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Evaluating post-pandemic compound risk impacts in China-led infrastructure projects: A comparative study of Malaysia and Indonesia

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ABSTRACT

Post-pandemic transport infrastructure projects increasingly operate in compound risk environments shaped by interacting Supply Chain Disruption (SCD), Labour and Health Constraints (LHC), Financial and Capital Pressure (FCP), and Regulatory and Institutional Uncertainty (RIU). Although prior research has examined project risk and governance mechanisms separately, limited empirical evidence explains how layered risk exposure simultaneously erodes project performance (PP) and stimulates adaptive governance responses. Drawing on Dynamic Capabilities Theory (DCT), this study develops and tests a governance-buffering framework that conceptualises compound risk impacts (CRI) as a higher-order construct and positions governance adaptation capability (GAC) as an intermediate mechanism between risk exposure and performance outcomes. Data were collected from 300 project-based respondents with direct governance or risk-coordination experience in Malaysia and Indonesia and analysed using partial least squares structural equation modelling (PLS-SEM). The findings reveal a competitive mediation pattern: compound risk is negatively associated with PP through the direct pathway, while its positive association with GAC contributes to a positive indirect pathway to performance. The indirect buffering relationship partially counterbalances, but does not fully eliminate, the negative direct relationship between CRI and PP. Multi-group analysis detected no statistically significant differences in the examined structural relationships between the Malaysian and Indonesian respondent groups. The study extends DCT to multi-actor infrastructure ecosystems and contributes to megaproject governance research by demonstrating the dual-path dynamics of disruption and adaptive reconfiguration under compound risk conditions. Practically, the results highlight the need to institutionalise adaptive governance processes to strengthen resilience in large-scale transport infrastructure development.

Contribution/Originality: This study contributes by modelling compound risk impacts (CRI) as a higher-order construct and explaining how governance adaptation capability (GAC) partially buffers respondent-assessed project performance (PP) deterioration in post-pandemic transport infrastructure projects. It extends Dynamic Capabilities Theory (DCT) to multi-actor megaproject governance using project-contextualised respondent evidence from Malaysia and Indonesia.

1. INTRODUCTION

Large-scale transport infrastructure projects are therefore an important component of generating national economic development and ensuring long-term competitiveness, especially within emerging economies where megaprojects are often used as tools of regional integration and structural change (Flyvbjerg, 2014; Flyvbjerg & Gardner, 2023). These projects are characterised by long implementation cycles, complex financing structures and a

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need for multi-stakeholder coordination, which makes them intrinsically prone to uncertainty and governance problems (Flyvbjerg, 2014; Geraldi, Maylor, & Williams, 2011).

The post-pandemic environment has intensified these vulnerabilities. Transport megaprojects are increasingly exposed to multifaceted disruptions involving supply-chain instability, labour-health constraints, financial volatility, and regulatory changes. Contemporary risk scholarship suggests that interconnected infrastructure systems are more likely to experience interacting and systemic risks than isolated disturbances (Renn, 2021; Schweizer, 2021). Such consecutive disruptions create environments of compound risk, where cascading failures may spread through contractual and organisational networks (Aven, 2011; Perrow, 1984).

This issue is also relevant to social economics because transport infrastructure disruption affects more than project delivery indicators. When compound risks delay, increase the cost of, or weaken the governance of major transport projects, the consequences may extend to unequal infrastructure access, unstable labour arrangements, delayed regional connectivity, and uneven distribution of development benefits. Governance adaptation therefore matters not only as a project-management response but also as a mechanism for protecting the social value of infrastructure investment under systemic uncertainty.

Conventional project-risk management approaches usually conceptualise risks as discrete categories that can be mitigated individually (Hillson, 2002). While these approaches still have their value, they may incorrectly disregard the cumulative and interdependent nature of uncertainties characterising megaproject contexts (Renn, 2021; Schweizer, 2021). Consequently, understanding how the risk environment, as a compound, affects the performance of projects has become an increasingly pressing research issue.

At the same time, governance scholarship has underlined that performance outcomes under uncertainty are not determined by risk exposure alone but also by adaptive capacity (Boin & van Eeten, 2013; Linkov, Trump, & Keisler, 2018). Adaptive governance is commonly associated with flexibility, coordination, and institutional responsiveness under systemic turbulence (Chaffin, Gosnell, & Cosens, 2014; Folke, Hahn, Olsson, & Norberg, 2005). This view is compatible with Dynamic Capabilities Theory (DCT), which argues that organisational performance in turbulent environments depends on the ability to sense, seize, and reconfigure resources (Teece, 2018; Teece, Pisano, & Shuen, 1997).

Despite growing concern about infrastructure resilience and megaproject governance, empirical research has rarely conceptualised compound risk as a higher-order construct for understanding interacting dimensions of uncertainty. Moreover, limited evidence explains whether risk exposure simultaneously undermines respondent-assessed project performance (PP) and triggers adaptive governance mechanisms. Comparative validation of such governance-buffering mechanisms remains limited in Southeast Asian infrastructure contexts.

In order to fill these gaps, the current study aims to develop and empirically test a governance buffering framework that combines compound risk conceptualisation with DCT. Utilising survey data gathered from transport infrastructure-related projects in Malaysia and Indonesia, the study looks at the direct and indirect pathways of connecting compound-risk impacts with governance adaptation capability (GAC) and PP.

In this study, China-led infrastructure projects refer to large-scale transport infrastructure projects in which one or more Chinese state or corporate actors hold a principal role in project financing, ownership or development, or project delivery, rather than participating only as peripheral suppliers, consultants, or service providers. This definition recognises that Chinese transnational infrastructure projects are organised through varied combinations of financial institutions, state-owned enterprises, private firms, host-country agencies, and other project partners, rather than through a single standard delivery model (Leutert, 2024; Schaefer & Mohan, 2024).

This study contributes to the literature in three ways. First, it enriches risk-management research by conceptualising compound risk as a higher-order, interdependent construct in megaproject governance. Second, it extends DCT to multi-actor project ecosystems through a project-contextualised operationalisation of GAC based on

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respondent assessments of specific project settings. Third, it provides bounded cross-country empirical evidence from Malaysia and Indonesia while acknowledging that the findings remain limited to these two Southeast Asian contexts.

2. LITERATURE REVIEW

2.1. Compound Risk in Infrastructure Projects

Large-scale transport infrastructural projects operate in environments characterized by high interdependence, long implementation periods and complex multi-stakeholder governance structures (Flyvbjerg, 2014; Geraldi et al., 2011). Traditional research on project risk has generally conceptualised risk as discrete categories - such as financial risk, regulatory risk or operational disruption - viewed separately in project management frameworks (Hillson, 2002). Contemporary scholarship, however, is focusing on the aspects or nature of modern infrastructure systems now experiencing interacting and systemic risks rather than milieus of isolated events, especially in megaproject environments of institutional and financial interdependencies (Renn, 2021; Schweizer, 2021).

Compound risk refers to the interaction of multiple risk dimensions that jointly increase systemic vulnerability. In post-pandemic settings, transport megaprojects are confronted by overlapping Supply Chain Disruption (SCD), Labour and Health Constraints (LHC), Financial and Capital Pressure (FCP), and Regulatory and Institutional Uncertainty (RIU). When these risk pressures intersect, they may propagate coordination failures across contractual and organisational networks. Although previous studies have recognised the complexity of projects (Aven, 2011; Geraldi et al., 2011) empirical studies have rarely reconceptualised compound risk as a higher-order interdependent construct that affects both governance and performance.

2.2. Governance Adaptation Capability (GAC) and Project Performance (PP)

Governance structures are central to the question of dealing with uncertainty in the context of large infrastructure projects. Scholarship in the field of project governance foregrounds the importance of instrumentalities of coordination of stakeholders, a contract to alignment, and oversight at the institutional level for the stability of performance (Ahola, Ruuska, Artto, & Kujala, 2014; Too & Weaver, 2014). Under conditions of systemic uncertainty, adaptive governance becomes of special salience. Adaptive governance focuses on flexibility, multi-level co-ordination, and institutional responsiveness (Chaffin et al., 2014; Folke et al., 2005).

Project governance research also indicates that governance should be understood as a multi-level arrangement rather than a single managerial tool (Biesenthal & Wilden, 2014; Derakhshan, Turner, & Mancini, 2019). This is relevant for the present study because governance adaptation in megaprojects may occur through contractual oversight, stakeholder coordination, organisational routines, and institutional alignment at the same time.

In the context of megaprojects, some of the governance elements that may need to be adapted are contract renegotiation, information-transparency mechanisms, fast-decision mechanisms, and cross-organisational coordination platforms. These mechanisms are crucial in cases of rigid types of governance arrangements that lead to coordination breakdowns. Recent research shows that flexible governance arrangements increase resilience and institutional responsiveness in the complex of megaprojects (Boin & van Eeten, 2013; Williams, Klakegg, Magnussen, & Glasspool, 2010). Nonetheless, governance is often used as a static design attribute and not as being dynamically activated when under compound risk exposure.

2.3. Dynamic Capabilities Theory (DCT) as the Theoretical Lens

In order to understand how organisations deal with the layered uncertainty, this study uses DCT as the main explanatory framework (Teece et al., 1997). Dynamic capabilities refer to an organisation's capacity to be in tune with what is changing in the environment, to seize what is emerging, and to reorganise resources in such a way that it can stay on course through turbulence (Eisenhardt & Martin, 2000; Teece, 2018). Unlike ordinary capabilities that

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support efficiency, dynamic capabilities allow new strategies to adapt to system shocks in a strategic manner (Teece, 2018; Teece et al., 1997).

Nevertheless, DCT should not be applied uncritically to project-based and temporary organisations. Megaproject coalitions are often temporary, contractually fragmented, and politically embedded, which may limit the stable organisational routines assumed in conventional dynamic-capability arguments (Biesenthal, Clegg, Mahalingam, & Sankaran, 2018; Mahalingam, 2022). Normal Accident Theory suggests that tightly coupled and complex systems may generate failures that cannot be fully controlled through adaptive reconfiguration (Perrow, 1984). High-Reliability Organisation theory, by contrast, emphasises mindfulness, redundancy, and continuous attention to operational signals as ways to reduce failure in hazardous settings (Roberts, 1990; Weick, Sutcliffe, & Obstfeld, 1999). These perspectives do not replace DCT in this study, but they sharpen its boundary conditions by showing why governance adaptation in temporary megaproject systems may be partial, contested, and insufficient to remove all performance losses.

In transport infrastructure projects, compound risk environments represent prolonged environmental turbulence that strains established governance routines and institutional arrangements across multi-actor networks (Biesenthal et al., 2018; Qiu, Chen, Sheng, & Cheng, 2019). Performance under such conditions depends not only on resource endowment but also on the capacity to reconfigure coordination mechanisms. GAC can therefore be conceptualised as a project-contextualised manifestation of dynamic capabilities in multi-actor governance systems.

2.4. Research Gap

Although there has been a growing amount of scholarly attention on infrastructure governance and management of project risks, there are some important missing elements.

First, recent research recognises that infrastructure systems are increasingly exposed to systemic and cascading risks and thus no longer isolated disturbances (Renn, 2021; Schweizer, 2021). In the context of megaproject environments, there are interdependencies of risk that add uncertainty to the contractual risk, financial risk, and operational risk across the board (Aven, 2011; Geraldi et al., 2011). Nevertheless, empirical models often use risks as single independent predictors instead of as interrelated dimensions creating a compound higher-order construct. Consequently, governance implications of the accumulation of layering of risk are insufficiently conceptualised.

Second, although the concepts of infrastructure resilience and adaptive governance have resurfaced in research post-pandemic (Boin & van Eeten, 2013; Chaffin et al., 2014), the dominating logic of empirical research still assumes a linear relationship between risk and performance. There are emerging empirical studies on megaproject governance that point to the fact that adaptive coordination mechanisms increase resilience in uncertainty and crisis conditions (Chaffin et al., 2014; Williams et al., 2010). Yet few research efforts are making empirical studies as to whether risk exposure simultaneously creates performance erosion and also activates adaptive reconfiguration processes. DCT suggests that environmental turbulence evokes both disruption and reconfiguration (Eisenhardt & Martin, 2000; Teece et al., 1997), although the empirical evidence of the operation of such combinations of mechanisms in the governance of megaprojects is limited.

Third, recent research on megaprojects is concerned with the institutional complexity and challenges of multi-actor coordination in different national contexts (Mahalingam, 2022; Qiu et al., 2019). Nevertheless, empirical studies of cross-national experiences with adaptive governance mechanisms faced with compound risk exposure are scarce. It is not clear from this work whether governance adaptation works in consistent ways across different institutional contexts and if buffering mechanisms are context-specific.

Taken together, these limitations suggest a need to develop an integrated framework that conceptualises compound risk as a higher-order inter-dependent construct, the need for governance adaptation as a dynamic capability, and their empirical testing in interaction in national contexts. Addressing such gaps, the current study

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develops a governance buffering perspective that describes the simultaneous functioning of disruption and adaptive reconfiguration in compound risk conditions in transport infrastructure projects.

3. HYPOTHESIS DEVELOPMENT

Based on the above literature review and theoretical background, this section proposes hypotheses about the interrelationship among compound risk impacts (CRI), GAC and PP. In accordance with the DCT, the suggested framework assumes that compound risk leads to both direct effects in terms of disruption and indirect effects in terms of adaptation mediated through governance reconfiguration mechanisms.

3.1. Compound Risk Impacts (CRI) and PP

Large-scale transportation infrastructure projects are inherently vulnerable to environmental turbulence, which is the result of the long duration and high capital intensity of such projects and their multidimensional coordination of multiple actors (Flyvbjerg, 2014; Geraldi et al., 2011). When confronted with compound risk conditions characterised by overlapping disruptions in the supply chain, labour instability, financial volatility and regulatory uncertainty, such projects may be confronted with increasing coordination breakdowns leading to cascading performance deterioration. Conventional literature on risk management argues that a build-up of uncertainty increases transaction costs and lowers the efficiency of operations (Aven, 2011; Hillson, 2002). Within megaproject situations, interdependent risks have the potential to increase cascading failures across both contractual and organisational subsystems (Perrow, 1984; Schweizer, 2021). These cumulative disruptions destroy schedule stability, damage cost control and limit delivery effectiveness. DCT further argues that when the environmental turbulence exceeds the ability of the organisation to adapt, the performance results suffer (Eisenhardt & Martin, 2000; Teece et al., 1997). In the infrastructure domain, the lack of proper governance reconfiguration in the face of a layer of uncertainties may directly undermine performance. Consequently, compound risk effects are anticipated to have a negative impact on the performance of the projects.

H_1: CRI negatively affects PP

3.2. CRI and GAC

While compound risk may directly impede performance, DCT also suggests that environmental turbulence can act as a stimulus for adaptive responses (Eisenhardt & Martin, 2000; Teece et al., 1997). Organisations facing higher uncertainty engage in sensing emerging threats, seizing opportunities for adjustment, and reshaping governance structures to regain alignment (Teece, 2018; Teece et al., 1997). In infrastructure megaprojects, compound risk exposure can lead to contract renegotiation, improved monitoring mechanisms, cross-organisational coordination platforms, and institutional realignment. Adaptive governance literature likewise emphasises systemic uncertainty as a driver of institutional flexibility and coordination innovation (Chaffin et al., 2014; Folke et al., 2005). Recent infrastructure studies have highlighted that governance mechanisms often change in response to crisis conditions rather than remaining static (Boin & van Eeten, 2013; Williams et al., 2010). Therefore, instead of being purely destabilising, compound risk may activate governance adaptation processes. Accordingly, CRI are expected to have a positive effect on GAC.

H_2: CRI positively influence GAC.

3.3. GAC and PP

Dynamic capabilities increase performance by giving organisations the ability to realign structures and processes in uncertainty (Eisenhardt & Martin, 2000; Teece, 2018). In project-based environments, adaptive governance supports the need for coordination efficiency, information transparency and quick decision-making, which help achieve reduced cascading disruptions. Infrastructure governance research suggests that flexibly coordinating and

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institutional responsiveness are part of resilience and stability of delivery (Derakhshan et al., 2019; Too & Weaver, 2014). Mechanisms of adaptive governance may reduce the spillovers of uncertainty and stabilise performance in compound risk exposure. At the level of GAC, project organisations are better able to cope with contractual complexity, realign expectations with stakeholders and avoid risk escalation into system failure. Consequently, governance adaptation is expected to have a beneficial impact on PP.

H_3: GAC positively affects PP.

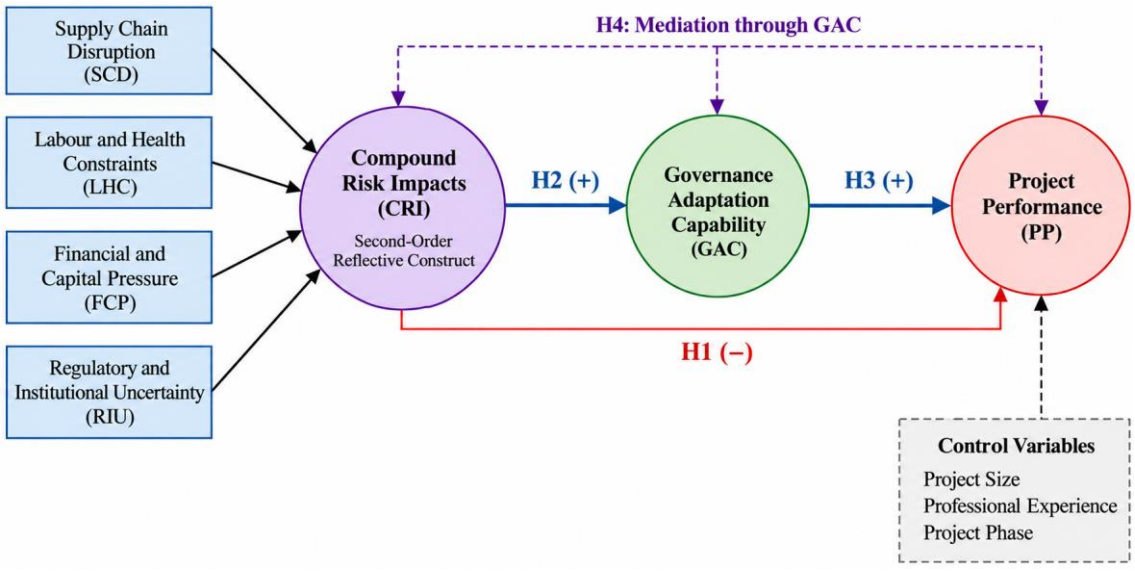
3.4. The Mediating Role of GAC

DCT has posited that environmental turbulence has impacts on performance outcomes through organisational reconfiguration mechanisms (Teece, 2018; Teece et al., 1997). In the circumstances of compound risk, two mechanisms may be simultaneous. First, risk accretion may directly destroy performance through adding to coordination costs and instability of operations. Second, exposure to turbulence may lead to the stimulation of governance adaptation processes that may partially compensate for losses of performance. This dual path logic suggests that the GAC works as a transmission mechanism between compound risk exposure and PP. Rather than a mere moderate to the relationship, the process of governance adaptation may mediate the relationship between the risk and performance by transforming turbulence into adaptive reconfiguration. Accordingly, the GAC is expected to mediate the relationship between CRI and PP.

H_4: GAC mediates the relationship between CRI and PP.

3.5. Conceptual Framework

Based on the above hypotheses, Figure 1 presents Compound Risk Impacts (CRI) as a second-order reflective construct comprising Supply Chain Disruption (SCD), Labour and Health Constraints (LHC), Financial and Capital Pressure (FCP), and Regulatory and Institutional Uncertainty (RIU). The model proposes a direct negative relationship between CRI and PP (H1), a positive relationship between CRI and GAC (H2), and a positive relationship between GAC and PP (H3). It further proposes that GAC mediates the relationship between CRI and PP (H4), creating an indirect adaptive pathway that may partially counterbalance the direct performance deterioration associated with compound risk. This dual-path design mirrors the concept of interacting disruptions in systemic-risk research and DCT on adaptive reconfiguration to help organisations adjust to turbulent environments (Renn, 2021; Schweizer, 2021; Teece, 2018).



Note: H4 represents the indirect CRI --> GAC --> PP mediation pathway. The dotted arrow represents the effects of the control variables on PP.

Figure 1. Conceptual framework and hypothesised relationships.

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4. METHODOLOGY

4.1. Research Design

This study adopts a quantitative research design using a structured survey questionnaire to examine the relationships among CRI, GAC, and PP in large-scale transport infrastructure projects. A cross-sectional perceptual survey approach was used to collect informed respondent assessments of compound risk exposure and adaptive governance practices in the post-pandemic context. The analysis is therefore based on respondent-assessed project observations rather than archival project records. Partial Least Squares Structural Equation Modelling (PLS-SEM) was used because it is appropriate for complex models, higher-order constructs, and mediation modelling in exploratory infrastructure governance research.

4.2. Sample and Data Collection

The target population included key project stakeholders involved in large-scale transport infrastructure projects in Malaysia and Indonesia. The eligible respondent population included contractors, consultants, project managers, and project owner or public authority representatives. The final analysed sample comprised respondents classified as contractors and consultants.

A focal project was determined to be China-led if it met any of three operational criteria for project classification. First, a Chinese policy bank, state-linked financial institution, or Chinese investor held a principal financing role in the project. Second, a Chinese entity acted as the project sponsor, developer, concessionaire, or equity participant with formal governance responsibilities. Third, a Chinese enterprise served as the lead engineering, procurement and construction contractor, turnkey contractor, or main contractor, with substantial responsibility for project design, procurement, coordination, or construction delivery. These criteria mirror divisions between Chinese financing, project development and project implementation in today's global infrastructure landscape (Joosse, Malik, Zhang, & Elston, 2025; Leutert, 2024; Schaefer & Mohan, 2024).

By itself, formal participation in the Belt and Road Initiative (BRI) was not deemed enough since projects under BRI might include different congregations of Chinese and host-country actors, financing models, ownership, and delivery. Likewise, the presence of limited participation by an actor from China, such as a supplier of equipment, a minor subcontractor, a consultant, a provider of technology or other peripheral services, did not make a project 'China-led' unless another Chinese actor was a principal financier, developer, governance partner or delivery actor (Leutert, 2024; Schaefer & Mohan, 2024).

Data collection was conducted through online and on-site structured questionnaires. The unit of analysis was the individual project-based respondent. Each respondent was asked to evaluate one focal large-scale transport infrastructure project with which they had direct governance or risk-coordination experience. Therefore, the study does not claim 300 archival project cases; rather, the final dataset consists of 300 respondent-level project observations based on informed assessments of specific project contexts.

A total of 387 questionnaires were distributed to eligible project stakeholders (see Table 1). Of these, 341 responses were returned, producing an initial response rate of 88.1%. After screening, 41 responses were excluded because they were incomplete, did not meet the respondent eligibility criteria, showed patterned response behaviour, contained excessive missing data, or appeared to be duplicate or suspicious entries. The final valid sample consisted of 300 responses, with 150 from Malaysia and 150 from Indonesia. This represents a valid response rate of 77.5% based on questionnaires distributed and a retention rate of 88.0% based on returned responses. Missing data were handled through case screening before PLS-SEM analysis. Responses with substantial missing values in the core construct items were removed, and only complete valid cases were retained for the final analysis. Because the final dataset contained complete responses for all measurement items used in the model, no statistical imputation was required.

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Table 1. Sample screening and response flow.

Screening stage / Reason	Number	Percentage / Note
Questionnaires distributed	387	100.0% of distributed questionnaires
Responses returned	341	88.1% response rate
Not returned	46	11.9% of distributed questionnaires
Excluded: incomplete responses	14	Removed before analysis
Excluded: did not meet eligibility criteria	9	No direct governance/Risk-coordination experience
Excluded: patterned/Straight-line responses	7	Data-quality screening
Excluded: excessive missing values or duplicate/Suspicious entries	11	6 excessive missing; 5 duplicate/Suspicious
Final valid responses retained for analysis	300	77.5% of distributed; 88.0% of returned

All construct items were measured using a seven-point Likert scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"). The demographic characteristics of the respondents and project characteristics are summarised in Table 2 to provide transparency regarding the sample structure and project context.

Table 2. Respondent Profile and Project Characteristics.

Category	Subcategory	Frequency	Percentage (%)
Country	Malaysia	150	50.0
	Indonesia	150	50.0
Organizational Role	Contractor	198	66.0
	Consultant	102	34.0
	Project Owner / Public Authority	0	0.0
Professional Experience	< 5 years	78	26.0
	5–10 years	93	31.0
	10–15 years	67	22.0
	> 15 years	62	21.0
Project Size (Investment Value)	< USD 100 million	85	28.0
	USD 100–500 million	114	38.0
	USD 500 million–1 billion	63	21.0
	> USD 1 billion	38	13.0
Project Phase	Ongoing	114	38.0
	Near Completion	72	24.0
	Completed	114	38.0

As shown in Table 2, the sample consisted of respondents with direct governance and project-delivery roles. Contractors formed the largest group, followed by consultants. No project owner or public authority respondents were represented in the final dataset. The distribution of professional experience indicates representation across junior, mid-career, and senior respondents. The variation in project size and project phase also supports contextual diversity in the project-based observations used for the analysis.

4.3. Measurement Development

A second order reflective construct comprised of four first order constructs was constructed: SCD, LHC, FCP and RIU were conceptualised as CRI. They are interrelated aspects of systemic risk exposure in transport infrastructure projects in the post pandemic era during which supply-chain, labour, financial, and regulatory risks can all happen at once and at the same time (Renn, 2021; Schweizer, 2021). Reflective indicators were drawn from the infrastructure risk and governance literature and adapted and contextualised for each dimension.

GAC reflects the extent to which the project governance structures can recombine the coordination mechanisms as they respond to uncertainty. PP metrics include schedule stability, cost control and operations effectiveness in compound risk conditions. Instruments were changed and contextualized for transport infrastructure projects for

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content validity. A pilot study was used to check for clarity and contextual appropriateness before full-scale data collection took place.

Because the constructs were measured through respondent perceptions, the instrument captures managerial assessments of risk exposure, governance adaptation, and PP rather than objective project records. This measurement choice is appropriate for examining perceived governance mechanisms, but the absence of objective indicators such as cost-overrun percentages, schedule-delay records, or audited performance data is acknowledged as an important interpretive boundary.

4.4. Data Analysis Procedure

Although covariance-based SEM (CB-SEM) is commonly used in confirmatory research, partial least squares structural equation modelling (PLS-SEM) was considered more appropriate for the present study for several methodological reasons. First, CRI was modelled as a reflective-reflective higher-order construct, which increased model complexity. PLS-SEM is suitable for estimating hierarchical component models through a two-stage approach and has been recommended for higher-order construct modelling (Hair, Sarstedt, Ringle, & Gudergan, 2023).

Second, the study focuses on predictive performance and mediation mechanisms within a complex governance framework rather than strict covariance-based model confirmation. Consistent with the variance-based orientation of PLS-SEM, the method is appropriate for exploratory and predictive modelling objectives in project management and governance research (Hair, Hult, Ringle, & Sarstedt, 2026).

Third, PLS-SEM is robust to deviations from multivariate normality in survey-based infrastructure data and can be applied in multi-group analysis (MGA), which is relevant to the Malaysia-Indonesia comparative design (Hair et al., 2026; Hair et al., 2023).

Accordingly, data analysis was performed using PLS-SEM. A two-step evaluation procedure was followed. First, the measurement model was assessed for indicator reliability, internal consistency reliability, convergent validity, discriminant validity, and multicollinearity. Second, the structural model was tested using bootstrapping with 5,000 resamples (Hair et al., 2026).

Multi-group analysis (MGA) was then conducted to examine cross-country structural consistency.

4.5. Higher-Order Construct Specification

CRI was modelled as a reflective-reflective higher-order construct by applying a disjoint two-stage approach. This specification is based on the theoretical conceptualisation of compound risk as a latent systemic condition that comes into existence from the co-varying turbulence of the environment and is not a mere aggregation of independent sources of risk.

While individual risk dimensions (SCD, LHC, FCP, and RIU) represent different operational domains, they are considered here to be manifestations of an underlying compound risk environment, with systemic interdependence. In infrastructure contexts in the post-pandemic, the dimensions of risk occur simultaneously and perpetuate each other as an overarching turbulence condition rather than independent formative contributors.

Accordingly, changes in the underlying compound risk environment are likely to be reflected in a range of risk dimensions simultaneously. Therefore, the first-order constructs are modelled as reflective indicators of the superior higher-order CRI construct.

Methodologically, the disjoint two-stage approach was used. In Stage 1, latent variable scores for the four first-order constructs (SCD, LHC, FCP, and RIU) were estimated. In Stage 2, these latent scores were used as reflective indicators of the higher-order construct. This strategy is recommended for hierarchical component modelling in PLS-SEM when higher-order constructs represent latent systemic conditions rather than simple composite indices (Hair et al., 2023). The high and statistically significant loadings of the first-order constructs on CRI support the reflective specification.

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4.6. Assessment of Common Method Bias

Because data for all the constructs were collected using a single survey instrument, common method bias (CMB) was assessed using both a procedural and a statistical evaluation.

Procedurally, a number of safeguards have been built in during questionnaire design and administration. The respondents were assured of anonymity and confidentiality to alleviate their evaluation apprehension. Items were carefully worded to minimise ambiguity and construct items were divided into separate sections in order to limit response pattern bias. Furthermore, the respondents were instructed to evaluate a specific project context so as to optimize cognitive focus and minimize random responding (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003).

Statistically, Harman's single-factor test was used as a preliminary diagnostic rather than as definitive evidence against common method bias (Podsakoff et al., 2003). Exploratory factor analysis indicated that the first unrotated factor accounted for 34.2 percent of the total variance, below the commonly used 50 percent heuristic. Because the single-factor test has limited diagnostic sensitivity, this result was interpreted together with the full-collinearity assessment rather than in isolation.

In turn, the full-collinearity assessment methodology suggested for PLS-SEM was followed by examining the variance inflation factors (VIF) of all latent constructs (Kock, 2015). All full collinearity VIF values were less than the conservative threshold of 3.3, providing additional evidence that common method bias was unlikely to materially affect the estimated relationships. Taken together, the procedural safeguards and the two statistical diagnostics reduce, but cannot entirely eliminate, common-method concerns.

5. RESULTS

The results are presented in sequence through measurement-model assessment, structural-model assessment, mediation analysis, and multi-group analysis.

5.1. Measurement Model Assessment

Prior to the evaluation of the structural relationships, it is imperative that the measurement properties of the constructs be evaluated. Following the procedures recommended in PLS, a reflective measurement model was analysed for indicator reliability, internal consistency reliability, convergent validity and discriminant validity (Hair et al., 2026).

5.1.1. Indicator Reliability

Indicator reliability was assessed by examining the outer loadings of all reflective indicators. The results are summarized in Table 3.

Table 3. Outer loadings (Reflective measurement).

Construct	Indicator	Loading
SCD	SCD1	0.831
SCD	SCD2	0.828
SCD	SCD3	0.839
SCD	SCD4	0.821
LHC	LHC1	0.830
LHC	LHC2	0.812
LHC	LHC3	0.820
LHC	LHC4	0.794
FCP	FCP1	0.841
FCP	FCP2	0.817
FCP	FCP3	0.838
FCP	FCP4	0.821
RIU	RIU1	0.819
RIU	RIU2	0.829

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Construct	Indicator	Loading
RIU	RIU3	0.841
RIU	RIU4	0.818
GAC	GAC1	0.810
GAC	GAC2	0.806
GAC	GAC3	0.792
GAC	GAC4	0.813
GAC	GAC5	0.798
PP	PP1	0.808
PP	PP2	0.836
PP	PP3	0.804
PP	PP4	0.777
PP	PP5	0.798
CRI	SCD	0.792
CRI	LHC	0.810
CRI	FCP	0.800
CRI	RIU	0.785

Note: CRI loadings are on its four lower-order component scores (SCD, LHC, FCP, RIU).

As presented in Table 3, all indicator loadings were in the acceptable range (0.777 to 0.841) which was above the recommended loading of 0.70 (Hair et al., 2026) indicating acceptable indicator reliability for all constructs.

5.1.2. Internal Consistency and Convergent Validity

To evaluate internal consistency reliability and convergent validity, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) were computed. The results obtained are summarized in Table 4 (Hair et al., 2026).

Table 4. Internal consistency reliability and convergent validity.

Construct	Cronbach's Alpha	Composite Reliability (CR)	AVE
SCD	0.849	0.898	0.688
LHC	0.830	0.887	0.662
FCP	0.849	0.898	0.688
RIU	0.846	0.896	0.684
GAC	0.863	0.901	0.646
PP	0.864	0.902	0.648
CRI	0.808	0.874	0.635

The results show that all Cronbach's alpha and CR index are above commonly accepted benchmarks and therefore evidence of internal consistency reliability. Furthermore, each AVE value is higher than 0.50, thus demonstrating that each construct has convergent validity (Hair et al., 2026).

5.1.3. Discriminant Validity and Collinearity

Discriminant validity was assessed by means of the heterotrait-monotrait ratio (HTMT) (Henseler, Ringle, & Sarstedt, 2015). The HTMT matrix is shown in Table 5.

Table 5. HTMT matrix (discriminant validity).

Construct	SCD	LHC	FCP	RIU	GAC	PP
SCD	1.000					
LHC	0.626	1.000				
FCP	0.619	0.626	1.000			
RIU	0.556	0.632	0.589	1.000		
GAC	0.366	0.412	0.449	0.394	1.000	
PP	0.150	0.095	0.101	0.081	0.336	1.000

Note: Construct level shown for SCD, LHC, FCP, RIU, GAC, PP.

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All HTMT values are below the conservative threshold criteria supporting sufficient discriminant validity among the constructs (Henseler et al., 2015). Moreover, the potential multicollinearity between the predictors of PP was examined based on the inner values of VIF. The results are presented in Table 6.

Project size, professional experience, and project phase were included as control variables because they may influence PP independently of compound risk and governance adaptation. Larger projects may face greater coordination complexity, more experienced respondents may assess governance and performance more accurately, and project phase may affect the salience of cost, schedule, and operational performance outcomes.

Table 6. Inner VIF for predictors of PP.

Predictor	VIF
CRI	1.242
GAC	1.244
Project Size	1.005
Experience	1.012
Project Phase	1.004

The VIF values are well below the critical cut-offs, indicating that collinearity does not pose a concern for structural model estimation. Overall, the measurement model demonstrates acceptable psychometric properties and supports the subsequent structural analysis (Hair et al., 2026).

5.2. Structural Model Assessment

Having verified the adequacy of the model of measurement to be carried out, the structural relations were tested using bootstrapping with 5,000 resamples. The estimated path coefficients and their associated statistics are summarised in Table 7. All the reported path coefficients (β) are standardized estimates calculated with the PLS algorithm (Hair et al., 2026).

Table 7. Path coefficients (Bootstrapping = 5,000).

Path	β (Standardized)	t-value	p-value	95% CI	Sig.
CRI-->GAC	0.434	8.73	<0.001	[0.336, 0.529]	***
CRI-->PP	-0.280	4.54	<0.001	[-0.402, -0.156]	***
GAC-->PP	0.412	6.97	<0.001	[0.298, 0.521]	***
Project Size-->PP	0.017	0.31	0.757	[-0.102, 0.129]	
Experience-->PP	0.049	0.93	0.353	[-0.058, 0.153]	
Project Phase-->PP	0.044	0.81	0.419	[-0.064, 0.148]	

Note: *** $p < 0.001$.

The results show that CRI have a significant positive effect on the GAC. Simultaneously with that, CRI has a significant negative direct effect on PP, which means accumulated risk pressures undermine the project delivery outcomes. GAC, in turn, has a positive effect on PP, and this seems to indicate that adaptive governance mechanisms should be able to contribute to stabilising project outcomes in situations of uncertainty. The control variables were not statistically significant.

To assess the explanatory power of the model, the coefficient of determination (R^2) was examined. The results are presented in Table 8.

Table 8. Coefficient of determination (R^2).

Endogenous Construct	R^2
GAC	0.189
PP	0.154

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The relatively low R^2 values for GAC (0.189) and PP (0.154) indicate that the model explains a modest proportion of variance, especially in PP. This is consistent with the multifactorial and politically embedded nature of megaproject outcomes, which are shaped by institutional, contractual, macroeconomic, leadership, and stakeholder conditions beyond governance adaptation. Therefore, the practical significance of the model should be interpreted cautiously: the framework identifies a meaningful governance-buffering mechanism, but it does not provide a comprehensive explanation of all performance variation in large transport infrastructure projects.

Table 9 presents the effect-size (f^2) results for the structural relationships and control variables.

Table 9. Effect size (f^2).

Effect	Predictor	f^2	Size
CRI --> GAC	CRI	0.232	Medium
CRI --> PP	CRI	0.075	Small
GAC --> PP	GAC	0.158	Medium
Project Size --> PP	Project Size	0.000	Negligible
Experience --> PP	Experience	0.003	Negligible
Project Phase --> PP	Project Phase	0.002	Negligible

CRI exhibits a medium effect on GAC ($f^2 = 0.232$) and a small direct effect on PP ($f^2 = 0.075$). GAC exhibits a medium effect on PP ($f^2 = 0.158$). In contrast, project size, professional experience, and project phase have negligible effect sizes (Hair et al., 2026).

Predictive relevance was assessed with the help of the blindfolding method (omission distance = 7), establishing the guidelines in PLS-SEM for cross-validated redundancy measures (Hair et al., 2026; Hair et al., 2023). Omission distance was chosen so that the number of observations was not an integral multiple of the omission distance. The Q^2 values are presented in Table 10.

Table 10. Predictive relevance (Q^2; blindfolding, omission distance = 7).

Endogenous Construct	Q^2
GAC	0.118
PP	0.042

Both endogenous constructs display Q^2 values greater than zero, indicating that the model has predictive relevance. However, the magnitude for PP remains modest (Hair et al., 2026).

5.3. Mediation Analysis

To determine if GAC acts as a transmission mechanism, the use of mediation analysis was performed through bootstrap procedures. The direct, indirect and total effects are reported in Table 11 (Hair et al., 2026; Zhao, Lynch, & Chen, 2010).

Table 11. Mediation effects (Bootstrapping = 5,000).

Effect Type	Effect	β	t	p	95% CI
Direct effect	CRI --> PP	-0.280	4.54	<0.001	[-0.402, -0.156]
Indirect effect	CRI --> GAC --> PP	0.179	5.19	<0.001	[0.112, 0.247]
Total effect	CRI --> PP (total)	-0.101	1.69	0.091	[-0.222, 0.015]

The results show a significant negative direct effect of CRI on PP ($\beta = -0.280$, $t = 4.54$, $p < 0.001$, 95% CI [−0.402, −0.156]). At the same time, the indirect effect through GAC is positive and statistically significant ($\beta =$

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0.179, t = 5.19, p < 0.001, 95% CI [0.112, 0.247]). Because the confidence interval for the indirect effect does not include zero, mediation is supported.

The total effect of CRI on PP is negative and statistically non-significant (β = -0.101, p = 0.091). Importantly, a non-significant total effect does not rule out mediation. When direct and indirect effects operate in opposite directions, they may offset each other and produce a reduced or statistically non-significant total effect (Zhao et al., 2010).

The opposite signs of the direct (negative) and indirect (positive) effects suggest that a mediation pattern found in competition exists. In this type of configuration, CRI occur concurrently (i) directly undermining PP and (ii) activating governance adaptation mechanisms that partially counterbalance performance erosion. The mediation effect is thus a process of buffering (as opposed to a mere transmission process).

This pattern is consistent with contemporary mediation typologies that distinguish competitive mediation from complementary and indirect-only mediation. The findings indicate that GAC operates as a compensatory dynamic mechanism that partially offsets, but does not eliminate, the negative consequences of compound risk exposure (Zhao et al., 2010).

5.4. Multi-Group Analysis

Given the cross-national sample, measurement invariance was determined using the MICOM (Measurement Invariance of Composite Models) procedure to avoid making meaningful comparisons between groups before conducting the multi-group analysis. The procedure to define MICOM has three steps in sequence: (1) configural invariance; (2) compositional invariance; and (3) the equality of composite means and variances (Henseler, Ringle, & Sarstedt, 2016).

First, configural invariance was supported because the measurement models, data-treatment procedures, and algorithm settings were identical in the Malaysian and Indonesian subsamples. Second, compositional invariance was confirmed through permutation testing, indicating that the composite scores were formed equivalently across the two groups. Third, the equality of composite means and variances was examined. The permutation results are summarised in Table 12 (Henseler et al., 2016).

Table 12. MICOM results (Malaysia vs Indonesia).

Construct	Mean diff (MY–ID)	95% CI (Mean)	p(Mean)	Var. diff	95% CI (var.)	p(var.)	Conclusion
CRI	-0.047	[-0.362, 0.352]	0.681	0.028	[-0.290, 0.341]	0.742	Equality supported
GAC	-0.012	[-0.314, 0.298]	0.812	0.033	[-0.281, 0.352]	0.769	Equality supported
PP	0.019	[-0.298, 0.322]	0.764	-0.041	[-0.339, 0.287]	0.701	Equality supported

As shown in Table 12, the confidence intervals for mean and variance differences have zero as a value and all p-values are above conventional significance values. As a result of this, equality of composite means and variances is supported for all constructs.

Because configural and compositional invariance were established and the mean and variance equality tests showed no significant differences, the results provide sufficient measurement invariance for MGA (Henseler et al., 2016).

Thereafter, multi-group analysis was performed using Henseler's MGA with bootstrapping based on 5,000 resamples per group to test for cross-country structural differences. The path comparison results are shown in Table 13 (Hair et al., 2026; Henseler et al., 2016).

No statistically significant differences are found between Malaysia and Indonesia for any structural path coefficient. Given that sufficient measurement invariance for MGA is established and structural path differences are

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non-significant, the governance-buffering mechanism linking CRI, GAC, and PP appears to operate consistently across the two institutional contexts.

Table 13. Multi-group analysis path differences between Malaysia and Indonesia.

Path	β (MY)	β (ID)	Δβ (MY-ID)	p(HMGA)	p(two-tailed)	Sig. diff.
CRI-->GAC	0.386	0.478	-0.092	0.179	0.359	No
CRI-->PP	-0.279	-0.264	-0.015	0.454	0.909	No
GAC-->PP	0.422	0.386	0.036	0.614	0.773	No
Project Size-->PP	-0.067	0.093	-0.160	0.089	0.178	No
Experience-->PP	-0.002	0.111	-0.112	0.151	0.302	No
Project Phase-->PP	0.026	0.055	-0.029	0.397	0.795	No

6. DISCUSSION

6.1. Interpretation of Main Effects

The respondent-based findings provide support for the proposed structural relationships and offer useful insight into how compound risk environments may shape perceived governance-performance dynamics in large transport infrastructure projects. First, the negative relationship between CRI and PP supports the argument that multi-layered environmental turbulence generates systemic coordination strain. Compared with isolated disruptions, compound risks operate through interdependent channels and amplify uncertainty across contractual, financial, and operational domains. This result is consistent with scholarship emphasising risk propagation across complex infrastructure systems (Renn, 2021; Schweizer, 2021). As risk layers accumulate, governance systems may face higher transaction costs, weaker information flow, and reduced inter-organisational stability. In such settings, respondent-assessed performance deterioration indicates cumulative structural pressure that may exceed routine absorptive capacity, consistent with DCT (Teece et al., 1997).

Second, the positive relationship between CRI and GAC attests to the dual nature of the environmental turbulence. Rather than playing the role of a destabilising force in and of itself, exposure to compound risk seems to catalyse adaptive governance responses. This finding builds on previous studies that suggest crises lead to innovations and reconfiguration of governance under the circumstances of megaprojects (Boin & van Eeten, 2013; Chaffin et al., 2014). Heightened uncertainty forces project actors to rethink contractual arrangements, strengthen monitoring systems and increase consideration of stakeholders. Consequently, compound risk functions as both a stressor and a catalyst at the same time, and thus reinforces the sensing-seizing-reconfiguring logic stated in DCT (Teece, 2018; Teece et al., 1997).

Third, the role of GAC in enhancing the performance of the project confirms the performance-enhancing nature of adaptive governance structures. In keeping with infrastructure governance studies (Derakhshan et al., 2019; Williams et al., 2010), the flexibility of coordination and institutional responsiveness smooths out cascading disruptions and stabilises outcomes of delivery. In highly interdependent transport projects, the mechanisms of adaptive coordination dampen uncertainty spill-overs, making volatile conditions manageable contingencies. These observations support the argument that dynamic capabilities are higher-order coordination mechanisms in complicated project ecosystems (Eisenhardt & Martin, 2000; Teece, 2018).

Taken together, the findings suggest that compound risk environments create not strictly linear effects. Instead, they precipitate simultaneous erosive and adaptive processes where they build up the ground for the competitive mediation pattern in the structural model.

6.2. Competitive Mediation and the Governance Buffering Mechanism

The mediation analysis reveals competitive mediation, in which the direct and indirect effects of CRI operate in opposite directions. This finding aligns with contemporary discussions of governance resilience in megaproject

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environments (Zwikael & Smyrk, 2015). CRI directly erode PP through coordination breakdowns and cost escalation, consistent with systemic risk theory (Aven, 2011). At the same time, higher compound risk is associated with stronger governance adaptation, which may help restore structural alignment to some extent.

From a Dynamic Capabilities perspective, this configuration is one of the balancing tensions between environmental strains and adaptive reconfiguration (Teece, 2018; Teece et al., 1997). Rather than establishing a causal sequence, the results are consistent with an adaptive-response pathway associated with environmental turbulence. This extends existing work on adaptive governance that is often conceptualising flexibility as a pre-existing structural attribute (Chaffin et al., 2014; Folke et al., 2005) by showing that the adaptive capacity may intensify when facing the compound exposure of doing so under escalating risk.

Importantly, the buffering effect is a partial rather than a complete effect. Infrastructure megaprojects have limitations of contractual rigidities, institutional path dependencies and resource limitations (Mahalingam, 2022; Qiu et al., 2019). Consequently, governance adaptation lessens - but does not stop - performance deterioration. Thus, the competitive mediation pattern contributes to an enhancement of resilience discourse by showing flexible capabilities as equivalent compensation processes in relation to absolute shields against systemic uncertainty.

6.3. Cross-Country Structural Consistency

The results of the multi-group analysis suggest that the structural relationships among CRI, GAC, and PP do not differ significantly between the Malaysian and Indonesian respondent groups. This cross-country consistency has theoretical importance. Although megaproject governance is embedded in diverse institutional contexts (Biesenthal et al., 2018; Mahalingam, 2022), the absence of significant path differences suggests that the governance-buffering mechanism may operate in broadly comparable ways across these two national settings.

Recent research highlights the importance of institutional environments in shaping governance design, but such environments may not necessarily alter the basic coordination dynamics within interdependent project systems (Qiu et al., 2019; Williams et al., 2010). The observed cross-country consistency should therefore be interpreted as evidence of comparable respondent-assessed mechanisms across Malaysia and Indonesia, rather than proof of universal invariance across all infrastructure settings.

From the viewpoint of dynamic capabilities, this cross-context consistency reinforces the argument that sensing and reconfiguration mechanisms can function as higher-order coordination mechanisms across comparable institutional settings (Eisenhardt & Martin, 2000; Teece, 2018). Accordingly, governance adaptation may be viewed as a potentially transferable stabilising mechanism in complex infrastructure ecosystems, while still requiring further validation in additional countries and project delivery contexts.

6.4. Theoretical Implications

This study plays three main roles from a theoretical perspective.

First, it advances DCT by the location in compound risk environments characterised by the interaction and cascading of uncertainties. While previous studies have considered the issue of turbulence in broad terms (Eisenhardt & Martin, 2000; Teece et al., 1997), not so much attention has been paid to the case of risk accumulation in layers of megaproject systems. By modelling compound risk as a higher-order construct, this study develops the theory to include multi-actor governance networks.

Second, the identification of a competitive mediation pattern adds both deep and diverse layers of insight to the empirical work of the study of resilience by showing that disruption and adaptation go together. Instead of assuming linear or purely moderating relationships, the results indicate a dual path dynamic in line with the models of systemic risk (Aven, 2011; Linkov et al., 2018). This re-conceptualisation of governance adaptation functions to the buffering mechanisms of attenuation, which, although not negating performance, reduce its rate of decline.

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Third, the bounded Malaysia-Indonesia comparison strengthens the application of dynamic capability logic to infrastructure governance beyond a single-country setting. Rather than claiming broad generalisability, the findings suggest tentative transferability of the governance-buffering mechanism across two Southeast Asian emerging-economy contexts.

Importantly, the low R^2 values for PP are consistent with the inherently multi-deterministic nature of infrastructure outcomes, which depend on political, financial, contractual, and institutional variables in addition to governance adaptation. Rather than invalidating the framework, the modest explanatory power highlights the complexity of performance dynamics in megaproject ecosystems.

7. CONCLUSION

The purpose of this study was to look at the relationship between CRI, GAC, and PP in transport infrastructure projects in Malaysia and Indonesia after the COVID-19 pandemic. The findings indicate that CRI is negatively associated with PP but positively associated with GAC, while GAC is positively associated with PP. The opposing negative direct and positive indirect pathways produce a competitive mediation pattern in which governance adaptation partially counterbalances, but does not completely offset, the performance deterioration associated with compound risk exposure. This dual-path pattern is in line with systemic-risk perspectives and DCT as both environmental turbulence can disrupt and stimulate adaptive reconfiguration (Renn, 2021; Schweizer, 2021; Teece, 2018).

The study makes a contribution by conceptualising the CRI as a higher-order construct consisting of four factors: SCD, LHC, FCP, and RIU. It also positions GAC as a project-contextualised dynamic capability operating within multi-actor infrastructure governance arrangements. This treatment goes beyond the DCT's applicability to stable organisational contexts by offering insights into how adaptive coordination could operate within the context of temporary, contractually fragmented and institutionally complex megaprojects (Mahalingam, 2022; Schaefer & Mohan, 2024; Teece, 2018).

No statistically significant differences were detected between the Malaysian and Indonesian respondent groups in the analysed structural relationships based on the multi-group analysis. The governance-buffering mechanism seems to be functioning in similar ways for the two samples, but cannot be claimed to be cross-nationally equivalent. In summary, the modest explanatory power also suggests that political, contractual, financial, institutional, leadership and stakeholder conditions remain important for the performance of infrastructure projects outside the scope of the present model. These results are therefore limited evidence of one governance-buffering mechanism, and not a complete account of what makes megaprojects successful (Flyvbjerg & Gardner, 2023; Mahalingam, 2022; Schaefer & Mohan, 2024).

8. LIMITATIONS

There are some limitations to this study. Firstly, the cross-sectional design limits the possibility of temporal/causal interpretation. The structural model supports the proposed statistical relationships between CRI, GAC, and PP, but is unable to assert whether the exposure to compound risk came before, or whether the governance adaptation came before, changes in PP. To be able to see how these relationships evolve throughout different phases of the project and throughout the periods, longitudinal or time-lagged evidence would be needed (Hair et al., 2026; Teece, 2018).

Secondly, all constructs were assessed with a single respondent questionnaire. The results are therefore based on the risk exposure, governance adaptation, and project performance assessments of informed respondents, not on verified project records. The procedural safeguards, Harman's single-factor test, and full-collinearity assessment reduce, but cannot completely eliminate, possible common-method concerns. Furthermore, subjective measures such as respondent-evaluated project performance are not enough to replace objective measures like actual cost overruns,

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schedule slippages, contractual claims, safety performance, or audited delivery results (Hair et al., 2026; Podsakoff et al., 2003).

Third, the model accounts for a modest amount of the variation in GAC and PP. This means that the framework explains only one type of governance-buffering mechanism, not a comprehensive explanation of PP. Political support, leadership capacity, financing arrangements, contractual design, procurement structures, alignment of stakeholders, institutional capacity, and macro-economic conditions not included in the present model are other factors that can affect megaproject outcomes (Flyvbjerg & Gardner, 2023; Mahalingam, 2022).

Fourth, the study is restricted to 300 respondent-level project observations from Malaysia and Indonesia. The data cannot be interpreted as 300 independent, verified archival project cases, but rather as one focal project context, as assessed by each respondent. The results must therefore be viewed as limited evidence provided by the two groups of respondents and the specific transport infrastructure settings and not necessarily as results that can be automatically generalised to other countries, other sectors of transport infrastructure, or other project delivery arrangements. This is especially important due to the fact that the infrastructure projects driven by China can vary in terms of their actors, funding mechanisms, ownership, delivery, and host country institutions (Mahalingam, 2022; Schaefer & Mohan, 2024).

Last but not least, the study identified GAC as a mediator and CRI as a reflective-reflective higher-order construct. The analysis did not explore whether GAC is also an organisational pre-existing capability or a dynamically emerging project response. The tested model did not include alternative higher order measurement specifications for CRI. Conclusions are therefore only valid for the mediation and measurement specifications investigated in the present study and should not be interpreted as implying that these specifications are better than all reasonable alternative specifications (Hair et al., 2026; Hair et al., 2023).

9. FUTURE RESEARCH

Future research should use longitudinal or repeated wave designs to examine how the variables of CRI, GAC, and PP evolve throughout the project lifecycle. Observations made in the planning, construction, commissioning, and operational phases could clarify the relationship between rising compound risk and governance adaptation, and how later adaptation relates to reduced performance deterioration. These designs would help provide greater insight into temporal order and how dynamic capabilities develop over time in the face of ongoing environmental turbulence (Hair et al., 2026; Teece, 2018).

Objective project-level evidence needs to be combined with respondent assessment in future studies as well. Survey metrics can be correlated with actual cost overruns, delays, contractual claims, procurement issues, financing adjustments, safety logs, and audited delivery results. This multi-source approach would reduce reliance on a single source and help to better gauge if perceived governance adaptation is aligned with observed PP (Flyvbjerg & Gardner, 2023; Podsakoff et al., 2003).

The explanatory framework may be extended by adding more institutional and organisational conditions. Other factors, such as leadership capability, political support, contractual flexibility, financing stability, stakeholder alignment, information transparency, interorganisational trust and institutional capacity could explain additional variation in governance adaptation and PP. These factors can be seen as boundary conditions, mediators, predictors, or moderators in the governance-buffering framework (Derakhshan et al., 2019; Mahalingam, 2022; Schaefer & Mohan, 2024).

Broader comparative research is also required to establish if the relationship being observed is consistent across project and institutional contexts. Future research could focus on further comparisons between other countries, the various infrastructure sectors, procurement processes, public-private partnerships, concession schemes and different forms of Chinese financing, ownership, development, and delivery participation. Such comparisons would help

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determine if the governance-buffering mechanism can be applied across contexts or if it is context-specific, depending on the regulatory, contractual, and actor configurations (Mahalingam, 2022; Schaefer & Mohan, 2024).

Further study of alternative theoretical and statistical specifications should be conducted. GAC can be explored as a mediator and/or moderator, as a pre-existing organisational capability, or as a capability that evolves in response to changing project circumstances. Alternative higher-order specifications of CRI should also be compared, together with stronger out-of-sample predictive assessments, to determine whether the proposed model remains robust under different measurement and structural assumptions (Hair et al., 2026; Hair et al., 2023; Teece, 2018).

10. POLICY IMPLICATIONS

The results suggest that compound risk must be addressed as an integrated governance issue instead of a set of independent operational problems. Public authorities, project owners, project contractors and governing agencies should consider integrated risk registers and early warning systems to track the interactions between SCD, LHC, FCP and RIU. Cascading pressures can be detected by cross-organisational information sharing before they materialise as more widespread contractual, financial and/or operational instability (Renn, 2021; Schweizer, 2021).

Governance adaptation should be institutionalised before substantial disruption or deterioration in performance occurs. Relevant arrangements can include pre-agreed escalation procedures, regular contractual review, cross-agency coordination committees, transparent information-sharing mechanisms, contingency decision protocols and clearly defined responsibilities among project actors. These arrangements are especially relevant in China-led project settings, since the responsibilities of the different actors involved in a project may be distributed differently over the different project phases, but they are dependent on one another (Mahalingam, 2022; Schaefer & Mohan, 2024).

GAC is also found to be only a partial buffer to compound risk, as the mediation result was competitive. The negative direct relationship between CRI and PP is partially mitigated by the positive indirect relationship, which goes through GAC. Adaptive governance should therefore not be used in place of, but in addition to, preventive risk assessment, realistic project appraisal, procurement safeguards, financing contingencies, contractual clarity, stakeholder coordination, and institutional oversight. Strengthening preventive governance capacity is more defensible than only changing governance after an already significant amount of performance deterioration has taken place (Flyvbjerg & Gardner, 2023; Renn, 2021).

The absence of statistically significant structural differences between the Malaysian and Indonesian respondent groups suggests that integrated risk governance and adaptive coordination may have relevance across both samples. However, this finding does not establish that identical policy arrangements will be effective in all national or institutional environments. Regional and cross-border infrastructure policies may adopt common principles of risk integration, accountability, information sharing, and adaptive decision-making, while implementation procedures should remain sensitive to local regulatory systems, institutional capacity, contractual arrangements, and project-specific actor configurations (Mahalingam, 2022; Schaefer & Mohan, 2024).

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