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Modeling the Relationship of Construction Safety Plan and Work Breakdown Structures with Protecting Property Safety of Precast Heritage Buildings

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ABSTRACT

The rapid urbanization of cities has increased the demand for multi-functional infrastructures, often leading to modifications of heritage buildings. The construction of parking structures atop these buildings, while addressing urban parking shortages, poses significant risks to their structural integrity. This study focuses on protecting the safety of precast heritage buildings during such construction projects by integrating a Construction Safety Plan (CSP) with a Work Breakdown Structure (WBS). By combining safety protocols and project management tools, the research introduces a comprehensive model aimed at minimizing the risks associated with construction-induced damages. The study employs a combination of archive analysis, surveys, and case studies, validated through expert consensus using the Delphi method. Results from multiple regression analysis indicate a significant positive relationship between CSP (X1), WBS (X2), and the protection of heritage building properties (Y). The findings suggest that implementing these models significantly enhances the safety of heritage properties, underlining the importance of systematic safety planning and construction management for preserving cultural heritage. Future research should explore the application of this model to various construction projects to further improve heritage preservation strategies.

Keywords: Construction Safety Plan, Work Breakdown Structure, Precast Heritage Building, Property Safety, Risk Management.

INTRODUCTION

In today's rapidly urbanizing world, the demand for multi-functional infrastructures has surged dramatically (Breuste & Artmann, 2020). Globally, cities are striving to balance modern development with the conservation of historically and culturally significant structures (Kong, 2017; Labadi & Logan, 2015; Rodwell, 2018; Serageldin et al., 2011). Heritage buildings, often revered for their architectural beauty and historical narratives, are increasingly pressured by urban expansion and the need for ancillary facilities such as parking structures (Bandarin & Van Oers, 2014). This global trend has not only led to innovative adaptive reuse projects but has also exposed these precious structures to unprecedented risks during construction phases (Hadwiansyah & Latief, 2022). Construction activities worldwide have repeatedly demonstrated that vibrational forces, unplanned structural changes, and environmental disturbances can compromise the integrity of heritage properties. As metropolitan areas continue to grow, the integration of modern amenities within or atop heritage structures is becoming a common yet complex engineering challenge (Barnett, 2020). Maintaining the balance between preserving cultural heritage and accommodating contemporary urban needs is imperative—not only to protect our past but also to ensure a sustainable future where innovation does not come at the cost of history (Hadwiansyah & Latief, 2022; Rudolf-Miklau et al., 2014).

Focusing on precast heritage buildings, the challenges are even more pronounced. These buildings, constructed using modern prefabrication methods while retaining historical value, demand special attention during any modification or addition (Lu et al., 2018). The specific problem arises when parking structures are proposed on top of such buildings—a solution that, while addressing urban parking shortages, risks inducing vibrations and structural alterations that could irreparably damage the original heritage fabric (Yavartanoo & Kang, 2022). In these cases, even slight miscalculations in construction activities can lead to long-term degradation of the building's physical integrity (Das et al., 2024; van Heerden, 2018). The inherent conflict between the heavy loads of modern infrastructure and the delicate nature of historic constructions necessitates a rigorous safety approach. Without a robust framework that anticipates and mitigates these risks, the potential for property damage increases, thereby threatening the preservation of cultural and architectural legacies (Fakrunnisa et al., 2023; Kaur et al., 2024; Roca et al., 2019). It is against this backdrop that the integration of a construction safety plan (CSP) with a work breakdown structure (WBS) becomes a critical component in ensuring that construction activities do not compromise the safety and longevity of these heritage assets.

The increasing demand for parking facilities often necessitates the construction of parking structures on top of heritage buildings that have high historical and architectural value. However, the construction process presents major challenges in maintaining the safety of heritage building properties, especially due to the nature of construction that often results in vibration, structural changes, or other environmental impacts that can damage heritage buildings. In this context, the implementation of a construction safety plan (CSP) integrated with the work breakdown structure (WBS) is crucial to protect the properties of precast heritage buildings (Doukari et al., 2022).

A review of the existing literature indicates a growing interest in safeguarding heritage structures during construction interventions. For instance, research by (Soleymani et al., 2023) examined the effects of vibrational forces on heritage buildings during urban development projects, highlighting that even minimal construction impacts could lead to significant deterioration over time. Similarly, (Kerzner, 2025) focused on the integration of safety protocols within construction planning, arguing that a systematic approach using work breakdown structures significantly enhances the predictability and management of potential risks. More recently, (Miran & Husein, 2023) proposed a framework that merged modern construction safety standards with heritage preservation strategies, emphasizing the need for models that are both comprehensive and adaptable to the complex demands of heritage structures. These studies collectively underscore the importance of adopting an integrated approach that not only anticipates construction-induced risks but also tailors safety measures to the unique characteristics of heritage buildings. Despite these valuable contributions, there remains a gap in the literature regarding the specific integration of a Construction Safety Plan with Work Breakdown Structures as a unified model—especially in the context of precast heritage buildings subjected to additional loads from parking structure development.

The urgency of this research is driven by the pressures of urban expansion and cultural heritage preservation, especially as limited parking space in cities leads developers to modify heritage buildings. Without proper safety planning, such projects risk irreversible damage to these historically significant structures. This study proposes a model that connects construction safety planning with work breakdown structures, ensuring each construction phase considers its impact on heritage properties.

The novelty of this research lies in its integrative approach, combining construction safety and heritage preservation. Unlike previous studies, this study systematically links the safety plan with work breakdown structures for precast heritage buildings, offering a proactive model for project managers and engineers. This fresh perspective enhances understanding of safety planning and construction scheduling, contributing to sustainable development without sacrificing cultural heritage.

This study aims to develop a model that explains the relationship between construction safety plans and work breakdown structures to protect precast heritage buildings. The research offers valuable guidelines for engineers, project managers, and policymakers, reducing the risk of property damage while preserving historical value. Additionally, it bridges the gap between construction management and cultural heritage conservation, encouraging improved risk management strategies and inspiring future research on similar integrative approaches.

METHOD

The research method in this study can be seen in Figure 1. as follows

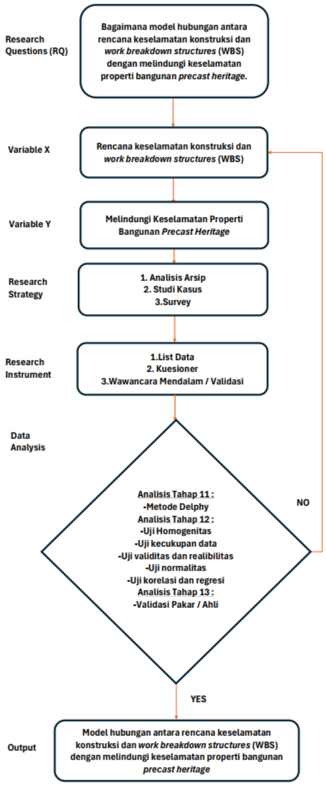


Figure 1. Flowchart of Research Methods

Source: Author's Report, 2024

This research approach combines archive analysis, surveys, and case studies. This combination of methods was chosen so that theoretical data from the literature could be integrated with expert perceptions and field insights, resulting in a comprehensive relationship model between construction safety plans, work breakdown structures (WBS), and the protection of precast heritage building properties.

Data Collection Strategies and Instruments

a. Archive Analysis: Review of journals, books, and related references to identify key indicators of the variables under study.
b. Survey (Questionnaire): The questionnaire was distributed to 100 expert respondents in the fields of construction, safety, and project management. Respondents were selected purposively with the criteria of at least 5 years of relevant experience and expertise. The questionnaire collected data on assessments, perceptions, and experiences related to the integration of WBS and safety plans.
c. Case Studies & In-Depth Interviews: Case studies were selected based on their relevance to the protection of heritage building properties, the representativeness of project types, and the availability of data. In-depth interviews were conducted with selected experts to obtain qualitative information to support and validate the survey data.

Implementation of the Delphi Method

To reach consensus on the variable indicators, the Delphi method was carried out in two rounds of iteration. A panel of 10 experts, selected based on their expertise in the fields of construction, safety, and heritage conservation, was asked to assess and provide feedback repeatedly until an agreement was reached (with a certain tolerance for differences).

Data Analysis and Statistical Tests

In the analysis, several tests are applied to ensure the robustness of the data and the validity of the findings. The homogeneity test is conducted using the Kruskal-Wallis method in SPSS version 27 to assess differences in respondent perceptions based on categories such as position, agency, education, and experience. To confirm the adequacy of the data for further analysis, the data adequacy test formula is applied. Validity is measured through product moment correlation, while reliability is tested using Cronbach's Alpha, with a value greater than 0.60 considered adequate. The normality of the data is checked using the One-Sample Kolmogorov-Smirnov test to ensure the residuals of the regression model are normally distributed. A correlation test is performed using the Pearson test (or Spearman test if the data is not normal) to measure the strength and direction of relationships between variables, based on correlation strength criteria like those proposed by Guilford. Finally, multiple regression analysis is conducted using SPSS version 27 to quantitatively determine the effect of independent variables on the dependent variable.

Model Validation

The results of the analysis are re-tested through discussions with experts to ensure that the resulting relationship model is in accordance with real field conditions and has broad applicability.

RESULT AND DISCUSSION

Stage 1 Data Analysis

In stage 1 data analysis is carried out by looking at the answers of the appointed experts whether they agree or disagree with the variables and variable indicators that have an influence on protecting the safety of heritage precast building properties. Of the five experts appointed, four of them have had experience related to heritage buildings.

The following are variables and variable indicators that will be validated and analyzed using the delphi method.

Table 1. Variables and Indicators of Variables X1, X2 and Y

Code	Variables	Code	Variable Indicator	Reference
(1)	(2)	(3)	(4)	(5)
X.1	**Construction Safety Plan**	**X.1.1**	**Workforce leadership and participation in construction safety**	

	X.1.1.1	Leaders' Concern for External and Internal Issues	PERMEN PUPR NO.10 of 2021
	X.1.1.2	SMKK Management Organization	PERMEN PUPR NO.10 of 2021
	X.1.1.3	Construction Safety Commitment and Workforce Participation	PERMEN PUPR NO.10 of 2021
	X.1.1.4	Supervision, Training, Accountability, Resources and Support	PERMEN PUPR NO.10 of 2021
	X.1.2	**Perencanaan keselamatan konstruksi**	
	X.1.2.1	Hazard Identification, Risk Assessment, Control and Opportunity (IBRP)	PERMEN PUPR NO.10 of 2021
	X.1.2.2	Management, engineering, and manpower action plans set out in goals and programs.	PERMEN PUPR NO.10 of 2021
	X.1.2.3	Fulfillment of Construction Safety standards and regulations	PERMEN PUPR NO.10 of 2021
	X.1.3	**Construction Safety Support**	
	X.1.3.1	Resources in the form of Technology, Equipment, Materials, and Costs	PERMEN PUPR NO.10 of 2021
	X.1.3.2	Workforce Competency	PERMEN PUPR NO.10 of 2021
	X.1.3.3	Organizational Care	PERMEN PUPR NO.10 of 2021
	X.1.3.4	Communication Management	PERMEN PUPR NO.10 of 2021
	X.1.3.5	Documented Information	PERMEN PUPR NO.10 of 2021
	X.1.4	**Construction Safety Operations**	
	X.1.4.1	Construction Safety Plan (CSP) Implementation Planning	PERMEN PUPR NO.10 of 2021
	X.1.4.2	Construction Safety Operation Control	PERMEN PUPR NO.10 of 2021
	X.1.4.3	Emergency Preparedness and Response	PERMEN PUPR NO.10 of 2021
	X.1.4.4	Construction Accident Investigation	PERMEN PUPR NO.10 of 2021
	X.1.5	**Performance Evaluation of SMKK (Construction Safety Management System) Implementation**	
	X.1.5.1	Monitoring or Inspection	PERMEN PUPR NO.10 of 2021
	X.1.5.2	Audit	PERMEN PUPR NO.10 of 2021

		X.1.5.3	Evaluation	PERMEN PUPR NO.10 of 2021
		X.1.5.4	Management Overview	PERMEN PUPR NO.10 of 2021
		X.1.5.5	Improved Construction Safety Performance	PERMEN PUPR NO.10 of 2021
X.2	**Work Breakdown Structure (WBS)**	**X.2.1**	**Work Breakdown Structure (WBS) Concept**	
		X.2.1.1	Division of work into smaller, manageable sub-components	Kerzner, H. (2020)
		X.2.1.2	Structure the WBS based on outputs to be achieved, not on activities or tasks.	PMI (Project Management Institute). (2021)
		X.2.1.3	Further development and decomposition of the WBS during the project	Walker, A. (2022)
		X.2.2	**Scope of Work Breakdown Structure (WBS)**	
		X.2.2.1	All work required to complete the project must be included in the WBS	Lewis, J.P. (2019)
		X.2.2.2	Identify the lowest level in the WBS where budget, time, and responsibility are assigned	Heagney, J. (2022)
		X.2.2.3	Stakeholder engagement in defining the scope of work to ensure all need and expectations are covered	Larson, E. W., & Gray, C.F. (2021)
		X.2.3	**Quality of Work Breakdown Structure (WBS)**	
		X.2.3.1	Ability to trace each component in the WBS to project objectives and stakeholder needs	Turner, R. (2019)
		X.2.3.2	Adherence to industry standards and best practices in the preparation of the WBS	Meredith, J. R., & Mantel, S. J. (2020)
		X.2.3.3	The WBS must be clear enough to be understood by all project team members.	Zwikael, O., & Smyrk, J. (2019)
Y	**Protecting the Property Safety of Precast Heritage Buildings**	**Y.1**	**Evaluation and monitoring of building structures to ensure integrity during and after construction**	
		Y.1.1	Frequency and Consistency of Structural Evaluation	Mezzina, M., & Russo, S. (2020)
		Y.1.2	Use of Real-Time Monitoring Technology	Gomes, G., & Araujo, M. (2018)
		Y.1.3	Environmental Impact Evaluation of Structures	Rodriguez, J., & Martinez, M. (2017)
		Y.1.4	Post-Construction Monitoring	Croci, G. (2018)

Y.1.5	Structure Safety Audit	Smith, P., & Sinha, S. (2021
Y.2	**Measurement and management of vibration and environmental impacts of construction activities on heritage buildings**	
Y.2.1	Vibration Monitoring	Azzara, R. M., & Mariani, S. (2019)
Y.2.2	Environmental Impact Management	Martinez, F., & Garcia, E. (2018)
Y.3	**Implementation of special protection procedures during construction activities to minimize damage to heritage buildings**	
Y.3.1	Use of Barricades and Covers	Young, C., & MacLeod, S. (2020)
Y.3.2	Implementation of Safe Work Procedures	Mazzoldi, M., & Bocciarelli, M. (2017)
Y.4	**Selection of construction materials that do not damage or change the original characteristics of heritage buildings**	
Y.4.1	Appropriate Material Selection	Torres, M., & Leon, J. (2016)
Y.4.2	Use of Heritage House Materials	Garcia, A., & Blanco, J. (2018)
Y.5	**Involvement of conservation experts in the planning and implementation of construction projects to protect heritage buildings**	
Y.5.1	Consultation with Conservation Experts	Pereira, L., & Da Silva, P. (2020)
Y.5.2	Collaboration with the Construction Team	Micallef, R., & Sammut, C. (2019)
Y.6	**Implementation of a monitoring system to monitor in real-time the condition of heritage buildings during the project**	
Y.6.1	Implementation of Continuous Monitoring System	Balzani, M., & Binda, L. (2021)
Y.6.2	Rapid Response to Structural Anomalies	De Stefano, A., & Ceravolo, R. (2020)
Y.7	**Development and implementation of specialized risk management plans to protect heritage buildings from potential damage during construction projects**	
Y.7.1	Development of Risk Management Plan	Smyth, H., & Walker, D. (2017)
Y.7.2	Periodic Risk Evaluation	Khan, M., & Shah, S. (2019)

Source: Author's Process, 2024

The experts agreed that all variables and variable indicators have an effect on protecting the property safety of precast heritage buildings. Thus, the consensus conducted using the delphi method among the experts stated that all variables and variable indicators have an effect on protecting the property safety of precast heritage buildings.

Phase 2 Data Analysis

After validating the variables with experts, the next step is to conduct a pilot survey to test the extent to which prospective respondents can understand and deal with the questions in the questionnaire. If respondents in the pilot survey have difficulty understanding the questions, improvements will be made to the questionnaire to make it easier to understand. Details can be seen in the appendix to this report. This questionnaire was distributed to 10 respondents according to the existing criteria. Based on the results of the pilot survey, it was found that the questionnaire was easy to understand so that it was continued with the next stage, namely a survey of respondents to provide an assessment of these variables and indicators.

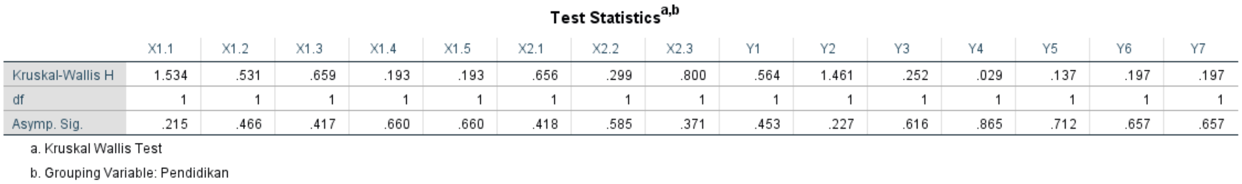
Stage 3 Data Analysis

The respondent survey was conducted to assess how influential the indicators were on protecting the safety of precast heritage building properties as measured by a Likert scale. With the provisions of scale 1 (very little influence) to scale 5 (very much influence). The respondent survey was distributed to 35 people who have experience in projects related to heritage buildings in their neighborhood. Based on the data collected through questionnaires from respondents, a number of tests were then conducted as follows:

Homogeneity Test

The homogeneity test aims to determine whether there are differences in perceptions among respondents based on categories such as agency, education, position, and experience. To conduct this homogeneity test, SPSS version 27 was used with the Kruskal-Wallis non-parametric method.

Table 2. Kruskall Wallis Test Results Educational Background of Respondents



Test Statistics[a,b]

	X1.1	X1.2	X1.3	X1.4	X1.5	X2.1	X2.2	X2.3	Y1	Y2	Y3	Y4	Y5	Y6	Y7
Kruskal-Wallis H	1.534	.531	.659	.193	.193	.656	.299	.800	.564	1.461	.252	.029	.137	.197	.197
df	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Asymp. Sig.	.215	.466	.417	.660	.660	.418	.585	.371	.453	.227	.616	.865	.712	.657	.657

a. Kruskal Wallis Test

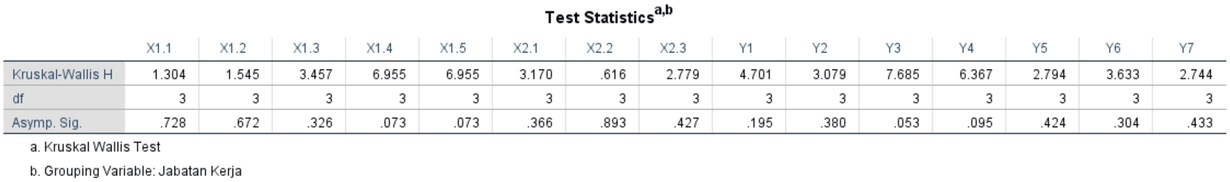
b. Grouping Variable: Pendidikan

Source: Author's Process (2024)

Based on the results of data processing and testing through SPSS in the table above, all Asym. Sig> 0.05 (level of significance). This indicates that there is no difference in understanding between respondents who have different educational backgrounds on the questionnaire.

The following are the results of processing and testing homogeneity using SPSS version 27 software, which aims to analyze the similarity of perceptions based on the respondent's job title.

Table 3. Kruskall Wallis Test Results Respondents' Work Position Backgrounds



Test Statistics[a,b]

	X1.1	X1.2	X1.3	X1.4	X1.5	X2.1	X2.2	X2.3	Y1	Y2	Y3	Y4	Y5	Y6	Y7
Kruskal-Wallis H	1.304	1.545	3.457	6.955	6.955	3.170	.616	2.779	4.701	3.079	7.685	6.367	2.794	3.633	2.744
df	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Asymp. Sig.	.728	.672	.326	.073	.073	.366	.893	.427	.195	.380	.053	.095	.424	.304	.433

a. Kruskal Wallis Test

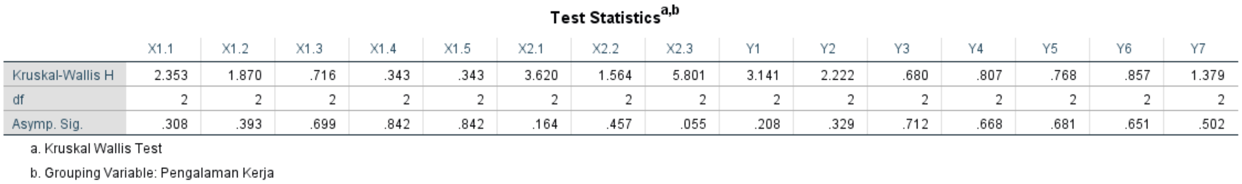
b. Grouping Variable: Jabatan Kerja

Source: Author's Process (2024)

Based on the results of data processing and testing through SPSS in the table above, all Asym. Sig> 0.05 (level of significance). This indicates that there is no difference in understanding between respondents of different positions on the questionnaire.

The following are the results of processing and testing homogeneity using SPSS version 27 software, which aims to analyze the similarity of perceptions based on the work experience of respondents.

Table 4. Kruskall Wallis Test Results Respondents' Work Experience Backgrounds



Test Statistics[a,b]

	X1.1	X1.2	X1.3	X1.4	X1.5	X2.1	X2.2	X2.3	Y1	Y2	Y3	Y4	Y5	Y6	Y7
Kruskal-Wallis H	2.353	1.870	.716	.343	.343	3.620	1.564	5.801	3.141	2.222	.680	.807	.768	.857	1.379
df	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Asymp. Sig.	.308	.393	.699	.842	.842	.164	.457	.055	.208	.329	.712	.668	.681	.651	.502

a. Kruskal Wallis Test

b. Grouping Variable: Pengalaman Kerja

Source: Author's Process (2024)

Based on the results of data processing and testing through SPSS in the table above, all Asym. Sig> 0.05 (level of significance). This indicates that there is no difference in understanding between respondents with different work experience on the questionnaire.

Data Sufficiency Test

The following are the results of the calculation of the data sufficiency test in the study

Table 5. Tabulation of Data Sufficiency Calculation

N	Sum_X1	Sum_X2	Sum_Y	SUM X1-SUM Y	(SUM X1-SUM Y)^2
				∑ Xi	∑ Xi^2
1	24	15	31	39	1521
2	24	15	32	39	1521
3	24	15	32	39	1521
4	24	14	30	38	1444
5	25	15	34	40	1600
6	24	15	33	39	1521
7	23	14	29	37	1369

N	Sum_X1	Sum_X2	Sum_Y	SUM X1-SUM Y	(SUM X1-SUM Y)^2
				$\sum X_i$	$\sum X_i^2$
8	22	15	28	37	1369
9	24	10	28	34	1156
10	24	14	30	38	1444
11	23	13	28	36	1296
12	24	15	31	39	1521
13	24	13	33	37	1369
14	25	15	34	40	1600
15	25	15	32	40	1600
16	25	15	31	40	1600
17	25	15	31	40	1600
18	24	14	28	38	1444
19	22	13	28	35	1225
20	24	14	30	38	1444
21	19	12	25	31	961
22	25	15	34	40	1600
23	24	15	31	39	1521
24	24	14	31	38	1444
25	24	14	32	38	1444
26	22	13	30	35	1225
27	25	15	34	40	1600
28	24	15	31	39	1521
29	24	14	31	38	1444
30	25	15	34	40	1600
31	24	14	28	38	1444
32	24	15	32	39	1521
33	25	15	34	40	1600
34	25	15	34	40	1600
35	25	15	33	40	1600
	Total			**1338**	**51290**

Source: Author's Process (2024)

Unknown:

N = 35

K = 2

S = 5%

Then:

$$N' = \left(\frac{\frac{2}{0{,}05} \sqrt{35\ (51290) - (1338)}}{1338} \right)^2$$

N' = 4.384654 < N (35), it can be concluded that the observations fulfill the conditions

Reliability Test

The following are the results of the reliability test on the respondent's questionnaire which was analyzed with the help of the SPSS version 27 application.

Table 6. Reliability Test Results

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.707	.779	5

Source: Author's Process (2024)

In the table above, it can be seen that the Cronbach's alpha value is 0.707, so it can be concluded that the questionnaire tested is reliable because the Cronbach's alpha value is greater than 0.6 and the reliability level of this study is reliable because the Cronbach's alpha value is between> 0.60 to 0.80.

Validity Test

In this study, the r table is seen at the 95% confidence level or 5% significance for a 2-sided test with 35 respondents, so it has an r table worth 0.334.The following are the results of the validity test on 10 research risk variables.

Table 7. Questionnaire Validity Test Results

Item-Total Statistics					
	Scale Mean if Item Deleted	**Scale Variance if Item Deleted**	**Corrected Item-Total Correlation**	**Cronbach's Alpha if Item Deleted**	**Conclusion**
X.1.1	66,71	19,857	0,829	0,946	Valid
X.1.2	65,63	21,299	0,575	0,951	Valid
X.1.3	65,71	19,857	0,829	0,946	Valid
X.1.4	65,71	19,857	0,829	0,946	Valid
X.1.5	65,71	19,857	0,829	0,946	Valid
X.2.1	65,71	19,857	0,829	0,946	Valid
X.2.2	65,83	19,087	0,857	0,945	Valid
X.2.3	65,86	19,538	0,705	0,949	Valid
Y.1.1	65,97	19,087	0,753	0,948	Valid
Y.1.2	66,03	19,029	0,753	0,948	Valid
Y.1.3	65,69	20,810	0,574	0,951	Valid
Y.1.4	65,83	20,499	0,475	0,954	Valid

Y.1.5	65,83	19,323	0,792	0,947	Valid
Y.1.6	65,89	19,398	0,719	0,948	Valid
Y.1.7	65,89	19,045	0,812	0,946	Valid

Source: Author's Process (2024)

By comparing the total correlation value obtained from SPSS processing results> from r table (0.334), it can be concluded that all variables are valid.

Correlation Test

Pearson Correlation

Based on the results of the analysis, it can be seen for the Construction Safety Plan variable (X1) that the Sig. (2-tailed) of 0.000 <0.05. So it can be interpreted that there is a significant relationship or correlation between the X1 variable and the Precast Heritage Building Property Safety variable (Y), with a Pearson correlation coefficient of 0.786, which shows a strong relationship. Furthermore, for the Work Breakdown Structures (X2) variable, the Sig. (2-tailed) of 0.000 <0.05. This means that there is a significant relationship or correlation between the X2 variable and the Y variable, with a Pearson correlation coefficient of 0.636, which also shows a strong relationship but is slightly lower than the relationship between X1 and Y. From this analysis, it can be concluded that the X1 and X2 variables are significantly correlated with Y. In addition, the relationship between variables that is positive with an average value above 0.50 indicates that the relationship between variables is quite close to each other.

Table 8. Pearson Correlation Test Results

Correlations

		Construction Safety Plan (X1)	**Work Breakdown Structures (X2)**	**Heritage Precast Building Property Safety (Y)**
Construction Safety Plan (X1)	Pearson Correlation	1	$.555^{**}$	$.786^{**}$
	Sig. (2-tailed)		.001	.000
	N	35	35	35
Work Breakdown Structures (X2)	Pearson Correlation	$.555^{**}$	1	$.636^{**}$
	Sig. (2-tailed)	.001		.000
	N	35	35	35
Heritage Precast Building Property Safety (Y)	Pearson Correlation	$.786^{**}$	$.636^{**}$	1
	Sig. (2-tailed)	.000	.000	
	N	35	35	35

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Author's Process (2024)

Spearman Correlation

Based on the results of correlation analysis using Spearman's rho, there is a strong positive correlation between Construction Safety Plan (X1) and Work Breakdown Structures (X2) with a correlation coefficient of 0.651 ($p < 0.01$), indicating that an increase in X1 is followed by an increase in X2. In addition, the relationship between X1 and Precast Heritage Building Property Safety (Y) is also significant, with a correlation coefficient of 0.779 ($p < 0.01$), indicating that the higher the value of X1, the higher the value of Y. The relationship between Work Breakdown Structures (X2) and Y also shows a significant positive correlation, with a coefficient of 0.669 ($p < 0.01$), indicating that an increase in X2 is associated with an increase in Y. Overall, these results indicate a strong and significant relationship between variables X1 and X2 to Y. From the table above, it can be seen that the relationship between variables is positive with an average value above 0.60, which indicates that the relationship between variables has a strong relationship with each other.

Table 9: Spearman Correlation Test Results

Correlations

			Construction Safety Plan (X1)	**Work Breakdown Structures (X2)**	**Heritage Precast Building Property Safety (Y)**
Spearman's rho	Construction Safety Plan (X1)	Correlation Coefficient	1.000	.651**	.779**
		Sig. (2-tailed)	.	.000	.000
		N	35	35	35
	Work Breakdown Structures (X2)	Correlation Coefficient	.651**	1.000	.669**
		Sig. (2-tailed)	.000	.	.000
		N	35	35	35
	Heritage Precast Building Property Safety (Y)	Correlation Coefficient	.779**	.669**	1.000
		Sig. (2-tailed)	.000	.000	.
		N	35	35	35

**. Correlation is significant at the 0.01 level (2-tailed).

Source: Author's Process (2024)

Normality Test

The results of the normality test in the study are shown in the table below:

Table 10. Residual value resultsOne-Sample Kolmogorov-Smirnov Test SPSS

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		35
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	1.30185225
Most Extreme Differences	Absolute	.120
	Positive	.102
	Negative	-.120
Test Statistic		.120
Asymp. Sig. (2-tailed)		.200[c,d]
a. Test distribution is Normal.		
b. Calculated from data.		
c. Lilliefors Significance Correction.		
d. This is a lower bound of the true significance.		

Source: Author's Process (2024)

Based on the one sample kolmogorov-smirnov test table, it can be seen that the normality test for the data above shows that the multiple regression model created has followed a normal distribution. This can be seen from the Asym sig value (2 Tailed) of 0.200> 0.05, thus it can be concluded that the data used in this study is normally distributed data.

Regression Analysis

Table 11. Model Summary Results

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.822[a]	.676	.656	1.34192
a. Predictors: (Constant), Work Breakdown Structures (X2), Construction Safety Plan (X1)				
b. Dependent Variable: Heritage Precast Building Property Safety (Y)				

Source: Author's Process (2024)

From the results of the regression analysis, it is known that there is an R square value, which is a value that shows how much the independent variable (exogenous) affects the dependent variable (endogenous). R squared is a number that ranges from 0 to 1 which indicates how much the combination of independent variables together affects the value of the dependent variable. The R-squared (R2) value is used to assess how much influence a particular independent latent variable has on the dependent latent variable. There are three categories of grouping on the R square value, namely the strong category, the moderate category, and the weak category (Hair et al., 2011). Hair et al. state that the R square value of 0.75 is included in the strong category, the R square value of 0.50 is in the moderate category and the R square value of 0.25 is in the weak category (Hair et al., 2011).

Based on the "Model Summary" output value above, the R Square value is 0.676. This value comes from squaring the correlation coefficient (R), which is 0.822 x 0.822 = 0.676. It is known that the coefficient of determination is 0.676 or 67.6%. This means that the variables X1 and X2 affect the variable (Y) by 67.6%. While the rest is influenced by other variables outside this regression equation.

Table 12. Coefficients Results

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	**Std. Error**	**Beta**	**t**	**Sig.**
1	(Constant)	-5.018	4.471		-1.122	.270
	Construction Safety Plan (X1)	1.150	.222	.626	5.177	.000
	Work Breakdown Structures (X2)	.600	.252	.289	2.386	.023

a. Dependent Variable: Heritage Precast Building Property Safety (Y)

Source: Author's Process (2024)

Based on the results of multiple regression analysis, the following model is obtained:

$$Y = -5.018 + (1.150)X1 + (0.600)X2$$

Stage 4 Data Analysis

Stage 4 data analysis was carried out with the final validation of the relationship model with experts. At this stage, discussions and validation were held again with 3 experts regarding the relationship model that had been analyzed. The following are the results of the recapitulation of the final validation of the construction safety plan relationship model with work breakdown structures by protecting the safety of the precast heritage building property.

Experts agree that the hypothesis of the relationship model is appropriate, but there are some notes in achieving the relationship model. The following is a recapitulation of validation results and expert comments regarding the relationship model between variables.

Table 13. Recapitulation of Expert Validation Results

No.	Hypothesis	Relationship between Variables	Value of t	Significance Value	Variable Relationship Based on Statistical Analysis Results
1	H1	Construction Safety Plan (X1) Affects *Work Breakdown Structures* (X2).	**0,882**	**0,000**	Positive and Significant Effect
2	H2	Construction Safety Plan (X1) Affects Property Safety of *Precast Heritage* Buildings (Y).	**5,177**	**0,000**	Positive and Significant Effect
3	H3	*Work Breakdown Structures* (X2) Affects the Safety of *Heritage Precast* Building Properties (Y).	**2,386**	**0,023**	Positive and Significant Effect

Source: Author's Process (2024)

Table 14. Expert Comments and Responses

No.		Expert Comment
1	H1	The Construction Safety Plan (CSP) affects the WBS significantly as safety needs to be integrated into the work structure to ensure risk mitigation at every stage of the project.
2	H2	A good RKK protects heritage property by implementing specific risk mitigation measures, such as vibration monitoring, environmental controls, and safe work procedures.
3	H3	A well-structured WBS ensures all safety measures are implemented, thus supporting the protection of heritage properties through organized and safe work management.

Source: Author's Process (2024)

Research Findings

This research aimed to determine the relationship model between variables, namely between construction safety plans (variable x1) with work breakdown structure (WBS) (variable x2) with protecting the safety of heritage precast building properties (variable y). In this stage, the author conducted archival analysis and literature studies from journals, research and references related to construction safety plans, work breakdown structures and protecting the safety of heritage building properties and also held discussions with a team of cultural heritage experts. Based on the process that has been carried out, the author compiles variables and variable indicators that have a close relationship with construction safety plans, work breakdown structures and protecting the safety of heritage building properties. Then a questionnaire was distributed to 35 respondents to provide an assessment of how much influence the variables and variable indicators have on protecting the safety of heritage precast building property. After obtaining data from distributing questionnaires to respondents, then statistical analysis is carried out to test the relationship model between the construction safety plan variable (variable x1) with the work breakdown structure (WBS) (variable x2) with protecting the safety of heritage precast building property (variable y).

Based on the results of multiple regression analysis, the following model is obtained:

$$Y = -5.018 + (1.150)X1 + (0.600)X2$$

The multiple linear regression analysis reveals that the constant value is -5.018, indicating that without a Construction Safety Plan (X1) and Work Breakdown Structures (X2), the safety of heritage buildings would be very poor. The regression coefficient for X1 is 1.150, showing a positive impact on safety, meaning that a 1-unit increase in X1 leads to a 1.150 increase in safety, assuming other variables are constant. Similarly, the coefficient for X2 is 0.600, indicating that a 1-unit increase in X2 results in a 0.600 increase in safety. Both variables X1 and X2 have significant t-values (5.177 for X1 and 2.386 for X2), with p-values less than 0.05, confirming their positive and statistically significant effect on the safety of heritage properties. In conclusion, the Construction Safety Plan and Work Breakdown Structures significantly enhance the safety of heritage buildings.

CONCLUSION

The conclusion of this study shows that the relationship between the construction safety plan (X1), the work breakdown structure (X2), and the protection of historic precast building property is positive and significant. The model equation $Y = -5.018 + (1.150) X1 + (0.600) X2$ shows that the protection of cultural heritage building property would be very poor without a construction safety plan and WBS. This underlines the important role played by X1 and X2 in ensuring the safety of cultural heritage property. This study highlights the importance of implementing comprehensive construction safety plans and structured work breakdown systems to protect historic building properties. Future research can explore the application of this model in various different construction projects, which has the potential to improve the safety standards of cultural heritage preservation efforts and contribute to the development of more effective strategies to protect historic buildings.

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