Sri Lanka confirms the use of WhatsApp loops as an improvised communication method (Weeks & Leite, 2021). In terms of training needs,

both literature and expert evidence consistently emphasised the necessity for differentiated training approaches across operational, supervisory, and managerial levels. Mourtzis et al. (2019), advocated that level division by arguing that employee's skills requirement based on the level and training programs should be specifically designed to align with the needs of each level. Further, that corroborates by (Almulla, 2023). At the operational level, workers require practical, experience-based learning to enhance system-wide understanding. Supervisory personnel need training in predictive tools, planning, and leadership, while managerial staff must be equipped to drive digital transformation and align maintenance strategies with organisational goals. As a discipline in the evolution of facilities management, these managerial requirements reflect the strategic focus (Nor et al., 2014). In comparison to the primary data in the Table 2, these claims are significantly substantiated through expert interviews. Besides, the experts confirm that classes and workshops are irregular and inadequately integrated with operational realities that resulting in a gap between theory and practice. Furthermore, experts demonstrated the absence of appropriate well-structured, standardized training programs in accordance with organizational strategic objectives which supports and elaborates the concerns already identified in the literature. The increasing complexity of machinery and the shift towards predictive, data-driven maintenance highlight the need for modern, hybrid training solutions. According to Mourtzis et al. (2020), blend learning models combining traditional and AR-enhanced approached to optimize skill acquisition and operational efficiency which is in line with the global trends. Expert perspectives strongly supported the integration of Augmented Reality (AR) as a viable strategy to meet these evolving needs at different levels. Ultimately, integrating AR into maintenance training can elevate technical competencies across all workforce levels and position Sri Lanka's apparel industry in line with global digital training practices.

6. CONCLUSION

This study offers critical insights into the current state of maintenance training practices and emerging needs within Sri Lanka's apparel industry. At present, training is largely informal and unstructured, dominated by on-the-job learning, ad-hoc workshops, and reactive knowledge-sharing mechanisms. While these methods deliver immediate practical exposure, they often fall short in fostering comprehensive theoretical understanding, leading to noticeable skill gaps in strategic and system-level maintenance thinking. Expert insights emphasise the urgent need for structured, integrated, and future-ready training frameworks that combine foundational hands-on skills with advanced technological tools. In particular, the integration of AR-based training solutions is identified as a strategic enabler, facilitating interactive, scenario-based, and readily accessible learning experiences. By adopting such innovative approaches, the apparel industry can address current competency deficits and develop a digitally skilled maintenance workforce that is aligned with global best practices and prepared for the evolving demands of modern manufacturing environments.

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