

Strategic Enablers of Industrial Resilience: Thematic Insights into Training Needs and Automation Anxiety within the Big Three Steel Companies

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Abstract

The rapid acceleration of Industry 4.0 has introduced a paradigm shift in the global industrial scenario, creating profound capability gaps within capital intensive industry. In this background, this qualitative multiple case study explored how three leading Indian steel manufacturers, namely Tata Steel, JSW Steel, and Steel Authority of India Limited (SAIL) design, deliver, and evaluate training and development (T&D) initiatives in the context of automation and occupational Health & Safety. Semi-structured interviews with senior HR and training leaders, supplemented by company documents, were analyzed using Braun and Clarke's reflexive thematic analysis. Six themes emerged: (a) training as a strategic enabler, (b) multi-level training needs analysis, (c) comprehensive and blended training portfolios, (d) Human tensions, (e) partial yet meaningful training impact and ROI evidence (Metrics), and (f) digital transformation of learning ecosystems, with notable contrasts between public and private sector organizations. A primary contribution of this research is the conceptualization of how a capital-intensive industry formulates its policies from a Human Capital Management (HCM) perspective for achieving technological transformation, zero accidents, and safe and green steel processes. Although private entities (Tata and JSW) exhibited superior proficiency in digital adoption, SAIL is endeavoring to navigate this process to the best of its ability under bureaucratic constraints. The findings of the study revealed that while training and development is essential for technological competitiveness, it also serves as vital tool for ensuring the highest safety standards. The study concluded with a recommendation for a more inclusive, data-driven learning system that aligns with sustainable development goals and decent work standards.

Keywords: *Training and Development, Qualitative Analysis, Steel Industry, Industry 4.0, India, HRD*

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1.0 Introduction & Background to the Study

The Indian steel industry plays a critical role in national economic development by contributing to gross domestic product (GDP), employment, and the supply of essential inputs for infrastructure, construction, transportation, and automotive manufacturing. As the world's second-largest steel producer, India's steel industry operates through capital-intensive, technology-driven, and safety proactive production systems, where workforce capability is a key determinant of productivity, safety, and competitiveness.

In recent years, the steel industry has been dynamically changed by the adoption of Industry 4.0 technologies, including automation, robotics, cyber-physical systems, artificial intelligence, digital manufacturing platforms, and predictive analytics maintenance. Empirical studies indicated that these technologies had altered job roles, skill requirements, and organizational structures within heavy manufacturing industries (Kamble et al., 2018; Frank et al., 2019; Tortorella et al., 2022). Consequently, organizations face growing challenges in aligning workforce skills with digitally enabled production environments.

Recent studies emphasized that technological investments alone are not sole to gain the benefits of Industry 4.0; rather, the availability of appropriately skilled and adaptable human resources is foremost (Sony & Naik, 2020; Ghobakhloo et al., 2021). Current studies in process and manufacturing industries highlighted persistent skill gaps

in areas such as digital literacy, automation control, data-driven decision-making, cross-functional problem-solving, and safety management in technologically driven environments (World Steel Association, 2022; ILO, 2023). These challenges are particularly pronounced in steel plants, where legacy workforces, increasing reliance on contract labour, and high safety risks coexist with rapid technological change.

In the contemporary policy landscape, industrial performance is increasingly evaluated against the framework of the **United Nations Sustainable Development Goals (SDGs)**. The steel industry directly intersects with several SDGs, particularly:

- a) Decent Work and Economic Growth ensure productive employment, safe working environments, and continuous skill development.
- b) Industry, innovation, and infrastructure promote technological modernization and sustainable industrialization.
- c) Good health and well-being can reduce workplace accidents, occupational diseases, and exposure risks.
- d) Responsible consumption and production lead to better process efficiency, environmental compliance, and sustainable operations.

Tata Steel, JSW Steel, and SAIL are emblematic of this transformation. Tata Steel, established in 1907, operates major integrated plants in Jamshedpur and Kalinganagar and has built a strong reputation for innovation, sustainability, and its Tata Steel Capability Development Institute (TSDCI), JSW Steel founded in 1982, runs key facilities in Vijayanagar, Dolvi, and Salem and has invested heavily in the JSW Learning Academy and digital learning tools. SAIL, a Maharatna public sector enterprises created in 1973, operates large integrated plants in Bhillai, Bokaro, Rourkela, and Durgapur and manages techno-managerial training through its Management Training Institute (MTI).

1.1 Research Questions

The above-discussed challenges were particularly pronounced in steel plants, where legacy workforces, increasing reliance on contract labor, and high safety risks coexist with rapid technological change. To understand how organizations navigate this complex transition, this study addresses two primary inquiries.

First, it investigates how leading Indian steel manufacturers design, align, and deliver their training and development ecosystems to meet the strategic demands of Industry 4.0 while navigating the diverse, multi-level needs of their workforce.

Second, the study explores the primary implementation challenges, human tensions, and evaluation hurdles encountered during this digital transition, specifically examining how public and private sector approaches differ in overcoming them.

1.2 Objectives of the Study

1.2.1 To investigate how Indian steel manufacturers strategically align T&D with Industry 4.0 and conduct multi-level Training Needs Analysis (TNA).

1.2.2 To analyze the design of blended training portfolios and identify implementation challenges like workforce diversity, production pressures, high safety risk and automation anxiety.

1.2.3 To evaluate training effectiveness frameworks and compare digital learning transformations between public and private sector firms.

2.0 Literature Review

2.1 Training and Development as Strategic HRM

Training and development has shifted from a narrow, activity-based function to a core element of strategic human resource management. Strategic training is understood as the deliberate alignment of learning initiatives with business strategy, competitive positioning, and long-term capability requirements (Garavan, Costine, & Heraty, 1995). Empirical studies associate systematic training investments with improved productivity, quality,

innovation, and financial performance across sectors (Tharenou, Saks, & Moore, 2007). In manufacturing settings, T&D supports multiple strategic aims, including technology adoption, safety improvement, and organizational agility, making it central to how firms compete in volatile environments (Hughey & Mussnug, 1997; Swanson & Holton, 2009).

In capital-intensive, high-risk industries such as steel, training is closely intertwined with operational excellence. Research on heavy industries underscores that sustained performance gains require not only technical skill development but also deliberate shaping of safety culture, problem-solving capabilities, and cross-functional collaboration (Mearns & Reader, 2008; Liker, 2004). From a strategic HRM perspective, training systems in such contexts become vehicles through which organizations translate strategic priorities such as digital transformation, lean operations, or sustainability into day-to-day practices and worker competencies (Noe, Clarke, & Klein, 2014).

2.2 Training Needs Analysis and Competence Development

Training needs analysis (TNA) is widely recognized as the foundation of effective T&D. Classic models conceptualize TNA as a three-level process that examines organizational priorities, task or job demands, and individual performance gaps (McGehee & Thayer, 1961; Goldstein & Ford, 2002). Subsequent work has extended this logic by incorporating competency models, performance management data, and strategic workforce planning into multi-level needs assessment (Moore & Dutton, 1978; Gupta, Lakshmi, & Aronson, 2000). In dynamic business environments, needs analysis must increasingly anticipate future skill requirements rather than respond only to current deficits (Becker & Bish, 2017).

Studies in technology-intensive manufacturing note that TNA processes are most effective when they integrate both quantitative indicators (e.g., defect rates, downtime, incident data) and qualitative insights from line managers and workers (Swanson & Holton, 2009). This combination enables organizations to capture not only observable performance gaps but also latent challenges such as resistance to new technologies or variations in learning readiness across demographic groups. In the context of Industry 4.0, researchers have highlighted the importance of mapping digital competencies, including data literacy, human-machine interaction, and cyber-physical system awareness to specific roles and processes, and then embedding these maps into systematic TNA frameworks (Frank et al., 2019).

2.3 Training in Manufacturing and Heavy Industry

Manufacturing organizations face distinctive training challenges stemming from diverse workforces, continuous operations, hazardous tasks, and rapid technological upgrading (Swanson & Holton, 2009). Research in heavy industries including oil and gas, mining, and steel emphasizes that safety training and technical training are often inseparable in practice because new technologies both reduce and reconfigure risks (Mearns & Reader, 2008). Studies of safety-critical sectors showed that effective programs go beyond compliance to address risk perception, safety climate, and behavioral norms on the shop floor (Geller, 2005).

At the same time, manufacturing firms are under pressure to develop multi-skilled workforces capable of flexible deployment across processes and equipment. Evidence suggested that cross-training and multi-skilling can enhance flexibility and responsiveness but require carefully sequenced learning pathways, structured on-the-job coaching, and supportive supervisory practices (Grobe & Kersten, 2015). In lean production systems, continuous improvement routines such as kaizen, problem-solving circles, and standard work audits are frequently positioned as ongoing learning mechanisms rather than discrete training events (Liker, 2004).

2.4 Evaluation of Training Effectiveness and ROI

The evaluation of training effectiveness has been dominated by Kirkpatrick's four-level model, which distinguishes reaction, learning, behavior, and results (Kirkpatrick & Kirkpatrick, 2016). Meta-analytic evidence generally supports positive associations between learning outcomes and behavior, but findings regarding the link to organizational results are more nuanced, partly because many contextual variables intervene between training and performance (Alliger, Tannenbaum, Bennett, Traver, & Shotland, 1997). Critics argue that the model tends to oversimplify complex causal chains and encourage a linear view of impact (Holton, 1996).

To address these gaps, ROI-focused approaches have been proposed that link training investments to financial and operational outcomes using cost–benefit analysis, utility analysis, or balanced scorecard frameworks (Phillips & Phillips, 2016). In manufacturing, relevant indicators include output per employee, defect rates, rework, equipment downtime, safety incidents, and employee turnover. However, researchers note that isolating training effects from parallel initiatives such as equipment upgrades, process redesign, or incentive changes remains challenging (Noe et al., 2014). More recent work suggested that combining quantitative metrics with qualitative evidence (e.g., critical incidents, narratives) and adopting systems perspectives that view training as one element within broader socio-technical change (Salas, Tannenbaum, Kraiger, & Smith-Jentsch, 2012).

2.5 Digital Learning, Industry 4.0, and HRD

Industry 4.0 technologies such as cyber-physical systems, IoT, big data analytics, and advanced robotics are reshaping both work and workplace learning. Digital learning tools, including learning management systems, e-learning modules, mobile microlearning, serious games, and VR/AR simulations, offer scalable and flexible ways to upskill large industrial workforces (Bondarouk & Brewster, 2016; Radianti, Majchrzak, Fromm, & Wohlgenannt, 2020). Meta-analytic reviews suggest that blended learning, which combines digital and face-to-face components, often yields better outcomes than either modality alone, particularly for complex skill sets (Means, Toyama, Murphy, & Baki, 2013).

In high-risk industries, simulation-based training using immersive technologies allows workers to practice dangerous tasks such as working at height, handling molten materials, or managing equipment failures without exposing them to actual hazards (Salas et al., 2012; Radianti et al., 2020). At the same time, scholars warn that digital learning can reproduce or deepen inequalities if it does not account for differences in digital literacy, language, access to devices, and work schedules (Bondarouk & Brewster, 2016). HRD literature therefore, increasingly emphasizes the design of inclusive digital ecosystems that provide personalized pathways, multilingual content, and data-informed support while remaining sensitive to worker diversity and union contexts.

2.6 Training and Development in the Indian and Steel-industry Context

Research on training and HRD in Indian organizations has highlighted the coexistence of sophisticated HR systems in leading corporations and more traditional, compliance-driven approaches in many other firms (Budhwar & Varma, 2010). Studies of Indian manufacturing point to challenges such as multilingual workforces, variable educational backgrounds, strong union presence in some segments, and differences between public sector enterprises and private companies in terms of flexibility, incentives, and performance management (Budhwar & Varma, 2010; Venkata Ratnam & Verma, 2011). These contextual features shape both the design and reception of training interventions.

Government initiatives such as the National Skill Development Mission, sector skill councils, and public–private skill partnerships have sought to address systemic skill shortages and raise workforce quality in manufacturing, including metals and heavy engineering (Mehrotra, Gandhi, & Sahoo, 2014). However, empirical work suggested that the effectiveness of these initiatives depends heavily on company-level commitment, the quality of training infrastructure, and the extent to which programs are aligned with actual shop-floor requirements (Mehrotra et al., 2014).

Specific scholarly analyses of training practices in the Indian steel industry remain limited but indicated that firms grapple with issues of safety culture, legacy technologies, and uneven adoption of modern HRD practices (Budhwar & Varma, 2010; Venkata Ratnam & Verma, 2011). The rapid diffusion of automation and digital control systems in integrated steel plants has intensified the need for structured TNA, continuous upskilling, and more rigorous evaluation of training effectiveness, particularly in relation to safety, productivity, and energy efficiency. This emerging context underscores the relevance of in-depth, qualitative studies that can capture how training is experienced by HR leaders and line managers as they navigate Industry 4.0 transformations in large, complex organizations.

3.0 Methodology

3.1 Research Design

Grounded in a constructivist ontology, this research views organizational reality as a dynamic product of social interaction and shared meaning within the industrial ecosystem. A qualitative multiple case study design was adopted because the study aimed to demonstrate complex organizational processes and participant perspectives in depth rather than to estimate prevalence or test causal hypotheses. Case study design enables a detailed examination of training practices within each organization while still permitting cross-case comparison to identify common patterns and meaningful differences.

3.2 Participants and Sampling

This study utilized a judgmental sampling technique, specifically focusing on criterion-based selection. The organizations Tata Steel, JSW Steel, and SAIL were chosen based on market leadership, diversity of ownership (two private and one public sector), geographic spread across major steel-producing regions, and evidence of established training infrastructure.

Within each organisation, one senior HR or learning and development leader and a line manager were identified as primary informants. Selection criteria included strategic involvement in T&D planning and budgeting, oversight of training operations, and familiarity with both policy and shop-floor realities. Although this two-informant (HR Leader and Line Manager) design limits the breadth of viewpoints within each case, it provides rich, integrative perspectives on organisational systems.

3.3 Data Collection

Primary data were gathered through semi-structured interviews with the three HR/T&D leaders, along with Line Managers. Interviews lasted between 60 and 90 minutes and were organized around six thematic domains: (a) strategic alignment of T&D with business objectives; (b) training needs analysis processes; (c) program design and implementation; (d) trainers and participant engagement; (e) evaluation and impact; and (f) digital transformation and future vision. Questions were open-ended to encourage narrative accounts and reflection on both successes and challenges.

With participant consent, interviews were documented through detailed note-taking that captured key phrases and, where possible, near-verbatim quotations to preserve participants' voices.

Secondary data included company training reports, safety and sustainability documents, descriptions of awards (e.g., Golden Peacock National Training Award), and publicly available materials on digital and safety learning initiatives. These documents were used to triangulate interview claims, enrich contextual understanding, and extract quantitative indicators such as approximate participation numbers and reported performance improvements.

4.0 Data Analysis

Data were analyzed using Braun and Clarke's six-phase thematic analysis framework. First, interview notes and documents were read repeatedly to build familiarity. Second, initial codes were generated to capture meaningful units related to the research questions, including codes such as "Strategic Integration," "Multi-Level TNA," "Safety Culture," "Automation Anxiety," "ROI Difficulty," and "Digital Learning Vision."

In the third phase, codes were clustered into preliminary themes, which were then reviewed, refined, and clearly defined. Within-case analyses were conducted first to understand each organization's T&D system holistically. These were followed by cross-case comparisons to surface shared practices, contrasting approaches, and public-private differences.

Reflexive notes were used to monitor how the researcher's prior knowledge of HRD and manufacturing might influence interpretation, especially when evaluating claims about impact and effectiveness.

4.1 Trustworthiness and Ethics

Several strategies were used to enhance trustworthiness. Data triangulation combined interviews with documentary evidence to corroborate assertions about training volumes, program types, and reported outcomes. Where feasible, synthesized findings were shared informally with participants for clarification and confirmation. Detailed description of organizational context seeks to help readers assess the transferability of insights to other capital-intensive industries.

Ethical principles included informed consent, confidentiality for sensitive organizational information, voluntary participation, and a commitment to represent participants’ views accurately and respectfully. Organization names were retained because they were already publicly associated with several of the described training initiatives; however, specific individual names and identifiable internal documents were not disclosed.

5.0 Findings of the Qualitative Analysis

Six major themes emerged from the analysis, capturing how training and development are conceptualized, organized, and experienced across the three organizations.

Theme 1: Training as Strategic Enabler and Lived Necessity

Across all three cases, T&D was described as a core strategic lever rather than an administrative overhead. Leaders consistently linked training to organizational priorities such as automation projects, safety and environmental compliance, operational efficiency, and leadership pipeline development. One HR head summarized the perspective succinctly: “Every training initiative is derived from business priorities such as automation, safety excellence, and building leaders for tomorrow.”

At Tata Steel, training priorities were closely tied to the digital transformation roadmap and initiatives such as the Kalinganagar Smart Factory. JSW Steel emphasized Industry 4.0 adoption, digital twins, and the transition toward green steel as drivers of capability building. SAIL aligned its training agenda with Ministry of Steel modernization plans and technology upgrades in large legacy plants.

Beyond strategic language, leaders also spoke about the human stakes of training. Training was seen as a way to help employees navigate uncertainty, develop confidence in new technologies, and maintain dignity in the face of automation-induced change. Several respondents noted that long-tenured workers often carried both deep experiential knowledge and understandable anxiety about digital systems, making empathy and communication essential parts of training design.

Table No. 1: Strategic Focus of T&D and Human Emphasis

Organization	Strategic focus of T&D	Human emphasis
Tata Steel	Digital roadmap, smart factory initiatives, sustainability KPIs	Supporting employees through automation; strengthening a proactive safety culture
JSW Steel	Industry 4.0 adoption, green steel transition, cost competitiveness	Helping workers move into automation-linked roles; engaging younger digital-native staff
SAIL	Modernization aligned with Ministry of Steel plans, technology upgrades	Reskilling an aging workforce; sustaining morale and safety in large legacy plants

Source: Prepared

Theme 2: Multi-level Training Needs Analysis as an Analytical and Relational Process

All three organizations reported using structured, multi-level TNA frameworks, operating at organizational, departmental, and individual levels. At the organizational level, training needs were derived from business plans, safety and sustainability targets, modernization roadmaps, and regulatory requirements. For example, Tata Steel linked training demands to annual business objectives and digital initiatives, whereas JSW Steel used HR analytics to identify emerging skills for Industry 4.0 and green steel projects. SAIL drew on modernization and capacity expansion plans issued by the Ministry of Steel.

At the departmental level, leaders relied on performance dashboards, machine downtime data, quality defect statistics, and safety audit findings to pinpoint operational skill gaps. Departments such as production, maintenance, and safety used this data to justify specific programs, such as training on predictive maintenance, process optimization, or behavior-based safety.

Individual-level needs were captured through performance appraisals, competency mapping exercises, supervisor feedback, on-the-job observations, and, in Tata Steel and JSW Steel, 360-degree feedback for managerial roles. Employees' own development aspirations were also considered, particularly in leadership and career advancement programs.

Leaders described TNA as a negotiation between data and dialogue. One respondent explained that while a "business impact matrix" was used to weigh programs based on strategic impact, cost, urgency, and potential ROI, "we still sit with line managers and ask what is really hurting on the shop floor." This combination aimed to ensure that training was both analytically grounded and experientially relevant.

Theme 3: Comprehensive, Blended, and Inclusive Training Portfolios

The three organizations maintained extensive training portfolios that covered safety, technical and operational skills, digital and automation capabilities, leadership and behavioral competencies, and sustainability awareness. Training reach was substantial: across the firms, tens of thousands of employees and contract workers participated in various programs each year.

Safety training was the most universal and emotionally salient category. Programs addressed PPE compliance, working at height, confined space entry, fire safety, and emergency response drills. Initiatives such as Tata Steel's "Suraksha 365" combined mandatory safety modules with behavior-based safety interventions and reportedly contributed to a 40% reduction in near-miss incidents and progress toward zero-fatality goals.

Technical and operations training included modules on blast furnace operations, process optimization, maintenance strategies, and equipment-specific training delivered in partnership with vendors. Digital and automation training covered SAP, data analytics, IoT applications, and digital twin-based process monitoring, with JSW Steel, for example, reporting an 8% reduction in furnace stoppages after a targeted digital twin program.

Leadership development was addressed through structured academies and targeted programs. Tata Steel's "Aspire" and JSW Steel's "EDGE" initiatives focused on mid-level and next-generation leaders, while SAIL's MTI delivered techno-managerial programs for managers across plants.

Blended delivery modes were common. Leaders estimated that around 60% of programs used hybrid formats, combining classroom instruction with e-learning modules on internal learning management systems. Digital platforms enabled microlearning in regional languages, making training more accessible for shift workers and contract staff with differing educational backgrounds.

Organizations also experimented with inclusive and tailored initiatives. Examples included evening diploma programs for employees seeking formal qualifications, multi-skilling programs for contract workers, VR plant walkthroughs for new recruits, and SAIL's "Reskill 50+" program to support older employees in adapting to new technologies.

Table No. 2: Illustrative Program Categories and Indicative Reach

Program category	Examples (Selected)	Indicative annual reach*
Safety	PPE compliance, emergency drills, behavior-based safety	30,000–35,000 employees across firms
Technical/operations	Blast furnace operations, process optimization, robotics	Several thousand per firm
Digital and Automation	SAP, data analytics, IoT, digital twins	1,800–4,000 per firm
Leadership/ behavioral	Leadership academies, soft skills, succession programs	800–1,000 per firm
Sustainability/Energy	ISO 50001, waste heat recovery, green steel awareness	Hundreds to low thousands per firm.

*Ranges based on interview and document estimates rather than precise counts.

Source: Prepared

Theme 4: Persistent Implementation Challenges and Human Tensions

Despite strong structures and substantial investment, leaders described training implementation as fraught with tensions. A central concern was automation-related skill obsolescence and the associated emotional impact on long-tenured employees. HR heads reported that older workers with deep mechanical expertise sometimes struggled with digital interfaces and felt threatened by younger, more digitally fluent colleagues.

Workforce heterogeneity created additional complexity. Organizations had to address the needs of permanent and contract workers, ageing employees and young graduates, and individuals with varying literacy and digital comfort levels. Designing standardized programs that would remain meaningful across such diversity was challenging, pushing trainers to adopt differentiated content and pacing.

Scheduling and production pressures were another recurrent challenge. Steel plants operate continuously, and taking people off the line for training risked production losses. Companies responded with rotational schedules, shift-wise sessions, short microlearning modules, and integration of training into daily routines, but HR leaders acknowledged that production often took precedence, especially during peak-demand or shutdown periods.

The importance of safety training was significant. Respondents described the psychological burden of knowing that inadequate or poorly absorbed training could lead to serious accidents or fatalities. Ensuring consistent safety training coverage across large, multi-location operations was especially difficult for SAIL, where plant size and multiple labor hierarchies increased the risk of uneven implementation.

Finally, all three organizations struggled with evaluating long-term behavioral change and ROI. While short-term reaction and learning data were relatively easy to collect, linking training to sustained changes in behavior, incident rates, or productivity posed methodological and practical challenges. One leader reflected that the organization “could show improvements after training programs, but many variables were moving together,” making it hard to isolate specific training effects.

Theme 5: Training Effectiveness, Impact, and the Search for Meaningful Metrics

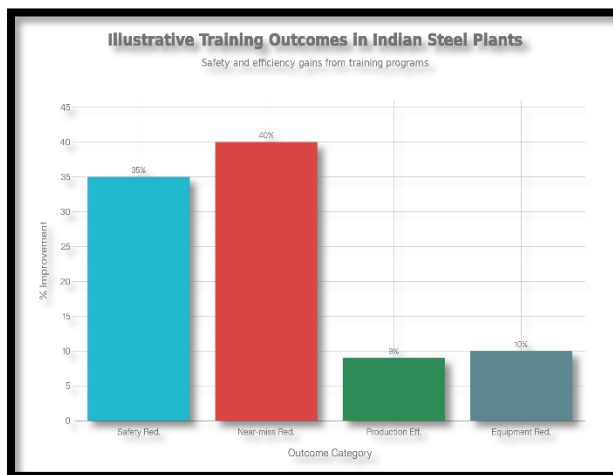
All three organizations reported using the four-level Kirkpatrick framework such as reaction, learning, behavior, and results, to structure their evaluation approaches. Reaction data were gathered through participant feedback forms; learning was assessed through pre- and post-tests; behavior change was evaluated via supervisor observations and follow-up discussions; and results were inferred from metrics such as accident rates, production efficiency, equipment downtime, and defect levels.

Leaders cited several positive outcomes associated with training initiatives. Safety programs were linked with 30 - 40% reductions in reported incidents and, in Tata Steel’s case, a 40% decrease in near-miss events. Operational training and digital skill programs reportedly contributed to 8–10% improvements in production efficiency and 8–12% reductions in equipment failures or furnace stoppages. A JSW Steel “Digital Future” initiative was said to have enabled around 85% of participants to transition successfully into automation-linked roles.

At the same time, respondents acknowledged that ROI calculations were often partial and approximate. Direct financial ROI analyses were conducted for some flagship programs, but comprehensive, standardized frameworks were still evolving. SAIL, in particular, relied more on manual evaluation systems, which limited the speed and granularity of insights.

Across cases, there was a shared aspiration to move towards more integrated, analytics-driven evaluation systems and competency dashboards that would connect training participation, skill levels, performance metrics, and career outcomes.

Figure 1: Illustrative reported business outcomes of training initiatives



Source: Created

Illustrative percentage improvements reported after key training initiatives in Tata Steel, JSW Steel, and SAIL

Theme 6: Digital transformation of learning ecosystems and public–private contrasts

Digitalization emerged as a unifying yet differentiated theme across the three cases. Tata Steel and JSW Steel had made significant progress in building digital learning ecosystems, including AI-enabled learning experience platforms, comprehensive learning management systems, virtual and augmented reality simulations, and mobile learning applications. These tools supported personalized learning paths, microlearning, gamification, and real-time assessments.

SAIL was at an earlier stage but had begun partnering with external platforms such as LinkedIn Learning Hub and had introduced “Work from Other than Workplace” (WoW) policies to allow flexible, self-paced learning. It also developed targeted programs such as “Reskill 50+” to address the needs of older employees facing new technologies.

Leaders across all three organizations articulated ambitious digital learning visions. They described goals such as achieving near-universal digital coverage by around 2027, integrating data on competencies, performance, and career trajectories, and using AI-based tools to recommend individualized learning pathways. At the same time, they recognized that digitalization was not purely technical; the shift had to be managed carefully to avoid excluding employees with lower digital literacy or limited access to personal devices.

Public–private contrasts were visible in pace and flexibility. Tata Steel and JSW Steel could often move more quickly in adopting new technologies and redesigning programs, whereas SAIL worked within more formalized procedures and legacy systems. However, SAIL’s initiatives around community skill development, flexible learning policies, and age-sensitive reskilling highlighted that impactful innovation was possible in public sector settings as well.

5.0 Discussion

The findings of this study suggested that HR and L&D leaders in the Indian steel industry have moved beyond traditional administration to become ‘mediators’ of a profound socio-technical transition. They occupy the critical space between the cold, algorithmic logic of digital modernization roadmaps and the warm, often turbulent realities of human “anxiety and fatigue.” This discussion highlights that the success of industrial modernization is not merely a function of capital expenditure on technology, but of the ability to manage the ‘anxiety of the interface.’

A critical point of analysis is the dual nature of digital learning tools. In one respect, digitalization serves as a democratizing tool, as seen in SAIL’s partnership with the LinkedIn Learning Hub and the "WoW" policy. These platforms allow contract workers in remote plants to access modules in regional languages via mobile devices, breaking down traditional barriers to knowledge. However, these same tools can become a ‘source of exclusion’ for the aging ‘50+’ demographic. The “Reskill 50+” program at SAIL and Tata’s empathetic communication strategies are vital because they seek to validate experiential knowledge. By pairing older workers’ deep mechanical intuition with younger workers’ digital fluency, HR leaders mitigate the institutional inertia that often plagues legacy plants.

The negotiation between data and dialogue identified in the TNA process reflects a deeper political dimension in SHRM. While data-driven matrices (e.g., defect rates, downtime) identify the what of training, the qualitative dialogue with line managers uncovers the why. This socio-technical approach ensures that T&D is not perceived as a top-down mandate but as a collaborative response to operational bottlenecks. Furthermore, the 40% reduction in near-misses at Tata Steel illustrates that when safety training is professionalized and integrated into the daily ‘lived experience’ of the worker, it directly influences the firm’s economic resilience by avoiding the prohibitive costs of industrial catastrophes.

Ultimately, the HR leader acts as a steward of a complex institutional architecture. They must balance the ‘production-training trade-off’ where taking a worker off a continuous production line carries immediate costs against the long-term risk of skill obsolescence. The transition toward AI-based individualized learning paths suggests a future where training is ‘just-in-time’ and work-embedded. However, as this study suggests, the ‘humanization’ of the shop floor remains the ultimate variable. Without addressing the psychosocial impact of automation, digital twins and smart factories will remain empty shells. The Indian steel industry’s journey demonstrates that a ‘future-ready workforce’ is built not just on bits and bytes, but on inclusive strategies that respect the dignity of the human worker within the automated system.

The digital divide between generations requires more than technical instruction; it requires ‘psychosocial support.’ Programs like SAIL’s ‘Reskill 50+’ illustrated that upskilling is most effective when it validates the experiential wisdom of older employees while teaching new digital tools. Furthermore, the persistent KPI conflict identified in Theme 4 suggested that until T&D outcomes are as heavily weighted as production in manager evaluations, the “production-training trade-off” will remain a systemic barrier.

6.0 Conclusion of the Study

The future competitiveness of the Indian steel industry is fundamentally anchored in the development of a ‘future-ready’ workforce through the implementation of humane, inclusive, and technologically integrated Training and Development (T&D) systems. This research confirmed that by elevating T&D from a peripheral administrative function to a central strategic enabler and lived necessity, organizations realize tangible dividends in industrial safety, operational efficiency, and employee morale. Central to this success is the adoption of a multi-level Training Needs Analysis (TNA), which functions as both an analytical and relational process to bridge the gap between shop-floor realities and corporate strategy. As the sector moves toward near-universal digital coverage by 2027, the evidence suggests that the modernization of the backbone of the economy must not treat technology as a replacement for human wisdom but rather as its primary enabler.

However, the transition to Industry 4.0 is not without friction; the study highlights persistent implementation challenges, ranging from automation anxiety and ‘anxiety of the interface’ to the inherent difficulties in establishing meaningful ROI metrics for intangible human capital. To mitigate these tensions, the ‘Big Three’ steel producers must continue to evolve their learning ecosystems into comprehensive, blended, and inclusive portfolios that address the public-private contrast and the diverse needs of a multi-generational workforce. Ultimately, a ‘humane-centric’ approach to digital transformation one that balances data-supported evaluation systems with a deep commitment to worker well-being, will be the deciding factor in whether the Indian steel industry successfully navigates the pressures of global sustainability and technological disruption.

Table No. 3: Summary of Final Themes

Theme	Core Insight
Strategic Integration	T&D is a strategic enabler, not an overhead cost.
Multi-Level TNA	TNA must be both data-driven and relational (manager feedback + analytics).
Inclusive Portfolios	Blended learning must be accessible and age-sensitive.
Human Tensions	Addressing automation anxiety is critical for successful adoption.
Meaningful Metrics	Transitioning from ROI to ‘value-based’ effectiveness measures.
Digital Ecosystems	Leveraging public-private contrasts to accelerate the 2027 digital vision.

Source: Prepared

7.0 Recommendations for the Indian Steel Industry

To successfully navigate the transition to Industry 4.0, it is recommended that HR practitioners and senior management prioritize Contextualized Training Needs Analysis (TNA) by blending quantitative analytics with direct qualitative dialogue from the shop floor. This ensures that training interventions address specific operational pain points rather than generic skill gaps. Furthermore, companies should adopt ‘Inclusive Digitalization strategies,’ such as offering multilingual support within digital learning ecosystems and developing age-sensitive reskilling programs (e.g., Reskill 50+). Such pathways allow veteran workers to adapt to digital interfaces while leveraging their experience to mentor younger staff. To minimize the 30–40% of safety incidents linked to human error, the industry must invest heavily in ‘Immersive Safety Training’ using VR/AR technologies to provide ‘zero-risk’ practice in hazardous, high-heat environments. Finally, organizations should utilize “Institutional Bricolage”

flexible policies that bypass bureaucratic hurdles to adopt the culture of continuous learning and ‘Skill India’ alignment.

8.0 Implications and Limitations of the Study

The theoretical implications of this research extend current HRM literature by providing a model for ‘human-centric’ Strategic Human Resource Management (SHRM) in capital-intensive sectors within emerging economies. By synthesizing global sustainability mandates (SDGs 3, 8, 9, and 12) and ILO labor standards into local training practices, this study demonstrated how heavy industry can ‘humanize’ the technological shift. Practically, the findings underscore the necessity for policy alignment with national digital mandates to ensure that the modernization of the industrial ‘backbone’ does not marginalize legacy workers. However, the study is subject to certain limitations. Being a qualitative study focused specifically on the ‘Big Three’ Indian steel companies, the findings may not be fully generalizable to smaller-scale steel enterprises or different industrial sectors. Additionally, the cross-sectional nature of the data provides a snapshot of current practices; therefore, there is a clear need for future longitudinal research to track how workers and managers negotiate the long-term pressures of digital transformation over time.

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