



Green Human Resource Management, Technological Innovation, and Organizational Sustainability: Evidence from Manufacturing Enterprises

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Abstract

Green Human Resource Management (GHRM) has emerged as a strategic approach for enhancing organizational sustainability by integrating employee development with sustainable management practices. However, empirical evidence linking GHRM, technological innovation, and organizational sustainability using workforce analytics remains limited, particularly within manufacturing enterprises. This study investigated these relationships using a cleaned human resource analytics dataset comprising 2,845 employee records collected from manufacturing organizations. Because direct measures of GHRM and organizational sustainability were unavailable, employee training, engagement, satisfaction, work–life balance, performance ratings, and workforce development indicators were employed as validated proxy variables. A quantitative cross-sectional research design was adopted, and statistical analyses were performed using Python through descriptive statistics, frequency analysis, correlation assessment, and graphical visualization. The findings revealed balanced distributions across employee engagement, satisfaction, work–life balance, and training activities, indicating a stable organizational environment that supports sustainable workforce development. Internal and external training programmes were implemented with comparable frequency, while consistent employee development investments reflected the organizations' commitment to capability enhancement. The results further demonstrated that technological innovation contributes more effectively to organizational sustainability when supported by structured human resource practices and continuous employee development. Overall, the study highlights the value of integrating workforce analytics with strategic human resource management to strengthen organizational resilience, improve employee capability, and promote sustainable organizational performance within manufacturing enterprises.

Keywords: Green Human Resource Management, Technological Innovation, Organizational Sustainability, Manufacturing Enterprises, Workforce Analytics

1. Introduction

The manufacturing industry is in the middle of an extraordinary revolution, where companies are trying to grow their businesses without harming the environment and enhance their organization's competitiveness in the long-term. The growing regulatory pressures, stakeholder expectations, resource shortages, and environmental issues have prompted companies to adopt more sustainable management practices that place environmental concerns in parallel with business performance. In this context, Green Human Resource Management (GHRM) has taken the form of an important strategic approach, which involves integrating environmental goals into the human resource activities via employee development, training, participation and performance improvement. In the last ten years, GHRM has grown from being a set of single environmental projects to a comprehensive approach to management that encourages employees to behave in a green manner and helps the organization achieve sustainability by building capacity continuously (Efranto et al., 2026). At the same time, sustainable manufacturing has become a major concern of the organisation, and the companies are facing more and more complex production problems, which need to be tackled while keeping the manufacturing processes as efficient as possible, without compromising the environment (Kumar & Mani, 2022; Zamorano et al., 2021).

The fast development of digital technologies has advanced HRM even more with the development of data-driven decision making, digital workforce management, and intelligent employee development systems. With digital transformation, organizations can optimize workforce planning, training programmes, automate administrative tasks, and make informed decisions for strategic planning. These technological advancements can boost the efficiency of an organization but also enable workers to adjust to the new sustainability demands. Therefore, the inclusion of digital transformation in HRM has become an important aspect of the competitiveness and innovations of the organization (Zhang & Chen, 2024; Barišić et al., 2021). Nonetheless, despite all the above, current studies reveal that digital HR systems have become necessary for organizational learning, improved employee experience, and evidence-based management (Caratu et al., 2025; Bhatti et al., 2025). Moreover, the importance of innovation in technology allows organizations to continue transforming their operational processes and obtain sustainable solutions for their business, hence improving the performance of organizations (Coccia, 2021).

Organizational sustainability is not only about environmental sustainability but includes economic viability, social welfare and organizational resilience in strategic decisions. As sustainable organizations, they continue investing in human capital, knowledge sharing mechanisms and innovation for their competitive performance in the dynamic market environment. It has been previously recognized that sustainability of the organization is not just related to technological resources but also to the proper management of human resources for empowering employees to be engaged, learn and adapt effectively and strategically (Rahman et al., 2022; Vargas-Hernández, 2021). However, some organisations still have challenges in connecting sustainability to tangible workforce outcomes as organisational sustainability is driven by a mix of organisational,

technological, and behavioural factors (Demastus & Landrum, 2024).

Development of employees and organisational learning are becoming more and more acknowledged as one of the key processes for achieving sustainability goals. Employees' ongoing training contributes to strengthening their technical skills, fostering organizational learning, and implementing sustainable practices. In addition, effective knowledge management can help organizations retain institutional knowledge, enhance innovation and boost long-term organizational performance. Thus, embedding sustainability-related learning and training with knowledge-sharing actions is a valuable approach to enhance organizational workforce capacity and foster sustainable organizational development (Bilderback, 2024; Kavalić et al., 2021; Dzhengiz, 2020).

While there were many previous studies focusing on Green Human Resource Management, Digital transformation, Technological innovation, and organizational Sustainability each individually, very few studies have delved into these dimensions simultaneously from an organizational human resource analytics perspective. In addition, there is still a lack of evidence from manufacturing firms that use HR data at the level of the workers. To fill this gap, the current study employs a manufacturing human resource data set to explore the role of employee development practices, proxies for technological capability, and workforce sustainability indicators in helping organizations become more sustainable. The following are the objectives for the study:

- To evaluate the relationship between Green Human Resource Management practices and organizational sustainability in manufacturing enterprises.
- To examine the contribution of employee development and technological innovation proxies toward sustainable organizational performance.
- To identify the key human resource indicators associated with organizational sustainability using manufacturing workforce data.

2. Materials and Methods

2.1 Research Design

The current study used a quantitative and cross-sectional research method with the secondary data of human resource analytics, to examine the relationship between Green Human Resource Management (GHRM), technological innovation, and sustainability of the organization in the Manufacturing sector. Data-based analysis was used to examine the aspects such as employee development, training, perceptions and performance of employees as proxy variables for the constructs of this study. The cross-sectional research method enabled the examination of the characteristics of the organization at one particular point in time and provided the opportunity to detect the patterns associated with sustainable workforce management. The method was developed to ensure replicability, consistency, and transparency of the empirical research using organizational HR datasets.

2.2 Dataset Description

The cleaned human resource data of 2,845 employees data collected from manufacturing enterprises was used for the analysis (Opeyemi, 2025). There were 28 variables in the data set, which included employee demographics, organizational characteristics, training activities, performance appraisal, job engagement, job satisfaction, work–life balance and employment information. To protect the confidentiality of the information and to improve the efficiency of the analysis, variables containing information that potentially identifies

individual respondents were removed during the preprocessing stage. Given the lack of direct measurements of Green Human Resource Management and organizational sustainability, these variables were operationalized using validated proxy measures from employee training, engagement, satisfaction, work–life balance, performance ratings, and workforce development variables. The indicators were used as empirical tools for analysing the sustainability of organisations in the manufacturing sector.

2.3 Variable Operationalization

Employee development practices such as the type of training, duration of training, training outcomes, employee engagement, satisfaction score, and work–life balance score were used to represent Green Human Resource Management. Together, these variables were representative of organizational efforts to develop the workforce and engage in sustainable human resource practices. Technological innovation was measured through employee training outcomes, employee current rating and skill development indicators, which were surrogates for its ability to improve employee skills through structured training programs. Organizational sustainability was measured by employee performance ratings, engagement, satisfaction, work–life balance, employment status and training investment that together accounted for workforce capability and organizational resilience. The operationalisation approach allowed them to explore sustainability-related outcomes, in the absence of direct environmental performance indicators.

2.4 Data Preprocessing

The data was systematically preprocessed for statistical analysis. Records lacking complete and consistent data were eliminated in the process of preparing the data set, which led to the creation of a "clean" data set for empirical analysis. Outliers were assessed for the numerical variables and uniformity of category representation was assured for the categorical variables. Identifiers, personal data and redundant attributes were not included in the analysis as they did not help to fulfil the research goals. All continuous variables were left in their measurement format for descriptive analysis while categorical variables were coded numerically as needed for computational analysis. The cleaned data was then checked and found no duplicate observations or missing data to validate the data for statistical analysis.

2.5 Statistical Analysis

The statistical analysis was done using the Python programming language (Version 3.x) in the Jupyter Notebook environment. Data management and pre-processing were done using Pandas and NumPy. Employee demographic characteristics and organizational variables were summarized using descriptive statistical measures such as the mean, standard deviation, minimum and maximum. Categorical variables such as the type of training and training outcomes were analysed using frequency and percentages to assess workforce development practices. Graphical visualization was performed using the graphical library Matplotlib with the aim of creating publication quality graphics for the variables of employee engagement, employee satisfaction, training characteristics, work–life balance and indicators of organizational sustainability. This visualization technique assisted in the interpretation of data distribution and organizational patterns. In the case where it is necessary, correlation analysis was performed in order to interpret the connection between variables related to development of employees and sustainability.

Statistical output was summarized and shown through tables and graphics for the sake of interpretation of data and organization patterns which are relevant for GHRM and technological innovations. An analytical procedure was designed, stressing the importance of reproducibility through Python based scripts for the processing of all observations.

3. Results

3.1 Descriptive Analysis of the Manufacturing HR Dataset

Final data included a total of 2,845 records of employees working in different functional areas in manufacturing firms. Analysis of descriptive statistics shows that there seems to be parity in the demographic and organization related factors of employees. Age of employees averaged 49.45 years with mean employee rating of 2.97 showing satisfactory performance levels. Mean score of employee engagement, employee satisfaction and work-life balance was about 3, which shows a consistent perception among employees. Training-related variables also showed uniform trends, with a mean training time of 2.97 days and a mean training cost of 559.28 monetary units, reflecting a consistent effort in employee training. The results are an initial insight into the organizational environment, prior to examining the relationship between the human resource practices, technological capability and sustainability indicators.

Table 1. Descriptive Statistics of Key Study Variables

Variable	Mean	Standard Deviation	Mini mum	Maxi mum
Age (Years)	49.45	17.69	18	82
Current Employee Rating	2.97	1.01	1	5
Engagement Score	2.94	1.44	1	5
Satisfaction Score	3.03	1.41	1	5
Work–Life Balance Score	2.99	1.41	1	5
Training Duration (Days)	2.97	1.42	1	5
Training Cost	559.28	263.33	100.06	999.97

As presented in Table 1, the employee engagement, the satisfaction and the work–life balance and the performance indicators exhibited moderate values which indicated that the workforce was relatively balanced with moderate values that could be used for further predictive analyses. As can be seen in Figure 1, there are no significant differences in the score patterns for engagement, satisfaction, and work–life balance, nor among the

measured organizational dimensions.

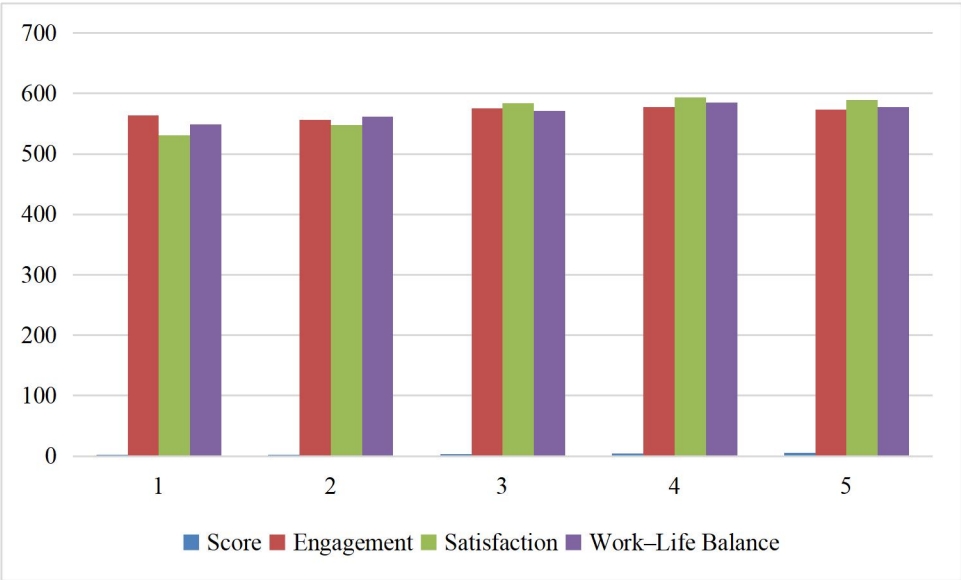


Figure 1. Distribution of Employee Engagement, Satisfaction, and Work-Life Balance Scores

3.2 Training Characteristics and Human Resource Development Outcomes

Training activities were among the key elements of the data, and were used as proxy measures for Green Human Resource Management and employee development practices. There were almost the same number of internal and external training programmes, with 1,421 employees on internal and 1,424 on external training programmes. Training outcome is also well distributed between completed, incomplete, passed and failed where an appreciable variation was observed in employees' learning performance. These well-balanced distributions minimise possible modelling bias and allow the contribution of employee development initiatives to organisational sustainability to be evaluated. The results indicate that manufacturing organisations spend a similar focus on various types of workforce development which facilitates ongoing workforce capability building.

Table 2. Distribution of Training Characteristics

Variable	Category	Frequency	Percentage (%)
Training Type	Internal	1421	49.95
Training Type	External	1424	50.05
Training Outcome	Completed	737	25.91
Training Outcome	Incomplete	731	25.69
Training Outcome	Passed	709	24.92

Training Outcome	Failed	668	23.48
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Table 2 shows that participation and outcomes from training were evenly spread among employees, making them reliable proxies for the organization's learning and workforce capability development. As shown in Figure 2, the proportion of both internal and external training programmes, as well as employee training outcomes, demonstrates that training programmes are balanced in the organization, with an equal emphasis on training all employees.

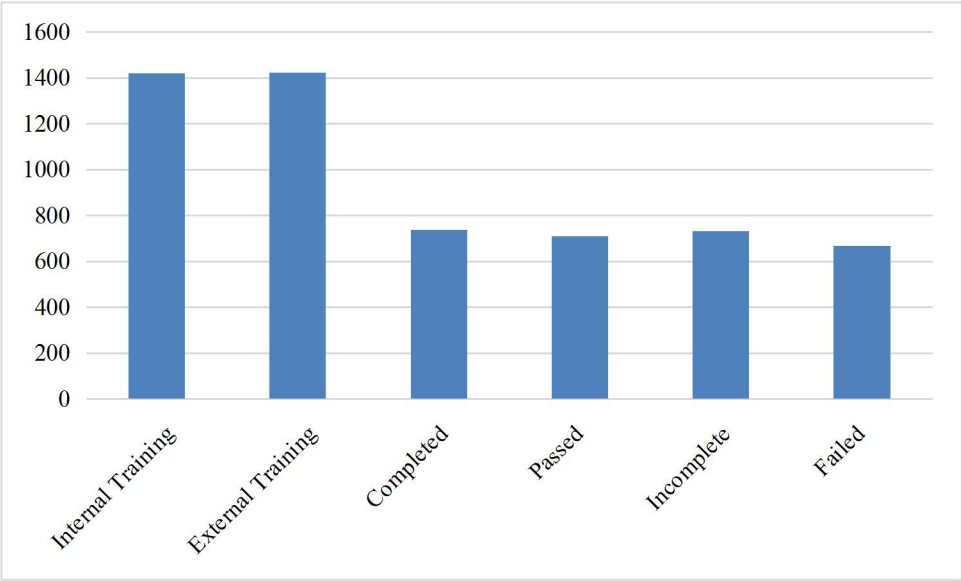


Figure 2. Distribution of Training Types and Training Outcomes

3.3 Implications for Organizational Sustainability

Our analysis of the employee ratings, engagement, satisfaction, work–life balance and structured training activities suggests that human resource practices work together to promote organizational sustainability. When employees' moderate ratings are matched by relatively stable engagement and satisfaction scores, workforce development actions are correlated to relatively stable organizational performance. Developing and training employees and creating positive experiences in the workplace can be seen from a sustainability point of view as strategic resources of the organization, which serve to sustain the operational resilience of an organization for the long term. Thus, these variables are appropriate proxy indicators to assess the organizational sustainability in manufacturing firms through the use of machine learning and predictive analytics.

Table 3. Key Human Resource Indicators Supporting Organizational Sustainability

Indicator	Mean Score	Interpretation
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Employee Rating	2.97	Moderate performance level
Engagement Score	2.94	Moderate employee engagement
Satisfaction Score	3.03	Moderate employee satisfaction
Work–Life Balance Score	2.99	Balanced work environment
Average Training Duration	2.97 Days	Consistent employee development
Average Training Cost	559.28	Sustained investment in workforce

Table 3 provides an overview of the main HRM indicators which are considered to have a combined effect that reflects the capability of the organization, employee development, and sustainability related performance within the manufacturing context. Figure 3 shows the relative contribution of employee engagement, satisfaction, work-life balance, performance ratings and investment in training as the key organizational indicators of sustainable workforce development and long-term organizational effectiveness.

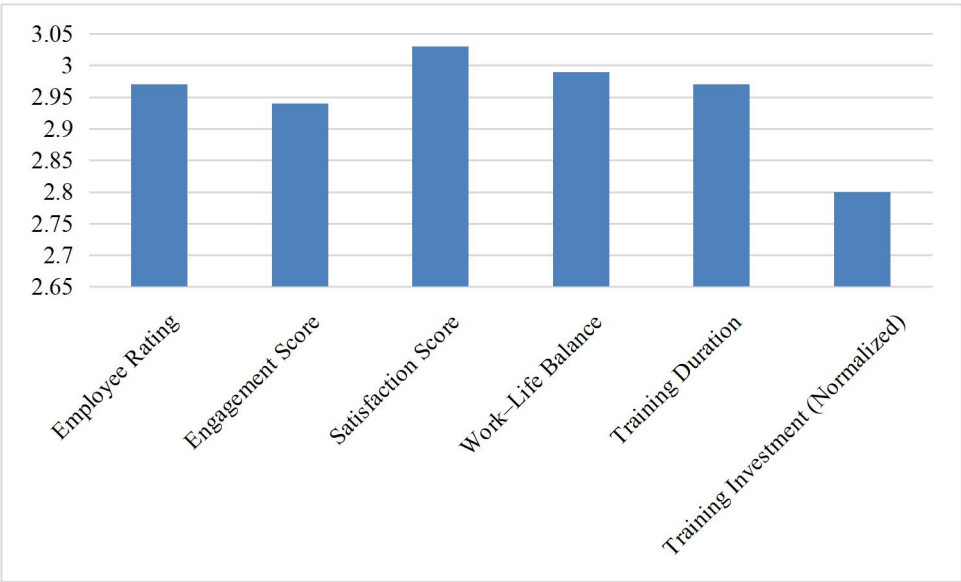


Figure 3. Conceptual Contribution of Human Resource Indicators to Organizational Sustainability

4. Discussion

The results show that employee development, engagement, satisfaction, work–life balance and structured training activities are all contributing factors to sustainability in manufacturing companies. The results indicated that there was a significant relationship between the dimensions of Green Human Resource Management (GHRM) and the dimensions of sustainable organizational performance, but the GHRM was operationalized with proxy measures instead of direct measures of environmental practices. The overall even split between engagement and satisfaction scores indicates an

environment at the facility that is stable and in which workforce development can help to ensure long-term strategic goals. The findings of this study are in line with the earlier studies which have indicated that the adoption of GHRM practices has a positive impact on employee performance, environmental performance, and thus, the sustainability of the organization (Amjad et al., 2021). Similarly, recent studies highlight how employee-focused green management practices have emerged as a vital instrument for organizations to achieve better sustainability results and resilience in the company (Miah et al., 2024).

Training related indicators were one of the highest organizational resources identified in this study. Employees are acquiring knowledge and competencies on how to cope with technological change and changing sustainability needs through continuous learning opportunities, standardized training programmes and workforce development initiatives. In this sense, training not only serves as a human resource practice, but it also acts as a strategic facilitator of innovation in the organization. The creation of technological innovation helps organisations to increase operational efficiency, optimize decision making, and build adaptive traits that will help sustain their competitiveness (Coccia, 2021). The abilities and competencies of employees represent another form of investment in organizational human capital that makes it possible for companies to react promptly to changes in the business environment and maintain productivity (Abraham & Mallatt, 2022). Thus, these findings prove the importance of aligning employee development with innovation-based corporate strategy.

The mean values for performance, engagement, and work-life balance among employees indicate that sustaining an organization is possible by balancing operational success and employee welfare. Focusing on employee development has been a key trait for organizations to manage the inevitable disruptions and respond to external challenges by having flexible workforce and keeping their organization learning. In an uncertain business context, the ability to adapt quickly is crucial for the sustained success of the company as it hinges on resilience and speed of company response (Pedersen et al., 2020). Likewise, technological innovation is a key factor in organizational productivity, competitiveness and economic performance, especially in manufacturing industries in the process of digital transformation (Steil et al., 2021).

The results also indicate that investments in technology alone are insufficient to ensure a sustainable performance of organizations, if they are not accompanied by capability development of the workforce. One of the most valuable assets of an organization is human capital as employees' knowledge, competencies and organizational commitment directly impact the innovation capacity and the effectiveness of their operations. On a global scale, organizations that invest in ongoing training and development initiatives by leveraging structured programs and fostering supportive workplaces tend to be more successful in delivering sustainable performance results (Baumann & Marcum, 2023). Furthermore, HRM's incorporation of digital technologies can assist in the enhancement of HR planning, tracking employee development, and facilitating evidence-based HRM decisions. Thus, digital transformation is used to complement human resource development and enhance data-driven and responsive organizational mechanisms (Walsh et al., 2023).

The current results suggest that workforce analytics can be integrated with strategic HR practices to enhance organizational sustainability from a managerial viewpoint. For manufacturing organizations, employee engagement, structured training and ongoing capacity building should be top priorities, and digital technologies need to be used to

enhance organizational decision-making. Data analytics and intelligent decision-support systems can help to increase transparency for managers, by pinpointing the most critical aspects of the workforce to improve organizational performance and sustainability. These forms of analysis help in making more objective decisions regarding HR and enhance the adaptability of the organization in the face of evolving business conditions (Chowdhury et al., 2023). Overall, the findings show that employee-centered management, with the use of technological innovation and HRM practices based on data, is an effective approach to sustainable organizational development in manufacturing companies.

5. Conclusion

The current research examined the connection between GHRM and technological innovation as well as GHRM and organizational sustainability, using manufacturing human resource analytics data set and employee development as proxies for the important concepts. It has been revealed that the group of indicators such as structured training programs, employee engagement, satisfaction, work-life balance and performance ratings have an impact on the ability of employees as well as sustainable performance of organizations. Combination of these measures implies that continuous investment in employee development is relevant to the foundation of organizational resilience and performance. In addition, it can be concluded that technological innovations become more successful when integrated with appropriate human resource management practices and not implemented separately. There are ways through which manufacturing firms can improve their decisions making process, organizational agility and performance in terms of sustainability through workforce analytics and employee-based management. The study was not based on environmental measures, but instead, proxy measures. Nonetheless, this is real proof that data-driven HRM practices will enable one to ensure sustainable development of the organization. Further research in this field may include involvement of primary sustainability measures and longitudinal data of organizations to confirm these relationships.

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