

Digitalisation Of Human Resource in The Age of Industry 4.0: A Review of Hr Practices and Its Challenges in Manufacturing Organisations

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ABSTRACT

The emergence of Industry 4.0 has catalysed a profound transformation in organizational design and operations, significantly influencing the domain of Human Resource Management (HRM). This scoping review maps and synthesizes existing literature on human resource (HR) practices and challenges in Industry 4.0 within manufacturing industries. Guided by the Arksey & O'Malley framework, a systematic search was conducted across Scopus, Web of Science, SpringerLink, Emerald Insight, IEEE Xplore, and Google Scholar, covering publications from 2010 to 2024. Key studies were selected based on inclusion criteria focused on HR functions in the context of Industry 4.0, resulting in 105 articles for thematic analysis. The review identifies prevalent HR practices, as digital recruitment, competency-building, engagement strategies, performance management, and employee well-being as major themes emerging from the review. Major challenges like digital skill shortages, resistance to change, implementation costs, data security, and limited empirical evidence from emerging economies, notably India as noteworthy. The findings underscore the strategic importance of HR in facilitating digital transformation, including agile structures, data-driven decision-making, and the evolution of workforce capabilities highlighting critical gaps in regional and applied research. This review contributes by offering both theoretical insights and practical directions for HR leaders and researchers seeking to enhance adaptive capacity in the digital manufacturing era

Keywords: Industry 4.0, human resource management, HR practices, Challenges of HR, HR digitalisation

INTRODUCTION

Industry 4.0, often referred to as the Fourth Industrial Revolution, represents a paradigm shift in industrial processes through the convergence of physical infrastructure and advanced digital technologies to develop intelligent and connected environments (1), (2). Unlike its predecessors, Industry 4.0 is not defined by a singular innovation but by the seamless integration of several advanced technologies namely cloud computing, Internet of Things (IoT), cyber-physical systems, big data analytics, and Artificial Intelligence (AI) (3), (4). These technologies collectively form the backbone of intelligent manufacturing and service ecosystems, facilitating real-time data exchange, decentralized decision-making, and the autonomous functioning of systems. IoT enables physical devices and machines to communicate with each other through embedded sensors, allowing the collection and transmission of vast amounts of data from production lines, equipment, and logistics (5), (6). Cloud Computing, by contrast, offers adaptable and scalable solutions for data storage and application deployment, significantly lowering infrastructure expenses while facilitating seamless collaboration across geographically dispersed

teams and operations (7). Big Data Analytics facilitates the exploration and interpretation of large, intricate datasets to uncover significant patterns, detect evolving trends, and derive insights that inform strategic decision-making (8), (9). Artificial Intelligence introduces automation and cognitive intelligence into systems, ranging from robotics in production to intelligent decision support systems in management (10). These technological components underpin multiple subdomains such as Supply Chain 4.0, Manufacturing 4.0, Maintenance 4.0, and Management 4.0. Each of these represents a digitally enhanced version of traditional operational domains, fundamentally altering how organizations create value, deliver products, and manage resources. Ultimately, the success of Industry 4.0 is not just dependent on the implementation of digital tools but on the systemic transformation of business models, workflows, and organizational culture to harness the full potential of these technologies, (11), (12).

Human Resource Management (HRM) has evolved from a support function focused on administrative tasks to a strategic enabler that drives organizational success (13), (14). Traditionally, HRM concerned itself with recruitment, payroll, performance management, and

employee relations (15). However, the increasing complexity and competitiveness post industry 4.0 revolution have pushed HRM into a more strategic and transformative role. In contemporary organizations, HR professionals are expected to align human capital strategies with business objectives, foster a high-performance culture, and enable workforce agility and resilience. The growing emphasis on talent management, employee engagement, leadership development, and organizational learning reflects the shifting priorities of HRM from transactional to transformational domains (16), (17). Furthermore, the digital age brought in by the onset on I4.0 has introduced new responsibilities and opportunities for HRM, including the adoption of digital tools such as Human Resource Information Systems (HRIS), employee analytics platforms, and AI-driven recruitment systems (18), (19), (20). These tools allow HR professionals to make data-informed decisions, personalize employee experiences, and streamline HR operations. Additionally, HRM must address a diverse set of challenges such as managing multigenerational workforces, ensuring diversity and inclusion, fostering continuous learning, and maintaining employee well-being in digitally intensive workplaces. The emergence of remote work and hybrid workforce models further complicates HRM responsibilities, requiring new strategies in performance monitoring, digital collaboration, and employee engagement (21). As organizations after I4.0 integration, increasingly operate in volatile, uncertain, complex, and ambiguous (VUCA) environments, HRM becomes central to enabling organizational adaptability, innovation, and sustainability (22), (23). In this context, the competencies required of HR professionals extend beyond traditional interpersonal and administrative skills to include technological literacy, strategic thinking, and change management capabilities (24), (25). Thus, HR 4.0 is no longer confined to the back office, it stands at the forefront of organizational transformation, poised to shape and support the workforce of the future.

The purpose of this study is to systematically review how Industry 4.0 technologies are reshaping Human Resource Management (HRM) practices, with a particular emphasis on the diverse roles of HR in contemporary organizations. In addition, the paper synthesizes the challenges documented in existing literature to provide realistic directions for future research.

The convergence of Industry 4.0 technologies as described in Figure 1 with Human Resource Management gives rise to a new paradigm often termed HR 4.0 or SHRM 4.0, (26), (27) reflecting a digitally empowered and strategically aligned HR function that supports the broader goals of digital transformation. As depicted in the visual framework, Industry 4.0 technologies like IoT, Cloud Computing, Big Data, and AI are not confined to production or supply chain functions but permeate all areas of the organization, including human resources (28). This integration brings about profound changes in how human resources are recruited, trained, managed, and retained (29), (30). AI-powered platforms are revolutionizing talent acquisition through intelligent resume screening, behavioural assessments, and

predictive hiring models (31). IoT-enabled wearables and sensors provide real-time data on worker safety, productivity, and ergonomics, supporting smarter workforce management (32). Big Data and people analytics offer actionable insights into employee engagement, performance trends, and turnover risks, enabling (33), (34). Moreover, cloud-based HR platforms allow for seamless management of globally distributed teams, enabling flexibility and scalability in HR operations. This digital infusion into HRM leads to the emergence of capabilities like predictive workforce planning (35), adaptive learning environments (36), and hyper-personalized employee experiences (37).

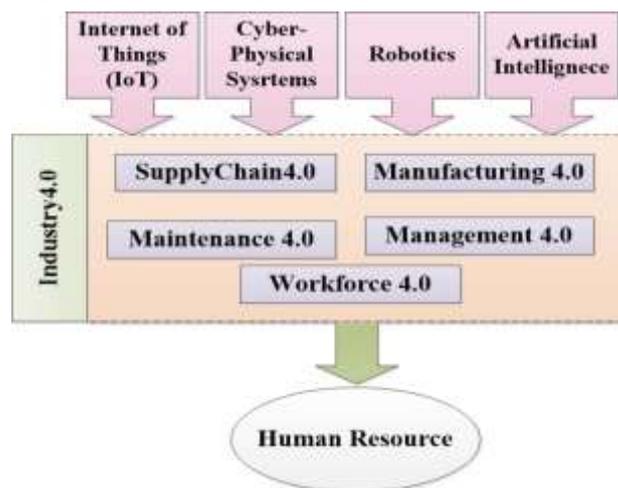


Fig.1 Technologies implement in Industry4.0 affect the Human resource.

From a strategic perspective, Industry 4.0 mandates a redefinition of workforce roles and competencies. The rise of automation and intelligent systems renders many traditional roles obsolete while creating new ones that demand interdisciplinary skills and digital literacy. HRM must therefore lead reskilling and upskilling initiatives to bridge the digital skills gap (38) (39), nurture a culture of continuous learning (40), and promote innovation. Workforce 4.0 emphasizes agility, self-management, and cross-functional collaboration qualities that HR must embed into recruitment criteria, training programs, and performance frameworks. Additionally, digital transformation introduces ethical concerns such as algorithmic bias, data privacy, and employee surveillance, which require HR to establish robust governance frameworks and promote responsible technology use (41). Organizational structures also become more fluid in the digital age, requiring HR to support decentralized decision-making, virtual leadership, and collaborative ecosystems (42). Ultimately, the fusion of Industry 4.0 and HRM represents a shift from mechanistic to organic organizational models, where human capital is viewed not merely as a cost but as a core asset in achieving digital excellence. In this new reality, Human Resource professionals are no longer gatekeepers of administrative compliance. They are change agents, digital enablers, and strategic partners in driving organizational growth (43), (44). Therefore, understanding and implementing HRM within the context of Industry 4.0 is not optional it is essential for building resilient, future-ready organizations that can thrive in the era of digital disruption.

Although HRM in the context of Industry 4.0 has gained increasing attention, significant gaps remain unanswered, especially pertaining to how evolving technologies are reshaping people management practices. Many prior studies have examined only selected factors influencing HR, offering a limited view of the broader transformation. In contrast, this study identifies and integrates a comprehensive set of influencing factors drawn from a wider range of review articles, providing a more holistic understanding of how Industry 4.0 technologies impact HR practices.

This study conducts a scoping review to systematically map HR practices and challenges in Industry 4.0, identify thematic trends, and highlight research gaps. It contributes by offering both theoretical insights and practical implications for HR professionals navigating digital transformation. Each HR factor is aligned with specific technologies, illustrating their influence on competencies, strategies, and organizational behaviour. The findings reveal emerging trends in digital HR, including agile structures, data-driven decision-making, and the evolution of workforce capabilities. The structure of the paper is as follows: Section 2 reviews HR practices and associated technologies; Section 3 addresses implementation challenges; and Section 4 presents the conclusions and study limitations.

2. METHODOLOGY

This study adopts a scoping review approach to map the evolving role of Human Resource Management (HRM) in the era of Industry 4.0. A scoping review was chosen because it allows the integration of fragmented scholarship, identification of key themes, and clarification of conceptual linkages between HR practices and emerging digital technologies. The review followed the framework proposed by Arksey and O'Malley (2005) and further refined by Levac et al. (2010), which is widely used in management and social sciences. Relevant literature was identified through a structured search of electronic databases including Scopus, Web of Science, and Google Scholar. Keywords combined terms related to "Industry 4.0", "Human Resource Management", "HR practices", "digital transformation", and "challenges". The search was limited to peer-reviewed journal articles, book chapters, and review papers published in English between 2010 and 2024, reflecting the period of significant Industry 4.0 development. Studies were included if they examined HR functions (such as recruitment, training, performance management, employee engagement, or organizational culture) in connection with Industry 4.0 technologies (AI, IoT, cloud computing, big data, etc.), the keyword "challenges of HR" were also screened. After screening titles, abstracts, and full texts, the selected studies were charted and categorized into HR function or HR challenges, and synthesized into thematic domains. Representative references were highlighted in tables and narrative discussion to illustrate key transformations, challenges, and gaps. This methodology ensures a comprehensive yet structured synthesis of the literature, offering both theoretical integration and a foundation for future empirical research.

This review was conducted using secondary data from published sources. As no human participants or animals were involved, ethical approval and informed consent were not applicable. Representative references were highlighted in tables and narrative discussion to illustrate key transformations, challenges, and gaps. This methodology ensures a comprehensive yet structured synthesis of the literature, offering both theoretical integration and a foundation for future empirical research.

2.0 INDUSTRY4.0 TECHNOLOGIES USED FOR HR PRACTICES

The transformation of human resource (HR) practices in the era of Industry 4.0 is deeply rooted in the integration of advanced digital technologies. As manufacturing industries navigate digital transformation, HR functions must also evolve from traditional administrative roles to strategic enablers of organizational agility and innovation. Four core technologies Cloud Computing, IoT, AI and Big Data Analytics, as shown in Figure 2 are increasingly adopted to modernize HR operations, improve employee experience, and enhance decision-making capabilities (27).

2.1. Internet of Things (IoT)

The IoT refers to the networked connection of physical devices embedded with software, sensors, and communication technologies that collect and process real time data. In the context of HR, IoT devices can monitor various aspects of employee activities, workplace safety, and environmental conditions(45).

Wearables such as smartwatches, biometric bands, and RFID tags are used in manufacturing plants to track worker movement, health parameters, and exposure to hazardous conditions. This data enables HR departments to identify safety risks, ensure compliance with occupational health regulations, and implement preventive measures to reduce workplace accidents. Additionally, IoT allows for real-time workforce management by tracking attendance, location, and productivity metrics. These insights help HR managers allocate resources more efficiently, ensure timely shift scheduling, and reduce downtime. As employee well-being becomes a strategic HR priority, IoT offers a proactive mechanism for fostering a safe and responsive working environment(46).

2.2 Cloud Computing

Cloud computing refers to the provision of a wide range of computing resources—such as servers, storage, databases, networking, software, and analytics via the internet. This technology allows organizations to access and manage IT services on demand, offering scalability, flexibility, and cost-efficiency (47). For HR practices, cloud computing revolutionizes how data is managed and processes are executed. Cloud-based Human Resource Information Systems (HRIS) centralize employee records, automate routine tasks such as payroll processing, benefits administration, and performance appraisals, and support self-service portals for employees (48). This digitization reduces paperwork, streamlines workflows, and enhances transparency. Cloud solutions also support virtual onboarding, e-learning platforms, and talent management

systems that are accessible from any location, enabling seamless HR operations in geographically distributed manufacturing setups. The flexibility and reliability of cloud platforms allow HR teams to focus on strategic initiatives such as workforce planning, employee engagement, and leadership development while ensuring real-time access to critical data for decision-making(49).

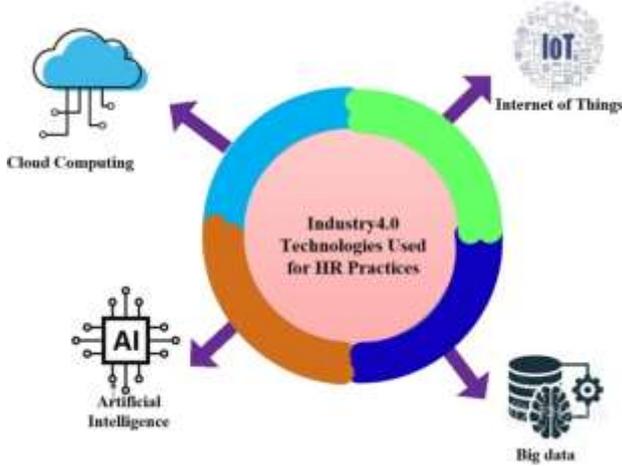


Fig.2 Industry 4.0 technologies used for HR Practices.

2.3. Big Data Analytics

Big Data Analytics encompasses the collection, processing, and examination of extensive structured and unstructured data to reveal underlying patterns, correlations, and trends that may not be immediately apparent, thereby supporting data-driven decision-making. In the realm of HR, big data plays a crucial role in improving the precision and effectiveness of workforce management strategies(50). Manufacturing firms generate extensive employee-related data from sources such as performance evaluations, attendance logs, training records, and exit interviews. By applying advanced analytics techniques, HR professionals can derive actionable insights to inform talent acquisition, predict attrition, identify high-potential employees, and measure employee engagement levels(50). Predictive analytics, in particular, helps forecast future workforce needs, optimize recruitment pipelines, and design data-driven learning and development (L&D) interventions(33).(51)

Moreover, big data supports diversity and inclusion initiatives by eliminating unconscious bias in hiring and promotions through objective, evidence-based assessments(33). Overall, big data analytics enhances the ability of HR to align its strategies with business goals and ensure that the right talent is in place to meet evolving operational demands(52).

2.4. Artificial Intelligence (AI)

AI involves the replication of human cognitive processes by machines, enabling them to learn, reason, and solve problems in ways that mimic human intelligence. In HR practices, AI is transforming various stages of the employee lifecycle from recruitment to retention(53). AI-powered platforms use machine learning algorithms and natural language processing to screen resumes, assess candidate profiles, and predict job fit based on historical hiring data and job descriptions. Chatbots are increasingly employed to automate interactions with candidates,

answer HR-related queries, and provide 24/7 support(54). AI entails the development of systems capable of performing tasks that typically require human intelligence, such as learning from experience, reasoning through information, and solving complex problems autonomously (55).

In training and development, AI enables adaptive learning experiences, recommending content based on individual learning styles and career goals. For manufacturing industries, where skill requirements are continually evolving due to automation and digitization, AI ensures that upskilling and reskilling initiatives are targeted and effective. Furthermore, AI facilitates unbiased decision-making and enhances HR's strategic contribution by enabling predictive insights into workforce trends(53,54).

3. STUDY OF HR PRACTICES IN THE ERA OF INDUSTRY 4.0

The role of HR while adopting I4.0 is perceived to act as an agent of change. However, it is in itself much more than that. It acts as an environment where all the various entities of an organisation come together to facilitate change within an organisation establishing mutual growth of all the entities with mutual cooperation from one another as mentioned in table.1. Human resource practices for the development of Operator 4.0 (OP4.0) identifies several key practices essential for adapting to Industry 4.0 technologies. These include effective staffing to select suitable candidates, job design to adapt to the changing nature of work, and continuous training to equip OP4.0 with the necessary skills. In order to understand these dynamics of HR, a detailed study of its role is done elaborately in the below section. Figure 3 represents the various HR practices performed by HR teams so as to seamlessly mitigate through industry 4.0 requirements. The practices are discussed in details in the following sections.



Fig.3: Various HR practices followed during the era of industry 4.0

3.1 Recruitment & Selection

The Fourth Industrial Revolution embedded with digital technologies transformed work, learning, leadership, management, recruitment, and interactions (56). The contributions of big data to human resource management practices leverages its use in recruitment and selection to structure their recruitment programs and functional career paths, however challenges like data quality, data privacy, and ethical concerns have also been noticed while in use

(57)). Impact of Industry 4.0 on various HR functions, such as job design and staffing have emphasized the importance of supporting innovation and learning within the organization. Effective recruitment processes are crucial for selecting candidates who can manage Industry 4.0 technologies and collaborate with other operators. Proper job design and redesign are necessary to adapt to the changing nature of work in Industry 4.0 (58). Job roles and required skill sets can be classified within the field of Big Data Analytics for ease of understanding. Four distinct job families: Business Analysts, Data Scientists, Big Data Developers, and Big Data Engineers can be considered for performing specific job roles. For each job family, the study delineates the necessary skill sets and the required levels of proficiency. Furthermore, the study presents a 'Big Data Job Families vs. Skill Sets Matrix,' designed as a practical tool for business leaders to organize recruitment strategies and define career trajectories, while also serving as a framework for academic institutions to shape relevant curricula and design specialized degree programs (59).

3.2 Training and Development Practices

There is a need for human resources departments in all companies to integrate elements such as "helping employees enhance their performance," and initiatives to improve job quality (60). There is a positive correlation between resilience, access to information, training, and the acceptance of technology. This would thereby lead to increased work engagement. There also exists a need for motivation among employees to boost their performance. Importance should be given to offering information and training to all employees to aid in Industry 4.0 transformations (61). Some organisations have engaged in undertaking external partnerships in training and personal development of employees to assist in speeding up the process of automation and improved their performance in a better way (38). A competency model can be used to define job profiles for Industry 4.0 vacancies and in competency-based curricula designing to achieve the goal of training efficiently (Prifti et al., n.d). Big data analytics (BDA) can significantly improve performance measurement systems (PMSs) by supplying valuable insights to decision-makers. The study suggests that BDA enhances the efficiency and effectiveness of decision-making by utilizing extensive internal and external data sets combined with multivariate statistical analysis (59). More effective training leads to a faster learning rate. It demonstrated that adopting a human-centered approach to enhance operators' skills and competencies in the new smart factory environment can improve their performance and job satisfaction (63).

3.3 Employee Engagement & Relation Practices

Organizations can secure their success and survival amidst technological disruptions by focusing on their people. The crucial role of HR in increasing employee engagement, creating personalized benefits, fostering trust within teams, promoting collaboration, and offering personal development opportunities would foster an environment of mutual growth and benefit to all. This would also help boost innovation and learning in the

organisation keeping pace with the technological advancements being adopted (64). Employee engagement plays a vital role in boosting productivity and performance within organizations. When employees are engaged, they are more motivated and dedicated to their work, leading to greater overall success for the organization (65). Advanced technologies can also enhance employee engagement by offering data-driven insights into employee needs and preferences, which in turn helps create a more engaging work environment (66). Productive employee engagement also fosters change and creates an environment of competitiveness. Research tools like surveys can help organisations introspect employee perspective (67).

3.4 Performance Appraisal & Feedback Practices

A transition from traditional performance management perspective is the need of the hour, which values seniority to one that emphasizes performance and results. In organizations adopting Industry 4.0, performance appraisal and feedback systems are increasingly data-driven and automated by integrating digital systems into performance management processes (60). From an HR perspective, these systems leverage advanced technologies such as big data analytics, artificial intelligence, and IoT to collect and analyze performance metrics in real-time. This enables more accurate and objective assessments of employee performance. HR can use these insights to provide personalized feedback, identify skill gaps, and tailor development plans. The focus is on continuous improvement and aligning individual goals with organizational objectives, fostering a culture of transparency, and enhancing overall employee engagement and productivity (65). A transition is being initiated by HR from a traditional performance management perspective that values seniority to one that emphasizes performance and results. This new approach rewards young and hardworking employees, reflecting the changing dynamics of the workforce in an era of rapid technological advancement (60). Effective performance management systems require regular monitoring, repetitive checks, and performance training to ensure that employees are meeting the evolving demands of their roles. HR is encouraged to foster an environment where employees feel empowered to provide feedback to managers and engage in discussions about company goals. This engagement is vital for motivating employees and aligning their performance with organizational objectives. Finally, it is very crucial that HR needs to ensure the level of relevance of performance metrics being used for the current technological landscape.

3.5 Attendance and Pay Roll

Both Industry 4.0 technologies and AI substantially influence various HR functions, such as recruitment, selection, HR planning, performance management, and payroll management. The integration of these technologies enhances efficiency and accuracy, leading to faster and more reliable HR processes. This technological advancement allows HR professionals to focus more on strategic tasks rather than routine operational duties,

contributing to a more strategic role for HR departments in achieving organizational goals (66). Measuring employee productivity through AI tools is identified as crucial for effective HR management. There is an emergence of cloud-based payroll systems, driven by advancements in communication and computer technology essential for modern business processes. A key benefit of these systems is their potential to reduce the likelihood of fraud through robust internal controls that enhance security and oversight. Effective internal controls are especially crucial when companies outsource payroll functions, ensuring timely and accurate payment of payroll taxes and avoiding penalties and double payments. The research also indicates that outsourcing payroll can be a strategic move for the industry 4.0 era, allowing industries or firms to focus on core competencies while leveraging the expert or skilled of specialized payroll service providers. Additionally, the adoption of cloud payroll systems aligns with broader Industry 4.0 trends of digitization and integration, characterized by increased connectivity and innovative business models (68).

3.6 Compensation Management Practices

Robust performance appraisal systems, effective knowledge management, and meaningful compensation systems are crucial for fostering innovation, continuous improvement, and retaining skilled personnel. The study emphasizes the need to develop both soft skills (e.g., creativity, adaptability, problem-solving) and hard skills (e.g., technical, digital skills) among employees (58). Effective compensation systems, encompassing both tangible and intangible benefits, are crucial for retaining skilled Operator 4.0 personnel. Here emphasis is given to the role of HR in enhancing employee engagement, designing personalized benefits, fostering team trust, encouraging collaboration, and supporting personal development, all of which contribute to a robust retention strategy (64). Amidst of technological disruptions organizations focusing on the workforce can secure their success and survival.

3.7 Safety And Health Practices

The adoption of industry 4.0 technologies, manufacturing organisations underwent significant human-machine collaborations for shaping up smart factories, safety and health practices therefore became significantly a core aspect among these organisations. It highlights the importance of operational activities affected by human performance and their capabilities. An experienced approach can help identify the required knowledge, skills, and competences for safe and effective execution (69). Furthermore, the applications of AI notably enhances HR agility, affecting aspects such as organizational network analysis and design. Key dimensions of AI impact include health and safety improvements, which positively influence employee well-being and productivity, and real-time feedback, which has varying effectiveness depending on the context (70). There are significant physical and mental health concerns specially among IT professionals due to long working hours and blurred boundaries between home and work, necessitating improved health

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and workplace security measures. The transformation of workspaces due to digitalization and increased outsourcing has diluted the role of HR, requiring a re-evaluation of HR practices (58). Feedback loops also assist in the modification of knowledge standards and ensure timely updation of knowledge as per the evolving changes in job descriptions at different stages. This method helps to follow safety and health standards by coordinating together with operations and design of tasks. Eventually it would lead to a higher level of readiness of manufacturing organisations (69).

3.8 Employee Motivation

HR can enhance employee motivation through performance-based rewards, promoting lifelong learning, empowering employees, recognizing soft skills, fostering a positive organizational culture, and implementing effective communication and feedback mechanisms. These strategies are crucial for motivating employees in the rapidly evolving landscape of Industry 4.0 (56). Emphasis has to be made for the shift towards performance-based compensation systems as a means to motivate employees (71). In the context of Industry 4.0, where skills and competencies are increasingly important, HR is encouraged to develop reward mechanisms that recognize and incentivize high performance, skill acquisition, and knowledge application (72). This approach aligns employee rewards with their contributions to the organization, fostering a sense of achievement and motivation. Motivating employees to engage in continuous skill development is crucial for adapting to the demands of Industry 4.0. By providing opportunities for training and professional growth, HR can enhance employee motivation and ensure that the workforce remains competitive and capable of utilizing new technologies effectively. Decentralized decision-making structure can empower employees, giving them greater autonomy in their roles (73). This empowerment can lead to increased job satisfaction and motivation, as employees feel more in control of their work and are encouraged to take initiative. The recognition and development of soft skills are highlighted as essential for employee motivation. HR is encouraged to incorporate the assessment of soft skills into recruitment and talent management processes (Maisiri et al., 2019). By valuing and rewarding these skills, organizations can motivate employees to enhance their interpersonal abilities, which are critical in a collaborative and digital work environment. Effective communication and feedback mechanisms are essential for maintaining employee motivation (75). HR should implement continuous feedback systems that allow employees to understand their performance and areas for improvement. Regular communication about organizational goals and individual contributions can enhance motivation by aligning employees' efforts with the broader objectives of the organization. The importance of work-life balance is emphasized as a factor in employee motivation. HR is tasked with implementing policies that support flexible working arrangements and promote employee well-being, which can enhance overall motivation and productivity (Aslan, 2019).

3.9 Retention Practices

Organizations that prioritize employee satisfaction and retention focus on several key strategies. Providing clear career advancement opportunities through training, professional development, and skill enhancement is essential in fostering growth and motivation among employees. To support work-life balance, the use of automated work logs ensures efficient time management and helps prevent burnout. Competitive salaries play a crucial role in attracting and retaining top talent, while a comprehensive benefits package including health insurance and retirement plans further enhances employee well-being. Additionally, the integration of advanced HR technologies, such as AI and analytics, supports strategic staffing, facilitates soft skill development, and encourages employee involvement in decision-making processes, ultimately creating a more engaged and productive workforce.

3.10 Organisation Culture Related Practices

Organizational culture is a pivotal factor in ensuring the effective adoption and implementation of Industry 4.0 initiatives (76). It can be considered as a resource which is unique, and challenging to replicate. An organizations culture comprises of multifaceted values, perceptions, expectations, and representations, that is portrayed by the conduct of an organisation and its business (77), (78). HR is vested to create a strong organizational culture which is

essential for successfully navigating the changes brought about by Industry 4.0. (79). Along with, there is a need for a culture that promotes commitment to technological change and innovation (79). This transformation is crucial for fostering an environment where employees are encouraged to adapt to new technologies and work processes. Organizations with a rigid culture may struggle to embrace digital transformation, (80) while those with a more flexible culture can respond more dynamically to market demands (81). A positive organizational culture can enhance employee engagement and motivation. When employees feel that their contributions are valued and that they are part of a collaborative environment, they are more likely to be committed to the organization and its goals. Leaders are responsible for modelling the desired behaviours and values that align with the goals of Industry 4.0. Effective leadership is necessary to create a culture that supports innovation, collaboration, and continuous learning (82) (83). HR must carefully manage this transition to ensure that the culture evolves in a way that supports the organization's strategic objectives in the context of Industry 4.0. Another important aspect of an organisations culture is to foster an atmosphere of continuous learning, which would lead to sustainable growth and promote innovation in the organisation (84). Such organisations aim at acquiring brilliance of knowledge and skills leading to enhanced competencies in its employees (85). Safety and security measures are now being incorporated into the organizational culture as an essential component for effective implementation of Industry 4.0 technologies in various departments (67).

Table 1 The Evolving Role of HR in the Era of Industry 4.0.

	Traditional Role (Pre-Industry 4.0)	Transformed Role in Industry 4.0	Key Enabling Technologies	Emerging Challenges	Representative References
Recruitment & Selection	Manual screening, job boards, campus drives	AI-driven recruitment, predictive analytics, digital employer branding	AI, Big Data, HRIS	Algorithmic bias, data privacy, skill–job mismatch	Madanchian (2024); Roul et al. (2024); Pillai & Srivastava (2024b); Dr. Vishwanath & Vaddepalli (2023)
Training & Development	Classroom-based training, generic skill-building	Continuous digital upskilling, adaptive e-learning platforms, VR/AR simulations	AI, Cloud, VR/AR, IoT	High cost of reskilling, resistance to digital learning	Stachová et al. (2019a); Vrchota et al. (2020); Vereycken et al. (2021a); Salvadorinho & Teixeira (2023a)
Performance Management	Annual appraisals, subjective assessments	Real-time performance dashboards, people analytics, outcome-based evaluation	Big Data, IoT, Cloud HR systems	Data accuracy, fairness, employee surveillance concerns	Garcia-Arroyo & Osea (2021a); Dahlbom et al. (2019); Bell et al. (2006); Long et al. (2013)
Employee Engagement & Well-being	Surveys, HR events,	Digital collaboration tools, wellness apps,	IoT wearables, AI chatbots,	Work–life imbalance, tech fatigue,	John et al. (2024); Podder et al. (2024);

	traditional feedback	personalized engagement strategies	Cloud platforms	maintaining human touch	Akdere & Egan (2020); Jha (2022)
Workforce Planning & Strategy	Static workforce planning, reactive HR policies	Predictive workforce analytics, agile HR strategies aligned with digital transformation	AI, Big Data, Cloud	Shortage of digital skills, uncertainty in future roles	Quddus Mohammed (n.d.); Vrchota et al. (2020); Liboni et al. (2019); Tsaramirsis et al. (2022)
Organizational Culture & Change Management	Hierarchical, compliance-driven structures	Agile, innovation-driven, collaborative ecosystems	AI-enabled knowledge sharing, Cloud platforms	Resistance to change, fear of job loss, ethical dilemmas	Jha (2022); Hassan et al. (2024); Dhanpat et al. (2020); Megdad & Çağlar (2024)

4. CHALLENGES OF HR

The effective adoption of Industry 4.0 technologies in India's manufacturing landscape, despite its potential to drive operational efficiency and competitive advantage, hinges on the resolution of complex and interrelated barriers. Organizations must develop strategies to overcome these barriers to fully leverage the benefits of this industrial revolution. Despite several benefits, certain key challenges identified while implementing industry 4.0 include high implementation cost, the need for skilled personnel, and the time-consuming nature of training employees to adapt to new systems. Along with these challenges industry 4.0 technologies and AI may also present considerable changes, their potential to transform HR processes is significant, leading to improved efficiency, engagement, agility, and strategic alignment within organizations (70). Furthermore, the HR department plays a critical role in promoting cultural, technological, and organizational changes, overcoming internal resistance, and placing employees at the centre of change initiatives (58). Figure 4 represents the various challenges faced by HR while adopting industry 4.0.



Fig. 4: Challenges faced by HR while navigating through industry 4.0

The transition to Industry 4.0 requires substantial organizational change, which can be met with resistance from employees. Many employees experience uncertainty about the future of work, particularly regarding job security and the skills required in a rapidly changing environment. This uncertainty can lead to fear and resistance to change among staff (30). Robust change management frameworks are essential to mitigate workforce apprehensions, facilitate technological adoption, and cultivate an organizational ethos of flexibility and innovation. Organizations must communicate the benefits of digital transformation clearly and involve employees in the transition process (56). The initial financial outlay for adopting Industry 4.0 technologies is substantial, often accompanied by uncertainty regarding the return on investment (ROI). Additionally, the workforce may lack the necessary knowledge and skills to effectively utilize these emerging technologies. The shift towards automated and data-driven processes demands a workforce with new skill sets. There is a notable gap in the availability and retainment of skilled personnel who are proficient in advanced technologies, which can hinder the effective implementation of industry 4.0 initiatives (86). This skills gap poses a significant barrier to successful implementation, as employees may struggle to adapt to new systems and processes. The absence of clear guidelines and regulations for implementing Industry 4.0 technologies can create confusion among organizations, hindering decision-making processes (87).

The successful migration toward Industry 4.0 necessitates the seamless incorporation of cutting-edge technological solutions including the IoT, AI, and big data analytics into legacy manufacturing infrastructures. This integration poses significant technical challenges, including compatibility issues with legacy systems and the need for substantial upgrades to infrastructure (A.T James et.al 2022). Companies therefore must manage vast amounts of data (big data) and develop extensive IT infrastructures, including communications networks and standardized interfaces for collaborative work (Hecklau.et.al 2016). The nature of these advanced technologies requires significant integration and coordination, leading to high interdepartmental activities. As automation and AI take

over routine tasks, HR must also ensure that employees remain engaged and motivated. This may involve redefining roles and responsibilities to provide meaningful work (89), (90). This cultural inertia can impede the transition to Industry 4.0. Furthermore, with the increased connectivity of devices and systems, data security becomes a critical concern as data management is a core aspect of these technologies, organizations must address potential vulnerabilities to protect sensitive information from cyber threats (91). Organizations must implement robust cybersecurity measures to protect sensitive information from potential breaches and ensure compliance with data protection regulations (92). This challenge necessitates a comprehensive approach to data governance and risk management (93).

Recruitment, selection and retainment role of human resources would require advanced practices, as the trend would shift from long term employment approach to skill and task-based approach (94). Existing recruitment and selection methods may become insufficient in identifying candidates who possess the skills required for new roles created by Industry 4.0 (60). Industry 4.0 thereby, requires and encourages creative approach with innovative thinking processes which necessitates the replacement of conventional recruitment processes with automation (A.T James et.al 2022). HR must ensure that diversity and inclusion are prioritized in hiring practices to foster innovation and creativity within teams. Industry 4.0 may require a shift in organizational structure to support more agile and cross-functional teams. HR needs to facilitate this transition and ensure that the new structure aligns with business goals (95). As automation and intelligent systems are integrated, some low-skilled employees may lose their jobs. This creates a need for HR to manage workforce transitions and support affected employees (30), (96) HR must evolve to become strategic partners within the organization, requiring specialists who can understand financial data and industry dynamics (97). This shift demands a redefinition of HR's mission, job definitions, and responsibilities. Navigating the legal implications of new technologies and ensuring compliance with regulations can pose additional challenges for HR. Assessing the impact of Industry 4.0 initiatives on workforce performance and organizational outcomes can be challenging (98), (99). There is a growing need for government support in funding research and establishing legal frameworks for big data usage, particularly concerning privacy protection (100) The integration of technology in the workplace can lead to new health and safety concerns, including mental health issues related to increased workloads or job displacement. HR must address these concerns by promoting employee well-being and providing support systems. They must ensure that employees are trained to work safely with new systems and that safety protocols are updated to reflect the changes in the workplace (101). Traditional performance management systems may not be suitable for the dynamic environment of Industry 4.0. HR needs to develop new metrics and evaluation methods that align with the goals of smart manufacturing and the contributions of employees in this context. Changing social values and demographic shifts, such as an aging workforce, create additional pressures on HR to adapt qualification

strategies and workforce management (102). This increased aging population can lead to a decrease in the number of individuals available for work. This situation complicates the recruitment of younger, tech-savvy employees who are essential for driving innovation in Industry 4.0 (103).

A significant number of enterprises exhibit inadequate strategic planning for Industry 4.0 adoption, resulting in operational ambiguities and HR misalignment. Through systematic identification and mitigation of these barriers, firms can effectively capitalize on Industry 4.0's transformative capabilities to achieve long-term competitive advantage in an increasingly digitized industrial landscape.

5. CONCLUSION

This study provides a comprehensive understanding of how Industry 4.0 technologies are influencing and transforming Human Resource Management. Unlike previous studies that focused on isolated variables or singular functions, our research integrates key HR practices such as recruitment, training, engagement, performance appraisal, compensation, and organizational culture with the core technological pillars of Industry 4.0, including AI, IoT, cloud computing, and big data. The findings highlight that HRM is no longer a peripheral support function but a strategic driver in shaping digitally agile and future-ready organizations.

The study emphasizes that each HR function must adapt to emerging technological demands. Recruitment now involves predictive analytics and AI-driven assessments, while training is shifting toward continuous, competency-based learning aligned with automation and digital fluency. Employee engagement, well-being, and safety have also taken on renewed importance in hybrid and technology-driven work environments. Furthermore, HR is central to managing organizational culture, ensuring adaptability, inclusivity, and openness to innovation during digital transformation. In addition to these opportunities, the study also identifies significant challenges, particularly in developing contexts. These include high implementation costs, skill shortages, employee resistance, and the need for cultural and structural realignment. HR professionals are increasingly required to balance the integration of advanced technologies with ethical considerations, data governance, and workforce transitions.

Overall, this research contributes to the growing literature on HRM and Industry 4.0 by offering a holistic framework that connects practice with technology. It also offers strategic insights for HR leaders, policymakers, and organizations aiming to navigate the complexities of digital transformation. As Industry 4.0 continues to evolve, HR's role as a change enabler, talent strategist, and cultural architect becomes more critical than ever.

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