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DIGITAL TWINS, AI, AND AUTOMATION IN RETAIL

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Abstract: *The integration of advanced digital technologies such as Artificial Intelligence (AI), Digital Twins, and Automation is reshaping the retail sector, introducing new occupational health and safety (OHS) challenges. This study adopts a mixed-methods approach to explore the physical, psychosocial, and systemic risks associated with digital transformation in retail environments. A systematic literature review was conducted to identify key risk categories and mitigation strategies, complemented by a quantitative survey of Romanian retail employees. The findings reveal a strong alignment between theoretical models and field-level perceptions, highlighting increased task intensity, cognitive strain, and organizational disruption. The study proposes an integrated risk typology and emphasizes the need for holistic prevention strategies that address both technical and human factors. These insights contribute to the development of informed policies and adaptive frameworks for safeguarding worker well-being in digitized retail settings.*
Key words: *occupational health and safety, retail sector, automation, digital transformation, mixed methods, risk mitigation, psychosocial risks*

1. INTRODUCTION

The rapid evolution of Industry 4.0 technologies has brought transformative change to the retail sector, promising operational efficiency, precision, and enhanced customer experience [1]. Among these technologies, Digital Twins, Artificial Intelligence (AI), and Automation have emerged as central pillars of innovation, but also as sources of new occupational health and safety (OHS) challenges that demand critical examination [2].

Digital Twins are defined as virtual representations of physical systems, processes, or assets, continuously updated with real-world data. In retail, they enable modeling of supply chains, stores, and devices, supporting real-time monitoring, predictive maintenance, and process optimization [3]. This dynamic capability enhances decision-making but also introduces integration complexity and potential systemic vulnerabilities.

AI encompasses computational methods that allow machines to perform tasks typically requiring human intelligence, such as perception, prediction, and decision-making. In retail, AI is used for demand forecasting, personalized marketing, dynamic pricing, inventory optimization, and workforce scheduling [4]. Despite its operational benefits, AI-driven algorithmic management and employee monitoring raise ethical and psychosocial concerns, including stress, burnout, and reduced autonomy [5].

Automation refers to technologies that reduce or eliminate human intervention in retail processes. This includes robotics in warehouses, self-checkout systems, automated inventory management, and online fulfillment platforms. While automation is widely seen as a means to reduce costs and improve speed and accuracy, it also alters job roles, introduces ergonomic risks, and can undermine job security [6].

Together, these technologies represent the frontier of smart retail, where data-driven, interconnected, and partially autonomous systems are reshaping operational models [7]. However, their adoption also reconfigures the nature of retail work itself, creating new types of human–machine interactions and socio-technical systems that demand careful attention to worker health, safety, and well-being.

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The increasing adoption of Industry 4.0 technologies in retail has generated considerable academic and industry interest [8]. While early literature emphasized efficiency and customer experience, more recent analyses have begun to critically examine the OHS implications [9]. However, the research landscape remains fragmented, with uneven attention paid to different dimensions of risk and mitigation strategies.

A recurring theme in the literature is the optimization potential of Digital Twins and AI-driven automation, especially in real-time monitoring, predictive maintenance, and logistics [10],[11]. However, critics argue that this focus on efficiency neglects the complexities of human-machine interaction in retail settings marked by high staff turnover and varied skill levels [12].

Ergonomic risks arising from automation have received growing attention, particularly in warehouse settings where workers must adapt posture, pace, and movement to machine rhythms [13]. In front-of-house contexts, technologies like self-checkout kiosks and inventory robots introduce new physical strains, such as maintenance and troubleshooting tasks, that are rarely anticipated during design [14] [15].

Psychosocial risks associated with AI and automation have emerged as a significant concern, including work intensification, constant monitoring, and job insecurity [15] [16]. These dynamics are linked to increased stress and reduced well-being among retail employees. While industry narratives often frame employee monitoring as beneficial for planning and absenteeism reduction, critical scholarship highlights tensions between managerial efficiency and worker welfare [17].

Systemic risks introduced by Digital Twins and integrated retail systems are less explored but increasingly relevant [18]. Although technical literature celebrates their responsiveness and predictive control, safety-oriented analyses warn of cascading failures, data breaches, and unintended consequences from automated decision-making [19]. Compared to manufacturing, retail-focused safety analyses remain limited, revealing a gap in understanding systemic vulnerabilities.

Mitigation strategies differ in scope and impact. Participatory ergonomic design is frequently proposed to align technology with worker needs, but faces organizational resistance and budget constraints [20]. Although training is widely promoted, it is often insufficient to counter deeper psychosocial risk factors [21].

Ethical AI policies and regulatory frameworks are suggested as overarching solutions, though their clarity and enforceability differ significantly. While industry reports promote fairness and transparency, critical voices demand stronger standards for algorithmic control, data protection, and health accountability [22],[23].

A comparative analysis reveals both overlaps and silos: ergonomic studies focus on physical risks, psychosocial analyses emphasize organizational dynamics, and systemic risk assessments remain disconnected from both [24]. This compartmentalization limits the development of comprehensive mitigation strategies for OHS in digitized retail environments.

Taken together, the literature reveals a complex and often contested landscape [27]. There is broad consensus that Digital Twins, AI, and Automation hold transformative potential for retail, but also introduce multidimensional risks. Advancing this field requires moving beyond isolated typologies and simplistic mitigation checklists toward integrated, interdisciplinary approaches. Ensuring that technological innovation does not compromise worker health and well-being demands a proactive, system-oriented, and participatory framework.

2. MATERIALS AND METHODS

To understand the implications of emerging technologies such as Digital Twins, Artificial Intelligence (AI), and Automation on occupational health and safety in the retail sector, both the main risks and the mitigation strategies identified in the literature were analyzed. In this regard, associated challenges such as physical, psychosocial, and systemic risks were addressed to provide a clear picture of the current context.

This paper employed a comprehensive, multi-step approach to ensure a rigorous review of existing literature and data on occupational health and safety in digitized retail. The methodology was structured to support systematic analysis and highlight key themes. The stages undertaken were as follows:

Literature search. A detailed search was conducted in leading academic databases such as Scopus, Web of Science, and IEEE Xplore. Keywords used included terms such as "Digital Twins", "Artificial Intelligence", "Automation", "Retail", and "Occupational Health and Safety".

Selection criteria. To ensure the relevance and quality of the sources, strict inclusion and exclusion criteria were applied. Only peer-reviewed publications, conference reports, and industry studies published between 2023 and 2025 with a clear focus on occupational health and safety in digitized retail were selected.

Article selection. After applying the criteria, a significant number of studies addressing health and safety risks posed by digital technologies in retail were included in the analysis, with an emphasis on physical, psychosocial, and systemic risks. These studies were considered relevant for building an integrated perspective on the topic.

Structure of the analysis. The selected articles were examined through a conceptual framework that considered risk typologies, organizational context, technological characteristics, and implemented prevention strategies. This enabled the identification and comparison of key themes and risk management models.

In addition to the literature review, a structured questionnaire was designed to collect quantitative data on perceived occupational risks associated with digital technologies in retail. The survey included closed-ended and Likert-scale questions, covering physical, psychosocial, and systemic dimensions. Participants were recruited from Romanian retail organizations, including both store and logistics staff. Data were collected anonymously via an online platform and analyzed using descriptive statistics.

Results. The literature review synthesized key themes regarding risk causes, employee impact, and mitigation effectiveness, shaping a clearer understanding of the challenges in safeguarding worker health in digitized retail. This structured approach enabled a focused analysis of specialist sources, offering valuable insights into occupational risks and prevention strategies amid the adoption of advanced digital technologies.

3. RESULTS

3.1 Barriers to occupational health and safety in the implementation of digital twins, AI, and automation in retail

The survey was conducted among employees from the Romanian retail sector, including staff from both physical stores and logistics centers. Their perceptions regarding task intensity and occupational risks are summarized in Table 1 and Table 2. Recent studies also highlight ergonomic risks in logistics operations, particularly in automated environments [34]. Cognitive overload has been identified as a growing concern in digitally mediated retail work [36]. Wearable technologies, while designed to enhance safety, may also contribute to physical discomfort and restricted movement [38]. These findings align with previous research on the physical and psychosocial impacts of digital transformation in retail [2],[8],[10],[27].

Table 1 presents the key barriers encountered in the implementation of Digital Twins, Artificial Intelligence, and Automation technologies within the retail sector, with a particular focus on occupational health and safety challenges.

Table 1

Barriers to occupational health and safety in the implementation of digital twins, AI, and automation in retail

Category	Barriers
Administrative barriers	Lack of clear planning regarding the integration of digital technologies in retail
	Organizational resistance to change ("Not In My Back Yard" attitude towards new technologies)
	Complicated bureaucratic procedures for implementing automation technologies
	Involvement of multiple departments or authorities in the decision-making process

	Lack of experience managing digital technologies within retail contexts
	Uneven application of health and safety regulations at the workplace
	Unclear administrative framework regarding responsibilities for occupational health and safety
	Insufficiently proactive management attitude towards integrating OHS into new technologies
Technological and technical barriers	Lack of standardization and economies of scale in the production and implementation of Digital Twins and AI in retail
	Underdeveloped IT infrastructure to support complex technologies
	Deficiencies in technical skills among employees and managers
	Lack of information and education regarding risks and best practices in technology use
	Insufficient technical and risk assessments related to health and safety impacts
Market barriers	Size and complexity of digital transformation projects
	High costs associated with advanced technology implementation
	Consumer resistance to technological changes in retail
	Lack of clear pricing rules in the context of digitalization
	Restricted access for new suppliers of innovative technologies
Economic barriers	High economic risk associated with investments in digital technologies
	Difficulties obtaining financing for digitalization projects
	Significant initial investment required for integrating Digital Twins, AI, and Automation

These barriers are categorized into administrative, technological and technical, market, and economic groups to provide a structured overview of the multifaceted obstacles that organizations face when adopting advanced digital solutions. Understanding these barriers is essential for developing effective strategies that facilitate safe and successful technology integration while safeguarding worker well-being in increasingly digitized retail environments.

The analysis of barriers reported by retail employees and managers reveals several significant challenges affecting the successful implementation of Digital Twins, AI, and Automation technologies. Approximately 48% of respondents identified a lack of clear planning for technology integration as a major administrative barrier, while 42% noted organizational resistance to change, often characterized by a "Not In My Back Yard" attitude towards new digital tools. Complicated bureaucratic procedures were cited by 35% as hindering progress, with 30% highlighting the difficulties arising from the involvement of multiple departments and authorities in decision-making processes.

A significant share of participants (40%) lacked experience in managing digital technologies in retail, while 37% cited unclear occupational health and safety responsibilities, compounding safety challenges. Additionally, 33% felt that management was not proactive enough in integrating health and safety into technological adoption.

On the technological and technical front, 45% of respondents pointed to the absence of standardization and economies of scale in the production and deployment of Digital Twins and AI as a critical barrier. Underdeveloped IT infrastructure was a concern for 38%, while deficiencies in technical skills among employees and managers were noted by 43%. Additionally, 39% of workers emphasized a lack of adequate information and education on the risks and best practices related to new technologies, and 34% reported insufficient technical and risk assessments addressing health and safety impacts.

Market-related barriers were also prominent, with 41% of participants citing the large scale and complexity of digital transformation projects as a key challenge. High implementation costs were a concern for 46%, and 29% reported consumer resistance to technological changes in retail environments. The lack of clear pricing mechanisms (25%) and restricted access for new technology suppliers (22%) further complicated market dynamics.

Economic barriers notably influenced the pace and scope of digital adoption. Nearly half of respondents (47%) cited high investment risk, while 43% reported challenges in securing financing. Additionally, 50% highlighted the substantial upfront costs required to implement Digital Twins, AI, and Automation effectively.

These findings underscore the nature of challenges facing retail organizations and highlight the need for coordinated administrative, technical, market, and economic strategies to facilitate safe and sustainable technological innovation.

Next, table 2 outlines the key factors influencing the adoption and occupational safety management of Digital Twins, AI, and automation technologies in the retail sector. These factors are grouped into three main categories: personal, psychosocial, and contextual to reflect the multidimensional nature of technology integration at the workplace. Personal factors focus on individual characteristics such as age, skills, and attitudes toward technological change.

Psychosocial factors highlight workers' perceptions of risk, job security, and stress in relation to new systems. Contextual factors address broader organizational and environmental conditions, including technological complexity, safety culture, policy frameworks, and regulatory standards. By structuring these components, the table provides a comprehensive view of the variables that can facilitate or hinder the safe and effective deployment of advanced technologies in retail environments.

In Table 2, the data collected from retail employees highlight several critical factors influencing the acceptance and safe integration of Digital Twins, Artificial Intelligence, and Automation technologies in their workplaces. Approximately 42% of respondents reported that their level of technical skills and digital literacy significantly affected their comfort and confidence in working alongside new automated systems.

This underscores the importance of targeted training and education programs. Additionally, 38% of employees voiced job security concerns, linking AI and automation to increased work demands and monitoring-related stress. Trust in management and technology providers proved crucial, with 45% noting that transparent communication and inclusive decision-making improved their acceptance of technological change.

Table 2

Influencing factors on the adoption and occupational safety management of digital twins, AI, and automation in retail

Factors	Components
Personal factors	Employee age
	Level of technical skills and digital literacy.
	Job role and experience within the retail sector.
	Attitudes towards technology and change.
Psychosocial factors	Awareness and understanding of occupational risks associated with new technologies.
	Perceived impact on job security and work intensity.
	Trust in management and technology providers.
	Stress levels and coping mechanisms.
Contextual factors	Technological characteristics: complexity, scale, and type of Digital Twins, AI, and automation systems.
	Organizational culture regarding health and safety.
	Policies and participatory approaches to employee involvement in technology adoption.
	Physical workplace layout and proximity to automated systems.
	External regulatory frameworks and industry standards.

From a contextual perspective, 50% of employees noted that the organizational culture regarding health and safety plays a pivotal role in shaping their attitudes towards these innovations. Physical aspects of the workplace, such as proximity to automated machinery, were reported by 35% as contributing to ergonomic risks and safety concerns.

Additionally, 40% of participants highlighted the need for clear policies and participatory approaches that involve workers in technology adoption strategies to foster a safer and more supportive environment.

Overall, the findings highlight the intricate interplay of personal, psychosocial, and contextual factors that must be considered to ensure technological progress in retail does not undermine worker health and well-being.

4. DISCUSSION

To fully grasp the occupational health and safety implications of Digital Twins, Artificial Intelligence (AI), and Automation in the retail sector, it is essential to understand not only the technological potential but also the human and organizational factors influencing their adoption and impact on workers [1],[3],[9]. Similar to how consumer attitudes shape the adoption of green energy technologies, employee perceptions, skills, and workplace culture significantly affect the integration and safe use of digital technologies in retail environments [12],[13],[21].

As evidenced by the reviewed literature and survey data, it is not sufficient to possess cutting-edge Digital Twins or AI systems; what matters equally is the readiness and willingness of retail employees to engage with these technologies safely and effectively [5],[6],[16]. For example, a considerable portion of retail workers reported experiencing psychosocial stress due to algorithmic monitoring and job insecurity, echoing concerns found in various studies [5] [16],[17]. Additionally, ergonomic challenges stemming from the interaction with automated equipment were frequently highlighted, indicating the need for thoughtful workplace design and participatory approaches [2],[26].

Similar to how the adoption of renewable energy depends on demographic and socio-economic factors, the acceptance and impact of digital retail technologies vary based on employee characteristics such as age, technical literacy, and job role [12],[13],[17]. Younger and more digitally literate employees tend to adapt more quickly and report fewer safety concerns, whereas older or less trained staff may face greater challenges [16],[17]. Moreover, organizational culture and management attitudes play an important role in shaping workplace safety outcomes, with proactive leadership correlating with better risk mitigation and worker well-being [6],[7],[25].

Market and economic factors also influence the pace and nature of digital transformation in retail [1],[4],[18]. High initial investments, uncertainty regarding returns, and complex project scales create barriers not unlike those faced in renewable energy sectors [1],[18], These challenges highlight the need for comprehensive planning, adequate financing, and regulatory frameworks that support both innovation and occupational health and safety [22],[23],[24].

In summary, the research indicates that while Digital Twins, AI, and Automation hold substantial promise for transforming retail operations, their successful and safe implementation depends on addressing a complex interplay of technological, organizational, and human factors [2],[8],[10],[27], Strategies that integrate employee training, participatory design, clear safety policies, and supportive management are essential to harness the benefits of digital technologies while protecting worker health and safety in the evolving retail landscape [6],[20],[25].

5. CONCLUSION

This study examined the occupational health and safety risks associated with the implementation of advanced digital technologies in the retail sector, focusing on physical, psychosocial, and systemic dimensions. By combining a systematic literature review with quantitative survey data, the research provided a comprehensive understanding of how employees perceive and experience these risks in digitized work environments.

The findings highlight a clear alignment between theoretical models and field-level perceptions. While physical risks such as repetitive strain and constrained postures remain prominent, psychosocial and systemic challenges, including cognitive overload, surveillance pressure, and organizational restructuring, are increasingly relevant in technology-mediated retail settings. These insights underscore the need for holistic prevention strategies that go beyond technical safeguards and address the broader organizational and human factors.

The study contributes to the growing body of research on digital transformation and worker safety by proposing an integrated risk typology and emphasizing the importance of contextual adaptation in mitigation efforts. However, limitations such as geographic scope and sample

size suggest that further research is needed to validate these findings across diverse retail environments and cultural contexts.

Future studies should explore longitudinal impacts of digital technologies on worker well-being, assess the effectiveness of emerging prevention models, and investigate cross-sectoral differences in risk perception and management. As retail continues to evolve, ensuring the health and safety of its workforce must remain a central priority in both technological design and policy development.

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Dualitate digitală, inteligență artificială și automatizare în retail

Integrarea tehnologiilor digitale avansate, precum Inteligența Artificială (IA), Dualitatea digitală și Automatizarea, transformă profund sectorul de retail, generând provocări noi în domeniul sănătății și securității ocupaționale. Studiul de față adoptă o abordare mixtă, combinând o revizuire sistematică a literaturii de specialitate cu date cantitative obținute prin intermediul unui chestionar aplicat angajaților din retailul românesc. Rezultatele evidențiază o corelare puternică între modelele teoretice și percepțiile din teren, subliniind intensificarea sarcinilor de lucru, suprasolicitarea cognitivă și perturbările organizaționale generate de digitalizare. Studiul propune o tipologie integrată a riscurilor și evidențiază necesitatea unor strategii de prevenție holistice, care să abordeze atât aspectele tehnice, cât și pe cele umane. Aceste contribuții sprijină elaborarea de politici informate și cadre adaptative pentru protejarea bunăstării angajaților în medii de retail digitalizate.

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