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The Role of Certified Workers in Increasing the Success of Building Construction Projects Through Risk Management and *Knowledge Management*

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Abstract
Building construction projects in Badung Regency, Indonesia, frequently encounter delays and operational disruptions that require competent personnel and systematic project management practices. This study examined the mediating roles of risk management and knowledge management in the relationship between certified construction workers and project success. A quantitative research design was employed, using questionnaire data collected from 50 managerial and technical construction personnel selected through purposive sampling across medium- and large-scale building construction projects. Of these, 47 valid responses were included in the final analysis using partial least squares structural equation modeling (PLS-SEM) with SmartPLS 4. A preliminary pilot study involving 20 respondents was conducted to assess the research instrument. The initial structural model, excluding mediating variables, demonstrated a positive and statistically significant relationship between certified workers and project success ($\beta = 0.405$; $t = 3.400$). However, after incorporating the mediating variables, the direct relationship became statistically nonsignificant ($\beta = -0.038$; $p = 0.335$). Certified workers demonstrated positive associations with risk management ($\beta = 0.399$) and knowledge management ($\beta = 0.465$), while risk management ($\beta = 0.605$) and knowledge management ($\beta = 0.302$) were positively associated with project success. The indirect relationship through risk management was statistically significant ($\beta = 0.241$; $p = 0.003$). Meanwhile, the indirect relationship through knowledge management ($\beta = 0.140$; $t = 1.739$; $p = 0.041$) required clarification regarding the application and justification of a one-tailed significance test, as the reported t-statistic would not meet the conventional 5% significance threshold for a two-tailed test. Overall, the findings suggested that workforce certification was associated with improved construction project outcomes primarily through the integration of professional competencies into structured risk management and organizational knowledge-sharing practices.

INTRODUCTION

Badung Regency, one of the major centers of economic growth in Bali Province, recorded a substantial increase in infrastructure and property investment through the third quarter of 2024, reaching IDR 13.78 trillion, equivalent to 157.31% of its annual investment target. This growth contributed to the expansion of building construction projects undertaken by domestic and foreign investors, creating greater demand for professional and competency-based project management

practices. Building construction projects are inherently complex because they involve multiple interdependent stages, including planning, design, construction method selection, quality assurance, scheduling, and cost control. Effective implementation also requires the coordinated involvement of qualified professionals from the initial planning stages through project completion (Abdelalim et al., 2025; PMI, 2021).

However, an increase in construction activity does not necessarily ensure successful project implementation (Garcés & Peña, 2023). Data collected from 121 building construction projects in Badung Regency indicated that 25 projects experienced delays, while five projects were terminated before completion. These delays were primarily attributed to technical factors, particularly inappropriate construction methods, suggesting deficiencies in technical competencies and project execution practices (Lestari et al., 2022). Similarly, Dharmayanti et al. (2022) identified workforce-related factors as the predominant contributors to delays in building construction projects in Badung Regency. In complex construction environments, inadequate planning, ineffective coordination, and insufficient project control during the early implementation stages frequently contribute to schedule delays, cost overruns, and reduced project performance (Abdelalim et al., 2025).

One of the underlying challenges contributing to these problems is the limited proportion of construction workers holding recognized competency certifications. According to data reported by the Ministry of Public Works and Public Housing (PUPR) in 2024, approximately 571,000 construction workers, representing less than 7% of the national construction workforce, held professional competency certifications. This situation is particularly concerning because Law No. 2 of 2017 concerning Construction Services establishes competency certification requirements for construction workers in accordance with their occupational classifications and qualification levels. The Construction Work Competency Certificate (Sertifikat Kompetensi Kerja, SKK) serves as formal recognition of workers' professional competencies. Previous research has demonstrated a statistically significant positive relationship between skilled, certified workers and construction project performance (Hussain et al., 2020). Competent workers may contribute to higher productivity, more efficient project execution, and reduced risks of rework and schedule delays (Abdulrahman et al., 2022). Conversely, inadequate workforce competencies may undermine risk identification and mitigation, increase the likelihood of construction defects and rework, and compromise project implementation stability (Abdelalim et al., 2025; Ayalp & Fatma, 2025).

Insufficient workforce competencies may also restrict the ability of construction personnel to identify, assess, and respond effectively to project risks, potentially increasing the likelihood of technical failures, schedule disruptions, and cost overruns. In many construction projects, risk identification, assessment, and mitigation practices remain reactive rather than preventive, limiting their effectiveness in controlling project performance across time, cost, and quality dimensions (Syahra & Setiawati, 2025; Wang et al., 2025). Developing effective risk mitigation strategies requires the involvement of technically competent and experienced professionals capable of understanding complex construction processes, anticipating potential disruptions, and implementing appropriate corrective measures (Ardiansyah, 2025; Hardiputra et al., 2025). Without adequate professional competencies, risk management decisions may become inconsistent, insufficiently informed, and repetitive, thereby reducing the effectiveness of project control mechanisms (Omer et al., 2019; Saleh & Alshehhi, 2024).

In addition to workforce competency limitations, disparities in technical expertise and knowledge-sharing practices among project teams represent significant challenges to successful building construction project implementation. Consequently, knowledge management plays an important role in supporting organizational learning, technical coordination, and project decision-making. Alongside risk management, knowledge management has been identified as a relevant factor associated with construction project success (Kurniawan et al., 2024; Nyallu & Deng, 2025). Effective knowledge management practices include documenting lessons learned, applying standardized and validated construction methods, evaluating the underlying causes of rework, and utilizing technical information to support evidence-based decision-making during project execution. Nevertheless, these practices are frequently constrained by inadequate knowledge-sharing cultures, insufficient project documentation systems, and pressures associated with demanding construction schedules (Aldayondri & Dachyar, 2025; Kurniawan et al., 2024).

Certified construction workers, risk management, and knowledge management represent three interconnected dimensions that may collectively contribute to building construction project success. Integrating professional competencies with systematic risk mitigation and effective knowledge-sharing practices may improve project performance in terms of schedule adherence, cost efficiency, and construction quality (Huda & Maliki, 2019). However, previous studies have generally examined these relationships separately. Several investigations have focused primarily on the relationship between risk management and construction project performance (Syahra & Setiawati, 2025; Wang et al., 2025), whereas others have independently investigated the contribution of knowledge management to construction project outcomes (Kurniawan et al., 2024; Saleh & Alshehhi, 2024). Consequently, empirical evidence concerning the simultaneous mediating roles of risk management and knowledge management in the relationship between certified construction workers and project success remains limited. This research gap highlights the need for an integrated analytical framework that examines how workforce certification relates to project outcomes through organizational risk management and knowledge management processes.

Based on these considerations, this study aimed to (1) examine the relationships among certified construction workers, risk management, knowledge management, and building construction project success; (2) evaluate the mediating role of risk management in the relationship between certified workers and project success; and (3) assess the mediating role of knowledge management in the relationship between certified workers and project success. The research focused on medium- and large-scale building construction projects in Badung Regency, involving managerial and technical construction personnel holding recognized Construction Work Competency Certificates (SKK), including qualifications issued through authorized Professional Certification Institutions (Lembaga Sertifikasi Profesi, LSP) or relevant government-recognized certification mechanisms. The findings were expected to contribute to the theoretical understanding of workforce certification and construction project performance while providing practical recommendations for local governments, construction service providers, and professional training institutions seeking to strengthen workforce competencies, risk management practices, and organizational knowledge management systems.

METHOD

This study employed a quantitative survey design to examine the relationship between certified construction workers and the success of medium- and large-scale building construction projects in Badung Regency, Bali, with risk management and knowledge management as mediating variables. Primary data were collected through questionnaires administered to construction personnel involved in project implementation and control, supplemented by observations, interviews, project documentation, and relevant literature. Respondents were selected using purposive nonprobability sampling based on their active involvement in construction projects, minimum diploma-level education, relevant technical or managerial positions, at least one year of professional experience, and possession of a valid Construction Work Competency Certificate (Sertifikat Kompetensi Kerja, SKK) at qualification level 5 or higher. A total of 50 respondents participated in the survey, of whom 47 were included in the final analysis after three responses exhibiting uniform response patterns were excluded. The research procedures are summarized in Table 2, while the geographical location of the study area is presented in Figure 1.

Table 2. Research Stages

Yes	Stages	Remarks
1	Start and identify issues	Identify problems for the success of building construction projects
2	Literature study	Theoretical studies and previous research
3	Determination of the research location	Building construction projects in Badung Regency
4	Determination of variables and respondents	Variables X, M1, M2, Y and respondent criteria
5	Questionnaire preparation	Description of indicators into statement items
6	Validity and reliability tests	If it does not comply, return to the questionnaire; if it complies, proceed to the next stage
7	Questionnaire distribution	Primary data collection from respondents
8	Data analysis (SEM-PLS)	Evaluation of *the outer model* and *inner model*
9	Results and discussion	Interpretation of hypothesis test results
10	Conclusion and suggestions, done	Drawing conclusions and recommendations

Source: Processed from research flow chart



Figure 1. Research Location

Source: Research illustration supplied in the original manuscript.

The research instrument consisted of a structured questionnaire measuring respondent and project characteristics, certified workers, risk management, knowledge management, and project success, as presented in Table 3. Responses were measured using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). Prior to the main survey, a pilot test involving 20 respondents was conducted to assess item validity using Pearson's product–moment correlation, with a critical correlation coefficient of 0.444 (df = 18; $\alpha = 0.05$), and internal consistency reliability using Cronbach's alpha, with a minimum acceptable threshold of 0.70. The analyses were performed using IBM SPSS Statistics, version 25. Following questionnaire administration and supporting field observations, the collected data were screened for incomplete responses and noninformative response patterns. These procedures were used to assess the preliminary validity and internal consistency of the measurement instrument, although they did not establish its validity across different populations or research settings.

Table 3. Research Variables and Indicators

Variables/Dimensions	Code	Indicator
Certified Worker (X) – Knowledge	PTP1–PTP8	Understand work methods and quality standards; understand work drawings and technical specifications; understand the stages of implementation; understand K3 procedures; know the use of PPE and equipment; understand the identification of hazards and risks; understand the principles of quality control; pass the competency test
Certified Worker (X) – Skills	PTK1–PTK10	Carry out work according to work methods; read and apply work drawings; calculate volume and prepare work plans; identify potential hazards; control the risk of work accidents; use equipment and technology appropriately; implement quality control; *problem solving* (field obstacle solutions); organize daily and team tasks; have physical proof of certificate (SKK)
Certified Worker (X) – Work Attitude	PTS1–PTS9	Discipline and compliance with discipline; meticulous and responsible; maintaining neatness and cleanliness of work areas; complying with SOPs and safety procedures; commitment to quality; teamwork; caring for safety and the environment; initiative and quick decision-making; compliance with the national registration (LPJK)
Risk Management (M1)	MR1–MR8	Early data collection of potential disturbances; assessment of the urgency of risks based on opportunities and impacts; preparation of mitigation, transfer, or avoidance action plans; routine monitoring of risk dynamics; maintaining building integrity through the accuracy of methods and specifications; implementation of K3 procedures and equipment maintenance; optimization of coordination between *stakeholders*; documentation of risk events and the effectiveness of their handling
Knowledge Management (M2)	KM1–KM8	Collection of new technical information; exchange of technical information between team members; recording of obstacles and solutions into *lessons learned*; use of past experience as a basis for decision-making; ease of access to technical data; availability of joint evaluation rooms; use of digital platforms; safeguarding of knowledge assets in the organization
Project Success (Y)	KP1–KP10	Completion on time; on budget; according to technical specifications (quality); high work safety/*zero accidents*; project stability; owner and stakeholder satisfaction; labor productivity; low *rework*; compliance with standards and regulations; application of sustainability principles

Source: Results of the synthesis of research indicators

The final 47 valid responses were analyzed using partial least squares structural equation 442ulfilmen (PLS-SEM) with SmartPLS 4 to evaluate the measurement and structural models. The measurement model was assessed using indicator loadings (≥ 0.70), average variance extracted (AVE ≥ 0.50), heterotrait–monotrait ratios (HTMT < 0.90), Cronbach's alpha (≥ 0.70), and composite reliability (≥ 0.70). The structural model was evaluated using path coefficients, coefficients of determination (R^2), predictive performance (Q^2predict), effect sizes (f^2), and bootstrapping procedures to examine the indirect effects of risk management and knowledge management as mediating variables. Statistical significance was evaluated by distinguishing between one-tailed and two-tailed hypothesis tests, particularly for the indirect effect through knowledge management ($p = 0.041$), which appeared to reflect a one-tailed test and therefore required explicit methodological justification. The findings were interpreted in accordance with the study's purposive sampling approach, considering the limitations of causal inference and generalizability to broader construction worker populations (Hair et al., 2022; MacKinnon et al., 2007).

RESULTS AND DISCUSSION

Characteristics of Respondents

The research was carried out on construction service companies working on medium- and large-scale building construction projects in Badung Regency. Of the 20 companies surveyed, all of them responded with a total of 50 respondents meeting the criteria. The characteristics of the respondents are presented in Table 4.

Table 4. Characteristics of Respondents

Characteristics	Categories	Percentage (%)
Project contract value		
	> IDR 50 billion	38
	IDR 2.5–10 billion	36
	IDR10–50 billion	26
Final education		
	Bachelor (D4/S1)	78
	Diploma (D1, D2, D3)	12
	Master (S2)	10
Certification level		
	Level 5	40
	Level 7	22
	Level 6	18
	Level 8	16
	Level 9	4
Departments		
	Quantity Surveyor	32
	Drafter	14
	Site Supervisor	14
	Project Manager	10

Characteristics	Categories	Percentage (%)
	Site Manager	6
	Deputy Project Manager	6
	HSE Supervisor	4
	Site Engineer	4
	Implementing MEP, BIM Modeller, Estimator, Structural Engineer, and others	2 each
Work experience		
	1–5 years	62
	> 10 years	16
	5–10 years	14
	< 1 year	8

Source: Primary data processed

Based on Table 4, respondents are dominated by projects with a contract value of more than IDR 50 billion (38%), D4/S1 education (78%), holding level 5 certification (40%), serving as *a Quantity Surveyor* (32%), and 1–5 years of work experience (62%). The composition shows that respondents have a higher education background, have competency certifications, and come from various strategic positions in the project, so it is relevant to assess research variables.

Testing of Research Instruments

The results of *the pilot study* on 20 respondents are presented in Table 5. All 53 statements have a calculated r greater than the r of the table 0.444 so that they are declared valid (Sugiyono, 2016). All variables also have *Cronbach's Alpha* above 0.70 with a very high interpretation, so the instrument is suitable for use in the main data collection.

Table 5. Instrument Validity and Reliability Test Results

Variable	Number of Items	Range r Calculate	r Table	Cronbach's Alpha	Remarks
Labor Certification	27	0,490–0,820	0,444	0,947	Valid, reliable
Risk Management	8	0,477–0,853	0,444	0,883	Valid, reliable
Knowledge Management	8	0,583–0,828	0,444	0,853	Valid, reliable
Project Success	10	0,503–0,864	0,444	0,900	Valid, reliable

Source: IBM SPSS Statistics 25 data processing results

Evaluation of the Outer Model

Of the 50 answers obtained, 3 answers were not used because they had the same answer pattern in all statement items, so the data analyzed amounted to 47 respondents. The conceptual model used as the basis of the analysis is shown in Figure 2.

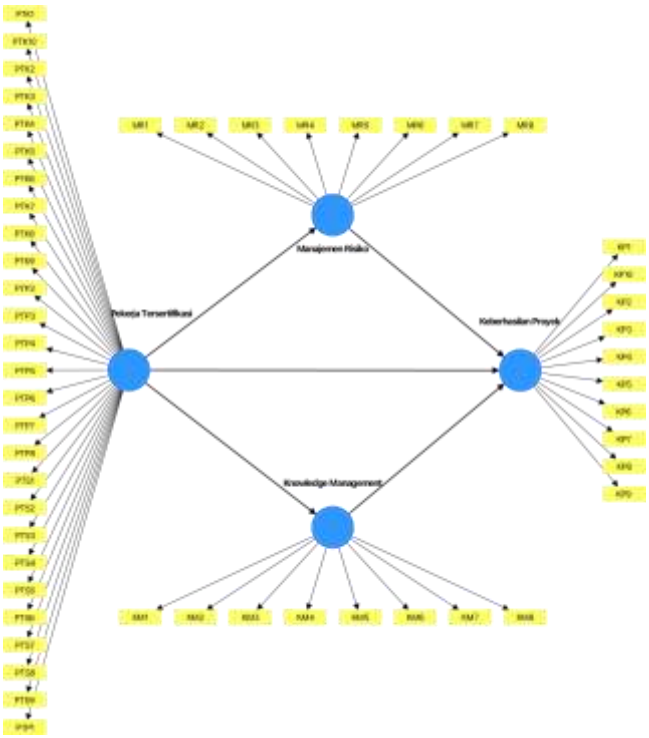


Figure 2. Research Latent Variable Model
Source: Research illustration supplied in the original manuscript.

Loading factor *testing* was carried out in four stages. In the first stage, the KP6 (0.665), KP9 (0.622), KP10 (0.636), KM2 (0.480), KM7 (0.573), MR4 (0.679), PTP6 (0.668), PTS3 (0.671), PTS5 (0.601), and PTS8 (0.686) indicators were deleted. In the second stage, the PTS9 (0.675) indicator was removed, and in the third stage the PTS4 (0.693) and PTS6 (0.693) indicators were removed. In the fourth stage, all indicators have a *loading factor* ≥ 0.70 as presented in Table 6.

Table 6. Final *Stage* Loading Factor Results

Indicator	LF	Indicator	LF	Indicator	LF	Indicator	LF
Project Success							
KP1	0,798	KP2	0,802	KP3	0,814	KP4	0,815
FP5	0,826	KP7	0,767	FP8	0,733		
Knowledge Management							
KM1	0,789	KM3	0,802	KM4	0,746	KM5	0,766
KM6	0,708	KM8	0,785				
Risk Management							
MR1	0,792	MR2	0,747	MR3	0,789	MR5	0,712
MR6	0,747	MR7	0,831	MR8	0,833		
Certified Workers							
PTP1	0,798	PTP2	0,762	PTP3	0,828	PTP4	0,749
PTP5	0,745	PTP7	0,742	PTP8	0,740	PTK1	0,795
PTK2	0,857	PTK3	0,734	PTK4	0,754	PTK5	0,723
PTK6	0,708	PTK7	0,821	PTK8	0,872	PTK9	0,747
PTK10	0,859	PTS1	0,729	PTS2	0,724	PTS7	0,705

Source: SmartPLS data processing results 4. Remarks: all indicators are valid (LF ≥ 0.70)

Furthermore, the results of the AVE, *Cronbach's Alpha*, and *Composite Reliability tests* are presented in Table 7, while the HTMT results are presented in Table 8. All constructs have an AVE ≥ 0.50, which means that each construct is able to explain more than 50% of the variance of its indicators. *Cronbach's Alpha values* are in the range of 0.860–0.964 and *Composite Reliability* 0.895–0.967 so that all constructs are reliable (Hair et al., 2022).

Table 7. AVE, *Cronbach's Alpha*, and *Composite Reliability Results*

Variable	AVE	Cronbach's Alpha	Composite Reliability	Remarks
Project Success	0,631	0,902	0,923	Valid, reliable
Knowledge Management	0,588	0,860	0,895	Valid, reliable
Risk Management	0,608	0,893	0,915	Valid, reliable
Certified Workers	0,595	0,964	0,967	Valid, reliable

Source: SmartPLS 4 data processing results

Table 8. *Heterotrait-Monotrait Ratio* (HTMT) Results

Variable	Project Success	Knowledge Management	Risk Management	Certified Workers
Project Success				
Knowledge Management	0,834			
Risk Management	0,885	0,871		
Certified Workers	0,351	0,484	0,404	

Source: SmartPLS 4 data processing results

All HTMT values are below 0.90 so that all constructs meet *the discriminant validity* criteria. The use of HTMT is more recommended because it has a higher sensitivity in detecting *discriminant validity* problems than the Fornell-Larcker criteria and *cross-loadings* (Hair et al., 2022).

Internal Evaluation of the Model Without Mediation Variables

Before including the mediation variables, an analysis of the direct relationship of certified workers to the success of the project was carried out (Figure 3). The mediator variable was declared as full mediation if the influence of the independent variables that were originally significant became insignificant after the mediator was included, and partial mediation if it remained significant (MacKinnon et al., 2007). A summary of the results is presented in Table 9.

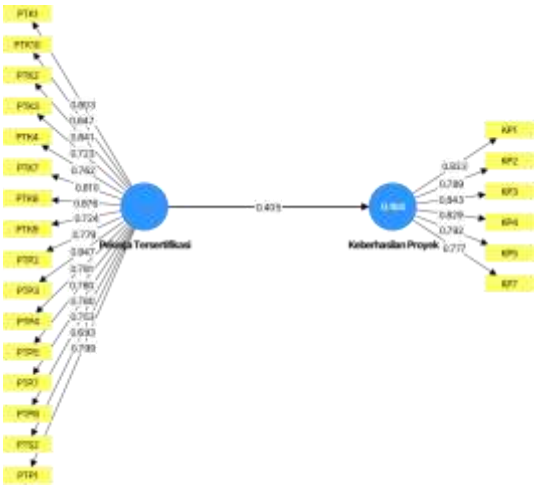


Figure 3. PLS-SEM Model Output *Algorithm* Without Mediation Variables
Source: Research illustration supplied in the original manuscript.

Table 9. Results of Model Evaluation Without Mediation Variables

Size	Value	Remarks
R^2 Project Success (R^2 *adjusted*)	0,168 (0,149)	Weak
Q^2predict (RMSE; MAE)	0,081 (0,992; 0,826)	Has predictive relevance
f^2 Certified Worker → Project Success	0,202	Moderate effects
Path coefficient (*sample mean*; STDEV)	0,405 (0,460; 0,119)	Positive
T-statistic; p-value	3,400; 0,000	Significant

Source: SmartPLS 4 data processing results

Table 9 shows that certified workers had a positive and significant effect on project success in the non-mediation model, with a path coefficient of 0.405, a T-statistic of 3.400 (> 1.96), and a p-value of 0.000 (< 0.05). An R^2 value of 0.168 indicates that certified workers only explained 16.8% of the variation in project success, while 83.2% was explained by other factors. This indicates that there are other factors at play, so risk management and *knowledge management* are further included as mediating variables.

Evaluation of the Inner Model with Mediation Variables

The results of the structural model test with mediation variables are shown in Figure 4, while the values of R^2, Q^2*predict*, and f^2 are presented in Table 10 and Table 11.

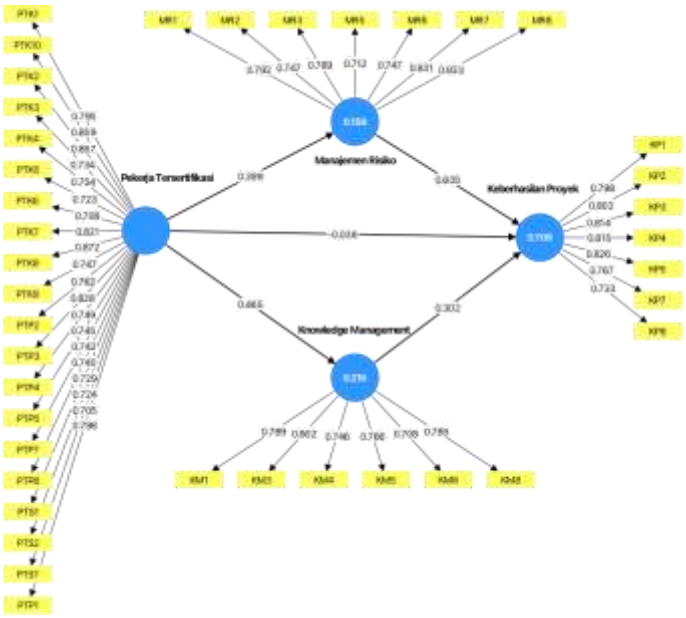


Figure 4. PLS-SEM Model Output *Algorithm*
Source: Research illustration supplied in the original manuscript.

Table 10. R-Square and Q-Square *Predict Values*

Endogenous Variable	R^2	R^2 *Adjusted*	Q^2predict	RMSE	MAE
Project Success	0,709	0,689	0,065	1,000	0,838
Knowledge Management	0,216	0,199	0,157	0,949	0,818
Risk Management	0,159	0,140	0,103	0,983	0,810

Source: SmartPLS 4 data processing results

The R^2 value of project success of 0.709 indicates that 70.9% of the variation can be explained by constructs in the model, much higher than the non-mediated model. *Knowledge management* and risk management have R^2 of 0.216 and 0.159, respectively. All Q^2 values are above zero so that the model has *predictive relevance*; knowledge management *Q^2 values* (0.157) are moderate, while risk management (0.103) and project success (0.065) are weak.

Table 11. Value *Effect Size* (f^2)

Relationships	f^2	Categories	Remarks
Certified Workers → Project Success	0,004	Very small	Low direct contribution
Certified Worker → *Knowledge Management*	0,275	Medium	Significant contribution
Certified Workers → Risk Management	0,189	Medium	Significant contribution
Knowledge Management → Project Success	0,120	Small	Limited contributions
Project Risk → Success Management	0,519	Large	Most powerful contribution

Source: SmartPLS 4 data processing results

Hypothesis testing was performed using *bootstrapping* (Figure 5). The results of direct influence are presented in Table 12 and indirect influence in Table 13.

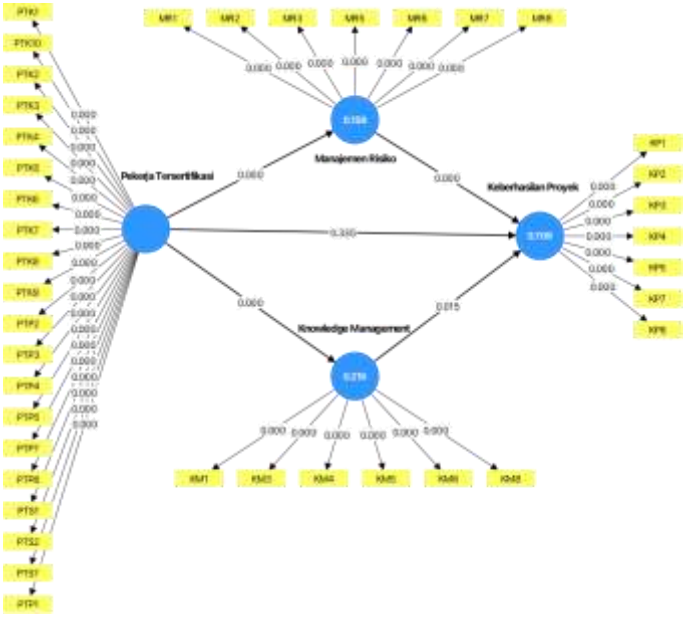


Figure 5. *SEM-PLS* Bootstrapping Result Model Output
Source: Research illustration supplied in the original manuscript.

Table 12. *Path Coefficient Bootstrapping Direct Effect Results*

H	Pathway	O	M	STDEV	T-stat	P	Ket.
H1	Certified Workers → Risk Management	0,399	0,426	0,111	3,584	0,000	Accepted
H2	Certified Worker → *Knowledge Management*	0,465	0,493	0,108	4,302	0,000	Accepted
H3	Certified Workers → Project Success	−0.038	−0.039	0,089	0,427	0,335	Rejected
H4	Project Risk → Success Management	0,605	0,613	0,116	5,207	0,000	Accepted
H5	*Knowledge Management* → Project Success	0,302	0,305	0,139	2,166	0,015	Accepted

Source: SmartPLS data processing results 4. O = original sample; M = sample mean; STDEV = standard deviation

Table 13. *Path Coefficient Bootstrapping Indirect Effect Results*

H	Pathway	O	M	STDEV	T-stat	P	VAF; Ket.
H6	Certified Worker → Risk Management → Project Success	0,241	0,262	0,088	2,751	0,003	118,72%; Accepted
H7	Certified Worker → *Knowledge Management* → Project Success	0,140	0,152	0,081	1,739	0,041	137,25%; Accepted

Source: SmartPLS 4 data processing results

Based on Table 12, H1, H2, H4, and H5 were accepted, while H3 was rejected because the direct influence of certified workers on the success of the project was not significant (T-statistic 0.427 < 1.96; p-value 0.335 > 0.05). Based on Table 13, the indirect influence through risk management (T-statistic 2.751 > 1.645; p-value 0.003) and through *knowledge management* (T-statistic 1.739 > 1.645; p-value 0.041) was significant, so H6 and H7 were accepted. The VAF

values of 118.72% (0.241/0.203) and 137.25% (0.140/0.102) exceeded 100% because the direct influence was negative and insignificant, so the VAF was used as supporting information and was not mechanically interpreted. Because the direct influence was not significant while the indirect influence was significant, risk management and *knowledge management* acted as *full mediators*.

The relationship between certified workers, risk management, *knowledge management*, and project success. Certified workers have a positive and significant effect on risk management (coefficient of 0.399). This relationship can be explained through the indicator with *the highest outer loading*, namely PTK8 (0.872) in the form of *problem solving* ability in providing technical solutions when there is a mismatch between plans and field conditions. This ability helps identify problems early and determine the necessary actions. Risk risk and impact assessments are important because certain risks can have a major impact on cost and time performance (Won et al., 2024), while risk management is related to controlling delays, cost overruns, quality degradation, and occupational safety issues (Al-Balawneh & Tarabieh, 2024).

Certified workers also had a positive and significant effect on *knowledge management* with a coefficient of 0.465, stronger than its relationship with risk management. Field problem-solving skills (PTK8) allow workers to acquire practical knowledge which is then managed through the KM3 indicator (0.802), namely recording obstacles and field solutions into *lessons* learned. Knowledge management processes and technologies have a significant relationship with project performance, with skilled labor, learning from experience, communication, and feedback as important factors (Abdulrahman et al., 2022). Knowledge gained from project experience can be reused to support decision-making and performance improvement on subsequent work (Zhang et al., 2024).

Certified workers had no direct significant effect on the success of the project in the complete model (coefficient −0.038; $p = 0.335$). The direction of the negative coefficient could not be interpreted as a negative influence because it was insignificant. In the model without mediation, the effect was positive and significant (0.405; $p = 0.000$), in line with the finding that labor skills play a role in the achievement of project performance (Hussain et al., 2020). The decrease in the coefficient after the mediator was inserted met the full mediation criteria, so that the influence of the competency of certified workers was channeled through risk management and *knowledge management*. These findings are consistent with studies showing that professional certifications do not always directly determine project success because project achievement is also related to team capabilities and problem-solving (Padilla & Pino, 2021), and that project management certifications do not have a significant direct effect on project performance (Farashah et al., 2019). This mediation mechanism is supported by research showing that risk management and *knowledge management* contribute to project success through mediation roles (Al-Balawneh & Tarabieh, 2024; Kallow et al., 2023).

Risk management is the most dominant factor for project success with a coefficient of 0.605 and f^2 0.519 (large effect). This dominance can be attributed to the MR8 indicator (0.833), which is the documentation of risk events and the effectiveness of their handling, as well as the highest project success indicator KP5 (0.826), which is project stability or minimal disruption due to risk. When risk, handling actions, and response effectiveness are documented, the project team can recognize problem patterns and determine actions in the next condition, thus helping to anticipate delays, reduce the cost consequences of rework, maintain quality, and reduce the potential for work

accidents. Integration and communication between project parties also play a role in improving the implementation of risk management (Song et al., 2025).

Knowledge management also has a positive and significant effect on project success with a coefficient of 0.302, lower than risk management. Recording *lessons learned* (KM3) provides benefits when the information is reused; for example, method errors that cause rework can be recorded as causes, solutions, and preventive measures as a reference for the preparation of subsequent methods. The application of knowledge from previous projects to ongoing projects has been shown to improve the time performance of construction projects (Gyimah et al., 2023), and project knowledge management supports knowledge-based decision-making for improved construction performance (Zhang et al., 2024).

The role of certified workers through risk management mediation. Risk management acts as a full mediator in the relationship between certified workers and project success (coefficient 0.241; p = 0.003). These findings are in line with research showing that risk management capabilities mediate in full the relationship between supply chain management effectiveness and performance (Ghosh & Sar, 2022), that risk management is a connecting variable between project management methodology and construction project success (Javaid et al., 2022), as well as that risk mitigation mediates the relationship between top management support and construction project performance (Astana et al., 2024). The added value of this study lies in the placement of certified workers as an initial factor that drives the risk management process; certification is not only seen as evidence of competency 450ulfilment, but as a capacity that translates into project risk identification, assessment, mitigation, and control.

The role of certified workers through *knowledge management mediation*. *Knowledge management* also plays a role as a full mediator (coefficient 0.140; p = 0.041). The role of *knowledge management* mediation in linking human resource input to the success of construction projects is also found in other contexts (Al-Balawneh & Tarabieh, 2024; Abdulrahman et al., 2022). These findings are also in line with research showing that staff performance mediates in a full relationship between the performance of subprofessional staff and the success of road supervision projects (Amir et al., 2025), which gives the impression that the contribution of human resources to the success of projects can take place through intermediary mechanisms. Thus, the benefits of certification do not stop at individual capabilities, but develop into organizational benefits when the knowledge and experience of the workforce are documented, shared, and reused in solving project problems.

CONCLUSION

This study concluded that certified construction workers were positively and significantly associated with risk management and knowledge management practices in building construction projects in Badung Regency. Although certified workers demonstrated a statistically significant positive relationship with project success in the model without mediating variables, their direct relationship became statistically nonsignificant after risk management and knowledge management were incorporated into the structural model. Both mediating variables exhibited positive relationships with project success, with risk management demonstrating the stronger association. The findings supported a statistically significant indirect relationship through risk management, while the significance of the indirect relationship through knowledge management depended on the justification of the reported one-tailed hypothesis test. These results suggested

that workforce certification was associated with improved project outcomes primarily when professional competencies were translated into systematic risk identification, assessment, mitigation, and monitoring, alongside effective knowledge documentation, sharing, and application. Construction company managers were therefore encouraged to complement competency certification with practical training in risk assessment, problem-solving, incident documentation, and structured lessons learned processes. Professional certification bodies and government agencies responsible for construction services were also encouraged to promote the integration of workforce certification with standardized risk management and organizational knowledge management systems through appropriate policies and institutional support. Future research should examine additional organizational factors, including top management support, organizational culture, and project leadership, while expanding the geographical coverage, project categories, and sample sizes. Longitudinal and qualitative approaches were also recommended to provide a deeper understanding of the mechanisms linking certified workforce competencies, risk management, knowledge management, and construction project success.

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CONFLICT OF INTEREST

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AUTHOR'S CONTRIBUTION

Ni Putu Anggita Putri Bali Sinarta contributes to research design, data collection and processing, system development, result analysis, and article manuscript preparation.

GENERATIVE ARTIFICIAL INTELLIGENCE USAGE STATEMENT

In the process of compiling this article, the author uses generative artificial intelligence (AI) as a tool in language refinement, writing structure, and grammar improvement. The use of AI is carried out on a limited basis and remains under the supervision of the author. All data, analysis, interpretation, and scientific substance in this article have been checked and verified by the author. The author is solely responsible for the accuracy, authenticity, and final content of the manuscript.

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