Developing an ISO 56002-Based Organizational Innovation Readiness Model for Renewable Energy Power Plants in Indonesia

Maulana Ardianto Budi Prakoso[1], Yusuf Latief [2]
[1,2]*(Civil Engineering Department, University of Indonesia, Indonesia)*

ABSTRACT *: Indonesia is undergoing an energy transition toward increasing the utilization of renewable energy to support sustainable development and achieve net-zero emission targets. In this process, renewable energy power plants face increasingly complex operational challenges, requiring organizations to maintain system reliability, operational efficiency, and continuity of electricity supply through adaptive and sustainable innovation capabilities. However, most renewable energy power generation companies in Indonesia still lack a structured framework to prepare organizational readiness for innovation management system implementation. This study aims to develop an ISO 56002-based organizational innovation readiness model to enhance the operational performance of renewable energy power plants in Indonesia. The study also examines the mediating role of the innovation management system using the Partial Least Squares Structural Equation Modelling (PLS-SEM) method. The findings are expected to provide a strategic framework for improving innovation capability and operational performance in renewable energy power plants in Indonesia.*

KEYWORDS - *ISO 56002, Innovation Management System, Organizational Readiness, Operational Performance, Renewable Energy*

I. INTRODUCTION

The development of renewable energy power plants in Indonesia has increased significantly over the past two decades, driven by government policies supporting the energy transition toward clean energy adoption and the achievement of net-zero emission targets by 2050 [1].

Despite this growth, renewable energy power plants continue to face increasingly complex operational challenges that require strong organizational capabilities to maintain system reliability, operational efficiency, and sustainable electricity generation. Operation and maintenance (O&M) organizations are required to address various technical and managerial issues, including transmission and protection systems, infrastructure and equipment maintenance, spare parts management, information governance, environmental and social management, stakeholder communication, occupational health and safety, as well as quality assurance and production control. Furthermore, the integration of renewable energy into modern power systems demands greater operational flexibility, digitalized infrastructure, and adaptive capabilities to ensure reliable and efficient energy supply [2].

These conditions encourage O&M organizations not only to focus on routine operational activities, but also to strengthen innovation capabilities in solving operational problems, improving asset performance, and maintaining energy supply continuity. According to ISO 56002:2019, organizational innovation capability is determined by the organization's ability to understand its business environment, identify opportunities, and establish a sustainable and integrated innovation management system [3].

To support sustainable innovation implementation, organizations are required to possess an adequate level of organizational readiness. Santos et al. [4] defined organizational readiness as the capability of an organization to prepare its resources, leadership, culture, competencies, structure, and internal systems to effectively support innovation implementation and organizational change.

Previous studies have indicated that organizational readiness and effective innovation implementation may contribute to improved operational performance [5]. In the power generation sector, operational performance is commonly reflected through indicators such as reliability, availability, operational efficiency, downtime reduction, effectiveness of operation and maintenance (O&M) activities, and the capability to maintain a stable and continuous energy supply [6].

However, limited studies have examined the mediating role of innovation management system implementation in the relationship between organizational readiness and operational performance, particularly within renewable energy power plant organizations in developing countries. Therefore, this study aims to develop an ISO 56002-based organizational innovation readiness model and analyze its influence on operational performance through the mediating role of innovation management system implementation in renewable energy power plants in Indonesia.

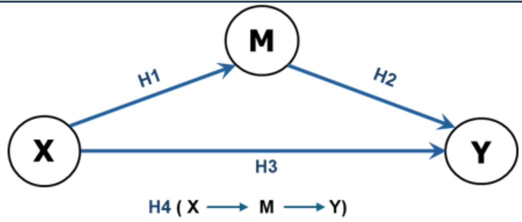
I.1 RESEARCH OBJECTIVES

This study aims to analyze the relationship between organizational readiness, innovation management system implementation, and operational performance in renewable energy power generation companies. Specifically, the study examines the influence of organizational readiness on ISO 56002-based innovation management system implementation, the effect of innovation management system implementation on operational performance, and the mediating role of innovation management system implementation in linking organizational readiness to operational performance improvement.

I.2 RESEARCH FRAMEWORK

The research framework consists of three main components: input, process, and outcome. The input component represents organizational readiness factors, including leadership commitment, organizational culture, resource availability, competencies, governance, and technological readiness. The process component involves the implementation of an ISO 56002-based innovation management system that supports innovation planning, opportunity identification, knowledge management, performance evaluation, and continuous improvement initiatives.

The outcome component focuses on operational performance improvement in renewable energy power plants, reflected through indicators such as reliability, availability, operational efficiency, downtime reduction, operation and maintenance (O&M) effectiveness, and continuity of energy supply. The proposed framework assumes positive relationships among organizational readiness, innovation management system implementation, and operational performance. These relationships were subsequently evaluated using the PLS-SEM approach to determine the structural relationships and the strength of influence among variables.



Research Variables
(X) Organisation Readiness
(M) Innovation Management System
(Y) Operation Performance

Theoretical Hypothesis
H1: Organizational readiness has a positive effect on the implementation of an ISO 56002-based Innovation Management System.
H2 : An ISO 56002-based Innovation Management System has a positive effect on the Power plant operational performance
H3: Organizational readiness has a positive effect on the Power plant operational performance
H4: Innovation Management System can mediate the relationship between organizational readiness and the operational performance of the company.

Figure 1. Operation Research Model

II. THEORETICAL REVIEW

II.1 ORGANISATIONAL READINESS

Organizational readiness refers to the capability of an organization to prepare and align its leadership, culture, competencies, resources, technology, and internal systems to effectively support innovation implementation and organizational change [7]. Organizations with a high level of readiness are generally more capable of reducing resistance to change, accelerating innovation adoption, improving operational efficiency, and strengthening organizational competitiveness [8].

In the context of renewable energy power plants, organizational readiness plays an important role in supporting adaptive operational capabilities, continuous improvement initiatives, and the implementation of innovation management systems required to maintain sustainable operational performance.

II.2 Operational Management System and Innovation Management Systems.

An operational management system is a structured system used by organizations to manage, control, and coordinate all operational activities to ensure that work processes are carried out effectively, efficiently, consistently, and in accordance with organizational objectives. This system includes operational planning, process control, asset maintenance, resource management, performance monitoring, and operational evaluation to ensure the achievement of reliability, availability, service quality, and operational efficiency. In the context of power generation organizations, an operational management system plays a critical role in maintaining continuity of energy supply, operational stability of power plants, effectiveness of operation and maintenance (O&M) activities, as well as controlling downtime and operational losses (Heizer et al)[9].

According to International Organization for Standardization ISO 56002 [3], an Innovation Management System is defined as a set of interrelated organizational elements established to systematically develop, implement, maintain, and continuously improve organizational innovation capabilities. Meanwhile, Joe Tidd and John Bessant [10] explain that innovation management does not merely focus on the creation of new ideas, but also on the organization's capability to manage, implement, and sustain innovations to improve organizational performance.

In the context of the renewable energy industry, an innovation management system can be defined as a structured system used by organizations to systematically manage innovation processes to enhance operational performance, asset reliability, operation and maintenance (O&M) efficiency, and organizational capability in adapting to technological developments and the ongoing energy transition. This system includes idea management, improvement development, knowledge management, innovation evaluation, data-driven decision-making, and the integration of innovation with organizational strategy and sustainable power plant operations. Furthermore, an innovation management system supports continuous improvement, predictive maintenance, digital operations, asset optimization, and sustainable enhancement of operational performance.

Therefore, the fundamental difference lies in the fact that an operational management system primarily focuses on maintaining organizational stability, operational control, and efficiency, whereas an innovation management system focuses on enhancing the organization's capability to adapt, evolve, and generate valuable innovations for future sustainability and competitiveness.

Table 1. Comparison between IMS & OMS

Aspect	Operational Management System	Innovation Management System
Objective	To maintain operational stability, efficiency, and compliance	To promote innovation, adaptability, and competitiveness
Focus	Efficiency, quality, safety, and procedural compliance	Creativity, improvement, and value creation
Approach	Preventive and corrective	Predictive and learning-oriented
Organizational Culture	Discipline, consistency, and compliance	Collaboration, creativity, and innovation
Risk Management	Risks are minimized	Risks are managed as opportunities for innovation
Decision-Making	Based on SOPs and historical experience	Based on data, insights, and strategic opportunities
Output	Operational stability and	New products, processes, or

Aspect	Operational Management System	Innovation Management System
	process consistency	significant improvements
ISO Standards	ISO 9001, ISO 14001, ISO 45001	ISO 56002
Employee Role	Process executor	Source of ideas and innovation agent
Expected Result	Stable and efficient operations	Adaptive and sustainable organization

II.3 Operational Performance

Operational performance refers to the capability of an organization to conduct operational activities effectively, efficiently, reliably, and sustainably in achieving production and service objectives [11]. In the power generation sector, operational performance is commonly reflected through indicators such as reliability, availability, operational efficiency, downtime reduction, operation and maintenance (O&M) effectiveness, and continuity of energy supply.

Previous studies have emphasized the importance of effective O&M strategies in improving operational performance. Kumar and Saini [12] explained that effective O&M practices contribute to operational cost reduction and improved power plant performance, while Abdulla et al. [13] highlighted that O&M quality plays a critical role in maintaining the reliability and efficiency of power generation systems.

In power plant operations, efficiency and reliability are considered key performance indicators. Power plant efficiency refers to the capability of a generation system to convert primary energy into electrical energy with minimum energy losses [14]. Higher efficiency levels indicate better energy utilization, lower operational costs, and improved operational sustainability. Meanwhile, operational reliability refers to the capability of a power generation system to continuously generate and deliver electrical energy in a stable and safe manner while minimizing operational disturbances and forced outages [15].

In Indonesia, operational performance measurement in power plants generally refers to indicators such as Equivalent Availability Factor (EAF), Equivalent Forced Outage Rate (EFOR), Capacity Factor (CF), Planned Outage (PO), and Unplanned Outage (UO). Higher EAF values and lower EFOR values indicate better operational reliability and operational performance of power generation systems [16].

II.4 Quantitative Research For Modelling

In this study, organizational readiness and innovation management system implementation were treated as latent variables that could not be measured directly. Therefore, measurement was conducted using multiple indicators designed to capture respondents' perceptions regarding their organizational conditions [17]. The indicators were evaluated using a five-point Likert scale ranging from 1 ("Strongly Inappropriate") to 5 ("Strongly Appropriate"). The collected data were subsequently analyzed using Partial Least Squares Structural Equation Modelling (PLS-SEM).

According to Hair et al. [18], PLS-SEM is a variance-based structural equation modelling approach widely used for prediction-oriented research and the analysis of complex relationships among latent constructs. This method was considered appropriate for the present study because it enables simultaneous evaluation of both measurement and structural models.

The measurement model evaluation included outer loading, Average Variance Extracted (AVE), cross loading, Heterotrait-Monotrait ratio (HTMT), Cronbach's Alpha, and Composite Reliability. Indicators with outer loading values above 0.60 and AVE values above 0.50 were considered acceptable [18]. Discriminant validity was evaluated using cross loading and HTMT criteria, with HTMT values below 0.90 considered acceptable [19]. Reliability was assessed using Cronbach's Alpha and Composite Reliability, with minimum acceptable values of 0.70 [18].

The structural model evaluation included the coefficient of determination (R^2), path coefficients, T-statistics, and P-values. Relationships among variables were considered statistically significant when T-values exceeded 1.96 and P-values were below 0.05 [18].

II.5 DATA ADEQUACY TEST

The data adequacy test was conducted using G*Power based on Cohen's statistical power approach. Since the PLS-SEM model in this study evaluates predictive relationships among variables using a regression-based approach, the F-test option Linear multiple regression: Fixed model, R^2 deviation from zero was selected as the most appropriate statistical procedure for determining the minimum sample size requirement [20]. This approach is consistent with the variance-based estimation principle of PLS-SEM, which focuses on the explained variance (R^2) of endogenous constructs [18].

An A priori power analysis was employed to estimate the minimum sample size prior to data collection. The analysis was performed using predetermined statistical parameters, including significance level (α), statistical power, effect size, and number of predictors. These parameters were used to ensure that the study possessed adequate statistical power to detect significant relationships among variables within the proposed PLS-SEM model.

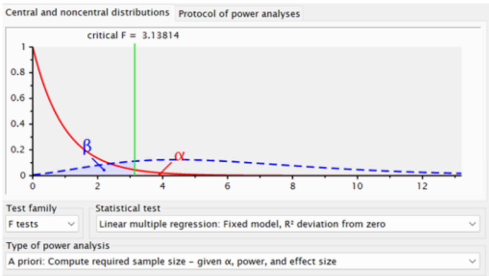


*Figure 2. G*Power Computation to determine number of samples*

These parameters were used as the basis for evaluation in this study to ensure that the statistical analysis possessed adequate power for detecting significant relationships among variables. The evaluation also aimed to determine whether the minimum sample size requirement was sufficient to support the reliability and validity of the PLS-SEM analysis results.

III. RESEARCH METHOD

Prior to the PLS-SEM analysis, the variables and dimensions were validated through expert judgment to ensure the relevance and clarity of the questionnaire indicators. Expert feedback was used as the basis for refining the questionnaire items before data collection. The experts evaluated each indicator using a five-point Likert scale ranging from 1 ("strongly inappropriate") to 5 ("strongly appropriate"). The collected evaluations were subsequently analyzed using the Content Validity Index (CVI).

According to Lynn [21], the CVI is commonly used to assess the relevance and clarity of questionnaire items based on expert evaluation. A CVI value of 1.00 is recommended when five experts are involved, while a CVI value above 0.78 is considered acceptable when the number of experts ranges from six to ten.

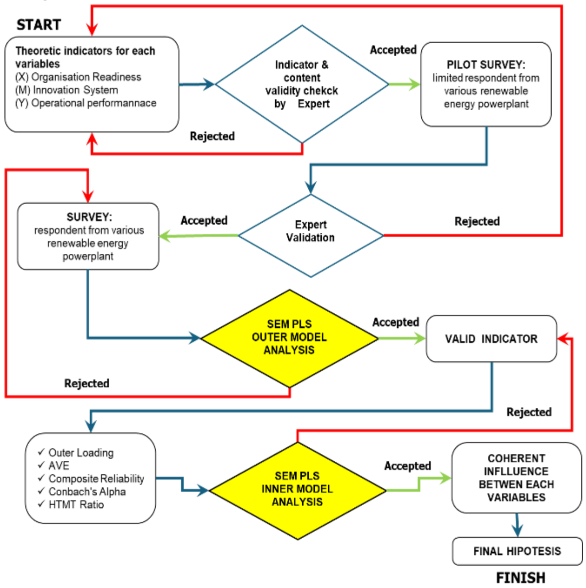


Figure 3. Research Flowchart

Table 2. Variable Validity Index

VARIABLE	DIMENSION	CVI
(X) Organizational Readiness	X.1 Leadership & Strategy	1,00
	X.2 Organizational Culture	0,83
	X.3 Resource Readiness	1,00
	X.4 Governance & Structure	1,00
(M) Innovation Management System Implementation	M.1. Innovation Process	1,00
	M.2. Integration	1,00
	M.3. Performance Management	1,00
	M.4.Continuous Improvement	0,83
(Y) Operational Performance	Y.1. Efficiency	1,00
	Y.2. Reliability	1,00
	Y.3. Cost Performance	1,00
	Y.4. Energy Output	1,00

$$I - CVI = \frac{n_e}{N}$$

n_e = number of experts rating the item as relevant

N = total number of expert validators

This study involved 99 respondents from various types of renewable energy power generation companies. Validation by six expert reviewers was conducted to refine the indicators prior to questionnaire distribution. Consequently, perception-based assessments were obtained from each respondent regarding the condition of their respective operation and maintenance (O&M) organizations.

Table 3. Background of Respondents

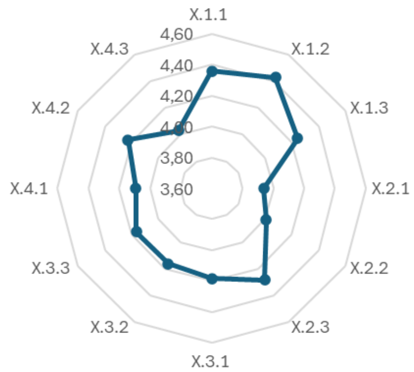
Demographic Characteristics	Category	Number of Respondents
Renewable Energy Power Plant	Hydroelectric	55
	Solar Photovoltaic	32
	Geothermal	10
	Wind Farm	2
Years of Experience	< 5 years	1
	5 to 10 years	23
	11 to 20 years	41
	> 20 years	34
Formal Education	PhD	1
	Master Degree	34
	Bachelor Degree	56
	Associate Degree	8
Total Respondents		**99**

Data collection regarding respondents' perceptions of their respective companies was conducted using a five-point Likert scale. This scale was employed to measure the respondents' level of assessment toward various aspects of the company. The response categories ranged from 1 to 5, where 1 indicated "very poor," 2 indicated "poor," 3 indicated "fair," 4 indicated "good," and 5 indicated "very good." The use of the Likert scale enabled the researcher to quantify respondents' perceptions systematically and analyze the data statistically. For example, in dimension X.2 (*Organizational Culture*), one indicator concerns the company's support for the implementation of new ideas. If a respondent selects an answer with a score of 3, it indicates that, in their opinion, the O&M organization has a culture that "fairly" supports the implementation of new ideas, particularly after undergoing an adequate assessment and evaluation process. In practice, this type of discourse is commonly found in initiatives involving the modernization of supporting automation processes that still rely on conventional methods, as well as improvements to protection systems.

IV. Findings & Discussion

IV.1 Analysis of The Organizational Readiness

Based on the data collection results, an organizational readiness index was obtained. The analysis indicates that the organization demonstrates a good level of readiness, as the average response score exceeded 4. Nevertheless, one indicator remained below 4, namely indicator X.2.1 (*Organizational support for new idea*). Some respondents perceived the support for new ideas as low to moderate. Innovative ideas are still considered vulnerable to risks that may reduce organizational performance. Consequently, organizations tend to maintain the existing equilibrium (status quo), causing proposed changes to often encounter resistance [22]. Therefore, a structured change process is required to stabilize new practices derived from innovative ideas in order to improve operational performance.



ORGANIZATION READINESS (x)		
X.1 Leadership & Strategy	X.1.1	Manajemen Commitment
	X.1.2	Clear Vision
	X.1.3	Clear Strategic Planning
X.2 Organizational Culture	X.2.1	Support for New Ideas
	X.2.2	Risk Mitigation Planning
	X.2.3	Cross functional collaboration
X.3 Resource Readiness	X.3.1	Resaource Availability
	X.3.2	Allocated Budget
	X.3.3	Supporting Technology Availability
X.4 Governance & Structure	X.4.1	Documented Innovation Process
	X.4.2	Structurized Organisation
	X.4.3	Periodic Evaluation

Figure 2. O&M Organizational Readiness Index at the Respondents' Workplace

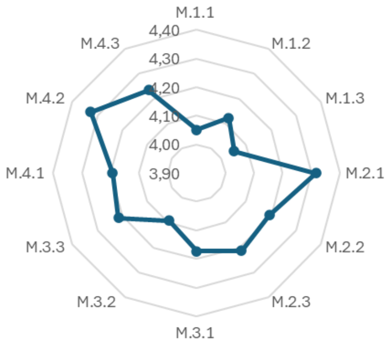
IV.2 Analysis of The Innovation Implementation Capacity

Most renewable energy power generation companies have implemented standardized management systems such as ISO 9001, ISO 45001/OHSMS, ISO 14001, and ISO 50001. The implementation of these standards has established organizational practices related to process management, documentation, performance evaluation, risk control, internal auditing, and continuous improvement. These conditions provide an important foundation for implementing the ISO 56002 Innovation Management System, which adopts similar management principles, including leadership, continual improvement, and the Plan-Do-Check-Act (PDCA) cycle [22], [23].

Organizations that have adopted ISO-based management systems generally possess structured mechanisms for document control, KPI monitoring, corrective actions, competency development, and periodic management review. These capabilities strengthen organizational readiness for systematic innovation management implementation within renewable energy power plant operations.

The innovation implementation index presented in Figure 3 indicates that most renewable energy power plant organizations demonstrated relatively good readiness for implementing innovation management practices. Existing operational management systems can support innovation implementation through structured idea management, operational improvement evaluation, predictive maintenance initiatives, digital operational systems, and continuous improvement programs [2], [22].

Previous studies also indicate that organizations with mature quality management systems are generally more prepared to adopt innovation management systems. Rezak and Djenouhat [4] explained that organizations implementing ISO 9001 possess stronger organizational foundations for accelerating ISO 56002 implementation due to their familiarity with system-based management approaches and continuous improvement practices. Overall, these findings indicate that existing management systems contribute positively to organizational readiness and support sustainable innovation management implementation in renewable energy power plant organizations.

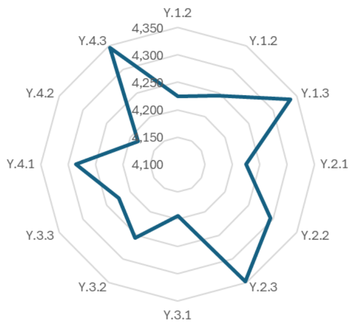


INNOVATION IMPLEMENTATION (M)		
M.1. Innovation Process	M.1.1	Systematic idea management
	M.1.2	Clear innovation stages
	M.1.3	Consistency in innovation implementation
M.2. Integration	M.2.1	Integration of innovation into operations
	M.2.2	Innovation support for business targets
	M.2.3	Alignment of innovation with strategy
M.3. Performance Management	M.3.1	Availability of innovation KPIs
	M.3.2	Innovation monitoring
	M.3.3	Evaluation of innovation outcomes
M.4. Continuous Improvement	M.4.1	Continuous improvement
	M.4.2	Organizational learning
	M.4.3	Adaptation to change

Figure 3. O&M Innovation Implementation Index at the various Renewables Power Plant in Indonesia

IV.3 Analysis of The Operational Performance

The radar chart in figure 4 shows that respondents perceive the Operational Performance at their workplace to be in a good category, with all indicators having average scores above 4.1. This indicates that the organization is considered to have relatively stable and effective operational performance in supporting power generation activities.



ORGANISATIONAL PERFOMANCE (Y)		
Y.1. Efficiency	Y.1.2	Improved operational efficiency
	Y.1.2	Reduction in operational losses
	Y.1.3	Optimization of resource utilization
Y.2. Reliability	Y.2.1	Reduction in downtime
	Y.2.2	Increased availability
	Y.2.3	Operational system stability
Y.3. Cost Performance	Y.3.1	Operational cost efficiency
	Y.3.2	Optimization of cost utilization
	Y.3.3	Operational cost control
Y.4. Energy Output	Y.4.1	Increased energy production
	Y.4.2	Increased capacity factor
	Y.4.3	Improved performance ratio

Figure 4. Operational Performance Index at the various Renewables Power Plant in Indonesia

The highest scores are found in Y.4.3 (Improved performance ratio) and Y.1.3 (Optimization of resource utilization), indicating that respondents perceive the organization as performing well in improving resource utilization effectiveness and overall plant operational performance. The high score in Y.2.3 (Operational system stability) also suggests that the power plant operational system is considered sufficiently stable and reliable.

Meanwhile, relatively lower scores are observed in Y.3.1 (Operational cost efficiency) and Y.4.2 (Increased capacity factor). This indicates that although overall operational performance is already good, there is still room for improvement, particularly in operational cost efficiency and optimization of energy production capacity.

Overall, these results indicate that the respondents' organizations have achieved good operational performance and can support the sustainable implementation of operational innovation.

IV.4 DATA ADEQUACY TEST

The G*Power analysis was conducted using an effect size (f^2) of 0.15, significance level (α) of 0.05, statistical power of 0.80, and two predictors. According to Cohen's classification, an effect size of 0.15 represents a medium effect size, indicating a moderate relationship among variables. The number of predictors was determined based on the maximum number of exogenous variables influencing an endogenous construct in the PLS-SEM model.

The analysis results indicated a minimum sample size requirement of 68 respondents with an actual statistical power of 0.804, exceeding the recommended threshold of 0.80. These results confirm that the sample size used in this study was sufficient to detect significant relationships among variables and support the reliability of the PLS-SEM analysis.

Table 4 presents the input parameters used in the G*Power analysis, while Table 5 summarizes the output results of the statistical power analysis.

*Table 4. Input Parameter of G*Power Analsyis*

Input Parameters		
Determine =>	Effect size f²	0.15
	α err prob	0.05
	Power (1−β err prob)	0.80
	Number of predictors	2

*Table 5. Output of G*Power Analysis*

Output Parameters	
Noncentrality parameter λ	10.2000000
Critical F	3.1381419
Numerator df	2
Denominator df	65
Total sample size	68
Actual power	0.8044183

IV.5 SMART EQUATION MODELLING

The structural model results indicate that organizational readiness (X) has a strong positive effect on innovation management system implementation (M) with a path coefficient of 0.870. Furthermore, innovation management system implementation significantly influences operational performance (Y) with a coefficient value of 0.717. In contrast, the direct effect of organizational readiness on operational performance was weak and insignificant (-0.016), indicating that the relationship between organizational readiness and operational performance is primarily mediated by innovation management system implementation. The indirect effect value of 0.623 further confirms the presence of a strong mediation mechanism within the structural model, as presented in Table 6.

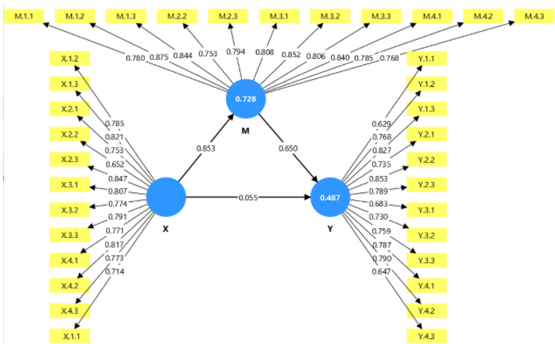


Figure 5. SEM PLS Research Model

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Table 6. Path & Indirect Analysis Result

Path Coeff		Indirect Effect
X → M	**0.870**	X → M → Y
M → Y	**0.717**	**0.623**
X → Y	-0.016	

The measurement model evaluation demonstrated satisfactory convergent validity and reliability. Most indicators achieved outer loading values above 0.70, while several indicators with loading values between 0.60 and 0.70 remained acceptable for PLS-SEM analysis, as shown in Table 7. In addition, all constructs achieved AVE values above the recommended threshold of 0.50, indicating adequate convergent validity, as presented in Table 8.

The construct reliability analysis also demonstrated strong internal consistency. Cronbach's Alpha and Composite Reliability values for all constructs exceeded the recommended threshold of 0.70, confirming that the indicators consistently measured their respective constructs and that the measurement model was suitable for further structural model evaluation, as shown in Table 9

Table 7. Outer Loading Coefficient

Outer loadings - Matrix

	M		X		Y
M.1.1	0.772	X.1.2	0.782	Y.1.1	0.630
M.1.2	0.878	X.1.3	0.813	Y.1.2	0.769
M.1.3	0.832	X.2.1	0.603	Y.1.3	0.827
M.2.1.	0.665	X.2.2	0.654	Y.2.1	0.736
M.2.2	0.765	X.2.3	0.846	Y.2.2	0.853
M.2.3	0.788	X.3.1	0.813	Y.2.3	0.790
M.3.1	0.800	X.3.2	0.774	Y.3.1	0.682
M.3.2	0.853	X.3.3	0.796	Y.3.2	0.729
M.3.3	0.802	X.4.1	0.769	Y.3.3	0.759
M.4.1	0.841	X.4.2	0.816	Y.4.1	0.785
M.4.2	0.780	X.4.3	0.777	Y.4.2	0.789
M.4.3	0.761	X.1.1	0.711	Y.4.3	0.649

Table 8. AVE Values

Variable	Average variance extracted *(AVE)*
M	0.635
X	0.587
Y	0.566

Table 9. Construct Validation Test

Variable	Composite reliability *(rho_a)*	Composite reliability *(rho_c)*	Cronbach's alpha
M	0.948	0.954	0.947
X	0.940	0.944	0.935
Y	0.933	0.940	0.930

The cross-loading evaluation results presented in Table 10 indicate that most indicators satisfied the discriminant validity criteria adequately. Each indicator generally demonstrated the highest loading value on its corresponding construct compared to the other constructs, indicating that the indicators were able to represent their respective latent variables appropriately.

Indicators belonging to construct M consistently showed higher loading values on construct M than on constructs X and Y. For example, indicator M.3.2 achieved a loading value of 0.853 on construct M, which was substantially higher than its loading values on construct X (0.698) and construct Y (0.593). A similar pattern was also observed in construct Y, where indicator Y.2.2 demonstrated the highest loading value on construct Y (0.853), compared to construct M (0.542) and construct X (0.494). These results indicate that the indicators possess adequate discriminant capability in distinguishing their respective constructs.

Table 10. Cross Loading Coefficient

Discriminant validity - Cross loadings

	M	X	Y
X.3.2	0.721	0.774	0.530
X.3.3	0.673	0.796	0.489
X.4.1	0.692	0.769	0.419
X.4.2	0.755	0.816	0.559
X.4.3	0.756	0.777	0.368
Y.1.1	0.415	0.250	0.630
Y.1.2	0.588	0.547	0.769
Y.1.3	0.567	0.426	0.827
Y.2.1	0.415	0.375	0.736
Y.2.2	0.542	0.494	0.853
Y.2.3	0.529	0.479	0.790
Y.3.1	0.408	0.353	0.682
Y.3.2	0.541	0.465	0.729
Y.3.3	0.498	0.448	0.759
Y.4.1	0.517	0.517	0.785
Y.4.2	0.602	0.522	0.789
Y.4.3	0.616	0.505	0.649
X.1.1	0.577	0.711	0.453

Discriminant validity - Cross loadings

	M	X	Y
M.2.3	0.788	0.653	0.605
M.3.1	0.800	0.668	0.591
M.3.2	0.853	0.698	0.593
M.3.3	0.802	0.624	0.558
M.4.1	0.841	0.734	0.536
M.4.2	0.780	0.651	0.530
M.4.3	0.761	0.628	0.618
X.1.2	0.636	0.782	0.440
X.1.3	0.700	0.813	0.533
X.2.1	0.477	0.603	0.372
X.2.2	0.535	0.654	0.374
X.2.3	0.708	0.846	0.566
X.3.1	0.700	0.813	0.432
X.3.2	0.721	0.774	0.530
X.3.3	0.673	0.796	0.489
X.4.1	0.692	0.769	0.419
X.4.2	0.755	0.816	0.559
X.4.3	0.756	0.777	0.368

For construct X, most indicators also demonstrated the highest loading values on their intended construct. However, several indicators showed relatively high cross-loading values on construct M. As presented in Table 10, indicator X.4.3 achieved a loading value of 0.777 on construct X and 0.756 on construct M, while indicator X.4.2 obtained loading values of 0.816 on X and 0.755 on M. Similarly, indicator X.3.2 showed a loading value of 0.774 on construct X and 0.721 on construct M. These relatively close loading values indicate that constructs X and M have a strong conceptual relationship and may share several overlapping characteristics.

This finding is consistent with the previous HTMT and Fornell-Larcker analyses, which also suggested potential discriminant validity concerns between constructs X and M. Nevertheless, since all indicators still demonstrated their highest loading values on the intended constructs, the cross-loading criterion can generally still be considered acceptable.

Overall, the cross-loading analysis confirms that the measurement model possesses acceptable discriminant validity and remains suitable for further structural model evaluation, although the relationship between constructs X and M should be interpreted with additional caution due to their relatively high conceptual association.

Table 11. SEM - PLS Bootstrapping Result

Path coefficients - Mean, STDEV, T values, p values

	Original sample (O)	Sample mean (M)
M -> Y	0.717	0.729
X -> M	0.870	0.873
X -> Y	-0.016	-0.020

Path coefficients - Mean, STDEV, T values, p values

	Standard deviation (STDEV)	T statistics (|O/STDEV|)
M -> Y	0.151	4.738
X -> M	0.027	31.649
X -> Y	0.166	0.097

The bootstrapping results presented in Table 11 demonstrate that the structural model exhibits a strong mediation relationship among the variables. The relationship between organizational readiness (X) and innovation management system implementation (M) produced a path coefficient of 0.870, with a T-statistics value of 31.649 and a P-value of 0.000. These results indicate a very strong and statistically significant positive effect of organizational readiness on innovation management system implementation. The high T-statistics value and the P-value below the 0.05 significance threshold confirm the robustness of this relationship.

Furthermore, the relationship between innovation management system implementation (M) and operational performance (Y) also demonstrated a positive and significant effect, with a path coefficient value of 0.717, a T-statistics value of 4.738, and a P-value of 0.000. This finding indicates that effective implementation of the innovation management system contributes significantly to improving operational performance in renewable energy power plant organizations.

In contrast, the direct relationship between organizational readiness (X) and operational performance (Y) showed a coefficient value of -0.016, with a T-statistics value of 0.097 and a P-value of 0.923. These results indicate that the direct effect of organizational readiness on operational performance is statistically insignificant. The coefficient value was also very small and slightly negative, suggesting that organizational readiness alone does not directly improve operational performance without the support of innovation management system implementation.

Overall, the results presented in Table 11 indicate that organizational readiness influences operational performance primarily through the mediating role of innovation management system implementation. Although the direct effect of X on Y was statistically insignificant, the paths between X → M and M → Y were both positive and significant, confirming the presence of a full mediation effect within the structural model. These findings imply that organizational readiness alone is insufficient to improve operational performance unless it is effectively operationalized through structured innovation management system implementation practices.

V RESULT & SUGGESTIONS

The PLS-SEM results demonstrate that organizational readiness significantly influences innovation management system implementation, which subsequently enhances operational performance in renewable energy power plant organizations. The hypothesis testing results confirmed that Hypothesis 1 (H1), which proposed a positive influence of organizational readiness on innovation management system implementation, was accepted. Furthermore, Hypothesis 2 (H2), which proposed a positive influence of innovation management system implementation on operational performance, was also accepted.

In contrast, Hypothesis 3 (H3), which proposed a direct positive influence of organizational readiness on operational performance, was rejected because the relationship was statistically insignificant. However, the indirect effect analysis confirmed that Hypothesis 4 (H4), which proposed the mediating role of innovation management system implementation in the relationship between organizational readiness and operational performance, was accepted. These findings indicate the presence of a strong full mediation effect within the structural model.

The results suggest that operational performance improvement is not solely determined by the organization's readiness condition, but more importantly by the organization's capability to operationalize readiness into structured innovation management practices. In this context, innovation management system implementation serves as a critical organizational mechanism that translates organizational preparedness into measurable operational outcomes.

The study also confirms that dimensions such as leadership commitment, innovation culture, organizational governance, internal communication, human resource competency, and organizational system support play important roles in strengthening innovation implementation effectiveness within renewable energy power plant organizations.

From a practical perspective, renewable energy power generation companies should strengthen structured innovation management practices through systematic idea management, innovation performance evaluation, cross-functional collaboration, organizational learning, predictive maintenance development, digital operational systems, and continuous improvement programs. These initiatives can support improvements in operational reliability, availability, efficiency, downtime reduction, and sustainable operational performance.

Furthermore, organizations are encouraged to integrate innovation management practices with existing operational management systems such as ISO 9001, ISO 45001, ISO 14001, and ISO 50001 to establish a more adaptive, data-driven, and sustainable operational management framework. In the context of renewable energy power plants, such integration can strengthen organizational adaptability in responding to technological development, operational complexity, and long-term energy transition challenges.

Overall, this study contributes to the growing body of knowledge on innovation management in renewable energy organizations by demonstrating the mediating role of innovation management system implementation in linking organizational readiness to operational performance improvement.

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