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Toward a Smart Geopark: Penta-Helix Collaboration and Renewable Energy Readiness in Geopark Galunggung, Indonesia

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ABSTRACT

Geoparks are increasingly expected to integrate conservation, sustainable tourism, digital innovation, and renewable energy, yet emerging geoparks often lack the institutional conditions required for such transformation. This study examines the roles of Penta-Helix Collaboration and Smart Governance in strengthening Institutional Readiness, as well as the relationships between Institutional Readiness, Renewable Energy Readiness, and Smart Geopark Readiness in Geopark Galunggung, Indonesia. A quantitative explanatory design was employed using a five-point Likert-scale questionnaire administered to 70 stakeholders representing government, business, academia, community, and media. The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The results show that Penta-Helix Collaboration positively influences Institutional Readiness ($\beta = 0.356$, $p = 0.003$), while Smart Governance has a stronger positive influence ($\beta = 0.509$, $p < 0.001$). Institutional Readiness strongly influences Renewable Energy Readiness ($\beta = 0.743$, $p < 0.001$), which in turn positively influences Smart Geopark Readiness ($\beta = 0.672$, $p < 0.001$). These findings indicate that Smart Geopark development requires more than digital or tourism innovation; it depends on institutional capacity, collaborative governance, and preparedness for renewable energy integration. The study contributes a readiness-oriented perspective to geopark development by connecting governance, institutional preparedness, and sustainable energy integration. For policymakers, strengthening multi-stakeholder coordination, smart governance, institutional capacity, and feasible renewable-energy initiatives is essential for advancing Geopark Galunggung toward Smart Geopark development.

1. INTRODUCTION

Geoparks are increasingly recognized as more than areas for geological conservation. Their development brings together geoconservation, tourism, education, local economic development, and community participation [1-6]. This broader role also creates a governance challenge, since the development of a sustainable geopark involves actors with different responsibilities, interests, and resources [5, 7-10]. Effective coordination among these actors is therefore important, particularly in areas where geopark development is still being established.

Renewable energy (RE) provides an opportunity to strengthen the environmental sustainability and low-carbon orientation of geopark development. However, the availability of renewable energy potential does not automatically translate into implementation. Regulatory support, institutional capacity, infrastructure, stakeholder commitment, and implementation capability are also required [11-15]. Renewable energy integration in a geopark is consequently not only a technological matter but also a governance challenge. Collaborative governance becomes relevant because environmental and tourism-related initiatives increasingly require coordination beyond the boundaries of a single institution [16-19].

The Penta-Helix approach provides a framework for such coordination by bringing together government, business, academia, community, and media. Previous studies have applied this approach to innovation, tourism, smart-city development, destination management, and sustainable development [20-38]. Alongside collaboration, digital transformation has changed the way public institutions coordinate and deliver services. Smart Governance emphasizes the use of digital technologies, information, participation, transparency, and data-driven decision-making [39-44]. In the context of geopark development, Penta-Helix collaboration and Smart Governance can therefore play complementary roles: collaboration connects the relevant actors, while smart governance supports the information and institutional processes through which those actors coordinate.

Yet, collaboration and digital governance may not be sufficient when the institutions involved are not ready to undertake the required changes. Organizational readiness concerns the extent to which an organization possesses the

structures, resources, capabilities, and commitment needed to implement change [45-47]. This issue is particularly relevant to Geopark Galunggung. Regional documentation describes Galunggung as a planned geopark development area, with the identification of its geodiversity and geoheritage being undertaken as a basis for further development. The research proposal similarly identifies institutional, collaborative, digital, and renewable-energy readiness as important conditions for moving toward Smart Geopark development.

The readiness perspective changes the research question. Rather than asking whether Galunggung has already achieved Smart Geopark performance, it is more appropriate to ask whether the institutional and governance system is prepared to move in that direction. This study consequently distinguishes three forms of readiness. Institutional Readiness refers to preparedness in regulation, organizational support, human resources, infrastructure, and administration. Renewable Energy Readiness concerns preparedness to integrate renewable energy, while Smart Geopark Readiness reflects preparedness for technology-enabled, innovative, sustainable, and digitally supported geopark management. These distinctions follow the operational framework developed in the research proposal.

Recent research in the International Journal of Sustainable Development and Planning provides a useful comparison. Yulianti et al. [48] examined institutional capacity, Penta-Helix collaboration, renewable energy adoption, and sustainable tourism performance in Green Canyon, Indonesia. Their findings demonstrate the importance of institutional capacity and Penta-Helix collaboration in supporting renewable energy adoption and sustainable tourism [48]. The present study addresses a different stage of development. Rather than examining renewable energy adoption and tourism performance, it focuses on the readiness pathway preceding such outcomes. This distinction is important for an emerging geopark such as Galunggung, where institutional and governance foundations are still being developed.

Based on this perspective, the study examines a pathway from Penta-Helix Collaboration and Smart Governance to Institutional Readiness, followed by Renewable Energy Readiness and Smart Geopark Readiness. The study aims to determine how collaborative and smart governance mechanisms contribute to institutional preparedness and how this preparedness supports renewable-energy integration and the transition toward Smart Geopark development in Geopark Galunggung, Indonesia. In doing so, the study shifts attention from the performance of an already established smart destination toward the governance and institutional conditions needed to prepare an emerging geopark for a sustainable, digitally enabled, and renewable-energy-oriented transition.

2. LITERATURE REVIEW

2.1 Penta-Helix collaboration and institutional readiness

Geopark development requires coordination among government, business, academia, communities, and other stakeholders because conservation, tourism, education, infrastructure, and local economic development cannot be managed effectively by a single actor [5, 6, 9, 10]. Collaborative governance emphasizes dialogue, shared understanding, and joint capacity among actors involved in collective action [16, 18]. The Penta-Helix model extends this approach by connecting government, business, academia, community, and media in addressing complex development issues [21, 31, 32].

Such collaboration is particularly important when a destination is still developing its institutional foundations. Different actors provide regulatory authority, knowledge, resources, local experience, investment, and public communication. Their interaction can strengthen organizational support, human-resource capacity, infrastructure development, and administrative coordination. Recent evidence from Indonesia also indicates that Penta-Helix collaboration can help translate institutional capacity into renewable-energy and sustainable tourism initiatives [48].

Institutional readiness refers to the extent to which an organization or system is prepared to implement change. It includes organizational support, resources, capabilities, and collective commitment to change [49-51]. In an emerging geopark, therefore, stronger collaboration among relevant actors is expected to improve the institutional conditions required for further development.

H1: *Penta-Helix Collaboration positively influences Institutional Readiness*.

2.2 Smart Governance and institutional readiness

Smart Governance emphasizes the use of digital technologies, information, participation, transparency, and responsiveness to improve public-sector decision-making and service delivery [40, 41, 43, 52]. Its relevance to geopark management lies not simply in the adoption of digital technologies, but in their capacity to improve coordination, information sharing, stakeholder participation, and institutional responsiveness.

These functions are closely related to organizational readiness. Institutions that can integrate information, engage stakeholders digitally, respond to emerging needs, and use technology in administrative processes are better positioned to manage complex development initiatives. The Smart Governance construct in this study consequently covers transparency, data integration, digital participation, technology utilization, and service responsiveness. For an emerging geopark, Smart Governance is therefore expected to strengthen the organizational and administrative conditions necessary for transformation.

H2: *Smart Governance positively influences Institutional Readiness*.

2.3 Institutional readiness and renewable energy readiness

Renewable-energy integration requires more than the existence of local energy potential. Policy support, organizational capacity, infrastructure, stakeholder commitment, and implementation capability are also necessary conditions [53]. This makes institutional readiness an important foundation for renewable-energy development.

The readiness literature emphasizes that successful change depends on organizational support, resources, capabilities, and commitment [49, 50, 54]. These conditions correspond closely with the requirements for renewable-energy implementation. In this study, Renewable Energy Readiness therefore encompasses local renewable-energy potential, policy support, infrastructure, stakeholder support, and readiness for implementation. Where institutional arrangements are sufficiently prepared, renewable-energy potential is more

likely to be translated into practical initiatives. Thus:

H3: *Institutional Readiness positively influences Renewable Energy Readiness*.

2.4 Renewable energy readiness and smart geopark readiness

Sustainable geopark development requires the integration of conservation, tourism, education, innovation, and local development [1-3, 5, 6, 8-10]. Renewable energy can contribute to this transition by supporting more sustainable infrastructure and resource use. However, its importance extends beyond energy supply because renewable-energy initiatives also require technological capability, infrastructure, stakeholder participation, and institutional coordination.

These conditions overlap with the broader characteristics of a smart and sustainable geopark. Previous studies have emphasized innovation, digitalization, sustainable management, conservation, education, and stakeholder engagement as important elements of contemporary geopark development [3, 11, 12, 55]. The present study therefore conceptualizes Smart Geopark Readiness as preparedness for smart management, digital tourism, sustainable area management, tourism innovation, and integrated conservation and education. Renewable Energy Readiness is consequently positioned as an intermediate step toward broader Smart Geopark transformation.

H4: *Renewable Energy Readiness positively influences Smart Geopark Readiness*.

2.5 Conceptual framework

Taken together, the literature suggests a sequential readiness pathway. Penta-Helix Collaboration and Smart Governance represent complementary governance mechanisms that can strengthen Institutional Readiness. Institutional Readiness provides the foundation for Renewable Energy Readiness, which in turn supports Smart Geopark Readiness. This structure places institutional preparedness at the center of the transition and distinguishes the study from research that focuses primarily on renewable energy adoption or sustainable tourism performance. The proposed research model and hypothesized relationships are presented in Figure 1.

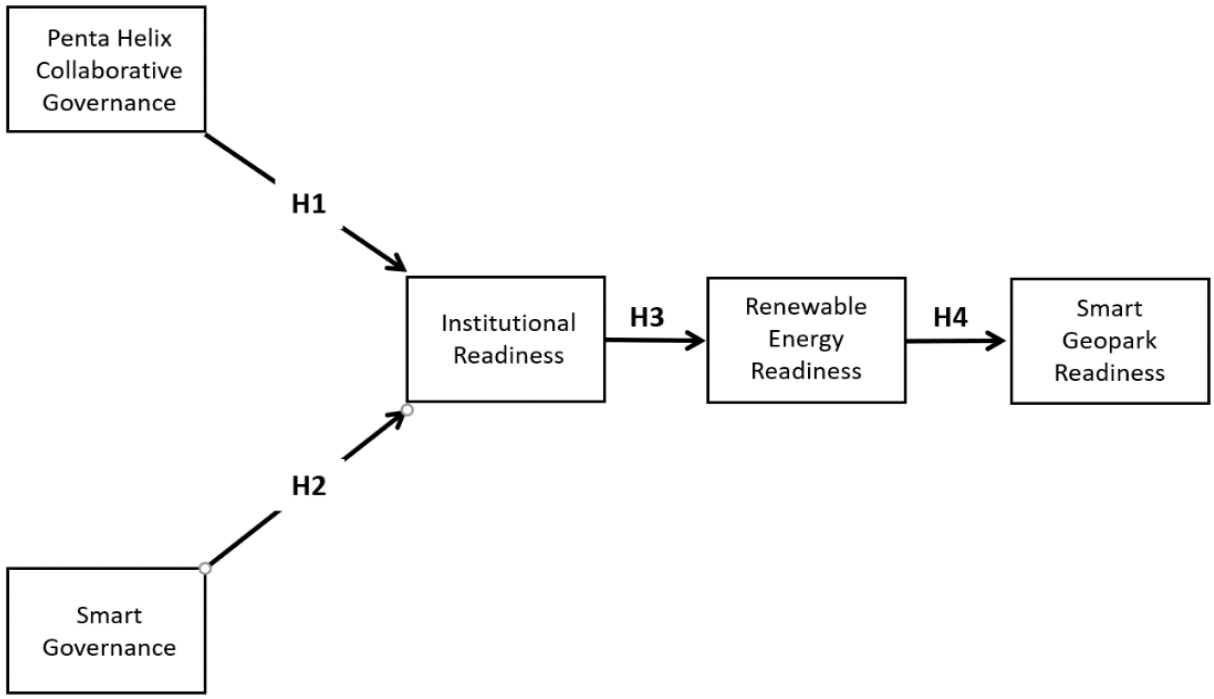


Figure 1. Research model

3. METHODOLOGY

3.1 Research design and sampling

This study employed a quantitative explanatory design to examine the relationships among Penta-Helix Collaboration, Smart Governance, Institutional Readiness, Renewable Energy Readiness, and Smart Geopark Readiness [56]. The research was conducted in the Geopark Galunggung development area, Tasikmalaya Regency, Indonesia. The study used non-probability purposive sampling, selecting stakeholders with relevant knowledge or involvement in geopark development [57]. Respondents represented the five Penta-Helix groups: government, business, academia, community, and media.

Sample size adequacy was assessed using the inverse square root method proposed by Kock and Hadaya [58]. Assuming a 5% significance level, 80% statistical power, and a directional test, the minimum sample size is determined using $N_{min}=(2.486/|\beta_{min}|)^2$. Based on the smallest statistically significant path coefficient in the final model ($\beta = 0.356$), the minimum required sample size was approximately 49 observations. The final sample of 70 observations therefore exceeded the minimum sample size requirement.

3.2 Data collection and measurement

Data were collected through a structured questionnaire using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree) [59]. The study examined five

constructs: Penta-Helix Collaboration was adapted from [16, 18]; Smart Governance from [40, 41, 43, 52]. Institutional Readiness from [49-51, 54]; Renewable Energy Readiness from [53]; and Smart Geopark Readiness from [2, 3, 12, 60, 61]. The specific indicators and their sources are presented in Table 1.

Table 1. Operational variables

Variables	Indicator	Code
Penta-Helix Collaboration	Stakeholder Participation	PH1
	Stakeholder Trust	PH2
	Shared Commitment	PH3
	Joint Decision Making	PH4
	Collaborative Communication	PH5
Smart Governance	Transparency	SG1
	Data Integration	SG2
	Digital Participation	SG3
	Technology Utilization	SG4
	Digital Service Responsiveness	SG5
Institutional Readiness	Regulatory Readiness	IR1
	Organizational Support	IR2
	Human Resource Capacity	IR3
	Infrastructure Readiness	IR4
	Administrative Readiness	IR5
Renewable Energy Readiness	Local Renewable Energy Potential	RE1
	Renewable Energy Policy Support	RE2
	Renewable Energy Infrastructure Readiness	RE3
	Stakeholder Support for Renewable Energy	RE4
	Readiness for Renewable Energy Implementation	RE5
Smart Geopark Readiness	Smart Management Readiness	SGR1
	Digital Tourism Readiness	SGR2
	Sustainable Area Management	SGR3
	Sustainable Tourism Innovation	SGR4
	Conservation & Education Readiness	SGR5

3.3 Data analysis

Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS. PLS-SEM was selected to examine the predictive relationships among the latent constructs [62]. The analysis comprised two stages. First, the measurement model was assessed through indicator outer loadings, internal consistency reliability, convergent validity, and discriminant validity [62, 63]. Second, the structural model was evaluated using bootstrapping to assess the significance of the hypothesized path coefficients. The structural model was further assessed using the coefficient of determination (R^2), effect size (f^2), predictive relevance (Q^2), and inner variance inflation factor (VIF). Model fit was additionally assessed using the standardized root mean square residual (SRMR).

4. RESULTS

4.1 Respondent characteristics

A total of 70 responses were retained for the final analysis. The respondents represented the main stakeholder groups involved in the development of Geopark Galunggung, including government and public institutions, business and tourism actors, academics, communities, local residents, and media. The detailed demographic and stakeholder characteristics of the respondents are presented in Table 2.

Table 2. Respondent characteristics

No.	Characteristic	Information	Distribution	
			Frequency	Percentage (%)
1.	Gender	Male	58	82.86
		Female	12	17.14
		Amount	70	100
2.	Age	21-30 years old	22	31.43
		31-40 years	20	28.57
		41-50 years	17	24.29
		>50 years	11	15.71
		Amount	70	100
3.	Education	High School/ Equivalent	11	15.71
		Diploma (D3/D4)	1	1.43
		Bachelor degree (S1)	34	48.57
		Masters (S2)	13	18.57
		Doctorate (S3)	11	15.71
		Amount	70	100
4.	Stakeholder group	Government /OPD	14	20.00

State-Owned Enterprises/Ministries	11	15.71
Village Government	1	1.43
MSMEs/ Entrepreneurs	5	7.14
Academic / Researcher	9	12.86
Community / NGO / Community Organization / Community Leader	8	11.43
Communities around the Geopark Location	9	12.86
Pokdarwis / Association Tourism / Business Group	7	10.00
Press/ Online Media/ Influencers	6	8.57
Amount	70	100

Source: Research results (2026).

4.2 Measurement model

The measurement model was assessed using indicator outer loadings, internal consistency reliability, and convergent validity. The retained indicators showed outer loadings ranging from 0.617 to 0.945, exceeding the minimum acceptable level of 0.50 [62]. Cronbach's alpha values ranged from 0.781 to 0.891, while rho_A values ranged from 0.790 to 0.919. Composite reliability values ranged from 0.859 to 0.920, indicating satisfactory internal consistency. The AVE values ranged from 0.567 to 0.731, exceeding the recommended threshold of 0.50. These results indicate that the constructs demonstrate adequate reliability and convergent validity. The detailed measurement model results are presented in Table 3.

4.3 Discriminant validity

Discriminant validity was assessed using the heterotrait–monotrait ratio (HTMT), following Henseler et al. [63]. All HTMT values were below the commonly recommended threshold of 0.90. The highest value was observed between Penta-Helix Collaboration and Renewable Energy Readiness (0.866), followed by Institutional Readiness and Renewable Energy Readiness (0.856), while Renewable Energy Readiness and Smart Geopark Readiness showed an HTMT value of 0.828. These results indicate that the constructs demonstrate adequate discriminant validity in the final model. The HTMT values for the constructs are reported in Table 4.

Table 3. Measurement model assessment

Variable	Items	Outer Loading	Cronbach's Alpha	rho_A	Composite Reliability	AVE
Penta-Helix Collaboration (PH)	PH1	0.621	0.841	0.882	0.888	0.617
	PH2	0.716				
	PH3	0.831				
	PH4	0.883				
	PH5	0.846				
Smart Governance (SG)	SG1	0.872	0.891	0.919	0.920	0.699
	SG2	0.916				
	SG3	0.700				
	SG4	0.766				
	SG5	0.904				
Institutional Readiness (IR)	IR1	0.617	0.868	0.893	0.914	0.731
	IR3	0.894				
	IR4	0.923				
	IR5	0.945				
Renewable Energy Readiness (RE)	RE1	0.783	0.808	0.835	0.866	0.567
	RE2	0.695				
	RE3	0.849				
	RE4	0.790				
	RE5	0.629				
Smart Geopark Readiness (SGR)	SGR2	0.817	0.781	0.790	0.859	0.604
	SGR3	0.772				
	SGR4	0.798				
	SGR5	0.719				

Source: Research results (2026).

Table 4. Heterotrait–monotrait ratio (HTMT)

	IR	PH	RE	SG	SGR
IR					
PH	**0.811**				
RE	0.856	0.866			
SG	**0.821**	**0.805**	**0.614**		
SGR	**0.623**	**0.812**	**0.828**	**0.762**	

Source: Research results (2026).

4.4 Hypothesis testing

The structural model was evaluated using bootstrapping to assess the hypothesized relationships. All four hypothesized relationships were positive and statistically significant. Penta-Helix Collaboration positively influenced Institutional Readiness ($\beta = 0.356$, $t = 2.980$, $p = 0.003$), while Smart Governance showed a stronger positive effect on Institutional Readiness ($\beta = 0.509$, $t = 4.464$, $p < 0.001$). Institutional Readiness had a strong positive effect on Renewable Energy Readiness ($\beta = 0.743$, $t = 12.021$, $p < 0.001$), while Renewable Energy Readiness positively influenced Smart Geopark Readiness ($\beta = 0.672$, $t = 10.513$, $p < 0.001$). Therefore, all four hypotheses were supported. The bootstrapping results for the hypothesized relationships are illustrated in Figure 2.

The model explained 63.0% of the variance in Institutional

Readiness, 55.2% in Renewable Energy Readiness, and 45.2% in Smart Geopark Readiness. The Q^2 values of 0.433, 0.294, and 0.259, respectively, indicate positive predictive relevance for all endogenous constructs. The f^2 values ranged from 0.187 to 1.231, with the largest effects observed for Institutional Readiness → Renewable Energy Readiness (f^2 = 1.231) and Renewable Energy Readiness → Smart Geopark Readiness (f^2 = 0.824). Inner VIF values ranged from 1.000 to 1.830, indicating no critical collinearity among the predictor constructs. The SRMR values were 0.153 for the saturated model and 0.171 for the estimated model.

Common method bias was assessed using the full collinearity VIF approach. The VIF values were 3.987 for Institutional Readiness, 2.882 for Penta-Helix Collaboration, 3.776 for Renewable Energy Readiness, 3.247 for Smart Governance, and 2.453 for Smart Geopark Readiness. Most values were below 3.3, although Institutional Readiness and Renewable Energy Readiness showed comparatively higher values. Therefore, common method bias cannot be considered entirely absent and is acknowledged as a potential limitation of the cross-sectional, self-reported survey design. The structural model assessment and hypothesis-testing results are presented in Table 5.

Table 5. Structural model assessment and hypothesis testing

Hypothesis		*β*	t-Value	p-Value	*f²*	VIF	*R²*	*Q²*	Decision
H1	PH → IR	0.356	2.980	0.003	0.187	1.830	0.630	0.433	Supported
H2	SG → IR	0.509	4.464	0.000	0.383	1.830			Supported
H3	IR → RE	0.743	12.021	0.000	1.231	1.000	0.552	0.294	Supported
H4	RE → SGR	0.672	10.513	0.000	0.824	1.000	0.452	0.259	Supported

Source: Data processed by researchers (2026).

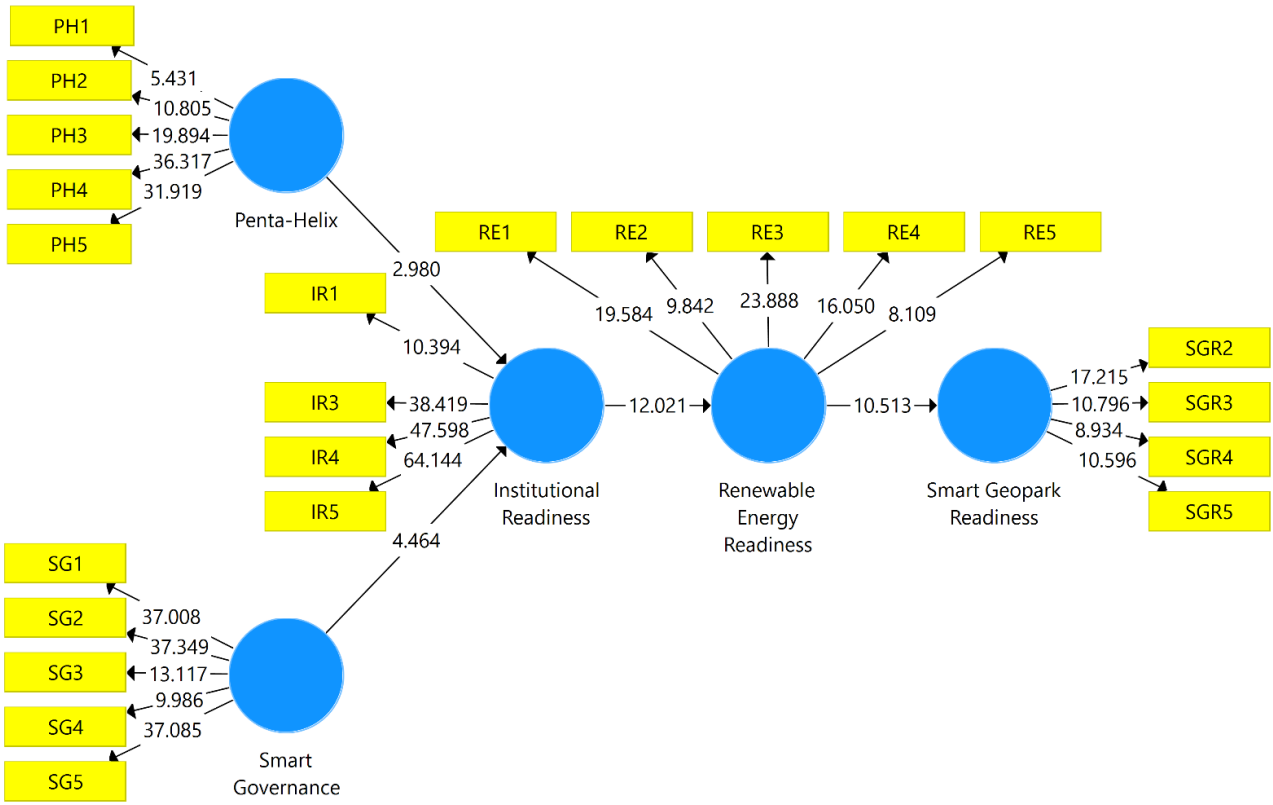


Figure 2. Bootstrapping
Source: SmartPLS Output (2026).

5. DISCUSSION

The findings confirm that Penta-Helix Collaboration has a positive and significant effect on Institutional Readiness (β = 0.356, p = 0.003). This finding supports the collaborative governance perspective, which emphasizes dialogue, shared understanding, trust, and joint capacity as important foundations for addressing complex public problems [16, 18]. In the context of Geopark Galunggung, collaboration among government, business, academia, community, and media provides complementary knowledge, resources, networks, and local experience that can strengthen organizational support, human-resource capacity, infrastructure, and administrative coordination. Thus, collaboration should not be understood merely as stakeholder participation but as an institutional resource for preparing the destination for further development. This interpretation is consistent with research emphasizing the importance of governance arrangements and stakeholder relations in Indonesian geopark development [64].

Smart Governance also has a positive and significant effect on Institutional Readiness (β = 0.509, p < 0.001). The stronger coefficient compared with Penta-Helix Collaboration suggests that the ability to manage information, utilize technology, facilitate participation, and provide responsive public services

is particularly relevant to institutional preparedness. This finding reinforces the argument that smart governance extends beyond technological adoption and involves changes in governance processes, information use, participation, and institutional responsiveness [40, 41, 52]. It also supports the view that smart governance in tourism destinations requires context-specific institutional arrangements rather than simply introducing digital technologies [65]. For Geopark Galunggung, digitalization therefore needs to be directed toward improving coordination, information sharing, public participation, and administrative services.

The relationship between Institutional Readiness and Renewable Energy Readiness is positive and highly significant ($\beta = 0.743$, $p < 0.001$). This result is consistent with readiness theory, which emphasizes organizational commitment, resources, capabilities, and contextual support as important conditions for implementing change [49-51]. The finding is particularly relevant because Renewable Energy Readiness in this study is not defined solely by the availability of renewable-energy resources but also includes policy support, infrastructure, stakeholder support, and implementation preparedness. This broader understanding is consistent with research on energy-transition readiness, which highlights the interaction of technological, institutional, regulatory, economic, and social conditions [53]. Consequently, the renewable-energy potential of a destination does not automatically translate into implementation capacity; institutional preparedness is required to convert potential into feasible initiatives.

Renewable Energy Readiness has a positive and significant effect on Smart Geopark Readiness ($\beta = 0.672$, $p < 0.001$). This finding supports the conceptualization of Smart Geopark Readiness as a multidimensional construct encompassing smart management, digital tourism, sustainable area management, tourism innovation, and conservation and education. In this sense, renewable energy represents more than an energy solution. It can form part of the infrastructure and sustainability orientation required to support a more innovative, environmentally responsible, and technologically enabled geopark. This interpretation is consistent with the broader geopark literature, which positions geoparks at the intersection of conservation, education, tourism, community development, and sustainable territorial management [3, 12, 61, 66]. It is also consistent with recent empirical evidence from Indonesian tourism destinations showing the relevance of Penta-Helix collaboration and renewable-energy initiatives to sustainable tourism development [48].

From a policy perspective, the findings suggest that the development of Geopark Galunggung should begin with institutional preparation rather than immediately pursuing the technological attributes of a Smart Geopark. Local government needs to strengthen a sustained coordination mechanism among the five Penta-Helix actors while improving digital information systems, participation mechanisms, and administrative responsiveness. Institutional preparation should also address regulatory support, organizational roles, human-resource capacity, infrastructure, and implementation mechanisms. For renewable energy, policy should move beyond mapping local potential toward feasible pilot projects, supporting infrastructure, regulatory arrangements, and stakeholder participation. Such an approach is consistent with the broader direction of sustainable tourism planning, where renewable energy and multi-stakeholder collaboration are increasingly treated as interconnected elements of destination transformation [48].

Overall, the findings indicate that Smart Geopark development depends on the readiness of the institutions and stakeholders that will implement it. Penta-Helix Collaboration and Smart Governance provide important governance conditions, while Institutional Readiness and Renewable Energy Readiness represent important organizational and sustainability-related conditions. The study therefore extends previous research that has tended to examine geopark development, smart governance, or renewable-energy adoption separately by bringing these dimensions into a single empirical model. This perspective is particularly relevant for Geopark Galunggung, which is still developing its institutional foundations and has not yet reached the stage of an established Smart Geopark.

Several limitations should nevertheless be considered. First, the use of purposive sampling and a cross-sectional design limits the generalizability of the findings and does not allow causal relationships to be established beyond the tested structural model. Second, common method bias cannot be considered entirely absent because the study relies on single-source, self-reported data, and the full collinearity VIF values for Institutional Readiness (3.987) and Renewable Energy Readiness (3.776) were relatively high. Future studies could address these limitations through larger and more diverse samples, longitudinal designs, and multi-source data, while further testing the model across different geopark contexts.

6. CONCLUSIONS

This study examined the relationships among Penta-Helix Collaboration, Smart Governance, Institutional Readiness, Renewable Energy Readiness, and Smart Geopark Readiness in Geopark Galunggung, Indonesia. The findings demonstrate that the development of a Smart Geopark is strongly associated with the institutional and governance conditions that support sustainable transformation. All four hypothesized relationships were statistically supported.

Penta-Helix Collaboration positively influenced Institutional Readiness ($\beta = 0.356$, $p = 0.003$), while Smart Governance showed a stronger positive influence ($\beta = 0.509$, $p < 0.001$). Institutional Readiness had a strong positive effect on Renewable Energy Readiness ($\beta = 0.743$, $p < 0.001$), which in turn positively influenced Smart Geopark Readiness ($\beta = 0.672$, $p < 0.001$). These findings indicate that Smart Geopark development should not be approached solely through digitalization, tourism innovation, or technological adoption. Rather, it requires institutional capacity, effective governance, multi-stakeholder collaboration, and preparedness to integrate renewable energy into geopark development.

The study contributes to the literature by providing a readiness-oriented perspective on Smart Geopark development and by empirically connecting collaborative governance and smart governance with institutional and renewable-energy preparedness. In the context of Geopark Galunggung, the findings suggest that strengthening institutional capacity and coordination among government, business, academia, communities, and media should precede or accompany technological and energy-related interventions.

For policymakers and geopark stakeholders, the results emphasize the importance of establishing clear institutional arrangements, strengthening cross-stakeholder coordination, improving governance capacity, and developing feasible

renewable-energy initiatives as part of the transition toward Smart Geopark development. Given the purposive sampling and cross-sectional nature of the study, as well as the potential for common method bias in self-reported data, future research should employ larger and more diverse samples, longitudinal designs, and multi-source data to validate and extend the findings across different geopark contexts.

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