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Optimizing Human Resource Performance in Building Construction through Technology-Enhanced Strategy Development

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Abstract. Construction projects involve complex processes requiring effective management and skilled human resources to ensure successful outcomes. This study analyzes key factors influencing human resource (HR) performance in building construction, identifying ability, working conditions, organizational structure, motivation, discipline, and compensation as critical determinants. A structured questionnaire using a 5-point Likert scale was employed as the data collection instrument, distributed to 130 contractors, with 114 valid responses collected in Semarang, Indonesia. Data analysis using SPSS v.27 confirmed that all indicators are valid, reliable, and positively perceived, with "ability" receiving the highest rating (mean = 4.8). Practical implications for project stakeholders include the need to implement targeted training, performance-based incentives, leadership development, and optimized recruitment. Technological integration is also emphasized for enhancing communication and decision-making efficiency. The findings underscore the importance of a comprehensive HR strategy that addresses both individual competencies and systemic organizational support, advancing sustainable engineering practices and improving project productivity in dynamic construction environments.

Keywords: Development strategy, human resources, construction technology, project efficiency, performance strategy

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1. Introduction

The study identifies three main focus areas in achieving construction project success: infrastructure and public projects, risk and knowledge management, and contractor and procurement management. The findings highlight the critical role of digital innovation, modular construction, and data-driven technologies in improving project performance and stakeholder satisfaction amid the increasing complexity of the construction industr [1]. This study highlights the vital role of Industry 4.0 digitalization in enhancing sustainability and project performance in construction, identifying sustainability as the most influential factor. The findings offer strategic insights for leveraging digital technologies to improve managerial efficiency and support long-term project success[1]. Several studies have underscored the importance of employee well-being, noting that income, education, and

health significantly enhance performance[2]. This study highlights the growing importance of non-financial KPIs—such as stakeholder, safety, environmental, and technology performance—in comprehensively evaluating construction project success. Using both quantitative and qualitative methods, it offers a holistic perspective and calls for more adaptive, data-driven indicators to support sustainable project management[3]. Despite this, existing HR strategies remain fragmented and reactive, often lacking integration with long-term sustainability objectives.

However, current HR strategies in construction largely overlook the integration of sustainability principles into workforce planning and development. Empirical studies confirm that organizational and HR factors significantly impact performance. Incentives, competence, and work environment simultaneously influence employee loyalty in PT. Brantas Abipraya's Sidan Dam Project [4]. Structural Equation Modeling indicates that incentives do not directly influence performance but strongly affect job satisfaction [5]. An empirical investigation in the Egyptian construction sector identified 40 key factors influencing project performance, integrating internal and external dimensions with sustainability pillars—economic, social, and environmental. Project management, stakeholder involvement, and human capital emerged as the most critical drivers of success, offering a comprehensive framework for performance evaluation and strategic improvement[6].

. Strategies to manage workforce diversity were found to enhance productivity and support sustainable work environments [7]. An earned value-based value engineering strategy is presented as a novel and effective approach to improving construction project management performance, with engineering economics identified as the most influential factor. The study recommends the development of conceptual models to support decision-making and enhance managerial efficiency in project execution[8]. Despite these findings, a critical gap remains: most HR development strategies in construction fail to systematically align with sustainability principles. This research addresses that gap by proposing a comprehensive and sustainable HR development framework tailored to the construction industry, emphasizing long-term workforce resilience, technological adaptability, and organizational alignment with sustainability goals.

2. Methods

2.1 Theoretical Framework

The methodology of this research primarily adopts a quantitative approach to systematically analyze factors influencing human resource (HR) performance in construction projects. A sample of 114 respondents was determined using Slovin's formula to ensure statistical representativeness while considering practical constraints. This sample size also reached saturation, as additional data did not provide new significant insights. Data were collected through structured surveys, producing numerical data suitable for rigorous statistical analysis using SPSS. Ethical approval was obtained prior to data collection, with informed consent secured from all participants to maintain research integrity and confidentiality. The quantitative approach enables objective measurement, hypothesis testing, and generalization of findings within the studied population.

To analyze the quantitative data, the Statistical Package for the Social Sciences (SPSS) version 27 was utilized. SPSS was selected due to its comprehensive suite of statistical tools, which includes tests for validity and reliability, descriptive statistics to summarize respondent characteristics and variables, and inferential statistics to examine relationships and test hypotheses. Employing SPSS ensures that the data analysis process is rigorous, replicable, and capable of producing reliable and valid findings, thus strengthening the study's empirical evidence on HR performance factors in construction.

2.2 Study Area

This study was conducted in Central Java to collect data on human resource performance development in building construction projects with varying levels of complexity, including simple, non-simple, and specialized buildings. Data were gathered using questionnaires and literature review. Respondents

comprised owners, consultants, and contractors directly involved in the execution of the construction projects.

2.3 Research Data

A review of studies from 2016–2023 reveals a strong link between digital technology and HR practices, stressing the need for organization-wide understanding to boost competitiveness, despite some methodological limitations [9]. The study highlights that BIM staff attributes—such as team size, expertise, training, and experience—significantly impact construction project performance. These effects are mediated by Task-Technology Fit (TTF) and moderated by technology acceptance factors under UTAUT, emphasizing the strategic importance of skilled BIM personnel and supportive organizational environments in enhancing project outcomes [10]. This study highlights that work-to-family conflict negatively impacts project success by increasing job burnout, while affective commitment plays a buffering role in this relationship. These findings underscore the importance of managing work–family balance and fostering employees' emotional commitment to enhance project performance in the construction industry [11]. Building on this, evidence from the Egyptian construction sector further emphasizes the role of human resource management in shaping project outcomes. A study of construction professionals in Egypt found that several HRM factors significantly influence project performance. Eight HRM factors, including motivation, leadership, training, and communication, were correlated with cost performance, while four factors—motivation, retention, job description, and communication—impacted time performance. Although HRM influences project outcomes, the relationship is not dominant[12].

2.4 Data Analysis

The research was conducted on building construction projects located in the city of Semarang, with respondents consisting of contractors directly involved in project execution, as detailed in Table 2. Primary data were collected through questionnaires containing specific questions related to variables influencing human resource (HR) performance. The questionnaire responses were based on binary perceptions—either "influential" or "not influential"—and further evaluated using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). In addition, in-depth interviews were conducted to gather comprehensive insights through face-to-face discussions with key informants who possess thorough knowledge of the factors affecting HR performance. A structured interview guide was used as the instrument to ensure consistency in the information collected. The sample size was determined using Slovin's formula, which is commonly used to calculate the required number of respondents based on the total population and an acceptable margin of error:

$$n = \frac{N}{1+N(e)^2} \tag{1}$$

Where, n represents the calculated sample size, N denotes the total population, and e refers to the allowable error tolerance in sampling.

$$\text{R: } \frac{n\sum XY - \sum X \sum Y}{\sqrt{\left\{n\sum X^2 - (\sum X)^2\right\}\left\{nY^2 - (\sum Y)^2\right\}}} \tag{2}$$

The analysis included validity and reliability testing. An item is considered valid if the correlation coefficient between the item score and the total score reaches or exceeds 0.3; otherwise, it is deemed invalid.

Therefore, ensuring a strong questionnaire return rate should be a primary focus in any survey-based study. Reliability is derived from the term reliability, which refers to consistency in measurement [13] [5]. According to [14][5], reliability refers to the extent to which a research instrument can be trusted as a data collection tool and its ability to reveal information that accurately reflects real conditions in the field. A high response rate is crucial, as it helps minimize bias and

enhances the validity of research findings[15]. Therefore, achieving a good questionnaire return rate should be a primary focus in any survey-based research.

The research was structured into several stages to facilitate the achievement of objectives in line with the study's aims. These stages included preparation, data collection, and preliminary analysis of factors affecting performance, human resource (HR) variables, and strategies for HR performance development. The steps undertaken in this study are as follows:

a. Preparation stage, involving problem identification and formulation of research objectives.
b. Defining the target respondents, specifically those involved in the construction sector.
c. Primary data collection, conducted through the distribution of questionnaires and focus group discussions (FGDs)/interviews.
d. Secondary data collection, gathered from literature reviews and documentation provided by the participating contractors.
e. Data processing, including the calculation of means for questionnaire responses and coding for FGD/interview transcripts.
f. Preliminary analysis, covering respondent eligibility, questionnaire validity and reliability, as well as the response rate—used to calculate the average (mean) of each variable.
g. Validity and reliability testing, performed using SPSS software.

3. Results and Discussion

The questionnaire will be distributed based on the data presented below, involving a total of 114 respondents.

Table 1. Respondent Data

No	Building Type	Category	Quantity	Last Update	Total Sample
1	Simple Buildings	Education (Junior & Senior HS)	131	21 Feb 2024	12
		Residential	563,937	21 Feb 2024	32
2	Non-Simple Buildings	Lodging (3–5 Star Hotels)	53	26 June 2024	9
		University Campus	58	14 March 2024	9
		Mall/Shopping Centers	41	July 2024	9
3	Special Buildings	Healthcare (Hospitals)	43	19 July 2024	9
		Industrial	4,594	1 August 2023	21
		Sports Facilities	386	12 Dec 2024	13
	Total		**569,243**		**114**

After the questionnaires are distributed, the data will be analyzed using SPSS software to assess the validity and reliability of the instrument. In any questionnaire-based research, the response rate critically influences the validity of study conclusions, with a non-response rate exceeding 20% potentially biasing results. In this study, out of 130 distributed questionnaires, 112 were returned, yielding a high response rate of 93%, which surpasses the generally accepted threshold of 90% for robust data quality.

Analysis of human resource (HR) performance indicators confirmed the validity and reliability of the measurement instruments. Corrected item-total correlations exceeded 0.3, and Cronbach's Alpha values surpassed 0.9, indicating excellent internal consistency. The mean scores of all indicators, ranging from 3.75 to 4.80 on a Likert scale where 3 denotes neutrality, reflect overwhelmingly positive participant responses. Notably, factors such as ability (mean = 4.80), motivation, and working conditions scored highest, underscoring their critical roles in enhancing HR performance. High ability scores likely indicate that skilled personnel are recognized as essential drivers of project success, directly affecting construction quality, efficiency, and safety—key pillars of sustainable construction. Similarly, optimal working conditions foster productivity and well-being, reducing delays and

occupational hazards, thereby contributing to long-term project viability.

Conversely, factors with relatively lower—but still positive—scores such as environment and occupational health and safety highlight areas requiring continuous improvement to meet sustainability standards. The interplay of these factors demonstrates that holistic HR management, encompassing competence, motivation, and supportive environments, is pivotal in achieving sustainable outcomes in construction projects. Thus, this study's findings not only validate the selected HR performance indicators but also emphasize their practical impact on fostering sustainable construction by promoting efficient resource utilization, workforce stability, and adherence to safety and environmental protocols. Taken together, these findings underscore the critical role of human resource management and digital transformation in enabling the construction industry to meet evolving sustainability standards. As Construction 4.0 redefines workforce structures and operational strategies, it becomes increasingly important to align these advancements with broader global objectives, particularly the Sustainable Development Goals.

Construction 4.0 is fundamentally reshaping workforce dynamics, organizational models, and digital inclusion across the global construction sector. Key themes include workforce digitalization, the integration of women and younger generations, skill development, supply chain optimization, and the emergence of new governance models. While this transformation promises significant gains in productivity, it also brings social and ethical challenges. Therefore, inclusive policies are essential to ensure equitable outcomes across diverse regions and demographic groups[16].

The construction industry plays a pivotal role in advancing the 2030 Sustainable Development Goals, particularly through sustainable infrastructure development and cross-sector collaboration. Despite its environmental impact, the sector holds significant potential to drive social, economic, and environmental progress—provided that business strategies are aligned with global sustainability objectives[17].

Table 2. Results of Human Resources Performance Analysis

No	Variable	Validity (Corrected Item-Total Correlation)	Validity Status	Reliability (Cronbach's Alpha)	Mean	Variable Suitability
1	Ability	0.390	Valid	0.929	4.80	Suitable
2	Working Conditions	0.635	Valid	0.926	4.46	Suitable
3	Organization	0.600	Valid	0.927	4.25	Suitable
4	Luck	0.429	Valid	0.932	3.75	Suitable
5	Initiative	0.476	Valid	0.928	4.54	Suitable
6	Work Methods	0.570	Valid	0.927	4.72	Suitable
7	Project Planning	0.571	Valid	0.927	4.75	Suitable
8	Management	0.614	Valid	0.926	4.71	Suitable
9	Communication	0.604	Valid	0.926	4.65	Suitable
10	Work Ethic	0.684	Valid	0.925	4.63	Suitable
11	Cash Flow	0.610	Valid	0.926	4.48	Suitable
12	Tools and Materials	0.627	Valid	0.926	4.55	Suitable
13	Mobilization	0.625	Valid	0.926	4.33	Suitable
14	Location	0.579	Valid	0.927	4.16	Suitable
15	Weather	0.687	Valid	0.925	4.22	Suitable
16	Environment	0.731	Valid	0.922	4.24	Suitable

No	Variable	Validity (Corrected Item-Total Correlation)	Validity Status	Reliability (Cronbach's Alpha)	Mean	Variable Suitability
17	(K3)	0.633	Valid	0.926	4.46	Suitable
18	Collaboration	0.736	Valid	0.924	4.32	Suitable
19	Balance	0.736	Valid	0.924	4.23	Suitable
20	Employee Welfare	0.519	Valid	0.927	4.55	Suitable
21	Discipline	0.627	Valid	0.926	4.66	Suitable
22	Loyalty	0.628	Valid	0.926	4.44	Suitable
23	Motivation	0.671	Valid	0.925	4.50	Suitable
24	Competence	0.561	Valid	0.927	4.52	Suitable
25	Experience	0.615	Valid	0.926	4.58	Suitable
26	Compensation	0.595	Valid	0.926	4.32	Suitable

The table summarizes the validity, reliability, and mean score analyses for human resource performance indicators. All indicators are valid, with Corrected Item-Total Correlation values ranging from 0.505 to 0.755, and highly reliable with Cronbach's Alpha between 0.901 and 0.911. Mean scores range from 4.07 to 4.63, indicating strong positive perceptions from respondents and confirming the indicators' suitability for further analysis. Further analysis shows that ability, motivation, and working conditions received the highest ratings. This indicates that technical competence, employee engagement, and a supportive work environment are seen as the most critical factors in workforce performance. These aspects contribute significantly to sustainable construction by enhancing productivity, reducing turnover, and ensuring consistent project outcomes.

The high ratings of these factors highlight the importance of investing in human capital through training, fair compensation, and safe working conditions. Meanwhile, factors like environmental and safety concerns scored slightly lower, indicating a need for improvement. Therefore, future HR strategies should balance productivity and social-environmental responsibilities to fully support sustainable construction practices.

Human resource (HR) performance in building construction is influenced by various factors, with "ability" emerging as the most dominant based on the highest mean score of 4.8. This highlights the practical need for strategies such as targeted training, performance-based incentives, and improved recruitment to enhance workforce competence. For example, in a major infrastructure project in Jakarta, targeted skill development programs led to a 15% increase in productivity and a significant reduction in rework[18]. Similarly, a leading construction firm in Surabaya reported that performance-based incentives improved employee motivation and project delivery times. Despite its valuable insights, the study is limited by its regional focus in Semarang and cross-sectional design, which may not capture broader or long-term dynamics. Future research should expand to different regions, adopt longitudinal methods, and explore how HR development aligns with sustainability goals in construction practices.

Table 3. Results Of Data Analysis Of Development Strategy

No	Variable	Validity (Corrected Item Total Correlation)	Valid/Invalid	Reliability (Cronbach's Alpha)	Reliable/Not Reliable	Mean	Meets Criteria	Suitable as Variable
1	Training and Development	0.505	Valid	0.911	Reliable	4.46	Meets	Suitable

No	Variable	Validity (Corrected Item Total Correlation)	Valid/Invalid	Reliability (Cronbach's Alpha)	Reliable/Not Reliable	Mean	Meets Criteria	Suitable as Variable
2	Incentive Provision	0.563	Valid	0.911	Reliable	4.10	Meets	Suitable
3	Work Evaluation	0.690	Valid	0.904	Reliable	4.42	Meets	Suitable
4	Career Development	0.658	Valid	0.905	Reliable	4.36	Meets	Suitable
5	Organizational Culture Development	0.727	Valid	0.903	Reliable	4.07	Meets	Suitable
6	System Management	0.740	Valid	0.902	Reliable	4.47	Meets	Suitable
7	Recruitment and Selection Improvement	0.733	Valid	0.902	Reliable	4.20	Meets	Suitable
8	Organizational Structure Development	0.755	Valid	0.901	Reliable	4.12	Meets	Suitable
9	Project Leadership	0.713	Valid	0.903	Reliable	4.63	Meets	Suitable
10	Construction Technology	0.711	Valid	0.903	Reliable	4.45	Meets	Suitable
11	Safety and Comfort	0.702	Valid	0.903	Reliable	4.50	Meets	Suitable
12	Financial System	0.662	Valid	0.905	Reliable	4.51	Meets	Suitable
13	Network Expansion	0.676	Valid	0.905	Reliable	4.25	Meets	Suitable
14	Trust Building	0.722	Valid	0.903	Reliable	4.43	Meets	Suitable

These reflect common issues in Indonesia's infrastructure programs, emphasizing the need for adaptive HR and project strategies. This study validated 14 HR development variables, all of which were found to be valid ($r > 0.50$), reliable (Cronbach's Alpha > 0.90), and positively rated (mean > 4.0), with project leadership (4.63) and financial systems (4.51) scoring highest.

. The implementation of Building Information Modeling (BIM) significantly contributes to the development of smart and sustainable building structures through enhanced energy efficiency, environmental risk assessment, climate adaptation strategies, and real-time monitoring. These findings highlight BIM's transformative role in promoting environmentally conscious construction practices [19]. The BIM-NS-ML framework offers practical benefits by automating deep excavation analysis, enabling real-time simulations, and improving safety predictions. These findings highlight the need to align HR development with digital innovation for sustainable construction. On-site technologies positively impact workers' self-assessed performance and information access, with more technologies used correlating to better outcome [20].

4. Conclusion

Human resource (HR) performance in building construction is influenced by various factors, with "ability" emerging as the most dominant based on the highest mean score of 4.8. This highlights the practical need for strategies such as targeted training, performance-based incentives, and improved recruitment to enhance workforce competence. Despite its valuable insights, the study is limited by its regional focus in Semarang and cross-sectional design, which may not capture broader or long-term dynamics. Future research should expand to different regions, adopt longitudinal methods, and explore how HR development aligns with sustainability goals in construction practices.

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