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Navigating The Smokestack Revolution: A Critical Analysis Of Digital Transformation And The Evolution Of Strategic Human Resource Management At Jindal Steel & Power Limited, India

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Abstract

The Indian steel sector, as part of the country's infrastructural dreams and economic sovereignty, is undergoing a paradigm shift driven by Industry 4.0 principles. This change goes beyond a technological upgrade and will lead to a paradigm shift in human capital strategies. This paper examines a symbiotic and yet discordant association between digital transformation (DT) and human resource management (HRM) practice in this vital industry. The study uses a one- longitudinal case study methodology, which will utilize an in-depth approach to study, focusing
on the example of Jindal Steel and Power Limited (JSPL), a well-known leader in technological adoption. Four research objectives (to map the DT initiatives at JSPL; to analyze the effect on strategic HRM functions; to define the mediating role of organizational culture and leadership in this interaction; and to synthesize a contextual framework of human-technology integration in capital-intensive sectors in the emerging economies) guide the study. Triangulation of data was based on 42 semi-structured interviews, non-participant observation, and internal document and performance metrics analysis between 2019-2024. It has been found that DT is a disruptor and enabler of HRM. Although it has resulted in the establishment of data-centric roles, AI-driven recruitment, and VR-based training, it has also contributed to the creation of a so-called digital skills dichotomy, employee anxiety, and the creation of conflicts between algorithmic management and tacit and experiential knowledge. The results of the study confirm that the success of DT does not depend on the technological sophistication but the active, human-oriented approach of HRM based on transparent change management, ongoing dialogue, and investment in the skills of the soft adaptation alongside the hard technical adaptation. The study has contributed to the emerging body of

literature on HRM 4.0 in emerging economies and provides evidence-based suggestions to practitioners and policymakers, who are aiming at future-proofing the conventional manufacturing industries.

Keywords: Digital Transformation; Strategic Human Resource Management; Industry 4.0; Indian Manufacturing; Technological Change.

1. Introduction

1.1 The Macroeconomic and Strategic Imperative

Indian steel is not just an economic segment, but it is also a strategic asset core to the development story of this nation. Being the second-largest producer of crude steel in the world producing 125 million tonnes in 2023 (World Steel Association, 2024), its development is closely connected to such a flagship government project as the National Infrastructure Pipeline (NIP) and the program Atmanirbhar Bharat (Self-Reliant India). The National Steel Policy 2017 is projected to have a production capacity of 300 million tonnes by the year 2030, which requires unprecedented productivity, quality, and sustainability leaps (Ministry of Steel, 2017). At the same time, the Fourth Industrial Revolution is reshaping the global manufacturing environment through merging cyber-physical systems, the Internet of Things (IoT), and artificial intelligence (AI) (Schwab, 2016). In the case of the Indian steel industry, the adoption of this digital transformation (DT) is no longer a tactical option that allows the company to gain a competitive edge but an essential need to survive and remain relevant in the world.

1.2 The Human Resource Paradox in Technology Change.

Although the technological aspects of Industry 4.0, including smart factories, predictive analytics, and robotics, have been widely written about, the human aspect has not been thoroughly covered, especially in the resource-intensive industries of the past. Implementation of technology is usually regarded as an engineering or IT initiative, and human resource management (HRM) is introduced as an afterthought to control the people side. This is a major flaw in this techno-centric approach. Vial (2019) claims that DT is a holistic process, which reconstructs the organizational value creation, and requires alterations in structures, processes, and, most importantly, skills and mindsets. The main paradox is the development of a dual-pressure system: DT replaces routine, manual tasks on the one hand and sets acute demands on developed digital, cognitive and social skills on the other hand (World Economic Forum, 2023). This puts the HR function in the center
of the change, which is supposed to bridge the growing skills divide, redesign jobs, and an attitude
of continuous learning amidst natural resistance to change.

1.3 Situating the Gap: The Indian Steel Industry.

The Indian situation is a set of distinct complications. It is defined by a multi-generational composition of the workforce, with its experienced veterans who possess the vast experience of tacit knowledge of the traditional steelmaking process, as well as a younger generation that is more at home with digital interfaces. The cultures in organizations tend to be hierarchical, and automation should be viewed with skepticism in unionized settings since it is perceived as a menace to employment security. Additionally, technological change can be extremely rapid relative to the formal technical education curriculum development and cause a mismatch in the supply and demand of talent in the market. The empirical studies that analyse the reconfiguring of the HRM systems in such a setting are very scarce and lacking in detail. The majority of the literature is either too theoretical about HR 4.0 (Strohmeier, 2020) or based on the Global North, as they do not consider the socio-cultural and institutional realities of such a large emerging economy as India.

1.4 Justification of the case: Jindal Steel and Power Limited (JSPL).

This paper takes the form of a critical case study where an emphasis is placed on Jindal Steel and Power Limited (JSPL). JSPL is an extreme or revelatory example (Yin, 2018) because it dedicates itself publicly and

aggressively to digitalization, which is reflected in its Plant 4.0 program under the integrated steel plant in Angul, Odisha (one of the largest and most modern in Asia). The firm has made investments in collaborations with world leaders such as Siemens in digital twins and SAP in enterprise resource planning. The investigation of JSPL will enable exploring the phenomenon of DT-HRM interactions in which this process is most likely to be found and the challenges and strategies are most significant, which can generate productive information fueling the theory and practice.

1.5 Objectives and Hypotheses of the Research.

To fill the specified gap, the following research objectives (ROs) guide the given research:

RO1: To tabulate and organize the portfolio of digital transformation projects implemented in the operational and management sphere of the Angul plant of JSPL.

RO2: To critically examine how these DT initiatives are influencing the design and implementation of the core strategic HRM functions, such as talent acquisition, learning and development, performance management, and employee engagement.

RO3: To define and assess the most important organizational (e.g., leadership, culture), technological, and human drivers of the improvement or impediment of alignment of HRM with digital strategy at JSPL.

RO4: To come up with an integrated, contextually sensitive framework describing the channels of developing digital agility and future-oriented HRM capabilities within the Indian heavy industry sector.

H1: The strength of digital technology adoption (e.g., the density of IoT sensors, the number of AI use cases) in a production unit and the share of the HR budget spent on upskilling/reskilling programmes in a unit are positively and significantly related.

H2: The level of technological investment is not a strong factor that influences the perceived effectiveness of digital transformation at JSPL compared to the quality of change management and leadership communication.

1.6 Structure of the Paper

The article continues with a synthesized literature review, with the formation of the theoretical basis. This is then succeeded by a detailed description of the research methodology. The findings are then displayed in a thematic way and discussed with reference to the literature available, testing the hypotheses put forward. The paper ends with the theoretical contributions, implications of the study in practice, limitations, and future research directions.

2. Literature Review (Synthesized and Critical)

2.1 Theoretical Anchors

Resource-Based View (RBV) and Dynamic Capabilities: According to the RBV (Barney, 1991), a sustained advantage is the result of valuable, rare, inimitable and non-substitutes (VRIN) resources. The capacity to capitalise on technology becomes a major VRIN resource in the DT context. This is further expanded by the dynamic capabilities framework (Teece et al., 1997) which focuses on how an organisation can integrate, build, as well as reconfigure its internal capabilities in the face of fast changing environments. The main tool of developing such human-based dynamic capabilities is HRM.

Technology-Organisation-Environment (TOE) Framework: This model (Tornatzky and Fleischer, 1990) offers a sound framework of analysing the adoption of DT. Technological context covers the technologies that are available including AI and IoT. The organisational environment includes the size of the firm, structure and most importantly HRM slack and preparedness. The environmental environment comprises the level of competition and government policies like Production Linked Incentive (PLI)

scheme on steel. According to this paper, HRM is a central feature of the organisational situation that mediates the absorption of the technological situation.

2.2 Digital transformation in the heavy industry.

The published literature on Industry 4.0 in the manufacturing sector brings up the use of digital twins to simulate processes (Tao et al., 2019) and AI to predictively keep machines up to date. Nevertheless, review by Frank et al. (2019) observes that there is more of technical than managerial studies. The steel industry, in particular, is studied in terms of metallurgical enhancements or energy efficiency through AI, and little to no interest is given to the issue of workforce (Ghosh, 2020).

2.3 Digital Age of HRM (HRM 4.0).

HRM 4.0 is a term referring to the transition to an administrative supporting role, a dramatic change in favor of a strategic and data-driven role (Strohmeier, 2020). Key themes include:

- Talent Management: A shift to digital sourcing, gamified testing, and the focus on the learnability and cognitive flexibility in lieu of fixed qualifications (Cappelli and Keller, 2017).

- Learning & Development: The emergence of micro-learning, learning experience platforms (LXP) and immersive technologies, including virtual reality (VR) as a method of safety and technical training (Baldwin et al., 2021).

- Performance Management: The fall of the annual reviews in favour of ongoing, data-based feedback loops as well as goal-setting platforms like the OKRs (Objectives and Key Results).

- People Analytics: Applying data to anticipate attrition, workforce planning, and sentiment of employees (Marler & Boudreau, 2017).

2.4 The Critical Research Gap

As the streams on DT and HRM 4.0 are developing, they do that in parallel without much intersection. No processual research studies exist that follow the manner in which the introduction of a particular digital tool (e.g., an IoT furnace) initiates a sequence of changes in HR practices (job-description adjustment, new training courses, modified KPIs, etc.). This gap is particularly intensive in the emerging economies, where institutional gaps and cultural peculiarities contribute to the adoption in a different manner. The paper will endeavour to address this gap by offering a fine, process-based examination of a critical Indian sector.

3. Research Methodology

3.1 Design and Philosophical Standpoint.

The research is based on a critical realist philosophy that realises an objective reality but appreciates that our knowledge about it is informed by social and organisational contexts (Bhaskar, 1978). A single longitudinal case study was used, which is an exploratory-descriptive research methodology that is the most suitable to answer how and why questions concerning a modern phenomenon in its natural environment (Yin, 2018).

3.2 Case Setting and Unit of Analysis.

The unit of analysis is the main unit of analysis, which is the digital-transformation-HRM interplay in the Angul plant of JSPL. Embedded units comprise various departments (e.g., blast furnace, hot-rolling mill, HR, IT), as well as levels of employees.

3.3 Data Collection (Triangulation)

Data will be collected by employing a combination of diverse techniques (Triangulation). The period of data collection was between September 2022 and March 2024.

Primary Data:

- Semi-structured interviews: 42 interviews (average time per interview 55 minutes) with the General Managers, Plant Heads, HR Business Partners, IT engineers, shop-floor technicians, and union representatives. Saturation was achieved.

- Non-participant observation: More than 120 hours in the Central Control Room, Maintenance Wing, and the training academy- Digi-Udaan.

Secondary Data: Internal documents (Digital Strategy Blueprint, 2021, HR policy manuals, 202023), annual reports (20192023), anonymised productivity dashboards, and training completion records.

3.4 Data Analysis

Qualitative: The reflexive thematic analysis was used to analyse interview transcripts and field notes (Braun and Clarke, 2022). NVivo14 was used to code the data, transferring semantic codes (e.g., safety training in VR) to latent themes (e.g., simulated experience-based learning as a risk mitigation strategy).

Quantitative: Secondary performance data were washed and analysed in SPSS 29 in order to reinforce qualitative results.

Statistical methods employed: Descriptive statistics (mean, SD), paired-sample t-test (to compare the mean time between failure-MTBF-before/after predictive maintenance AI), Pearson correlation (to investigate the connection between training hours and performance measures).

3.5 Ethical Rigor and Validity

Informed consent was taken with anonymity (with codes like SM -01 referring to senior manager). The construct validity was achieved through three major aspects: triangulation of data and member checking with two key informants. A case-study protocol was used in search of reliability.

4. Results and Discussion

4.1 Digital Environment in JSPL Angul (Meeting RO1) The DT portfolio of JSPL is diversified:

Operational Technology(OT): AI-based computer vision of surface flaws in hot-rolled coils (surface defect protection cuts quality escapes by an estimated 18 percent). Ladle cars that have sensors and are connected to IoT to monitor their positions in real-time and temperature.

Information Technology (IT): Complete full-scale SAP/4HANA built integration business planning. An operator views a real-time process parameter mobile app, called Knight, to log problems.

Human-Technology Interface: Crane and locomotive simulators- Virtual-reality simulation of crane and locomotive functions on campus is now used to train employees and conduct regular refresher courses.

4.2 Implication on Strategic HRM Functions (Examining RO2 and H1)

Talent Acquisition: A shift in human resources has turned the recruitment paradigm to be more grade-centric campus-hiring model into a hybrid approach that embraces hackathons and digital problem-solving scenarios. At the same time, there have also emerged new occupational families, i.e., the ones of Automation Engineer and Data Steward -Production.

Learning and Development (L&D): The programme named Digi-Udaan, in collaboration with Coursera Enterprise, has resulted in a statistically significant correlation ($r = 0.72$, $p < 0.05$) between the number of courses undertaken by departmental staff in data-analytics and the increase in the efficiency of the unit per year, which allows preliminary empirical support of H1. However, in qualitative interviews, a check-box mentality of some workers towards course completion was revealed.

Performance Management: Performance Indicators: Digital KPI has replaced traditional annual appraisals with quarterly project-based reviews (QPRs). An example of how technical and analytical tasks overlap can be a reduction in false alerts caused by a predictive-maintenance algorithm by a 15% margin, which is one of the goals that a maintenance engineer has at this point in time.

Employee Engagement and Culture: The MyJSPL application has an IdeaZone module where ideas on how to improve things should be submitted. However, the observational data revealed a lack of involvement in the shop-floor, hence COVID-telling a digital divide and a felt non-relation between high-tech ideals of management and the realities on the ground.

Table 1: Correlation between Digital Training Intensity and Operational Metrics (Sample Data from 5 Departments)

Department	Avg. Digital Training Hrs/Emp (2023)	% Reduction in Process Variance (2023 vs. 2022)	Employee Sentiment Score (1-5)
Hot Rolling Mill	45	12.5%	3.8
Blast Furnace	38	9.2%	3.2
Maintenance	52	15.1%	4.1
Logistics	28	5.5%	2.9
Quality Control	48	14.0%	3.9
Source: Compiled from JSPL Internal L&D and Production Data (2024).			

4.3 Enablers and Barriers: The Focal Place of Culture and Leadership (Answering RO3 and H2) The results offer a strong argument in favor of H2; socio-cultural barriers are the most significant obstacles.

Key Enabler: The visible leadership advocacy of senior leadership. The immediate involvement of the Managing Director in the establishment of the initiative titled DigiUdaan indicated a strategic value of the initiative.

Critical Barrier: Algorithm Aversion and Tacit Mastery. There was a general tendency that experienced workers to mistrust AI/ML recommendations. One of the superintendents, who had 28 years of experience, narrated as follows: The model claimed that coke rate was best. But the sounding weight of the sinking furnace said otherwise. We hacked into the system and avoided a chilling incident. Data exclusion was in false conspicuity with the parameter of sound (INT-SM- 07). This testament reinforces the incomparable importance of tacit knowledge that can only be acquired through embodiment and the necessity of HR systems that allow collaborative interplay of human knowledge and algorithmic intelligence, as opposed to wholesale replacement.

Change Fatigue: Employees stated that they were overwhelmed by the high rate of new system implementations - SAP, an IoT platform, and a modern mobile application - and thus were being triggered to disengage.

5. Conclusion

5.1 Key Findings Summary

DT at JSPL is a multi-layered process; the development of HRM is following the technological implementation at a slower rate and is still a significant factor determining the final success or failure of the enterprise.

The trends in HR practices are becoming more data-driven and personalized, which, at the same time, generates the threat of a two-tier workforce divided by varying digital literacy levels.

Change management ability of the organization turns out to be the strongest force of successful adoption, hence supporting the centrality of leadership and communicative processes (H2 supported).

Another insight is the discovery of a Tacit-Digital Interface as one of the key areas of possible tension and complement that is occurring; this result supports the idea that future HR systems should be designed to absorb and synthesise experience, knowledge, and data analytics.

5.2 Theoretical Contributions

This research paper builds on the TOE framework by explaining the organisational aspect, namely, how the HRM policies and culture serve as a filter against the technological assimilation. It also adds to the dynamic capabilities perspective by outlining certain micro-practices, including cross- functional digital teams, that create a human-focused adaptive capacity.

5.3 Practical Implications

Regarding JSPL/ Industry: Institute Digital Dialogue Forums, the operators and data scientists make common sense out of the results of algorithms. Digital Mentor should be formalized as a role, and change-management metrics of leadership scorecards should be included to make leaders accountable and continuously improve.

To the HR professionals, it is a must that the expertise in people analytics be developed, and that it works closely with CIOs when the initial stages are being set in place in technological projects. Digital mentorship and knowledge sharing should be developed as the priority paths of career development, which would lead to a culture of lifelong learning.

Industry-academia partnerships have been recommended to be given continued funding to policymakers, so that they will jointly design the curricula in emergent sectors like artificial intelligence to increase manufacturing capacities. At the same time, it is necessary to invest in digital literacy programs to retrain the old manufacturing workforce and bridge the skill divide.

5.4 Limitations and Future Research.

The single-case design has limitations to generalisability, but it offers rich depth. Future studies may consider comparative research among various Indian steel plants or study the impact of the trade union on the DT-HRM nexus. Career progression would provide a priceless understanding
of the potential consequences of the results of longitudinal tracking of career pathways post-DT.

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