Design Change Factors in Hospital Design-Build Projects: Variable Validation and RII Analysis

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| Submitted: May 22, 2026 | Revised: June 01, 2026 | Accepted: August 29, 2026 |

| Published: October 26, 2026 |

ABSTRACT

Hospital construction projects in island regions face compounded challenges that differ fundamentally from urban settings. This study investigates design change factors in hospital construction under the Design and Build (D&B) contract scheme, with empirical reference to the Tafaeri Hospital project in Nias and the Tarempa Hospital project in Anambas. A two-phase research design was employed. Phase one involved a preliminary survey using expert judgment, where five construction professionals evaluated 20 candidate variables derived from a systematic literature review, using a five-point Likert scale. Seventeen variables met the relevance threshold (mean ≥ 3.0) and were retained. Phase two involved a main survey distributed to 157 practitioners to measure the relative significance of each validated variable. Data were analysed through Pearson validity testing, Cronbach Alpha reliability assessment, and Relative Importance Index (RII) scoring. All 17 variables demonstrated valid correlation coefficients ($r > 0.156$, $p = 0.000$) and the instrument achieved high reliability (Cronbach Alpha = 0.897). The three highest-ranked variables were site condition changes (RII = 0.775), natural disaster impacts (RII = 0.767), and MEP system and medical equipment integration issues (RII = 0.708). These findings confirm that geographic vulnerability and technical complexity are the dominant design change drivers in island-based hospital D&B projects, and provide a validated empirical foundation for risk mitigation strategies in similar settings.

Keywords: design and build; design changes; hospital construction; Relative Importance Index; project delay

INTRODUCTION

The Indonesian government has committed to accelerating hospital infrastructure construction as a pillar of the national health system transformation roadmap running through 2027 [4]. This commitment aligns with two Sustainable Development Goals (SDGs): Goal 3 (Good Health and Well-being) and Goal 9 (Industry, Innovation and Infrastructure) [19]. In archipelagic territories such as the Nias and Anambas island groups, realising these targets demands navigating a complex intersection of logistical constraints, limited access, and regulatory requirements that are materially different from those encountered on the Indonesian mainland.

The Design and Build (D&B) contract scheme has been widely adopted for government hospital projects because it consolidates design responsibility and construction execution under a single contractual entity, theoretically enabling faster delivery through schedule overlapping [1, 13]. In practice, however, several researchers have demonstrated that D&B does not automatically eliminate design change risk; on the contrary, when owner project requirements remain underspecified at the outset, design modifications can multiply during the construction phase [18, 22]. This vulnerability is particularly pronounced in fast-track schemes where construction begins before the design has fully matured.

The Tafaeri Hospital in Nias and the Tarempa Hospital in Anambas exemplify this pattern. Both projects experienced a series of design changes during construction—ranging from room layout

pISSN 2302-4240
eISSN 2655-2086
Volume 15, Issue 4, December 2026, pp.01226-01234
DOI: http://dx.doi.org/10.32832/astonjadro.v15i4.23800 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

revisions and utility system modifications to technical adjustments triggered by discrepancies between initial design assumptions and actual site conditions. These changes directly extended project durations and elevated delay risk. The island logistics context amplified these effects, because re-procurement of materials requires far longer lead times than equivalent projects in urban areas.

Despite the substantial body of literature on construction delay [7], studies that specifically address design change factors in D&B hospital projects within Indonesian island settings remain scarce. The unique geographic context, the technical complexity of medical facilities, and the multi-dimensional interaction between internal project factors, external environmental conditions, and institutional arrangements constitute a research context that diverges from existing case studies. This study addresses that gap through a two-phase design: preliminary expert-judgment variable validation followed by a main survey measuring the relative importance of validated variables among 157 practitioners. The novelty of this study lies in applying the Relative Importance Index framework to design change variables specifically calibrated for island-region hospital D&B projects, producing the first empirically ranked profile of these factors for such settings.

Design and Build Contract in Hospital Projects

In a D&B contract, one entity assumes full responsibility for both design and physical execution under a single agreement. This arrangement is characterised by single-point responsibility, improved coordination, and potential schedule compression through overlapping design and construction phases [13]. Conceptually, integration under one contract reduces the inter-party fragmentation typical of traditional procurement. Yet research consistently shows that D&B does not eliminate design change risk, especially when owner requirements are not comprehensively defined before contractual commitment [18]. In fast-track contexts, immature design decisions at contract signing readily generate iterative revisions throughout construction [20].

Design Changes: Definitions and Sources

Design changes are defined as any modification to working drawings, technical specifications, or the scope of work occurring after a contract has been signed [8]. The literature identifies four principal source categories: technical factors, client factors, managerial factors, and external factors comprising regulations and site conditions [6, 16]. The consequences of design changes cascade across project performance dimensions, typically manifesting as schedule delays, cost overruns, rework, and contractual claims. Within D&B systems, these risks intensify when design and construction proceed in parallel without adequate front-end requirements definition.

Hospital Construction Complexity

Hospital projects occupy the highest tier of infrastructure complexity because they integrate specialised mechanical, electrical, and plumbing (MEP) systems, high-technology medical equipment installation, pressure-controlled HVAC systems, patient safety requirements, and dynamic healthcare accreditation standards [12]. The high interdependency among these subsystems means that a modification to one element frequently propagates changes to others, making design revision a near-inevitability in hospital construction [15]. Evidence from multi-project studies indicates that project delay in the construction sector results from multi-dimensional interactions among internal project factors, external environment, management and administration, and socio-institutional conditions [7].

Relative Importance Index

The Relative Importance Index (RII) is a widely adopted weighting technique in construction research that converts ordinal Likert-scale data into a comparative index for cross-variable benchmarking [3]. RII is computed as the ratio of the mean score to the maximum possible scale value (RII = Mean / Maximum Scale), yielding a normalised index between 0 and 1. Higher RII values indicate variables perceived as more important by respondents. The method enables transparent prioritisation of factors without requiring parametric distributional assumptions, making it well suited for practitioner survey data.

RESEARCH METHODS

Research Design This study employed a sequential mixed-methods design comprising two distinct phases, as depicted in Figure 1. Phase 1 (Preliminary Survey) conducted a systematic literature review to compile candidate variables, followed by expert-judgment validation using a five-point Likert scale. Phase 2 (Main Survey) distributed a structured questionnaire based on the validated variable set to a broader practitioner population, followed by statistical analysis.

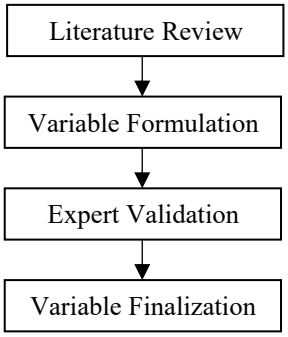


Figure 1. Research Flowchart (Authors, 2026)

Phase 1: Expert Validation (Preliminary Survey)

Candidate variables were formulated by synthesising findings from peer-reviewed literature on design change causes in construction projects, with particular attention to studies addressing hospital projects and D&B contracts. Twenty variables were initially identified and grouped into four conceptual dimensions: technical aspects, managerial and coordination aspects, client and stakeholder aspects, and external and contractual aspects (Table 1). Respondents for the preliminary survey were selected using purposive sampling, with the criterion of a minimum of five years of professional experience in construction management, design coordination, or D&B contract administration. Each respondent rated the relevance of every variable on a five-point Likert scale (1 = strongly irrelevant to 5 = strongly relevant). Variables with a mean score ≥ 3.0 were retained; those falling below this threshold were eliminated.

Table 1. Variable Synthesis (Authors, 2026)

Code	Variable	Operational Definition	Source
		Technical Aspects	
X1	Unclear specifications & design details from the outset	Insufficient drawing detail triggering revisions mid-project	[2], [9], [10]
X2	Errors and deficiencies in the initial design	Calculation errors, inaccurate drawings, or other technical mistakes	[2], [9], [18]
X3	Changes due to site conditions	Design adjustment because actual site conditions deviate from plan	[2], [9], [11]
X4	Changes due to construction errors	Design revision to rectify work not conforming to specifications	[9], [18]
X5	Changes due to material problems	Design alteration owing to material shortages, new specifications, or substitutions	[2], [9]
		Managerial & Coordination Aspects	
X9	Changes due to non-integrated design coordination	Modifications from insufficient cross-discipline integration (arch/struct/MEP) in D&B	[15]
X10	Delayed delivery of design documents	Design documents received late by the contractor or relevant parties	[2], [6], [11]

X11	Divergent interpretation of design	Differences in perception between client, contractor, and consultant regarding the design	[2], [6]
X12	Inadequate inter-party coordination	Weak communication causing design miscommunication	[2], [6], [11]
X13	Changes from cost/time estimation errors	Design revised to align with realistic budget or schedule	[5], [9]
		Client & Stakeholder Aspects	
X14	Changes from D&B contract risk management failures	Revision due to improperly managed contractual risks	[9]
X8	Changes from MEP system & medical equipment integration	Design revision due to mismatch between arch./structural design and MEP/medical equipment	[3], [20]
X15	Client requirement/request changes	Client modifies functional or aesthetic needs after design is made	[5], [9]
		External & Contractual Aspects	
X17	Changes from healthcare facility standards	Adjustment due to changes in or compliance with healthcare technical standards (ICU, OT, HVAC)	[17]
X18	Changes from regulations & permitting	Adjustment due to new regulations or permit requirements	[11], [21]
X19	Changes from environmental factors	Adjustment due to extreme weather, soil conditions, or other natural factors	[2], [11]
X20	Changes from natural disasters	Design revised due to earthquakes, floods, or force majeure	[2], [11]

Phase 2: Main Survey

The main survey instrument was built from the 17 variables that survived the expert validation process. The questionnaire was distributed to 157 construction practitioners with direct professional experience in building construction projects, particularly those who had been involved in D&B or healthcare facility projects. Respondents rated each variable on a five-point Likert scale (1 = no influence to 5 = very strong influence). Three statistical procedures were applied: (1) Pearson correlation validity testing, using the r table value for n = 157 at the 5% significance level (r table = 0.156) as the threshold; (2) Cronbach Alpha reliability testing, with alpha > 0.80 as the criterion for high reliability; and (3) Relative Importance Index ranking to prioritise variables by perceived importance.

RESULTS AND DISCUSSION

Expert Respondent Profiles

Five expert respondents participated in the preliminary validation. Their profiles are presented in Table 2. The age distribution was dominated by the 40–50 year cohort (40%), with the remaining respondents distributed across the 30–40, 50–60, and over-60 age brackets at 20% each. This composition reflects a balance between extensive field experience and contemporary professional perspectives on construction management practice.

Table 2. Expert Respondent Profiles (Authors, 2026)

Code	Age (yrs)	Education	Position	Experience

R1	>60	Master's	Construction Management Team Leader	>10 years
R2	50–60	Master's	Supervision Consultant	>10 years
R3	40–50	Bachelor's	Supervision Consultant	>10 years
R4	40–50	Bachelor's	Supervision Consultant	>10 years
R5	30–40	Master's	Academician	>10 years

Sixty percent of respondents held master's degrees (S2), with the remaining 40% holding bachelor's or Diploma-4 qualifications. All five respondents had more than ten years of professional experience in the construction sector, confirming that the validation was conducted by practitioners with deep contextual understanding of design change dynamics in integrated contracts.

Variable Validation Results

Table 3 presents the relevance scores assigned by each expert to the 20 candidate variables. Mean scores ranged from 2.20 to 4.20, with standard deviations between 0.45 and 1.58. Three variables failed to meet the relevance threshold (mean < 3.0) and were excluded from the research instrument: X6 (changes due to equipment problems), X7 (changes due to new construction technology), and X16 (changes due to acceleration requests). The remaining 17 variables were confirmed as relevant and were advanced to the main survey phase.

Table 3. Expert Validation Results — Preliminary Survey (Authors, 2026)

No	Expert Respondents					Mean	Std. Dev.	Remark
	1	2	3	4	5			
X1	4	4	4	3	4	3.80	0.45	Relevant
X2	4	3	4	3	4	3.60	0.55	Relevant
X3	4	5	4	3	5	4.20	0.84	Relevant
X4	3	3	2	3	5	3.20	1.10	Relevant
X5	3	3	3	2	4	3.00	0.71	Relevant
X6	2	2	3	2	4	2.60	0.89	Not Relevant
X7	2	2	2	3	2	2.20	0.45	Not Relevant
X8	4	3	4	4	5	4.00	0.71	Relevant
X9	2	4	2	3	5	3.20	1.30	Relevant
X10	2	5	2	3	3	3.00	1.22	Relevant
X11	5	4	2	3	4	3.60	1.14	Relevant
X12	1	5	2	3	4	3.00	1.58	Relevant
X13	2	4	2	3	5	3.20	1.30	Relevant
X14	2	5	2	3	5	3.40	1.52	Relevant
X15	1	3	4	4	5	3.40	1.52	Relevant
X16	2	2	2	2	3	2.20	0.45	Not Relevant
X17	4	2	4	3	3	3.20	0.84	Relevant
X18	3	3	2	3	5	3.20	1.10	Relevant
X19	4	3	2	4	5	3.60	1.14	Relevant
X20	2	3	2	3	5	3.00	1.22	Relevant

The elimination of X6 and X7 can be interpreted in light of D&B contract practice: construction equipment and construction technology methods are typically specified during the contractor's design phase and rarely become sources of mid-project revision once the D&B contract is signed. The exclusion of X16 (acceleration-driven changes) reflects expert perception that acceleration is

more often a response to an existing delay than an independent cause of design change, making it conceptually subordinate to other variables in the framework.

Phase 2 Results: Main Survey Analysis
Respondent Characteristics

The main survey collected responses from 157 construction practitioners. The respondent pool represented a range of professional backgrounds including supervision consultants, D&B contractors, project managers, and technical specialists with experience in construction management and healthcare facility planning. Total instrument scores ranged from a minimum of 23 to a maximum of 85, with a mean of 57.88 (SD = 11.77). The substantial variance in total scores reflects genuine diversity in practitioner perceptions regarding the relative influence of design change variables across different project contexts.

Validity and Reliability Testing

Validity was assessed using Pearson correlation coefficients for each item against the total score. With n = 157 at the 5% significance level, the critical r table value is 0.156. As shown in Table 4, all 17 variables produced r values exceeding this threshold, with coefficients ranging from 0.443 (E19) to 0.758 (T2). All p-values were 0.000, confirming statistical significance at the 1% level.

Table 4. Validity Test Results — Main Survey Instrument (Authors, 2026)

Code	r Calculated	r Table	Criterion	p-value	Criterion	Result
T1	0.740	0.156	r calc > r table	0.000	< 0.05	Valid
T2	0.758	0.156	r calc > r table	0.000	< 0.05	Valid
T3	0.555	0.156	r calc > r table	0.000	< 0.05	Valid
T4	0.648	0.156	r calc > r table	0.000	< 0.05	Valid
T5	0.649	0.156	r calc > r table	0.000	< 0.05	Valid
T8	0.587	0.156	r calc > r table	0.000	< 0.05	Valid
T9	0.647	0.156	r calc > r table	0.000	< 0.05	Valid
M10	0.632	0.156	r calc > r table	0.000	< 0.05	Valid
M11	0.740	0.156	r calc > r table	0.000	< 0.05	Valid
M12	0.650	0.156	r calc > r table	0.000	< 0.05	Valid
M13	0.709	0.156	r calc > r table	0.000	< 0.05	Valid
M14	0.699	0.156	r calc > r table	0.000	< 0.05	Valid
M15	0.580	0.156	r calc > r table	0.000	< 0.05	Valid
M17	0.443	0.156	r calc > r table	0.000	< 0.05	Valid
E18	0.447	0.156	r calc > r table	0.000	< 0.05	Valid
E19	0.443	0.156	r calc > r table	0.000	< 0.05	Valid
E20	0.443	0.156	r calc > r table	0.000	< 0.05	Valid

Reliability was assessed using Cronbach Alpha, which returned a value of 0.897. This figure exceeds the widely accepted threshold for high reliability ($\alpha > 0.80$), indicating strong internal consistency across the 17 items. The result confirms that the instrument measures a coherent construct and that the findings are sufficiently stable to support inferential interpretation.

Relative Importance Index Ranking

Table 5 presents the mean score, standard deviation, RII, and rank for each of the 17 validated variables, ordered from highest to lowest RII. Variable T3 (changes due to site conditions) ranked first with an RII of 0.775 and a mean of 3.873. This result reflects a pattern particularly acute in island settings: geotechnical and infrastructural data available during the design phase frequently fails to capture the actual complexity of site conditions at project commencement. In Nias and

Anambas, the combination of remote locations, limited pre-construction survey capacity, and challenging terrain means that design assumptions routinely require revision once earthwork begins.

Table 5. Variable Rankings Based on Relative Importance Index (Authors, 2026)

Code	Variable	Mean	Std. Dev.	RII	Rank
T3	Changes due to site conditions	3.873	0.966	0.775	1
E20	Changes due to natural disasters	3.834	1.085	0.767	2
T8	Changes from MEP system & medical equipment integration	3.541	1.053	0.708	3
M15	Client requirement/request changes	3.522	1.060	0.704	4
T9	Changes due to non-integrated design coordination	3.465	1.169	0.693	5
E18	Changes from regulations & permitting	3.459	1.089	0.692	6
M12	Inadequate inter-party coordination	3.420	1.267	0.684	7
E19	Changes from environmental factors	3.420	1.020	0.684	8
T1	Unclear specifications & design details from the outset	3.376	1.268	0.675	9
T2	Errors and deficiencies in the initial design	3.369	1.242	0.674	10
M17	Changes from healthcare facility standards	3.363	1.099	0.673	11
M13	Changes from cost/time estimation errors	3.325	1.111	0.665	12
M14	Changes from D&B contract risk management failures	3.299	1.016	0.660	13
M11	Divergent interpretation of design	3.229	1.055	0.646	14
T5	Changes due to material problems	3.191	1.127	0.638	15
M10	Delayed delivery of design documents	3.102	1.226	0.620	16
T4	Changes due to construction errors	3.089	1.227	0.618	17

Variable E20 (natural disaster impacts) ranked second (RII = 0.767, mean = 3.834). The prominence of this variable is noteworthy: natural disaster events are conventionally treated as force majeure in standard contract clauses, yet practitioners assigned them a high influence score. This finding highlights that in seismically and meteorologically active island environments—such as Nias, which lies near the Sunda subduction zone—the probability of design revision triggered by earthquake activity, flooding, or extreme weather is perceived as a realistic operational risk, not an exceptional event. Designers and project managers in such settings should incorporate robustness considerations and contingency design provisions from the outset.

Variable T8 (MEP system and medical equipment integration) ranked third (RII = 0.708, mean = 3.541), followed by M15 (client requirement changes, RII = 0.704) and T9 (non-integrated design coordination, RII = 0.693). These three variables collectively capture the intrinsic technical complexity of hospital construction. Medical facilities require the spatial coordination of multiple high-specification systems—structural, architectural, plumbing, electrical, gas supply, and HVAC—alongside clinical equipment whose specifications may evolve as procurement decisions are finalised. In D&B projects where design and construction proceed in parallel, late-arriving or changing equipment specifications are a persistent driver of design revision.

Variables at the lower end of the ranking—T4 (construction errors, RII = 0.618) and M10 (delayed document delivery, RII = 0.620)—still returned RII values above 0.60, indicating that they are considered moderately important rather than negligible. The relatively lower position of T4 may reflect the theoretical advantage of D&B contracts: because design and construction responsibility are unified, construction-error-driven design revisions should logically be fewer than in traditional procurement models, where the contractor may dispute design adequacy.

pISSN 2302-4240
eISSN 2655-2086
Volume 15, Issue 4, December 2026, pp.01226-01234
DOI: http://dx.doi.org/10.32832/astonjadro.v15i4.23800 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

Taken together, the RII ranking reveals that external and site-specific factors carry disproportionately high importance in island-region hospital D&B projects compared to findings from urban or non-island settings reported in prior literature. This has direct contractual implications: D&B agreements for hospital projects in archipelagic regions should include more detailed site-risk allocation clauses, stronger force-majeure provisions calibrated to local hazard profiles, and structured change-control procedures that account for the logistical amplifier effect of island supply chains.

CONCLUSION

This study produced two complementary outputs. First, through a preliminary expert survey, 17 of the initial 20 candidate variables were validated as relevant (mean ≥ 3.0), with three variables—X6, X7, and X16—eliminated for failing to meet the relevance threshold. Second, the main survey with 157 respondents confirmed that the research instrument is both valid (all r calculated > r table = 0.156) and reliable (Cronbach Alpha = 0.897).The RII ranking identified three top-priority design change drivers: site condition changes (T3, RII = 0.775), natural disaster impacts (E20, RII = 0.767), and MEP system and medical equipment integration issues (T8, RII = 0.708). The dominance of geographically sensitive and externally driven variables signals that island-region project environments impose a distinct risk profile on D&B hospital construction—one that differs in important ways from the urban and continental contexts that dominate the existing literature. From a practical standpoint, these findings recommend that D&B contracts for hospital projects in archipelagic settings explicitly address site-risk allocation, hazard-specific force-majeure clauses, and structured change-management procedures that factor in extended material lead times. Early and sustained engagement of clinical end-users (medical staff and hospital management) during the design phase is also critical to minimising late-stage requirement changes. This study has limitations. The empirical base is confined to two project locations in Nias and Anambas; generalisation to other island settings should be treated with caution. Furthermore, questionnaire-based measurement is perceptual and does not capture the quantitative magnitude of individual design changes. Future research should apply confirmatory factor analysis to identify latent dimensions among the validated variables, and pursue comparative multi-site studies to broaden the generalisability of findings. Incorporating actual change-order documentation as an objective data source would also strengthen the evidence base.

ACKNOWLEDGEMENT

The authors express gratitude to all expert respondents and survey participants who contributed their time and professional insights to this research. Appreciation is also extended to the Tamajagakarsa University Masters Program in Civil Engineering for institutional support throughout the study.

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