
# Modelling stakeholder resilience in relationship management in a changing environment of megaprojects

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# Modelling stakeholder resilience in relationship management in a changing environment of megaprojects


## Abstract

Given the importance of sustaining collaborative stakeholder relationships from the conflicts in a changing environment of megaprojects, this research develops a model to systematically analyse stakeholder resilience in relationship management from measurement, analysis and management perspectives. Through the NK model, dynamic stakeholder interactions can be accurately illustrated, and the network model provides a useful way to evaluate complex stakeholder structures. Then, stakeholder resilience is analysed in two dimensions, namely, stakeholder issue vulnerabilities and stakeholder capabilities, and the evolutions of these dimensions are considered. Afterwards, a stakeholder resilience map (including four resilient zones: dangerous, challenging, vigilant, and safe) is developed and validated using the Hong Kong–Zhuhai–Macao Bridge project. The critical stakeholder issue vulnerabilities and stakeholder capability limitations in relationship management at each project phase of megaprojects are also identified. This study provides an evidence-based practical approach to evaluate stakeholder resilience in relationship management in megaprojects. It extends resilience theory in project management at organizational levels whilst effectively bridging stakeholder and relationship management concepts.


**Keywords:** stakeholder resilience; relationship management; megaprojects; NK model

## 1. Introduction

Relationship management (RM) aims to build a collaborative environment amongst stakeholders by using proper management strategies for achieving project success (Zou et al., 2014, Zheng et al., 2017, Pryke and Smyth, 2012). Megaprojects with long-term durations involve many interdependent stakeholders (Mok et al., 2015). Therefore, RM plays an essential role for each stakeholder because it enhances collaborations for improved project performance (Liu et al., 2015). Internal and external stakeholders participate in megaprojects (Mok et al., 2015). Internal stakeholders refer to construction groups (owners, contractors, consultants, subcontractors, suppliers and workers) that are directly involved in the project execution (Ujene and Edike, 2015). External stakeholders mainly consist of the government and pressure groups (environmental groups, local communities, media and the general public) that affect or are affected by the project's process (Olander and Landin, 2008). RM amongst stakeholders is considered a critical component of stakeholder management in traditional construction projects (Yang and Shen, 2014). Compared with conventional projects, megaprojects have a more changeable project environment due to the complex stakeholder structures and dynamic stakeholder interactions, leading to new challenges in RM (Shen and Xue, 2021, Ford et al., 2024). On the one

hand, many issues concerned by stakeholders exist due to stakeholders' different interests in megaprojects (Li et al., 2012a), and these issues are interdependent among stakeholders, leading to the complexity of stakeholder structures.(Yang et al., 2009). The structures reflect the conflicting interests of stakeholders and result in the disruption of healthy stakeholder relationships (Mok et al., 2017a, Mok et al., 2017b). On the other hand, dynamic stakeholder interactions around stakeholder issues occur in the long-term project duration of megaprojects, causing unexpected conflicts to perturb collaborative relationships amongst stakeholders (Mok et al., 2017c). Given that stakeholder collaborations are adversely affected by stakeholder issues in megaprojects, understanding the resilience level of sustaining a collaborative relationship amongst stakeholders in megaprojects is essential and can help improve stakeholder RM to achieve project success (Yang et al., 2022, Morkan et al., 2023). Although previous studies have emphasized the concept of stakeholder RM to sustain collaborative relationships in stakeholder conflicts in the project (Yang and Shen, 2014), there is no existing comprehensive resilience studies in the stakeholder context (Naderpajouh et al., 2023). Thus, this research aims to establish a model for in-depth understands of stakeholder resilience in RM under a changing project environment. It is expected to answer the questions on 'What is the stakeholder resilience in RM?' and 'How to effectively measure, analyse, and management stakeholder resilience in RM in megaprojects?'

As stakeholder research is a critical part of organizational studies in project management (Naderpajouh et al., 2020), the definition of stakeholder resilience in RM can be taken reference from the resilience concept at the organizational level, which has been defined as the capability of an organization to withstand adverse conditions in a changing environment (Duchek, 2020, Burnard and Bhamra, 2011, Sajko et al., 2021). The research focus of organizational resilience includes reducing the vulnerability of organizations by enhancing capability with integrating organizational processes, engaging stakeholders, utilizing resources and increasing the awareness to prepare and respond to disruptions (Burnard and Bhamra, 2011). Therefore, previous research suggests that the measure of organizational resilience is dependent on finding the appropriate equilibrium between the vulnerabilities and capabilities of the organization (McManus et al., 2008), which shed a light on the analysis of stakeholder resilience in RM from stakeholder-issue vulnerabilities and stakeholder capabilities. On the basis of existing organizational resilience and stakeholder concepts, the authors defined 'stakeholder resilience' in RM as the 'capability of stakeholders to withstand stakeholder–issue vulnerabilities for recovering a collaborative relationship in a changeable project environment in RM'. The concept of stakeholder resilience in RM highlights the recovery capacity of collaborative relationships in a changeable project environment, which echoes the essence of the resilience concept defined as the ability to bounce back from a system in response to

changes (Hassler and Kohler, 2014, Bhamra et al., 2011). Moreover, stakeholder resilience introduces the resilience concept into stakeholder management, providing a new perspective to analyse how effective RM is in the presence of a changeable environment in megaprojects.

On the basis of this concept, stakeholder resilience in RM is determined by the balance between the vulnerability level of stakeholder issues and the capability level of relevant stakeholders, which was echoed by studies that consider vulnerabilities and adaptive capacity as two attributes for organizational resilience (Burnard et al., 2018, Burnard and Bhamra, 2011, Scholz et al., 2020). In this aspect, stakeholder issue vulnerabilities refer to the weaknesses that arise from stakeholder issues, which damage the collaborative relationship amongst stakeholders (Mok et al., 2017b). Therefore, the level of vulnerability of stakeholder issues in RM relies on the ability of stakeholders to strengthen and rebuild their relationships when facing disruptions caused by stakeholder issues. Stakeholder capabilities in RM refer to the ability to effectively manage stakeholder relationships by withstanding stakeholder issue vulnerabilities to achieve stakeholders' objectives and interests (Yang and Shen, 2014, Zou et al., 2014). The stakeholder capability to withstand stakeholder issue vulnerabilities can improve stakeholder resilience in RM (Ortiz-de-Mandojana and Bansal, 2016, Zhang et al., 2023). RM for stakeholders is resilient when the stakeholder issues are less vulnerable, and stakeholders have high capabilities to manage their relationships. If the high level of stakeholder issue vulnerabilities triggers conflicts amongst stakeholders with limited RM capability, the stakeholder collaborations will be seriously broken and difficult to restore. In megaprojects, stakeholder issue vulnerabilities and stakeholder capabilities are project specific. For instance, the Panyu Energy Project was considered highly vulnerable due to the environmental protection issue because the stakeholders paid too much attention to the pollution problem (Zhou et al., 2019). Meanwhile, the Hong Kong Express Rail Link was considered less vulnerable to the same issue because the stakeholders regarded land acquisitions and cultural village protections as their primary concerns. RM capabilities also vary in different projects even for the same stakeholder group (Li et al., 2012b). For example, the government as a stakeholder group failed to manage the conflicting relationships between local communities in the alignment of highway projects, leading to the stoppage and defunding of the projects (Zafar et al., 2020). By contrast, the government successfully coordinated the relationships of a vast number of stakeholders in the Shanghai Expo Project (Zhai et al., 2017). Given that the levels of stakeholder issue vulnerabilities and stakeholder capabilities vary in different projects, a reliable assessment approach must be developed to effectively manage stakeholder relationships targeting stakeholder resilience in each project.

Stakeholder resilience assessment sets a solid foundation to establish strategies for improving RM. Classical resilience

assessment at organizational levels is based on quantitative and qualitative indicators, which generate a score to represent the resilience level of an organization (Ruiz-Martin et al., 2018). The indicators were proposed by McManus et al. (2008), which were grouped by four categories (key vulnerabilities, adaptive capacity, situation awareness, and resilience ethos). The four categories were further tailor-made to develop other indicators for measurement (Whitehorn, 2010, Sanchis and Poler, 2013, Lee et al., 2013, Rahi and Bourgault, 2022). Despite the previous indicator-based research has provided dimensions for resilience assessment, stakeholder resilience assessment still faces a considerable challenge in megaprojects. Classical evaluation approaches cannot adapt to the changeable project environment in RM in megaprojects, which is led by complex stakeholder structures and dynamic stakeholder interactions (Xue et al., 2020b, Shen and Xue, 2021). The conventional scoreboard method has been criticized by organizational resilience studies that it relies too much on survey samples from quality respondents (Lee et al., 2013). However, with the increase in complexity and dynamics amongst stakeholders in the project environment of megaprojects, it is more difficult for project participants to objectively evaluate stakeholder resilience in RM during the survey due to the limitation in their own management experience (Shen and Xue, 2021). Hence, advanced methods must be developed to measure stakeholder resilience in RM under the project environment of complex stakeholder structures and dynamic stakeholder interactions.

When it comes to representing complex stakeholder structures, the network model provides a valuable method for illustrating the interrelationships between stakeholders and their respective issues in RM (Mok et al., 2015). The classical dyadic ties model, which was employed before the network model, regards the relationships between stakeholders as composed of dyadic links and disregards the interrelationship between stakeholder issues and stakeholders (Freeman, 1984). Hence, the traditional method cannot analyse the resilience problem at the stakeholder issue level, therefore cannot directly guide stakeholders in RM in industry practice (Yang et al., 2009). Compared with previous methods, the network model has the advantage of systematically representing the interrelationship between stakeholder issues and relevant stakeholders, which can assess stakeholder resilience in RM from a stakeholder issue perspective (Xue et al., 2020b). In terms of dynamic stakeholder interactions, NK modelling has the potential to evaluate stakeholder resilience, which can analyse stakeholders' capability in RM facing adverse changes in their interactions. The NK model is a special kind of the Agent-based models. Unlikely the classical Agent-based model that agents make decisions independently, NK modelling emphasizes the decision-making of the agents is interdependent, reflecting the dynamic stakeholder interactions in megaprojects (Mok et al., 2017a). Compared with system dynamics, NK modelling is more suitable for

evaluating the interdependent organisations in a large system (Giannoccaro et al., 2018). The NK model is a stochastic simulative approach adopted from biology to study an organization's interactions in a changing environment (Levinthal, 1997, Kauffman and Levin, 1987). The existing studies argue that the NK model is better suited than the system dynamics model for evaluating interactive organizations wherein accurate measurement of mutual influences is challenging (Ganco and Hoetker, 2009). They also identify two key benefits of using the NK model to analyse the dynamic stakeholder interactions. Firstly, the NK model can help assess the quality of a system (stakeholder issue) after interactions amongst its elements (stakeholders) (Giannoccaro, 2011, Xiang et al., 2024). With the score derived from the NK model to quantify the quality of a system, we can measure the vulnerability level of stakeholder issues during stakeholder interactions in megaprojects. Secondly, the NK model evaluates each element's adaptive capacity towards sudden changes in interactions (Giannoccaro et al., 2018). As a result, the capability level of each stakeholder in RM in a changeable environment can be measured. The NK model has been used with the network model to evaluate the variations in organizational performance resulting from a changeable environment (Capaldo and Giannoccaro, 2015). Therefore, integrating NK and network models is a promising approach to measure stakeholder resilience in megaprojects and provide strategies for improved RM. The approach has two features. First, the network model can evaluate the complexities between stakeholders and relevant issues, which is useful for identifying and addressing the RM challenges at the stakeholder-issue level. Second, the NK model enables to measure the dynamics of stakeholder interactions for each stakeholder-issue, which is beneficial to assess the varied stakeholder relationships in project development. By using the integrated models, it has a high potential to analyse the stakeholder resilience level in RM under a changing project environment.

To fill the gap of lack of resilience studies in the stakeholder context to understand the RM capability in stakeholder conflicts, this study introduces the concept of stakeholder resilience in RM and proposes a model for measuring, analysing, and managing stakeholder resilience in megaprojects. The model consists of three main components: a measurement function to evaluate stakeholder variations of RM in changeable environments, an analysis function to assess the evolution of stakeholder issue vulnerabilities and capabilities in RM, and a managerial map to classify stakeholder resilience and provide a management guide. To validate the proposed model, a real-project study of the Hong Kong-Zhuhai-Macao Bridge is conducted, providing empirical evidence on stakeholder resilience in RM in megaprojects.

## 2. Background

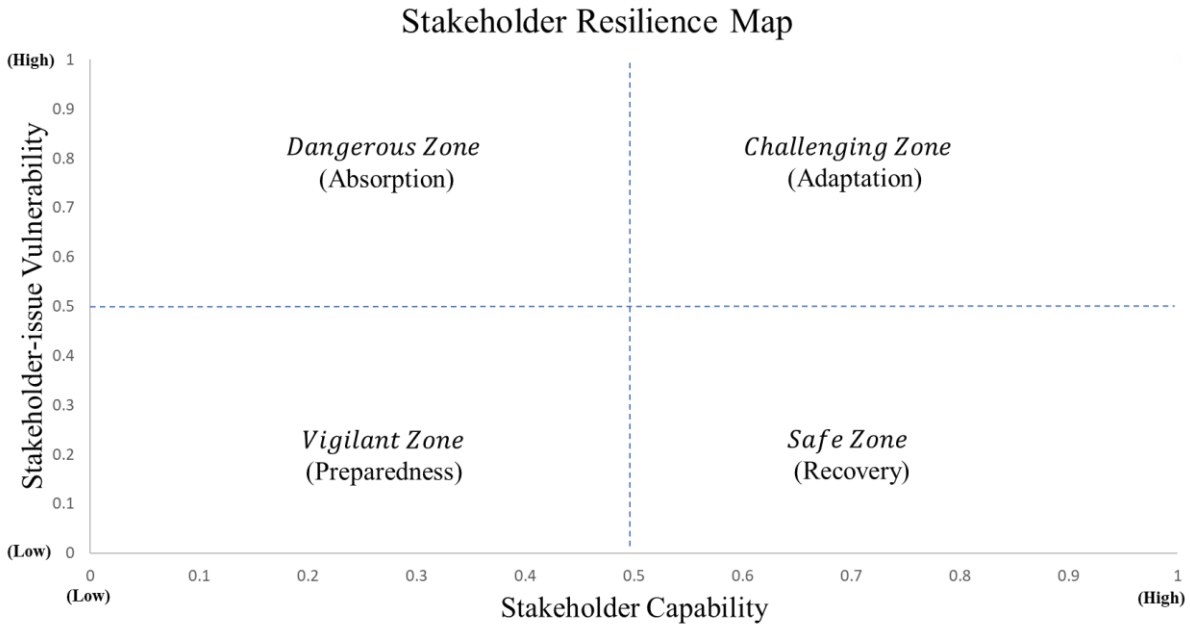
### 2.1 Stakeholder resilience evaluation techniques

Resilience metrics play a critical role in assessing resilience at organizational levels (Wood et al., 2019). Previous studies referred to organizational resilience as the balance between vulnerability and adaptive capability to withstand organizational turbulence because of disruptions (Bhamra et al., 2011, Thome et al., 2016). Based on the organizational resilience concept, resilience metrics were proposed by Pettit et al. (2013) to calculate the resilience score from two dimensions, namely, vulnerability and capability. If an organization's capability to withstand vulnerability is high, the organization is resilient with a high possibility of recovery from perturbations due to changes (Chowdhury and Quaddus, 2017). By adopting the resilience metrics set by Pettit et al. (2013), the stakeholder resilience level can be analysed by examining the balance between the vulnerability level arising from associated stakeholder issues and the capability level of relevant stakeholders.

In addition to the resilience metrics, the resilience curve is useful to map the relationship between system performance and the resilience process in the built environment. The resilience curve shows how system performance varies in the resilience process with four statuses: prepare, absorb, recover and adapt (Kurth et al., 2019). The four statuses have been introduced into resilience evaluation at organizational levels, which facilitates organizations to implement management strategies correspondingly in face of disruptions (Burnard et al., 2018, McManus et al., 2008).

On the basis of the resilience curve and metrics, our research further proposed a stakeholder resilience map (Figure 1) to assess and visualize the capability of stakeholders to maintain a collaborative relationship whilst facing stakeholder issue vulnerabilities in megaprojects. The map is established based on the metrics of stakeholder-issue vulnerability and stakeholder capability. It also connects stakeholder resilience management with the classical resilience curves by adopting four critical concepts: preparedness, absorption, recovery and adaptation (Kurth et al., 2019). There are four resilience zones in the map, namely, dangerous, challenging, safe and vigilant. In the Dangerous Zone, stakeholder resilience is weak, with a high level of stakeholder issue vulnerabilities and a low level of stakeholder capability. Thus, the stakeholder issues in this zone lead to heavy damage on collaborative relationships amongst stakeholders, and the broken relationship cannot easily bounce back to the original level. Resilience management in the Dangerous Zone requires to absorb the strongly negative impact of collaborative relationship disruptions due to the stakeholder issues. The previous resilience studies suggest that the positive attitudes and proactive actions are essential for organizations to cope with the outbreak of dangers (Kantur and İşeri-Say, 2012, Vogus and Sutcliffe, 2007, Iao-Jörgensen, 2023). In the Challenging Zone, stakeholder resilience is moderate and stakeholder issue vulnerability is serious, but stakeholder

capability is satisfactory. Given that the vulnerability level is high, collaborative relationship recovery around stakeholder issues in this zone is possible but full of challenges. Resilience management of the stakeholder issues in the Challenging Zone requires adaptation ability (Burnard et al., 2018). The existing organization studies prove that stakeholders should keep learning how to deal with vulnerabilities during the difficult period of relationship recovery (Lengnick-Hall et al., 2011, Phillips and Chao, 2022). The continuous learning from the failure is helpful for stakeholders to make adjustments in RM and adapt to the challenging environment. In the Safe Zone, stakeholder resilience is promising, with low stakeholder issue vulnerability and high stakeholder capability. The disruptive collaborative relationship due to the stakeholder issues in this zone can be fully recovered. Hence, resilience management of the stakeholder issues in the Safe Zone focuses on achieving a 'high bounce back' regarding the quality of collaborative relationship recovery. Management strategies aim to build stronger collaborative relationships amongst stakeholders compared with the status before the vulnerabilities' outbreak, which are echoed by organizational resilience studies (Lengnick-Hall et al., 2011, Ruiz-Martin et al., 2018). In the Vigilant Zone, given that stakeholder issue vulnerabilities and stakeholder capabilities are at the marginal level, stakeholder resilience is insignificant but still warrants vigilance. The previous resilience studies highlight the importance of preparation capabilities for organizations facing unexpected crises (Duchek, 2020, Kantur and İşeri-Say, 2012). Although the stakeholder issues in the Vigilant Zone do not adversely influence relevant stakeholders in general, the associated low-capability stakeholders are still encouraged to improve preparation before the conflicts suddenly escalate due to the unforeseeable vulnerabilities.




**<Figure 1 The Proposed Stakeholder Resilience Map>**

## 2.2 NK and Network Models

Changeable project environments are critical factors for understanding resilience at organizational levels (Lengnick-Hall et al., 2011, McManus et al., 2008). In megaprojects, stakeholders face a changeable environment due to the complex stakeholder structures and dynamic stakeholder interactions (Shen and Xue, 2021). In terms of complex stakeholder structures, the network model has been introduced into analyzing organizational resilience under the complex interorganizational structures (Kim et al., 2021). In megaprojects, the complex stakeholder structures are led by high interdependencies between stakeholder issues and stakeholders, which influence stakeholder resilience in RM from perspectives of stakeholder issue vulnerabilities and stakeholder capabilities. On the one hand, one stakeholder issue is involved by various stakeholders. Hence, stakeholder issue vulnerabilities may trigger conflicts to damage the collaborative relationship amongst stakeholders (Yang and Zou, 2014). On the other hand, one stakeholder joins a variety of stakeholder issues. Therefore, it is a challenging task for the stakeholder to sustain collaborative relationships in multiple stakeholder issues (Mok et al., 2017a). The network model has been proven effective in analysing the complex stakeholder structures caused by stakeholder-issue interdependencies (Zheng et al., 2016, Li et al., 2024). There are three components in the stakeholder-issue network models, including stakeholder issue nodes, stakeholder nodes, and stakeholder-issue links (Latapy et al., 2008, Xue et al., 2020b). With the three components, the network model systematically presents the complicated relationships between stakeholder issues and stakeholders, which is a useful approach for evaluating stakeholder resilience in RM (Mok et al., 2015).

In the aspect of dynamic stakeholder interactions, the agent-based model has been used to study dynamic organizational interactions in a changing environment (Wu et al., 2009). As a kind of agent-based model, the NK model is specialised in analysing how the organizations adapt to the turbulent environment. The model can evaluate the adaptive capacity of an organization to withstand shocks in dynamic organizational interactions, which is useful to measure stakeholder resilience in RM. The model was initially presented in 1987 to reveal the evolutionary patterns of genes in biology (Kauffman and Levin, 1987). Then, it was introduced to the organization management field in the 1990s to show how the adaptive capability of organizations affects system performance in a changing environment (Kauffman, 1993, Levinthal, 1997). The NK model is determined by N and K. The parameter N stands for how many stakeholders are in the system, and the parameter K stands for the interaction level of stakeholders in the system (Giannoccaro et al., 2018). Stakeholders have no interaction when K is equal to 0, whereas stakeholders interact with each other when K equals N-1 (Kauffman, 1993). After setting up the parameters N and K, a landscape is mapped to simulate the stakeholder interactions based on their interactive behaviours (Giannoccaro et al., 2018). To build up a landscape, the distributions

of the RM capability levels among stakeholders are critical to understand RM level during the stakeholder interaction. The statistical distribution can be obtained by empirical studies on stakeholder relationships. For instance, Xue et al. (2020a) assessed the stakeholders' RM capability level under various project issues, which provided a numeric reference to setting up the distributions for creating the landscape. Based on the established landscape, the scores assessing the quality of a system and the capability of each stakeholder are obtained to reflect the stakeholder's adaptability in the changing environment (Ganco and Hoetker, 2009). Although the NK model has not been introduced into stakeholder studies in project management, it has been utilized to simulate a group of interacting agents seeking solutions to a common event in a dynamic environment, which is similar to dynamic stakeholder interactions around the associated stakeholder issue in megaprojects (Capaldo and Giannoccaro, 2015). Therefore, integrating NK and network models to simulate the changeable environment of megaprojects is a promising approach.

### 2.3 Case Selection and Description

Case study is a classical exploratory method for validating new research theories and methods, and it is popular in stakeholder research (Yin, 2003, Xue et al., 2020b, Mok et al., 2017c). Single instrumental case study is an efficient approach to examine the validity of the proposed stakeholder resilience model and provides a project setting to verify the model results (Mok et al., 2017c, Yang and Shen, 2014). The information-oriented principle is adopted for case selection, similar to extant case studies on megaprojects (Flyvbjerg, 2006, Mok et al., 2017b). Two information criteria are implemented in case selection. Firstly, the selected case has a far-reaching impact on regional development with a highly complex and dynamic project environment. Secondly, the selected case has faced numerous and acute RM challenges amongst stakeholders during the project duration. Thus, the Hong Kong–Zhuhai–Macao Bridge (HZMB) project was selected as the case to examine the validity of the stakeholder resilience model.

The HZMB project is a globally recognized megaproject that links three significant regions in China, namely Hong Kong, Macao, and Guangdong Province. From a temporal standpoint, the project spans a duration of 16 years, encompassing the planning phase (2003-2009), the construction phase (2010-2017), and the handover phase (2018), thus exhibiting dynamic characteristics (timeline shown in Appendix 3). The project involves stakeholders from the regions under the "one country and two systems" scheme in the complex aspect. The scheme refers to the different regulation and culture systems between three regions, where Guangdong undertakes the mainland governance system while Hong Kong and Macao have their own administrative systems. The project stakeholders faced challenges in RM toward the collaboration among different systems. Thus, stakeholder RM for this project experiences hardships at each

project phase because of conflicts over various stakeholder issues. In the planning phase, stakeholder tensions occurred when the project bill faced a vote in the National People's Congress in 2008. At that moment, fierce debates among stakeholders over the issues around regional cost sharing, local labour participation, ecological protection, and economic benefit analysis regarding the project. In the construction phase, a juridical appeal that occurred regarding the environmental assessment review of HZMB heavily damaged the stakeholder relationships in 2011. Another environmental issue of pollution during construction works triggered stakeholder conflicts in 2014. Meanwhile, the cost overrun problem periodically occurred throughout the construction of HZMB, so the additional budget bills always seriously threatened stakeholder collaborative relationships. In the handover phase, the review of safety incidents heavily destroyed the stakeholder relationships, which damaged stakeholder collaborations in 2018. Thus, the frequent stakeholder tensions in HZMB provide the opportunity to examine the robustness of the proposed stakeholder resilience model.

### 2.4 Summary of literatures in modelling stakeholder resilience

Overall, the overview of stakeholder resilience in RM (shown in Table 1) is summarized from perspectives of the stakeholder resilience concept, measurement, analysis, and management based on the literature in the introduction and background sections, which sets a theoretical foundation for the following method development and case validation.

**Table 1 Overview of stakeholder resilience in RM**

| Research objectives | Research concepts | Research Findings | Relevant Literatures |
|---|---|---|---|
| Stakeholder resilience concept | Organizational resilience | It is defined as the capability of an organization to withstand adverse conditions in a changing environment. Previous research suggests that the measure of organizational resilience is dependent on finding the appropriate equilibrium between the vulnerabilities and capabilities of the organization | McManus et al., 2008<br>Burnard and Bhamra, 2011<br>Naderpajouh et al., 2020<br>Duchek, 2020<br>Sajko et al., 2021 |
| | Stakeholder-issue vulnerability | Stakeholder issue vulnerabilities refer to the weaknesses that arise from stakeholder issues, which damage the collaborative relationship amongst stakeholders. | Mok et al., 2017b<br>Scholz et al., 2020 |
| | Stakeholder capability | The stakeholder capability to withstand stakeholder issue vulnerabilities can improve stakeholder resilience in RM. | Ortiz-de-Mandojana and Bansal, 2016<br>Zhang et al., 2023 |
| | Stakeholder resilience | Stakeholder resilience in RM is determined by the balance between the vulnerability level of stakeholder issues and the capability level of relevant stakeholders, which was echoed by studies that consider vulnerabilities and adaptive capacity as two attributes for organizational resilience. | Burnard and Bhamra, 2011<br>Bhamra et al., 2011<br>Hassler and Kohler, 2014<br>Burnard et al., 2018<br>Scholz et al., 2020 |
| Stakeholder resilience measurement | NK model for evaluating dynamic stakeholder interactions | The NK model was introduced to the organization management field in the 1990s to show how the adaptive capability of organizations affects system performance in a changing environment. | Kauffman, 1993<br>Levinthal, 1997 |
| | | The NK model is determined by N and K. The parameter N stands for how many stakeholders are in the system, and the parameter K stands for the interaction level of stakeholders in the system. After setting up the parameters N and K, a landscape is mapped to simulate the stakeholder interactions based on their interactive behaviours. | Giannoccaro, 2011<br>Giannoccaro and Nair, 2016<br>Giannoccaro et al., 2018 |
| | | Based on the established landscape, the scores assessing the quality of a system and the capability of each stakeholder are obtained to reflect the stakeholder's adaptability in the changing environment. | Ganco and Hoetker, 2009<br>Capaldo and Giannoccaro, 2015<br>Xiang et al., 2024 |

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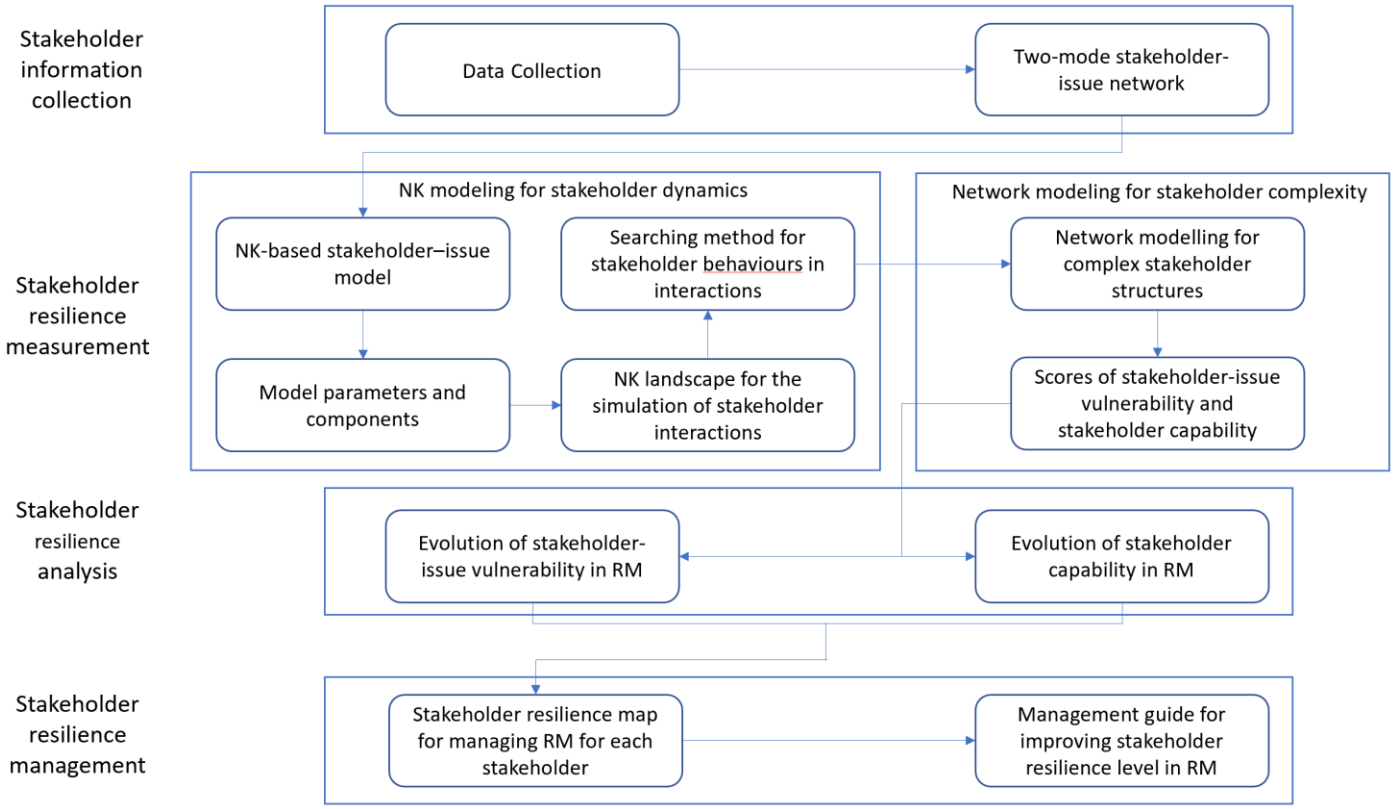
| | Network model for evaluating complex stakeholder structures | The network model has been proven effective in analysing the complex stakeholder structures caused by stakeholder-issue interdependencies. | Zheng et al., 2016<br>Mok et al., 2017a<br>Li et al., 2024 |
| | | There are three components in the stakeholder-issue network models, including stakeholder issue nodes, stakeholder nodes, and stakeholder-issue links | Latapy et al., 2008<br>Xue et al., 2020b |
| | | The network model systematically presents the complicated relationships between stakeholder issues and stakeholders, which is a useful approach for evaluating stakeholder resilience in RM | Mok et al., 2015<br>Kim et al., 2021<br>Shen and Xue, 2021<br>Naderpajouh et al., 2023 |
| Stakeholder resilience analysis | Evolution graph for stakeholder resilience analysis | Evolution graphs are critical to analysing the dynamics of resilience problems. Existing studies have proven that evolution graphs of the system's vulnerabilities and the elements' capabilities are useful in evaluating resilience from two important perspectives. | Jafarnejad et al., 2019<br>Liu, 2019<br>Ekanayake et al., 2021a<br>Ekanayake et al., 2021b |
| Stakeholder resilience management | Resilience metrics | Resilience metrics play a critical role in assessing resilience at organizational levels. The metrics were proposed to calculate the resilience score from two dimensions, namely, vulnerability and capability. | Bhamra et al., 2011<br>Pettit et al. 2013<br>Thome et al., 2016<br>Wood et al., 2019<br>Rahi and Bourgault, 2022 |
| | Resilience curves | The resilience curve shows how system performance varies in the resilience process with four statuses: prepare, absorb, recover and adapt. | McManus et al., 2008<br>Burnard et al., 2018<br>Kurth et al., 2019 |
| | Resilience maps | The resilience map connects stakeholder resilience management with the classical resilience curves by adopting four critical concepts: preparedness, absorption, recovery and adaptation. | Kurth et al., 2019 |
| | | Management strategies in the dangerous zone: the previous resilience studies suggest that the positive attitudes and proactive actions are essential for organizations to cope with the outbreak of dangers. | Vogus and Sutcliffe, 2007<br>Kantur and İşeri-Say, 2012<br>Iao-Jörgensen, 2023 |
| | | Management strategies in the challenging zone: the existing organization studies prove that stakeholders should keep learning how to deal with vulnerabilities during the difficult period of relationship recovery. | Lengnick-Hall et al., 2011<br>Burnard et al., 2018<br>Phillips and Chao, 2022 |
| | | Management strategies in the safe zone: management strategies aim to build stronger collaborative relationships amongst stakeholders compared with the status before the vulnerabilities' outbreak. | Lengnick-Hall et al., 2011<br>Ruiz-Martin et al., 2018 |
| | | Management strategies in the vigilant zone: the previous resilience studies highlight the importance of preparation capabilities for organizations facing unexpected crises | Kantur and İşeri-Say, 2012<br>Duchek, 2020 |

## 3. Research framework

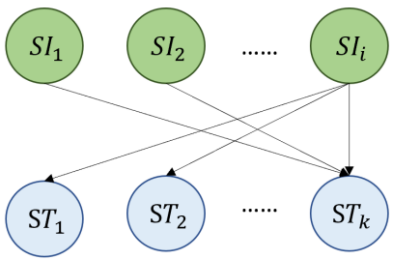
Dynamics and complexities are two critical features that make megaprojects different from traditional projects. Thus, our study proposes a model (Figure 2) to analyse stakeholder resilience in RM in a changing environment of megaprojects. As an effective method to explore organizational interactions in a complex adaptive system, the NK model analyses stakeholder interactions in RM from a dynamic perspective. Simultaneously, the network model evaluates the stakeholder structures in RM in a complex aspect. As a result, evolution graphs are plotted to show the variations in the severity of stakeholder issue vulnerabilities and competency of stakeholder capabilities regarding RM in the project timeline. With the assessment value of stakeholder issue vulnerabilities and stakeholder capabilities, a stakeholder resilience map is proposed. Each stakeholder issue can be drawn on the map to show the relevant stakeholder resilience in RM if it occurs. By referring to the stakeholder resilience map, project stakeholders understand how to enhance resilience level in RM around stakeholder issues with proper management strategies in megaprojects.




**<Figure 2 Framework of the stakeholder resilience model in RM>**

### 3.1 Data collection

RM faces challenges due to the interactions of various stakeholder issues and relevant stakeholders in the long-term project duration (Mok et al., 2017c). The primary task of data collection is to identify the stakeholder issues and relevant stakeholders during the project duration. In this study, the data on stakeholder issues and relevant stakeholders are collected from official project documents, including project reports, meeting minutes and newsletters. The process of data collection is made up of three steps. First, the desktop analysis is carried out for the stakeholder issue identification. The project issues which are concerned among stakeholders are extracted as stakeholder issues based on records in the project documents. Second, a list of relevant stakeholders around each stakeholder issue is identified according to the project documents. Third, the two-mode network model is used to present the complicated stakeholder structure (Figure 3), which clearly shows the relationships between stakeholder issues and stakeholders in RM in megaprojects. One mode stands for the stakeholder issue ($SI_i$), and the other mode represents the stakeholder groups ($ST_k$). The link connects the stakeholder issue ($SI_i$) and the involved stakeholder groups ($ST_k$).



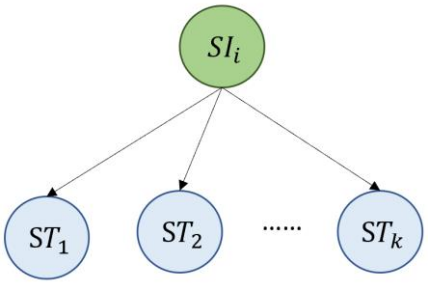
**<Figure 3 Two-mode stakeholder-issue network>**

## 3.2 Stakeholder resilience measurement

### 3.2.1 NK model for dynamic stakeholder interactions

a) NK-based stakeholder–issue model

A stakeholder issue refers to a project issue concerned by relevant stakeholders. Stakeholder interactions occur because of the need to address stakeholder issues. For instance, the issue of marine ecology protection involves governmental departments, contractors, designers, fishermen groups and local residents. Each stakeholder issue has a variety of involved stakeholders in megaprojects (Figure 4). The involved stakeholders continuously interact with one another to deal with the common associated issue. The NK model is adopted to evaluate the dynamic stakeholder interactions for each stakeholder issue. Each stakeholder issue ($SI_i$) and the relevant stakeholders ($ST_N$) form a basic NK model.




**<Figure 4 NK-based stakeholder issue model>**

b) Model parameters and components

A basic NK model has two parameters based on the classical NK modelling technique (Kauffman and Levin, 1987). As shown in Figure 3, $N$ means the number of participating stakeholders, and $K$ reflects the level of interactions amongst stakeholders. When the stakeholders interact with one another to deal with the common issue, the value of $K$ is equal to $N-1$, which means each stakeholder's decision on how to improve RM is influenced by the decisions of other relevant stakeholders.

The NK model has three components. Firstly, the decision vector $D=(d_1, d_2, \ldots, d_N)$ shows each stakeholder's decision on the strategy to promote RM around the common issue. According to previous studies, stakeholders choose either the formal or informal relational strategy to strengthen their relationships (Yang and Shen, 2014, Xue et al., 2020a). The formal relational strategy aims to enhance stakeholder relationships through contract and regulation systems, which set up official connections amongst stakeholders in scheduled project tasks. The informal relational strategy emphasizes the improvement of close working relations amongst stakeholders by establishing trust, friendship, shared goals and mutual influence. The two optional values for each stakeholder's decision $d_i$ are as follows:

$$d_i \in \{1 = formal\ relational\ strategy, 0 = informal\ relational\ strategy\}.$$

Secondly, the capability vector $C = (c_1, c_2, \dots, c_N)$ is generated based on the decision vector $D = (d_1, d_2, \dots, d_N)$. Each stakeholder's decision on relational strategy $d_i$ leads to a corresponding capability score $c_i$. Thus, understanding the effect of relational strategy decision $d_i$ on RM by $c_i$ is essential. The higher value of $c_i$ means the relational strategy decision $d_i$ has a stronger positive influence on the stakeholder capabilities of RM. An RM capability distribution ($D \sim C$) is used to measure the general scope of $c_i$ under each kind of relational strategy decision $d_i$.

Thirdly, in accordance with the systematic assessment of the NK model (Kauffman, 1993), the quality of RM $C(D)$ for the stakeholder issue is determined by each relevant stakeholder's capability score $c_i$. Thus, the value of $C(D)$ is represented by the mean of relevant stakeholders' capability scores $C(D) = (\sum_{i=1}^{N} C_i)/N$. The higher value of $C(D)$ represents a higher level of collaborative stakeholder relationship around the stakeholder issue, which also means a lower level of stakeholder issue vulnerabilities in RM.

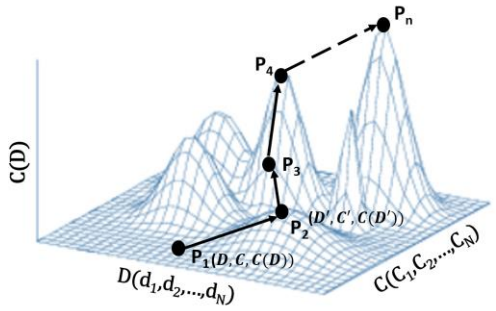
c) NK landscape for the simulation of stakeholder interactions

The NK landscape shows how organizations adapt to dynamic environments through frequent interactions (Kauffman and Johnsen, 1991). The NK landscape of one stakeholder issue in RM is formed by the decision vector $D = (d_1, d_2, \dots, d_N)$, capability vector $C = (c_1, c_2, \dots, c_N)$ and RM quality $C(D)$. As Figure 5 shows, $D$, $C$ and $C(D)$ stand for the axis of X, Y and Z, respectively. Dynamic stakeholder interactions frequently occur in megaprojects. For one stakeholder issue, the interaction process is as follows:

One stakeholder ($ST_1$) decides to change its strategy to improve its RM, changing the decision vector from $D = (d_1, d_2, \dots, d_N)$ to $D_{medium} = (d_1', d_2, \dots, d_N)$.

As stakeholders interact with each other in a project, each stakeholder's strategy is influenced by other relevant stakeholders' strategies. Thus, when one stakeholder changes its strategy, other stakeholders reassess and update their strategies simultaneously, converting the decision vector from $D_{medium} = (d_1', d_2, \dots, d_N)$ to $D' = (d_1', d_2', \dots, d_N')$.

Then, the decision vector switches from $D$ to $D'$ on the NK landscape. Each stakeholder may change its strategy according to its own decision. Point ($D$) frequently changes its position on the landscape until all the stakeholders are satisfied with their RM capabilities.




**<Figure 5 Stakeholder interaction simulation on the NK landscape>**

d) Searching method for stakeholder behaviours in interactions

The searching method reflects stakeholder behaviours in choosing and changing relational strategies in interactions, and it shows how the point moves on the NK landscape (Kauffman, 1993). There are two kinds of stakeholder behaviours in interactions. One behaviour in stakeholder interactions is seeking RM improvement of the whole system. The government and most internal project stakeholders (i.e. construction groups) aim to achieve enhanced RM quality during interactions (Ujene and Edike, 2015). If the new relational strategy can enhance collaborative relationships among all stakeholders $C(D_{n+1})> C(D_n)$, the stakeholders will decide to change the current strategy to a new one. Another kind of behaviour is focusing on the enhancement of the stakeholders' own interests. Some external project stakeholders (i.e. environmental groups, political parties and local communities) oppose the project because its success is not their shared goal (Olander and Landin, 2008). They only concentrate on expanding their benefits in RM rather than achieving the system's aim in stakeholder interactions. For this kind of stakeholders, the strategy will be changed only if the switch can improve their own capabilities of RM ($C_{n+1}^i>C_n^i$). This study considers the two stakeholder behaviours in dynamic interactions. The searching method is presented as follows:

When the search initiates,

If $C(D_{n+1})> C(D_n)$ and each $C_{n+1}^i>C_n^i$, $i \in j$:

$$D_n = D_{n+1}$$

$$C_n = C_{n+1}$$

$$C(D_n) = C(D_{n+1}),$$

where *j* stands for the stakeholder groups who only care about their capability improvement.

With the searching method, the assessment indicators of RM after dynamic stakeholder interactions are revealed, including the RM quality of stakeholder issue $C(D)_{final}$ and each stakeholder's RM capability $(C^{ST_k})_{final}$ after dynamic interactions.

### 3.2.2 Network modelling for complex stakeholder structures

RM is required to deal with the complex stakeholder structures. As shown in Figure 3, each stakeholder issue ($SI_i$) connects relevant stakeholders ($ST_k$). Hence, the RM quality of each issue $SI_i$ is $C(SI_i)$, which is equal to the final-status RM quality score $C(D)_{final}$ of its own NK model. A higher value of $C(SI_i)$ means lower stakeholder issue vulnerabilities in RM.

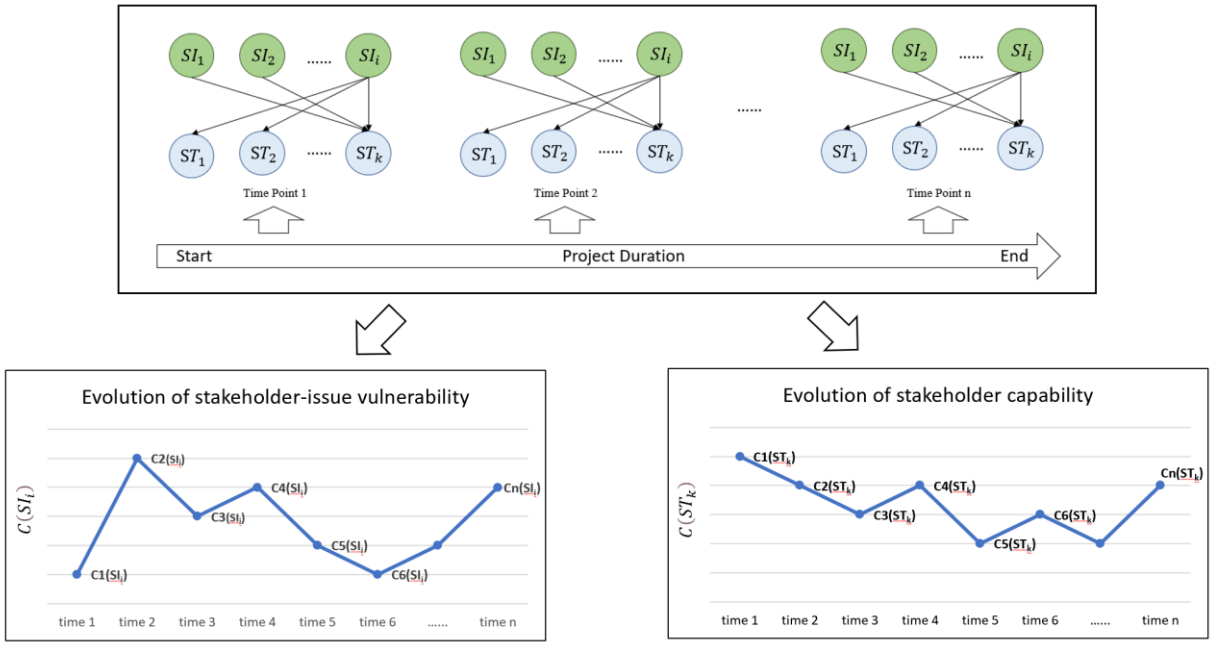
As Figure 3 shows, each stakeholder $ST_k$ participates in multiple associated issues within the network. Thus, the RM capability of $ST_k$ is determined by its capability score in each involved issue. The formula is shown below:

$$C(ST_k) = \frac{\Sigma(C_{SI_i}^{ST_k})_{final}}{The\ number\ of\ invovled\ issue\ SI_i},$$

where $(C_{SI_i}^{ST_k})_{final}$ means the final status RM capability score of a stakeholder group $ST_k$ under its involved issue $SI_i$.

## 3.3 Stakeholder resilience analysis

Based on the concept, analysis of stakeholder resilience in RM depends on the indicators of stakeholder issue vulnerabilities and stakeholder capabilities, the values of which are derived from the proposed NK–network model. A megaproject has a long-term project duration (Flyvbjerg, 2014). Therefore, two-mode stakeholder issue networks are established at various time points in a project. According to Section 3.2.1, each stakeholder issue network at a given time point is an input to form basic NK–network models. As a result, the levels of stakeholder issue vulnerabilities and stakeholder capabilities at each time point in the project duration can be measured by the proposed NK–network model in Section 3.2, leading to the evolution graphs shown in Figure 6. Evolution graphs are critical to analysing the dynamics of resilience problems (Jafarnejad et al., 2019, Liu, 2019). Existing studies have proven that evolution graphs of the system's vulnerabilities and the elements' capabilities are useful in evaluating resilience from two important perspectives (Ekanayake et al., 2021b, Ekanayake et al., 2021c). The values of $C(SI_i)$ and $C(ST_k)$ in the Y-axis of graphs represent the level of stakeholder issue vulnerabilities and stakeholder capability, respectively. As the $C(SI_i)$ and $C(ST_k)$ are derived from the proposed model, the evolution graphs can be established automatically for all the projects. In summary, the evolution of stakeholder issue vulnerabilities and stakeholder capabilities is traced by the NK–network model, which is helpful in evaluating stakeholder resilience in RM in the development of megaprojects.




**<Figure 6 Evolution of stakeholder issue vulnerabilities and stakeholder capabilities>**

### 3.4 Stakeholder resilience management

With the values derived from the NK–network model, the vertical and horizontal axes of the proposed stakeholder resilience map in Figure 1 are quantitatively assessed. The vertical axis represents the value of stakeholder issue vulnerabilities ($V(SI_i)$). A vertical value close to 1 indicates that the issue is highly vulnerable in RM, with the value $V(SI_i)$ being equal to (1- $C(SI_i)$). The horizontal axis stands for the value of stakeholder capabilities ($C(ST_k)$). A high horizontal value equates to a good stakeholder's RM capability for dealing with the stakeholder issue. Each stakeholder issue can be drawn on the map to show the relevant stakeholder resilience in RM if it occurs. Based on the Section 2.1, the corresponding management strategies are provided for stakeholder issues in each zone of the map, which effectively guide stakeholder resilience improvement in RM in megaprojects.

The proposed stakeholder resilience map (Figure 1) provides a new theoretical approach for stakeholder management by mapping the resilience level of stakeholder-associated issues. Extant stakeholder studies have adopted classical approaches for mapping stakeholders, such as the 'power–urgency–legitimacy' model, the 'power–interest' matrix and the stakeholder circle methodology (Mitchell et al., 1997, Scholes et al., 2002, Bourne and Walker, 2008). Traditional methods focus on categorizing stakeholder groups. Whereas the proposed stakeholder resilience map groups stakeholder issues by showing resilience levels based on stakeholder issue vulnerabilities and stakeholder capabilities. The proposed map is helpful for stakeholder management at the project-issue level, which is essential for the recovery of stakeholder relationships affected by stakeholder issue vulnerabilities in the project duration.

## 4. Case validation

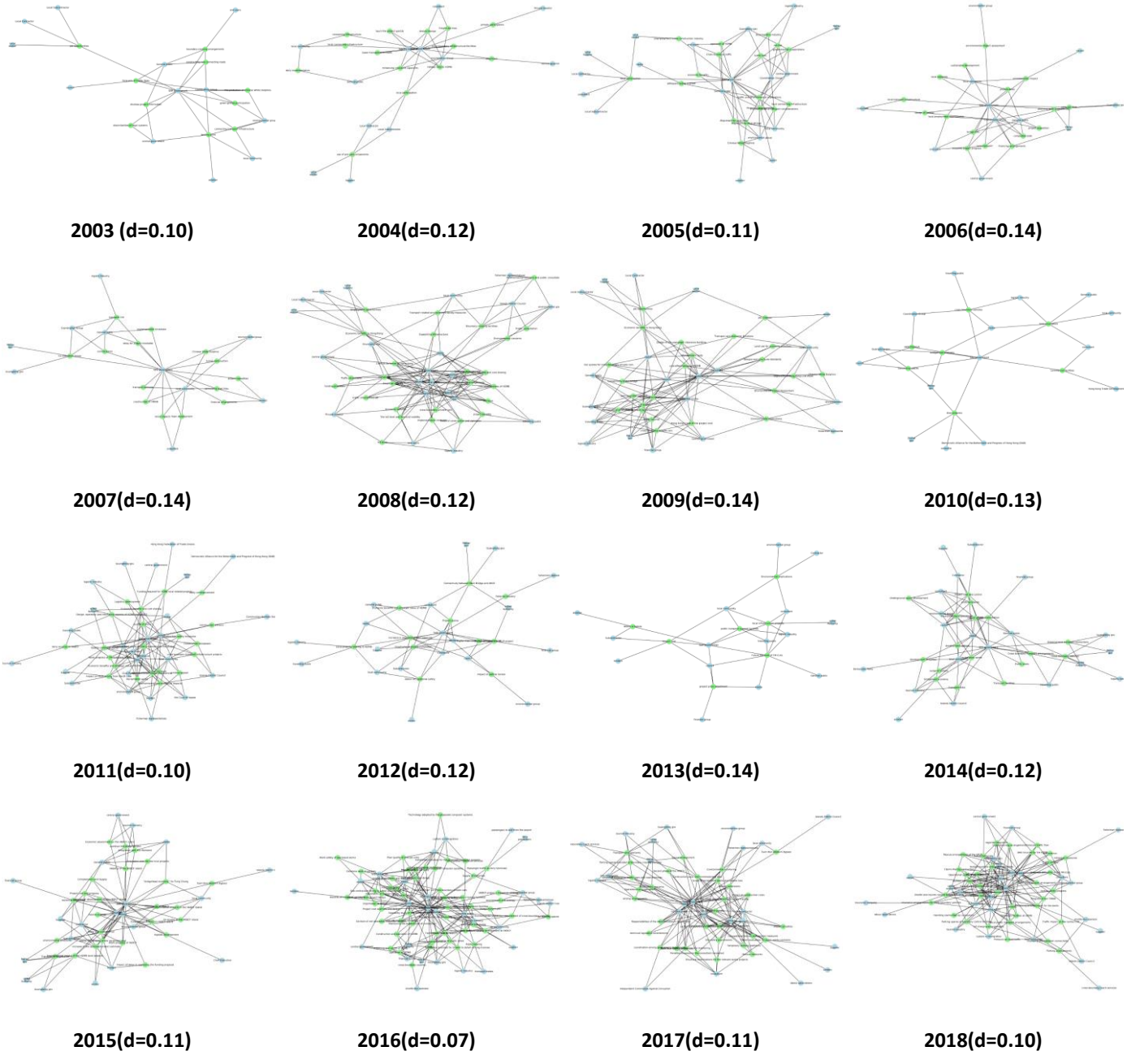
The case of HZMB was used to validate the proposed NK–network model of RM resilience for stakeholders in megaprojects. The validation process followed the framework of the model (Figure 1). Firstly, data on stakeholder issues and relevant stakeholders were collected from the project documents. Timestamped, two-mode, stakeholder-issue networks were established annually for HZMB. Secondly, RM resilience was measured by applying the integrated NK and network models with customized parameters based on the stakeholder data of HZMB. Thirdly, the results of stakeholder issue vulnerabilities and stakeholder capabilities in RM were analysed and tracked in the timeline of HZMB. Lastly, the resilience maps of RM were generated for the planning, construction, and handover stages of the project, based on the evolutionary outcomes of the two indicators. Furthermore, the proposed resilience model's effectiveness was assessed by comparing its results with the actual situation of the project.

### 4.1 Results of data collection

The collection of project documents served as the primary source of data for this research. The Hong Kong council archive preserved the documents and kept them open to the public. In total, 1266 project documents were collected for building the two-mode stakeholder issue networks. Following the data collection process in Section 3.1.1, there were 335 stakeholder issues identified in the project duration (see Appendix 1). To better interpret the results, the stakeholder issues were categorized by 10 groups from three levels of perspectives: organizational (communication, coordination, collaboration), project (cost, schedule, quality, safety) and societal (labour, environment, transparency), according to the classification in the previous studies (Xue et al., 2020a). In addition, three stakeholder groups were identified in HZMB: the government, construction groups and pressure groups, echoed by the previous studies that the three stakeholder groups play key roles in the development of megaprojects (Li et al., 2016). Under each stakeholder group, it had a list of project stakeholders. In total, there were 17 kinds of project stakeholders identified in HZMB (see Appendix 2). Moreover, the networks were formed by establishing connections between the identified stakeholder issues and the respective stakeholders who are involved in them. Then, three experts each from the government, construction groups and pressure groups were invited to cross-validate the identified stakeholder issues, stakeholder groups and their links. Afterwards, the timestamped, two-mode stakeholder issue networks were built year by year from 2003 to 2018, which included planning (2003–2009), construction (2010–2017) and handover (2018) phases (in Figure 7).

The density of the annual stakeholder issue networks was calculated (Figure 7) to show the network size changes in the project duration. Generally, a large network size equates to a low density value (Wasserman and Faust, 1994). The density changes of the network indicate the stakeholder issues concentrated at the late project stage of HZMB (2015–

2018) according to the relatively low level of density values in this period. The multiple stakeholder issues that erupted at the late project phase exerted heavy stress on stakeholder capability to sustain collaborative relationships amongst stakeholders. Specifically, the figure clearly showed the development history of HZMB. Between 2003 and 2007, HZMB was at the conceptual planning stage so that the stakeholder relationships were relatively simple. In 2008, the stakeholder issues had the first outbreak due to the decisive moment when the National Congress passed the Project Bills. From 2010 to 2014, the stakeholder interactions were not intensively as the construction works were generally undergoing smoothly. The only outburst of stakeholder conflicts was in 2011 when the project faced serious challenges in environmental impact assessment. However, since 2015, HZMB had experienced a series of stakeholder intentions due to the time delay, cost overruns, safety incidents, quality issues, and operational arrangements, reflecting in the highly complicated stakeholder network structures.

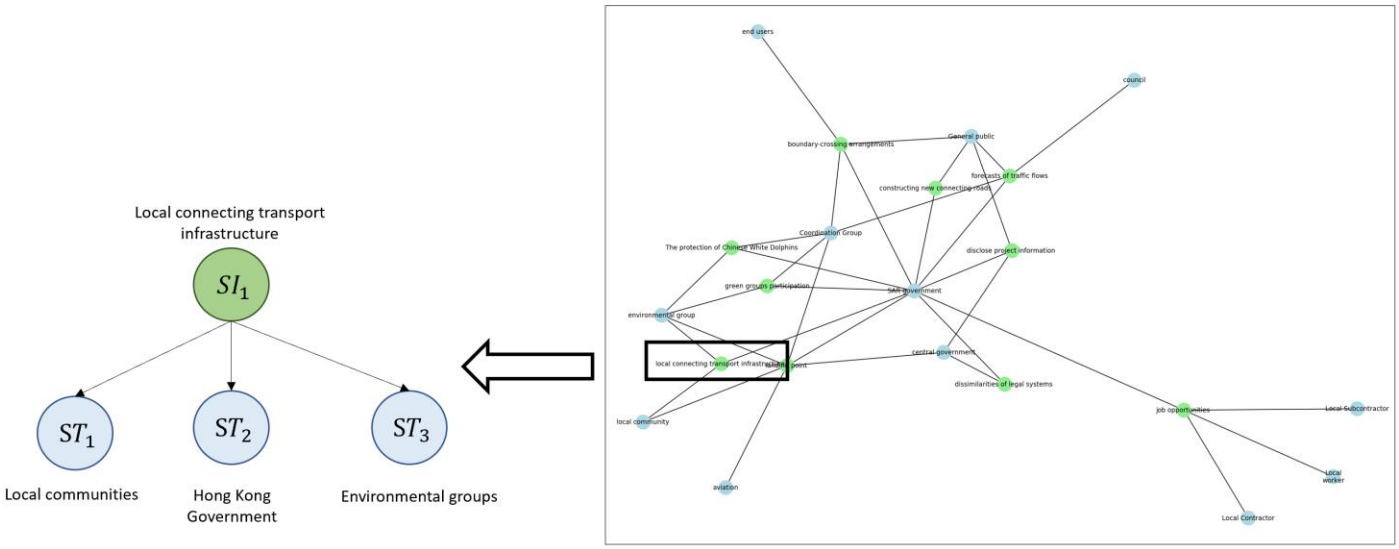


***Note: 'd' stands for the density of the network***

**<Figure 7 Timestamped two-mode stakeholder-issue networks in HZMB>**

## 4.2 Operationalization and parameterization of the measurement model

The NK-network model operation process followed the stakeholder resilience measurement. Each annual stakeholder-issue network was computed. Three parameters were set in the proposed measurement model. With the stakeholder-issue network of 2003 as an example (in Figure 8), model parameterization is explained as follows.

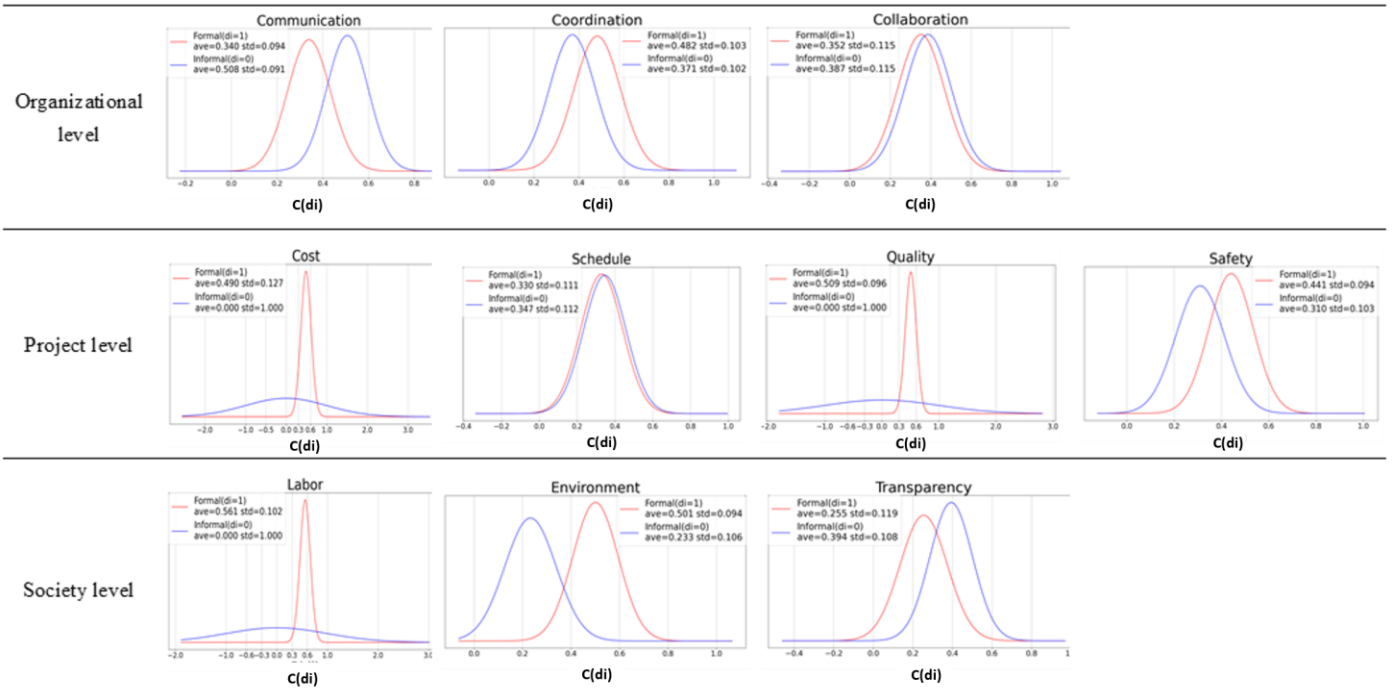



**<Figure 8 An example of model operationalization and parameterization >**

Firstly, the stakeholder-issue network of 2003 has 10 stakeholder issues. Given that each stakeholder issue forms a basic NK model, 10 basic NK models are available for 2003. There are two parameters of the basic NK model, including stakeholder numbers ($N$) and stakeholder interaction levels ($K = N - 1$). For instance, the local connecting transport infrastructure issue (in Figure 8) is relevant to three stakeholders. Hence, $N = 3$ and $K = 2$ in the model.

Secondly, each stakeholder makes decisions on relational strategies to enhance its RM. Hence, the capability distribution ($D{\sim}P$) is a critical parameter to simulate the capability score ($p_i$) under each relational strategy ($d_i$). The capability distribution of RM strategies (Figure 9) was assessed by Xue et al. (2020a) on ten kinds of stakeholder issues, which are consistent with the stakeholder-issue classifications in data collection. In Xue et al.'s research, the capability distributions of RM strategies (formal and informal) concerning ten distinct stakeholder issues were measured with the structural equation model. The distributions provide insights into how different strategies influence the stakeholder capabilities in RM. Given that the distributions were established using empirical data collected in China by Xue et al. (2020a), they can be applied to the case context because most stakeholders in HZMB are Chinese or organizations with Chinese backgrounds and cultures. Here we take local connecting transport infrastructure issue (Figure 8) as an example

to show how the capability distribution is allocated for each basic NK model. As the issue belongs to the coordination category, the capability distribution can be found in the second plot from the left of the organisational level in Figure 9. In the figure, "ave" represents the parameter of the average value, and "std" stands for the parameter of the standard deviation value. With these two values, the capability distribution can be determined. Hence, the capability distribution is $C \sim N(0.482, 0.103)$ under formal relational strategies and $C \sim N(0.371, 0.102)$ under informal relational strategies.

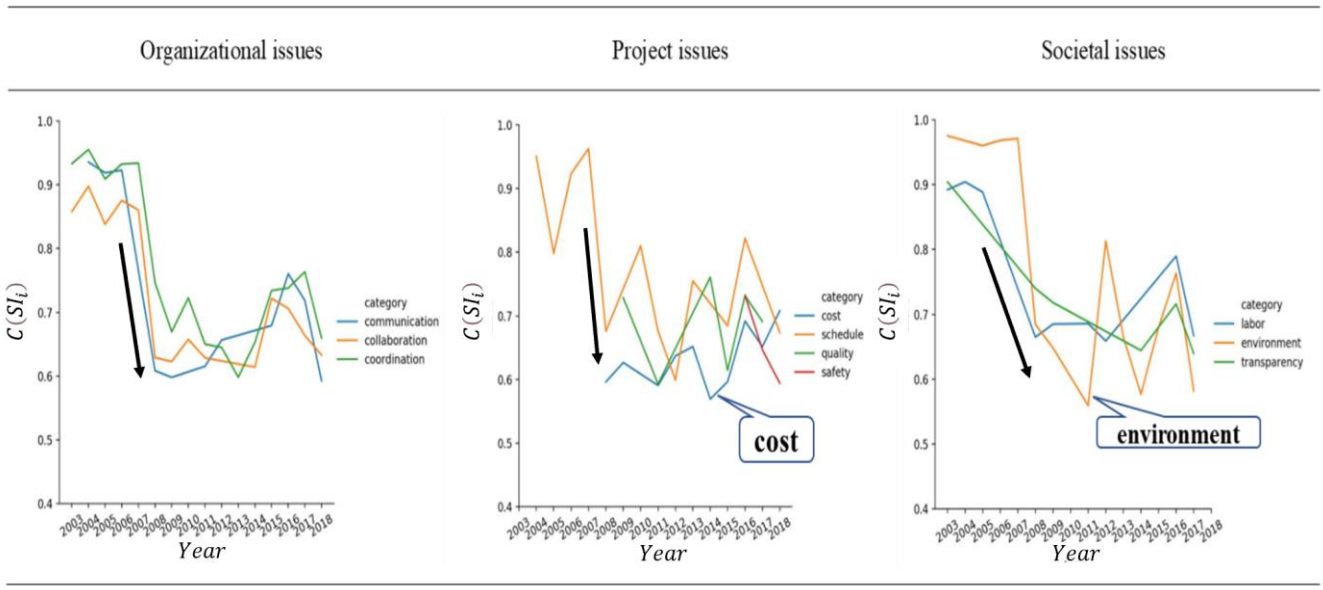



**<Figure 9 Capability distribution of RM strategies on stakeholder issues>**

Thirdly, the parameters of stakeholder behaviours in interactions are essential to evaluate RM among stakeholders. According to Section 3.2.1, two kinds of stakeholder behaviours are involved in interactions. Behaviour One seeks the improvement of RM for the whole system. By contrast, stakeholders with Behaviour Two only care about the improvement of their own RM. In the case study, the government and construction groups follow Behaviour One, whereas the pressure groups manifest Behaviour Two. In the given example, the Hong Kong government belongs to the government, which follows Behaviour One. The local communities and environmental group are under the category of pressure groups, which follows Behaviour Two.

After setting up the parameters of the measurement model, the model was implemented using Python 3.7 with three programming libraries. The NK library was used to simulate the dynamic stakeholder interactions, and the Network X library was adopted to evaluate the complex stakeholder structures. The Matplotlib library was employed to plot the evolution graphs of stakeholder issue vulnerabilities (Figure 10) and stakeholder capabilities (Figure 11) as well as the stakeholder resilience maps (Figure 12) in the development of HZMB.

### 4.3 Evolution of stakeholder-issue vulnerabilities

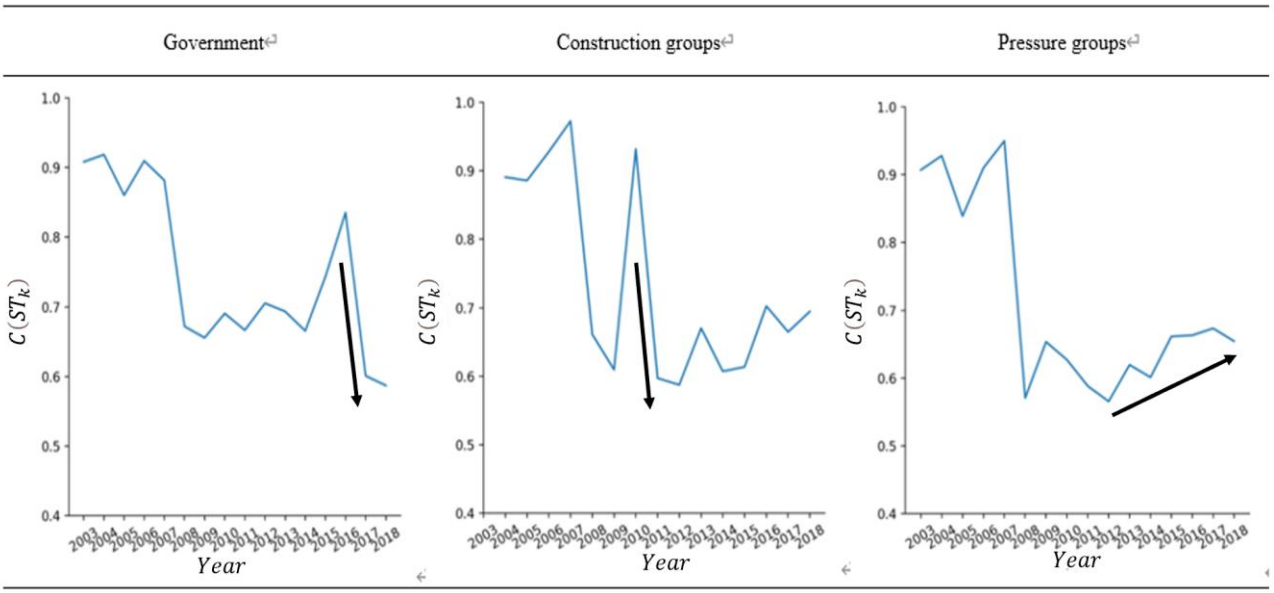



**<Figure 10 Evolution of stakeholder issue vulnerability in HZMB>**

Three features were detected by the proposed NK–network model (Figure 10). Firstly, the model results showed that all three kinds of stakeholder issues experienced a sharp decrease in 2008, indicating the high level of stakeholder issue vulnerabilities in RM at that time. The detected drop was proven by the reality of HZMB when the vote of the project bill triggered stakeholder tensions at that critical decision-making moment.

Secondly, the line of cost-related issues was placed lowest amongst all project issues, which suggested it was vulnerable in RM. The high level of cost-issue vulnerabilities was in line with the continuous stakeholder conflicts around cost overruns during the construction phase in HZMB. Thirdly, the line of the environmental issue reached the bottom in 2011 and 2014, respectively. The environmental-issue vulnerabilities in RM matched the case history of stakeholder collaborations disruption when the juridical appeal that occurred regarding the environmental assessment review in 2011 and the heavy pollution due to construction works in 2014.

### 4.4 Evolution of stakeholder capabilities



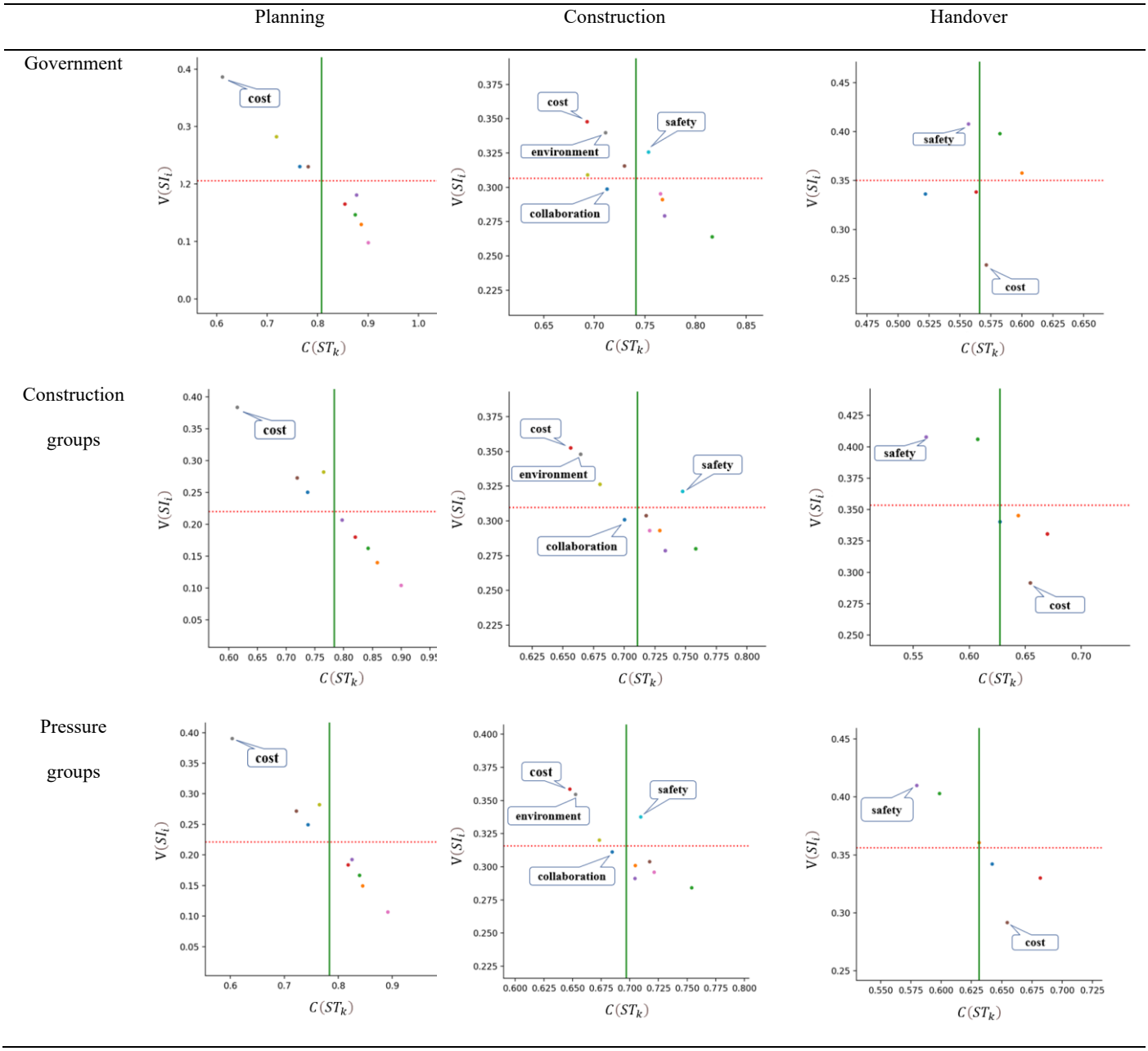

**<Figure 11 Evolution of stakeholder capabilities in HZMB>**

The variations in stakeholder capability levels were also detected by the proposed stakeholder resilience model (Figure 11). Firstly, the model results revealed that the government line had a drop in 2017, indicating its low RM capabilities at that time. The detected plummet was in line with the case history that the government was heavily criticised by the pressure groups in the review of safety incidents in 2017. Secondly, the line of construction groups experienced a significant decline in 2011. The limited RM capabilities of the construction groups at that time was verified by the case that they collided with pressure groups on the juridical review of environmental impact assessment in HZMB. Thirdly, the line of pressure groups steadily went up from 2012 to 2018, which implicated the pressure groups' RM capabilities were gradually enhanced since 2012. Enhancement of RM capabilities was proven by the case that fewer stakeholder relationship disruptions were triggered by the pressure groups after 2012.

### 4.5 Stakeholder resilience map

The resilience level of stakeholder issues in RM were mapped in three project phases by the proposed stakeholder resilience model (Figure 12). Firstly, the model results showed the dynamics of least resilient stakeholder issues was detected in RM, as they placed in the dangerous zone in three phases. For instance, the damaged collaborative relationships due to cost issues were hard to recover in the planning phase. The cost and environmental issues were fragile in stakeholder resilience in RM in the construction phase. The safety issues turned out to be the least resilience in RM for stakeholders in the handover phase. These detected least resilient stakeholder issues matched the timeline of significant stakeholder conflicts in the real history of HZMB stated in Section 2.3. Secondly, the model results provided insights of classifying stakeholder issues into four different zones, which were useful to propose the corresponding strategies according to stakeholder resilience levels in RM. For instance, in the construction phase, the safety issues

were in the challenging zone and the collaboration issues stayed in the vigilant zone. In the handover phase, the cost issues were placed in the safe zone. The stakeholder resilience in RM regarding these issues will be analysed in the discussion section together with the case reality.




**<Figure 12 Stakeholder resilience map in the development of HZMB>**

### 4.6 Summary of case validation

Based on the framework, the proposed NK-network model was validated by the real-project case of HZMB. The validation followed the modelling process step by step, including data collection, stakeholder resilience measurement, analysis, and management. By setting up the parameters according to the case data, the model successfully generated the results of stakeholder-issue vulnerabilities, stakeholder capabilities, and stakeholder resilience in RM in HZMB from a dynamic perspective. After comparing the simulative results with the observations in HZMB, the findings derived from model results align with the project's development history, providing further evidence of the model's validity.

However, the model still has two limitations. First, it is time-consuming to build up the timestamped networks in data collection manually from large quantities of project documents, which may cause the missing of stakeholder information. Second, the simulation of the NK model requires the input of the capability distribution, which asks for prior relational empirical studies to provide numerical evidence. Thus, relational empirical research is a prerequisite which may constrain the model's accuracy.

## 5 Discussions and implications

On the basis of the research results given in Section 4, the empirical findings were further discussed to interpret the stakeholder resilience of RM in terms of critical stakeholder issue vulnerabilities, weakness of stakeholder capabilities and stakeholder resilience dynamics. The detailed discussions and implications are as follows.

### 5.1 Critical stakeholder issue vulnerabilities in RM

#### 5.1.1 Decision-making moment related stakeholder issue vulnerabilities

The stakeholder issue vulnerabilities were concentrated at the late planning stage, which was at the decision-making period of the megaproject. As indicated in Section 4.3, all the stakeholder issues became vulnerable in 2008 when the HZMB project bill and feasibility report were presented to the National People's Congress and faced a historic vote. The vulnerabilities related to stakeholder issues arose due to the combined effects of the complex and dynamic nature of stakeholders. On the one hand, as the project proposal faced the decision-making moment, various important stakeholder issues attracted a wide range of stakeholders in HZMB, such as bridge alignment, cost sharing between three regional governments, commercial development and environmental protection. The multiple stakeholder issues connected with stakeholders of different interests, leading to the difficulties of managing complex stakeholder relationships. On the other hand, all the stakeholder issues cannot be vague at the decision-making point. As the voting time of the project bills neared, an increasing number of debates occurred amongst various stakeholder groups, leading to the rapid increase in stakeholder interactions within a short period. The high level of dynamic stakeholder interactions in the decision-making point activated conflict amongst stakeholders with opposite interests, which made RM stress reach a tipping point.

#### 5.1.2 Cost-related vulnerabilities due to stakeholder complexity

The results in Section 4.3 indicates that cost was the most vulnerable stakeholder issue amongst the project-level issues in the construction phase from 2009 to 2016 (Figure 10), which was because of the high stakeholder complexity. Given that cost issues are highly related to stakeholders' core interests, they attract particular attention amongst many project

stakeholders. The broad stakeholder involvement in cost issues leads to conflicting concerns, which are likely to trigger stakeholder tensions. In HZMB, each round of additional bill votes dealing with the project's cost overrun caused confrontations amongst a wide range of stakeholders. Many involved stakeholders increased the difficulty of balancing the interests of various stakeholders, thereby making the cost issue the most vulnerable focus in RM in the construction phase.

#### 5.1.3 Environmental-related vulnerabilities due to stakeholder dynamics

According to Section 4.3, the environmental issue is the most vulnerable stakeholder issue in RM amongst all the societal issues in the construction and handover phases (Figure 10). The issue's high vulnerability is caused by dynamic stakeholder interactions in the long-term duration of a megaproject. The active stakeholder groups in the environmental issue are fixed, including the government and pressure groups. Given that the environmental issue is a critical concern for local communities and environmental groups, the frequent interactions amongst the project stakeholders trigger intensive confrontations regarding the unexpected environmental problems that emerge after construction work is initiated. In HZMB, the environmental conflicts happened when the project was appealed to the court because of the doubts about the environmental impact assessment report in 2011. The incident caused the project's suspension for a year, triggering tensions amongst the government and pressure groups. In 2014, another round of environmental conflicts escalated because of the construction pollution in local link projects connected with HZMB in Hong Kong. The relationship amongst the government and pressure groups was again damaged by the tensions induced by the delay of the local links. In 2018, the worries on air pollution caused by vehicle emissions in the upcoming bridge operation induced tensions between the government and pressure groups, causing their relationship to become fragile.

### 5.2 Weakness of stakeholder capabilities in RM

#### 5.2.1 Lack of flexibility for the government

The government faced challenges in RM in the late construction phase (Figure 11). The low RM capacity was due to the lack of flexibility. As the government always seeks the overall improvement of collaborative stakeholder relationships in interaction (Behaviour One), flexibility is an important capability to address stakeholder concerns in RM with compromising solutions. However, the case study indicates that government's flexibility is limited when the project is close to completion because the defects in project performance are revealed publicly. An example is the severe cost overrun and schedule delay at the end of the construction phase in HZMB. The unsatisfactory performance activated conflicts between the pressure groups (general public, political groups and residents) and the government. The

584 government still tried to sustain the collaborative relationships among stakeholders (Behaviour One during interaction)
585 through multiple accesses, like media, public hearings, and meetings. However, unlike in the early project phase, the
586 government could not fix the collaborative relationship by using flexible sources, such as adjusting the project proposal
587 and making a compromised agreement with relevant stakeholders.

588 **5.2.2 Insufficient preparedness for construction groups**

589 The construction group encountered difficulties in RM in the early construction phase (Figure 11). The insufficient
590 preparedness for stakeholder conflicts led to the weakening of the construction group's RM capability. As collaborative
591 relationships among stakeholders are essential for implementing construction works, the construction group always aims
592 at improving levels of stakeholder collaboration in interaction (Behaviour One). Compared to the government, the
593 construction group has less power and resources to cope with the urgent conflicts. Therefore, the preparedness is critical
594 to enhance the construction group's RM capability. In HZMB, the construction groups did not prepare for the outbreak
595 around environmental issues between pressure groups and the government. It is hard for construction groups to
596 coordinate with both sides because their aims were contrary. As the construction ensued at the initial stage, the opposition
597 pressure groups introduced various conflicts that interfered with the project commencement. Although the construction
598 group tried to cool down the tensions in stakeholder interactions (Behaviour One), it was failed to propose a solution
599 dealing with the unfamiliar but aggressive pressure groups due to a lack of preparedness.

600 **5.2.3 Slow adaptation for pressure groups**

601 As Figure 11 shows, the pressure group gained RM experience from the stakeholder tensions in the late planning phase
602 and the early construction phase. The pressure group's RM capability was steadily enhanced in the mid-construction
603 phase onwards, but the improvement was slow. As the group only cares about maximizing its own interests in interaction
604 (Behaviour Two), it is not easy for the pressure group to learn how to build a win-win relationship with the government
605 and construction group from the fierce conflicts, leading to the slow adaptation in its RM capability. Adaptation may
606 improve stakeholder resilience in RM but does not always boost a project's success. As too much focus on its own
607 benefits in stakeholder interactions (Behaviour Two), the pressure group may adapt to the conflicts with the government,
608 which gradually teaches the pressure groups how to push the government to disrupt the project. To avoid this situation,
609 the government should take a leading role in the adaptation process to actively establish communication with pressure
610 groups. In HZMB, adaptation was driven by the government's efforts on building an efficient and constructive
611 interactive pipeline with the pressure and construction groups. Through the pipeline, the pressure group understood that

612 legal communication access was more effective than unpeaceful confrontations. Therefore, the pressure group learned
613 to convey their opinions through public consultations and council members, which gradually improved the quality of
614 RM.

615 **5.3 Stakeholder resilience dynamics of RM**

616 **5.3.1 Stakeholder resilience in RM in the planning phase**

617 Cost issues result in low stakeholder resilience in RM at the planning stage (Ekanayake et al., 2021b, Ekanayake et al.,
618 2020). As shown in Figure 12, the results are located in the upper left of Zone One (dangerous zone), indicating that the
619 cost issues are least resilient in RM among the government and the construction and pressure groups. The cost issues
620 are highly vulnerable because they are the core interest of stakeholders in megaprojects. In the planning stage, the
621 pressure groups intend to reduce the cost which would save money for taxpayers. The construction groups call for a cost
622 increase that would benefit the local workers, contractors, and subcontractors. Thus, the conflicting interests of the two
623 stakeholder groups limited the capability of the government to sustain collaborative relationships with both. In HZMB,
624 the unrepaired collaborative relationships amongst the three stakeholder groups escalated to difficulties in project
625 approval in the council, which delayed the schedule of HZMB. According to the proposed stakeholder resilience map
626 (Figure 1), stakeholders should absorb the stakeholder disruptions arising from cost-related issues with positive attitudes
627 and proactive actions. In HZMB, the government actively proposed a 'bridge-headed' economic plan to develop
628 connective areas around HZMB. The new economic plan effectively alleviated the opposition of the pressure and
629 construction groups towards the project as they realized that support for HZMB would lead to further regional
630 development, which would also benefit them considerably. The proposal guided the stakeholders to put the conflicting
631 interests aside with a positive vision, which enhanced the stakeholder resilience in RM.

632 **5.3.2 Stakeholder resilience in RM in the construction phase**

633 According to Figure 12, the cost and environmental issues are in the dangerous zone with low stakeholder resilience in
634 RM in the construction phase. The cost issues introduce tensions between the government and pressure groups as cost
635 overruns frequently happen throughout the construction period in megaprojects. In HZMB, the frequent occurrence of
636 cost overruns resulted in the accumulated dissatisfaction and impatience of the pressure groups towards the government
637 about the cost issues, leading to the extreme difficulties of recovery of the broken collaborative relationship. In terms of
638 environmental issues, as the megaproject officially commences, the government and construction group lack
639 compromising solutions considering environmental concerns from the pressure groups because of the tight schedule. In

HZMB, the fierce anti-project environmental movement and the lack of compromising solutions made the stakeholder resilience in RM fragile. Based on the proposed stakeholder resilience map (Figure 1), proactive management strategies are essential to absorb the strong negative impacts on RM due to stakeholder issue vulnerabilities associated with 'cost' and 'environment'. In HZMB, a joint working team was set up including members from governmental departments, public representatives, and contractors. The joint working of the team members helped eliminate the strong dissatisfaction and cultivated a positive working attitude towards the unexpected conflicts due to cost overruns and environmental protection.

The safety issues are in the challenging zone during the construction phase (Figure 12). The safety issues are quite vulnerable in RM as safety incidents always seriously damage collaborative stakeholder relationships. However, the government departments and the construction groups have competent RM capabilities since they learn the experience from past projects. As safety issues frequently occur during the late construction phase, the proposed stakeholder resilience map (Figure 1) emphasizes that the stakeholders should improve their adaptation ability in RM by keeping learning on how to fix broken relationships in each conflict. In HZMB, the coordinating workshops involved by senior management teams from the stakeholders were organized to optimize the standard operating procedure in RM after each safety incident, which continuously improved stakeholder resilience in RM regarding safety issues.

The collaboration issues are in the vigilant zone at the construction phase (Figure 12), indicating the issues are not serious but required proper preparation to improve stakeholder resilience in RM. In HZMB, the cross-regional collaboration issues were not vulnerable as they were addressed under the "one country, two systems" policy. The central government had strong leadership to guide stakeholder collaboration in construction works. Meanwhile, the RM capabilities of the government, construction groups, and pressure groups also faced defects, because they were unfamiliar with the difference in standards, regulations, and cultures between Hong Kong, Macao, and Mainland China. As the collaboration issues place in the vigilant zone of the proposed stakeholder resilience map (Figure 1), preparedness is necessary to strengthen stakeholder relationships to avoid the unexpected escalation of conflicts regarding organizational collaboration. In HZMB, an information-sharing system was established among the government, construction groups, and pressure groups. The transparent information facilitated stakeholders to anticipate the potential conflicts in cross-regional collaboration and make precautionary measures, which enhance stakeholder resilience in RM.

**5.3.3 Stakeholder resilience in RM in the handover phase**

Figure 12 shows that the safety issues were in the dangerous zone at the handover phase. These results indicate that

safety issues occur in the construction period but bring about fragile stakeholder resilience in RM at the handover stage. In HZMB, the deaths and injuries of construction workers caused by safety incidents elicited the attention of pressure groups, leading to a scathing review of safety issues at the handover stage. As the consequences of safety incidents and relevant live losses cannot be changed during the handover stage, the compensation and apologies of the government and construction groups were ineffective in curing the damaged collaborative relationship amongst the government, construction groups, and pressure groups. Therefore, the stakeholder resilience for RM on safety issues was weak in the handover phase. The proposed stakeholder resilience map (Figure 1) suggests that it is critical to absorb the tensions due to 'safety' issues with proactive measures. In HZMB, open and smooth communication was established in the early handover phase among stakeholders, which helped relieve the waves of anger and doubt of the pressure groups in advance and added stakeholder resilience in RM.

The cost issues were located in the safe zone (Figure 12), which indicates the high level of stakeholder resilience at the handover stage to recover the collaborative relationships damaged by the cost overruns. On the one hand, very few additional cost overruns occur as the megaproject is close to completion, leading to the cost issue less vulnerable in RM. On the other hand, as there are fewer pressures on seeking extra bills for the project at the handover stage, a positive working environment is formed among the government, construction, and pressure groups, which enhances the stakeholder capabilities in RM. The proposed stakeholder resilience map (Figure 1) recommends the stakeholders achieve a higher quality of collaborative relationships regarding the cost issues during recovery. In HZMB, a mutual working mechanism was set up to invite members from the government, construction groups, and pressure groups to review the lessons from cost issues, which aimed at summarizing the best-practice collaborative solutions in RM for future megaproject development.

### 5.4 The stakeholder resilience model's scalability and adaptation in RM

The proposed stakeholder resilience model does not have project size and industry restrictions, The previous studies have proved that the Network models fit measurement of stakeholder involvement in both mega and conventional project size (Li et al., 2024, Ekanayake et al., 2021a). Meanwhile, the NK model has been widely used in organizational studies in multiple industries (Giannoccaro and Nair, 2016). Therefore, the integrated stakeholder resilience model enables to adapt to RM studies in various project sizes and industries. There are two elements of model inputs that require adjusting to the project context. First, the timestamped stakeholder-issue networks are established based on the various stakeholder relationships identified in the project documents. Second, the RM capability distributions are set up according to the

empirical stakeholder studies in the relevant industries.

The model's findings can be a valuable reference for different regions in the world, which share the similar context. For instance, the European megaprojects often require cooperation from different countries. The cross-border collaboration also faces the challenge of various regulation and culture systems in RM, which is quite like HZMB. The African megaprojects involve the contractors from different countries. The international collaboration increases the difficulties in RM to manage stakeholder complexities, which is also a big challenge in HZMB. Therefore, the case study of HZMB can provide useful implications to enhance stakeholder resilience in RM in multiple areas globally.

## 6. Conclusion

This study proposes an integrated quantitative and qualitative model to understand stakeholder resilience in the context of RM during megaprojects. The proposed model achieves stakeholder resilience evaluation in project studies through measurement, analysis and management. The stakeholder resilience measurement considers complex and dynamic conditions prevalent in megaprojects. The stakeholder resilience analysis tracks the changes of stakeholder issue vulnerabilities and stakeholder capabilities to reveal how the two critical resilience indicators vary in different phases of megaprojects. Then, a managerial map for stakeholder resilience of RM is designed based on the relationship between stakeholder issue vulnerabilities and stakeholder capabilities. The map helps stakeholders manage the resilience of RM by classifying criticalness and providing enhancement strategies at a detailed stakeholder-issue level.

Through the HZMB project, the proposed model is validated, and evidence on stakeholder resilience in RM in megaprojects is revealed. Firstly, the critical stakeholder issue vulnerabilities are identified, including the cost-related vulnerabilities caused by stakeholder complexity and the environmental issue-related vulnerabilities caused by stakeholder dynamics. All stakeholder issues become vulnerable at the decision-making moments due to the co-effects of stakeholder dynamics and complexities. Secondly, the stakeholder capability limitations of the three groups are explored, such as the lack of flexibility for the government, insufficient preparedness for the construction groups and slow adaptation for the pressure groups. Thirdly, the stakeholder resilience of RM is discussed from dynamic perspectives. On the basis of the proposed stakeholder resilience map, stakeholder issues are classified into four management zones based on the stakeholder resilience levels in RM, which the useful strategies are summarised to improve stakeholder resilience in RM in each project phase accordingly.

This research provides substantial theoretical contributions. First, the study establishes the new concept of 'stakeholder resilience' in RM, which comprehensively introduces the resilience concept to extend the knowledge body on

stakeholder management, including definition, measurement, analysis and management. Stakeholder resilience is helpful for understanding the stakeholder capabilities to recover collaborative stakeholder relationships after the onset of stakeholder issue vulnerabilities in megaprojects. It extends resilience theory in project management at organizational levels by integrating stakeholder and RM concepts. Second, the NK–network model is developed to understand stakeholder resilience in RM considering the changeable environment of megaprojects by introducing a complex adaptive system and network techniques. The new approach is useful in evaluating stakeholder resilience in RM under a changing megaproject environment. Third, the proposed stakeholder resilience map theoretically transforms the quantitative results into a qualitative management guide for better stakeholder resilience in RM. The map helps advance stakeholder management at the project-issue level; it groups stakeholder issues by mapping resilience levels in RM based on stakeholder issue vulnerabilities and stakeholder capabilities. In terms of practical contributions, the model results for HZMB can help decision-makers understand stakeholder resilience dynamics in RM in each project phase of megaprojects. Moreover, detailed management strategies are derived from HZMB to guide decision-makers in enhancing stakeholder resilience in various project phases.

Although the proposed stakeholder resilience model does not have regional restrictions, the case scenario is mainly in Hong Kong. The model's robustness can be tested further by applying it to many other regions. Other cases in multiple areas could be investigated in future studies to generalize and validate this study's proposed model. In addition, the automated text-mining method is waiting to be developed to replace the current manual approach for building up the timestamped stakeholder-issue networks more efficiently from the unstructured project documents. Meanwhile, the advanced Natural Language Processing (NLP) method is also expected to automatically set up the RM capability distributions under each relational strategy based on the relevant RM empirical literature in different regions. Furthermore, the model is expected to be applied to evaluate other complicated project issues (e.g., risk management and interface management) in megaprojects. Because the proposed model can analyse both the complex stakeholder structures and dynamic stakeholder interactions regarding various project issues in a changing project context.

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## Appendix 1

**Table 2 Type and Size of Stakeholder issues in HZMB in data collection**

| | Organizational level | | | Project level | | | | Societal level | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | communication | coordination | collaboration | cost | schedule | quality | Safety | labour | environment | transparency |
| 2003 | | 2 | 3 | | | | | 1 | 2 | 2 |
| 2004 | 3 | 2 | 4 | | 2 | | | 3 | | |
| 2005 | 2 | 2 | 7 | | 2 | | | 3 | 2 | |
| 2006 | 2 | 2 | 3 | | 7 | | | | 2 | |
| 2007 | | 3 | 6 | | 4 | | | | 3 | |
| 2008 | 7 | 1 | 9 | 2 | 1 | | | 1 | 5 | 1 |
| 2009 | 2 | 3 | 9 | 2 | | 1 | | 2 | 3 | 1 |
| 2010 | | 4 | 2 | | 1 | | | | | |
| 2011 | 2 | 1 | 3 | 2 | 6 | 1 | | 3 | 4 | |
| 2012 | 1 | 2 | | 5 | 1 | | | 1 | 1 | |
| 2013 | | 3 | | 2 | 1 | | | | 1 | |
| 2014 | | 8 | 3 | 1 | | 1 | | | 2 | 2 |
| 2015 | 1 | 7 | 1 | 3 | 3 | 1 | | | 6 | |
| 2016 | 6 | 10 | 13 | 4 | 4 | 4 | 7 | 3 | 4 | 2 |
| 2017 | 1 | 4 | 7 | 4 | | 5 | 9 | 2 | 2 | 2 |
| 2018 | 3 | 6 | 15 | 4 | 2 | | 2 | | | |

## Appendix 2

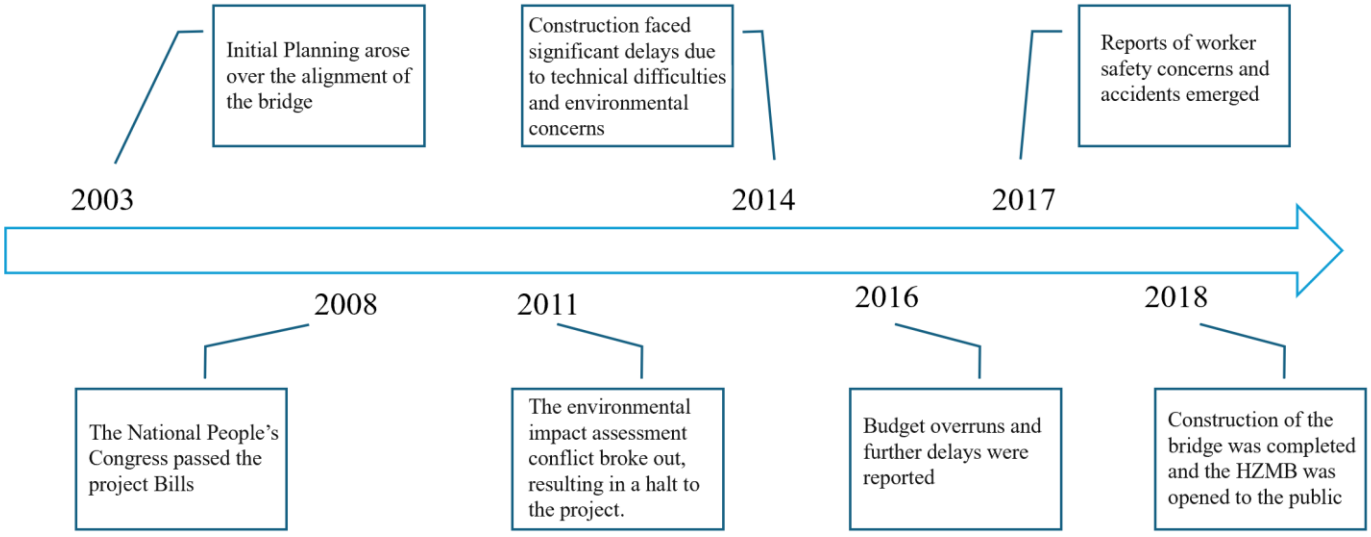
**Table 3 Type and Size of Stakeholders in HZMB in data collection**

| Stakeholder groups | Project stakeholders | Sum |
|---|---|---|

| | | |
|---|---|---|
| Construction groups | owner, contractors, consultants, subcontractors, suppliers | 5 |
| Government | Central government, Hong Kong government, Guangdong government, Macao government, legislative council, district council, coordination group of three regional governments | 7 |
| Pressure groups | local communities, media, environmental groups, political parties, general public | 5 |

941

942 **Appendix 3**




943

944 **Figure 13 Timeline in the development of HZMB**

Dear editor and reviewers,

Thank you for your precious time and valuable comments to guide us to improve our research. We followed the reviewers' advice to carefully address the comments. We are confident in addressing all the comments based on the valuable comments. Hopefully, our following explanations could match your expectations.

| Reviewers' comments | Response with the revision |
|---|---|
| Reviewer 1 | |
| C1: In general, the paper appears to be lengthy, and at times, there is a lack of focus. The abundance of background information, although related to the topic, might not be entirely relevant to your specific research, which can lead to confusion for the reader. Consider streamlining the content and maintaining a clear and concise focus on the core aspects of your study to enhance clarity and readability. | R1: The feeling of lack of focus is due to too much background information in the introduction part (134 lines). Following the comments, we thoroughly revised the lengthy introduction part to cut the redundant background information. Currently, the introduction is concisely focused on the core topic of stakeholder resilience in RM with the research significance, aim, questions, concepts, methods, gaps, and the manuscript outline. The revision is as follows. (Line 16 to Line 139)<br><br>**1. Introduction**<br>Relationship management (RM) aims to build a collaborative environment amongst stakeholders by using proper management strategies for achieving project success (Zou et al., 2014, Zheng et al., 2017, Pryke and Smyth, 2012). Megaprojects with long-term durations involve many interdependent stakeholders (Mok et al., 2015). Therefore, RM plays an essential role for each stakeholder because it enhances collaborations for improved project performance (Liu et al., 2015). Internal and external stakeholders participate in megaprojects (Mok et al., 2015). Internal stakeholders refer to construction groups (owners, contractors, consultants, subcontractors, suppliers and workers) that are directly involved in the project execution (Ujene and Edike, 2015). External stakeholders mainly consist of the government and pressure groups (environmental groups, local communities, media and the general public) that affect or are affected by the project's process (Olander and Landin, 2008). RM amongst stakeholders is considered a critical component of stakeholder management in traditional construction projects (Yang and Shen, 2014). Compared with conventional projects, megaprojects have a more changeable project environment due to the complex stakeholder structures and dynamic stakeholder interactions, leading to new challenges in RM (Shen and Xue, 2021, Ford et al., 2024). On the one hand, many issues concerned by stakeholders exist due to stakeholders' different interests in megaprojects (Li et al., 2012a), and these issues are interdependent among stakeholders, leading to the complexity of stakeholder structures.(Yang et al., 2009). The structures reflect the conflicting interests of stakeholders and result in the disruption of healthy stakeholder relationships (Mok et |

al., 2017a, Mok et al., 2017b). On the other hand, dynamic stakeholder interactions around stakeholder issues occur in the long-term project duration of megaprojects, causing unexpected conflicts to perturb collaborative relationships amongst stakeholders (Mok et al., 2017c). Given that stakeholder collaborations are adversely affected by stakeholder issues in megaprojects, understanding the resilience level of sustaining a collaborative relationship amongst stakeholders in megaprojects is essential and can help improve stakeholder RM to achieve project success (Yang et al., 2022, Morkan et al., 2023). Although previous studies have emphasized the concept of stakeholder RM to sustain collaborative relationships in stakeholder conflicts in the project (Yang and Shen, 2014), there is no existing comprehensive resilience studies in the stakeholder context (Naderpajouh et al., 2023). Thus, this research aims to establish a model for in-depth understands of stakeholder resilience in RM under a changing project environment. It is expected to answer the questions on 'What is the stakeholder resilience in RM?' and 'How to effectively measure, analyse, and management stakeholder resilience in RM in megaprojects?'

As stakeholder research is a critical part of organizational studies in project management (Naderpajouh et al., 2020), the definition of stakeholder resilience in RM can be taken reference from the resilience concept at the organizational level, which has been defined as the capability of an organization to withstand adverse conditions in a changing environment (Duchek, 2020, Burnard and Bhamra, 2011, Sajko et al., 2021). The research focus of organizational resilience includes reducing the vulnerability of organizations by enhancing capability with integrating organizational processes, engaging stakeholders, utilizing resources and increasing the awareness to prepare and respond to disruptions (Burnard and Bhamra, 2011). Therefore, previous research suggests that the measure of organizational resilience is dependent on finding the appropriate equilibrium between the vulnerabilities and capabilities of the organization (McManus et al., 2008), which shed a light on the analysis of stakeholder resilience in RM from stakeholder-issue vulnerabilities and stakeholder capabilities. On the basis of existing organizational resilience and stakeholder concepts, the authors defined 'stakeholder resilience' in RM as the 'capability of stakeholders to withstand stakeholder–issue vulnerabilities for recovering a collaborative relationship in a changeable project environment in RM'. The concept of stakeholder resilience in RM highlights the recovery capacity of collaborative relationships in a changeable project environment, which echoes the essence of the resilience concept defined as the ability to bounce back from a system in response to changes (Hassler and Kohler, 2014, Bhamra et al., 2011). Moreover, stakeholder resilience introduces the resilience concept into stakeholder management, providing a new perspective to analyse how effective RM is in the presence of a changeable environment in megaprojects.

On the basis of this concept, stakeholder resilience in RM is determined by the balance between the vulnerability level of stakeholder issues and the capability level of relevant stakeholders, which was echoed by studies that consider vulnerabilities and adaptive capacity as two attributes for organizational resilience (Burnard et al., 2018,

Burnard and Bhamra, 2011, Scholz et al., 2020). In this aspect, stakeholder issue vulnerabilities refer to the weaknesses that arise from stakeholder issues, which damage the collaborative relationship amongst stakeholders (Mok et al., 2017b). Therefore, the level of vulnerability of stakeholder issues in RM relies on the ability of stakeholders to strengthen and rebuild their relationships when facing disruptions caused by stakeholder issues. Stakeholder capabilities in RM refer to the ability to effectively manage stakeholder relationships by withstanding stakeholder issue vulnerabilities to achieve stakeholders' objectives and interests (Yang and Shen, 2014, Zou et al., 2014). The stakeholder capability to withstand stakeholder issue vulnerabilities can improve stakeholder resilience in RM (Ortiz-de-Mandojana and Bansal, 2016, Zhang et al., 2023). RM for stakeholders is resilient when the stakeholder issues are less vulnerable, and stakeholders have high capabilities to manage their relationships. If the high level of stakeholder issue vulnerabilities triggers conflicts amongst stakeholders with limited RM capability, the stakeholder collaborations will be seriously broken and difficult to restore. In megaprojects, stakeholder issue vulnerabilities and stakeholder capabilities are project specific. For instance, the Panyu Energy Project was considered highly vulnerable due to the environmental protection issue because the stakeholders paid too much attention to the pollution problem (Zhou et al., 2019). Meanwhile, the Hong Kong Express Rail Link was considered less vulnerable to the same issue because the stakeholders regarded land acquisitions and cultural village protections as their primary concerns. RM capabilities also vary in different projects even for the same stakeholder group (Li et al., 2012b). For example, the government as a stakeholder group failed to manage the conflicting relationships between local communities in the alignment of highway projects, leading to the stoppage and defunding of the projects (Zafar et al., 2020). By contrast, the government successfully coordinated the relationships of a vast number of stakeholders in the Shanghai Expo Project (Zhai et al., 2017). Given that the levels of stakeholder issue vulnerabilities and stakeholder capabilities vary in different projects, a reliable assessment approach must be developed to effectively manage stakeholder relationships targeting stakeholder resilience in each project.

Stakeholder resilience assessment sets a solid foundation to establish strategies for improving RM. Classical resilience assessment at organizational levels is based on quantitative and qualitative indicators, which generate a score to represent the resilience level of an organization (Ruiz-Martin et al., 2018). The indicators were proposed by McManus et al. (2008), which were grouped by four categories (key vulnerabilities, adaptive capacity, situation awareness, and resilience ethos). The four categories were further tailor-made to develop other indicators for measurement (Whitehorn, 2010, Sanchis and Poler, 2013, Lee et al., 2013, Rahi and Bourgault, 2022). Despite the previous indicator-based research has provided dimensions for resilience assessment, stakeholder resilience assessment still faces a considerable challenge in megaprojects. Classical evaluation approaches cannot adapt to the changeable project environment in RM in megaprojects, which is led by complex

stakeholder structures and dynamic stakeholder interactions (Xue et al., 2020b, Shen and Xue, 2021). The conventional scoreboard method has been criticized by organizational resilience studies that it relies too much on survey samples from quality respondents (Lee et al., 2013). However, with the increase in complexity and dynamics amongst stakeholders in the project environment of megaprojects, it is more difficult for project participants to objectively evaluate stakeholder resilience in RM during the survey due to the limitation in their own management experience (Shen and Xue, 2021). Hence, advanced methods must be developed to measure stakeholder resilience in RM under the project environment of complex stakeholder structures and dynamic stakeholder interactions.

When it comes to representing complex stakeholder structures, the network model provides a valuable method for illustrating the interrelationships between stakeholders and their respective issues in RM (Mok et al., 2015). The classical dyadic ties model, which was employed before the network model, regards the relationships between stakeholders as composed of dyadic links and disregards the interrelationship between stakeholder issues and stakeholders (Freeman, 1984). Hence, the traditional method cannot analyse the resilience problem at the stakeholder issue level, therefore cannot directly guide stakeholders in RM in industry practice (Yang et al., 2009). Compared with previous methods, the network model has the advantage of systematically representing the interrelationship between stakeholder issues and relevant stakeholders, which can assess stakeholder resilience in RM from a stakeholder issue perspective (Xue et al., 2020b). In terms of dynamic stakeholder interactions, NK modelling has the potential to evaluate stakeholder resilience, which can analyse stakeholders' capability in RM facing adverse changes in their interactions. The NK model is a special kind of the Agent-based models. Unlikely the classical Agent-based model that agents make decisions independently, NK modelling emphasizes the decision-making of the agents is interdependent, reflecting the dynamic stakeholder interactions in megaprojects (Mok et al., 2017a). Compared with system dynamics, NK modelling is more suitable for evaluating the interdependent organisations in a large system (Giannoccaro et al., 2018). The NK model is a stochastic simulative approach adopted from biology to study an organization's interactions in a changing environment (Levinthal, 1997, Kauffman and Levin, 1987). The existing studies argue that the NK model is better suited than the system dynamics model for evaluating interactive organizations wherein accurate measurement of mutual influences is challenging (Ganco and Hoetker, 2009). They also identify two key benefits of using the NK model to analyse the dynamic stakeholder interactions. Firstly, the NK model can help assess the quality of a system (stakeholder issue) after interactions amongst its elements (stakeholders) (Giannoccaro, 2011, Xiang et al., 2024). With the score derived from the NK model to quantify the quality of a system, we can measure the vulnerability level of stakeholder issues during stakeholder interactions in megaprojects. Secondly, the NK model evaluates each element's adaptive capacity towards sudden changes in interactions (Giannoccaro et al., 2018). As a result, the

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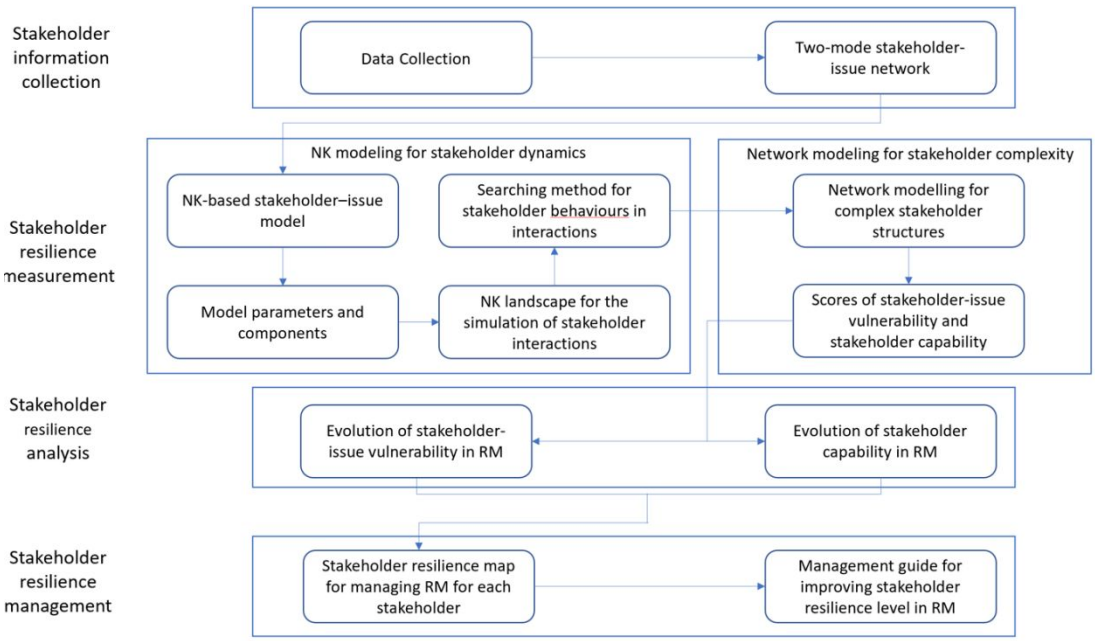
| | capability level of each stakeholder in RM in a changeable environment can be measured. The NK model has been used with the network model to evaluate the variations in organizational performance resulting from a changeable environment (Capaldo and Giannoccaro, 2015). Therefore, integrating NK and network models is a promising approach to measure stakeholder resilience in megaprojects and provide strategies for improved RM. The approach has two features. First, the network model can evaluate the complexities between stakeholders and relevant issues, which is useful for identifying and addressing the RM challenges at the stakeholder-issue level. Second, the NK model enables to measure the dynamics of stakeholder interactions for each stakeholder-issue, which is beneficial to assess the varied stakeholder relationships in project development. By using the integrated models, it has a high potential to analyse the stakeholder resilience level in RM under a changing project environment.<br>To fill the gap of lack of resilience studies in the stakeholder context to understand the RM capability in stakeholder conflicts, this study introduces the concept of stakeholder resilience in RM and proposes a model for measuring, analysing, and managing stakeholder resilience in megaprojects. The model consists of three main components: a measurement function to evaluate stakeholder variations of RM in changeable environments, an analysis function to assess the evolution of stakeholder issue vulnerabilities and capabilities in RM, and a managerial map to classify stakeholder resilience and provide a management guide. To validate the proposed model, a real-project study of the Hong Kong-Zhuhai-Macao Bridge is conducted, providing empirical evidence on stakeholder resilience in RM in megaprojects. |
| C2: I recommend that the authors consider adding a research method diagram to the paper. This visual representation will offer a clear snapshot of the research steps followed, aiding readers in better understanding the overall flow of the study. | R2: Following the comments, we drew the research method diagram in Figure 2, which matches each step in the following sub-sections of the method part.<br>  <br><br>**<Figure 2 Framework of the stakeholder resilience model in RM>**↵ |

C3: Regarding the literature review, I strongly recommend that the authors include a summary table of their comprehensive literature review. Such a table would not only help identify gaps in the existing literature but also enhance the contribution of this work by providing a clear overview of the relevant research in the field.

R3: Following the comments, we added a summary table of the comprehensive literature review from Line 255 to Line 260.

**2.4 Summary of literatures in modelling stakeholder resilience**

Overall, the overview of stakeholder resilience in RM (shown in Table 1) is summarized from perspectives of the stakeholder resilience concept, measurement, analysis, and management based on the literature in the introduction and background sections, which sets a theoretical foundation for the following method development and case validation.

**Table 1 Overview of stakeholder resilience in RM**

| Research objectives | Research concepts | Research Findings | Relevant Literatures |
|---|---|---|---|
| Stakeholder resilience concept | Organizational resilience | It is defined as the capability of an organization to withstand adverse conditions in a changing environment. Previous research suggests that the measure of organizational resilience is dependent on finding the appropriate equilibrium between the vulnerabilities and capabilities of the organization | McManus et al., 2008<br>Burnard and Bhamra, 2011<br>Naderpajouh et al., 2020<br>Duchek, 2020<br>Sajko et al., 2021 |
| | Stakeholder-issue vulnerability | Stakeholder issue vulnerabilities refer to the weaknesses that arise from stakeholder issues, which damage the collaborative relationship amongst stakeholders. | Mok et al., 2017b<br>Scholz et al., 2020 |
| | Stakeholder capability | The stakeholder capability to withstand stakeholder issue vulnerabilities can improve stakeholder resilience in RM. | Ortiz-de-Mandojana and Bansal, 2016<br>Zhang et al., 2023 |
| | Stakeholder resilience | Stakeholder resilience in RM is determined by the balance between the vulnerability level of stakeholder issues and the capability level of relevant stakeholders, which was echoed by studies that consider vulnerabilities and adaptive capacity as two attributes for organizational resilience. | Burnard and Bhamra, 2011<br>Bhamra et al., 2011<br>Hassler and Kohler, 2014<br>Burnard et al., 2018<br>Scholz et al., 2020 |
| Stakeholder resilience measurement | NK model for evaluating dynamic stakeholder interactions | The NK model was introduced to the organization management field in the 1990s to show how the adaptive capability of organizations affects system performance in a changing environment. | Kauffman, 1993<br>Levinthal, 1997 |
| | | The NK model is determined by N and K. The parameter N stands for how many stakeholders are in the system, and the parameter K stands for the interaction level of stakeholders in the system. After setting up the parameters N and K, a landscape is mapped to simulate the stakeholder interactions based on their interactive behaviours. | Giannoccaro, 2011<br>Giannoccaro and Nair, 2016<br>Giannoccaro et al., 2018 |
| | | Based on the established landscape, the scores assessing the quality of a system and the capability of each stakeholder are obtained to reflect the stakeholder's adaptability in the changing environment. | Ganco and Hoetker, 2009<br>Capaldo and Giannoccaro, 2015<br>Xiang et al., 2024 |
| | Network model for evaluating complex stakeholder structures | The network model has been proven effective in analysing the complex stakeholder structures caused by stakeholder-issue interdependencies. | Zheng et al., 2016<br>Mok et al., 2017a<br>Li et al., 2024 |
| | | There are three components in the stakeholder-issue network models, including stakeholder issue nodes, stakeholder nodes, and stakeholder-issue links | Latapy et al., 2008<br>Xue et al., 2020b |
| | | The network model systematically presents the complicated relationships between stakeholder issues and stakeholders, which is a useful approach for evaluating stakeholder resilience in RM | Mok et al., 2015<br>Kim et al., 2021<br>Shen and Xue, 2021<br>Naderpajouh et al., 2023 |
| Stakeholder resilience analysis | Evolution graph for stakeholder resilience analysis | Evolution graphs are critical to analysing the dynamics of resilience problems. Existing studies have proven that evolution graphs of the system's vulnerabilities and the elements' capabilities are useful in evaluating resilience from two important perspectives. | Jafarnejad et al., 2019<br>Liu, 2019<br>Ekanayake et al., 2021a<br>Ekanayake et al., 2021b |
| Stakeholder resilience management | Resilience metrics | Resilience metrics play a critical role in assessing resilience at organizational levels. The metrics were proposed to calculate the resilience score from two dimensions, namely, vulnerability and capability. | Bhamra et al., 2011<br>Pettit et al. 2013<br>Thome et al., 2016<br>Wood et al., 2019<br>Rahi and Bourgault, 2022 |
| | Resilience curves | The resilience curve shows how system performance varies in the resilience process with four statuses: prepare, absorb, recover and adapt. | McManus et al., 2008<br>Burnard et al., 2018<br>Kurth et al., 2019 |
| | Resilience maps | The resilience map connects stakeholder resilience management with the classical resilience curves by adopting four critical concepts: preparedness, absorption, recovery and adaptation. | Kurth et al., 2019 |
| | | Management strategies in the dangerous zone: the previous resilience studies suggest that the positive attitudes and proactive actions are essential for organizations to cope with the outbreak of dangers. | Vogus and Sutcliffe, 2007<br>Kantur and İşeri-Say, 2012<br>Iao-Jörgensen, 2023 |
| | | Management strategies in the challenging zone: the existing organization studies prove that stakeholders should keep learning how to deal with vulnerabilities during the difficult period of relationship recovery. | Lengnick-Hall et al., 2011<br>Burnard et al., 2018<br>Phillips and Chao, 2022 |
| | | Management strategies in the safe zone: management strategies aim to build stronger collaborative relationships amongst stakeholders compared with the status before the vulnerabilities' outbreak. | Lengnick-Hall et al., 2011<br>Ruiz-Martin et al., 2018 |
| | | Management strategies in the vigilant zone: the previous resilience studies highlight the importance of preparation capabilities for organizations facing unexpected crises | Kantur and İşeri-Say, 2012<br>Duchek, 2020 |

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| C4: As usual a final thorough proof-reading is recommended. | R4: Following the comments, we proofread the manuscript and strived to improve its communication as best as we can. |

| Reviewers' comments | Response with the revision |
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| Reviewer 2 | |
| C1: In the introduction section, consider providing a more explicit statement of the research objectives or questions early on. | R1: Following the comments, I added the clear statement of the research objectives and questions at the end of the first paragraph in the introduction section. Line 37-Line 42.<br><br>"Although previous studies have emphasized the concept of stakeholder RM to sustain collaborative relationships in stakeholder conflicts in the project (Yang and Shen, 2014), there is no existing comprehensive resilience studies in the stakeholder context (Naderpajouh et al., 2023). Thus, this research aims to establish a model for in-depth understands of stakeholder resilience in RM under a changing project environment. It is expected to answer the questions on 'What is the stakeholder resilience in RM?' and 'How to effectively measure, analyse, and management stakeholder resilience in RM in megaprojects?'" |
| C2: Include a brief overview of the proposed model's features | R2: Following the comments, we added an overview of the proposed model's features in the introduction section. Line 125-Line 131.<br><br>"Therefore, integrating NK and network models is a promising approach to measure stakeholder resilience in megaprojects and provide strategies for improved RM. The approach has two features. First, the network model can evaluate the complexities between stakeholders and relevant issues, which is useful for identifying and addressing the RM challenges at the stakeholder-issue level. Second, the NK model enables to measure the dynamics of stakeholder interactions for each stakeholder-issue, which is beneficial to assess the varied stakeholder relationships in project development. By using the integrated models, it has a high potential to analyse the stakeholder resilience level in RM under a changing project environment." |
| C3: In the background section, extend your critical analysis and include previous case studies related to the variables of this study. | R3: Following the comments, we included the previous case studies related to the model variables in the background section. Line 215- Line 220.<br><br>"After setting up the parameters N and K, a landscape is mapped to simulate the stakeholder interactions based on their interactive behaviours (Giannoccaro et al., 2018). To build up a landscape, the distributions of the RM capability levels among stakeholders are critical to understand RM level during the stakeholder interaction. The statistical distribution can be obtained by empirical studies on stakeholder relationships. For instance, Xue et al. (2020a) assessed the stakeholders' RM capability level under various project issues, which provided a numeric reference to setting up the distributions for creating the landscape." |

C4: Include a table of authors at the end of the background section, indicating the most relevant papers, authors, hypotheses, and findings.

R4: Following the comments, we added a summary table of the comprehensive literature review at the end of the background section from Line 255 to Line 260.

**2.4 Summary of literatures in modelling stakeholder resilience**

Overall, the overview of stakeholder resilience in RM (shown in Table 1) is summarized from perspectives of the stakeholder resilience concept, measurement, analysis, and management based on the literature in the introduction and background sections, which sets a theoretical foundation for the following method development and case validation.

**Table 1 Overview of stakeholder resilience in RM**

| Research objectives | Research concepts | Research Findings | Relevant Literatures |
|---|---|---|---|
| Stakeholder resilience concept | Organizational resilience | It is defined as the capability of an organization to withstand adverse conditions in a changing environment. Previous research suggests that the measure of organizational resilience is dependent on finding the appropriate equilibrium between the vulnerabilities and capabilities of the organization | McManus et al., 2008<br>Burnard and Bhamra, 2011<br>Naderpajouh et al., 2020<br>Duchek, 2020<br>Sajko et al., 2021 |
| | Stakeholder-issue vulnerability | Stakeholder issue vulnerabilities refer to the weaknesses that arise from stakeholder issues, which damage the collaborative relationship amongst stakeholders. | Mok et al., 2017b<br>Scholz et al., 2020 |
| | Stakeholder capability | The stakeholder capability to withstand stakeholder issue vulnerabilities can improve stakeholder resilience in RM. | Ortiz-de-Mandojana and Bansal, 2016<br>Zhang et al., 2023 |
| | Stakeholder resilience | Stakeholder resilience in RM is determined by the balance between the vulnerability level of stakeholder issues and the capability level of relevant stakeholders, which was echoed by studies that consider vulnerabilities and adaptive capacity as two attributes for organizational resilience. | Burnard and Bhamra, 2011<br>Bhamra et al., 2011<br>Hassler and Kohler, 2014<br>Burnard et al., 2018<br>Scholz et al., 2020 |
| Stakeholder resilience measurement | NK model for evaluating dynamic stakeholder interactions | The NK model was introduced to the organization management field in the 1990s to show how the adaptive capability of organizations affects system performance in a changing environment. | Kauffman, 1993<br>Levinthal, 1997 |
| | | The NK model is determined by N and K. The parameter N stands for how many stakeholders are in the system, and the parameter K stands for the interaction level of stakeholders in the system. After setting up the parameters N and K, a landscape is mapped to simulate the stakeholder interactions based on their interactive behaviours. | Giannoccaro, 2011<br>Giannoccaro and Nair, 2016<br>Giannoccaro et al., 2018 |
| | | Based on the established landscape, the scores assessing the quality of a system and the capability of each stakeholder are obtained to reflect the stakeholder's adaptability in the changing environment. | Ganco and Hoetker, 2009<br>Capaldo and Giannoccaro, 2015<br>Xiang et al., 2024 |
| | Network model for evaluating complex stakeholder structures | The network model has been proven effective in analysing the complex stakeholder structures caused by stakeholder-issue interdependencies. | Zheng et al., 2016<br>Mok et al., 2017a<br>Li et al., 2024 |
| | | There are three components in the stakeholder-issue network models, including stakeholder issue nodes, stakeholder nodes, and stakeholder-issue links | Latapy et al., 2008<br>Xue et al., 2020b |
| | | The network model systematically presents the complicated relationships between stakeholder issues and stakeholders, which is a useful approach for evaluating stakeholder resilience in RM | Mok et al., 2015<br>Kim et al., 2021<br>Shen and Xue, 2021<br>Naderpajouh et al., 2023 |
| Stakeholder resilience analysis | Evolution graph for stakeholder resilience analysis | Evolution graphs are critical to analysing the dynamics of resilience problems. Existing studies have proven that evolution graphs of the system's vulnerabilities and the elements' capabilities are useful in evaluating resilience from two important perspectives. | Jafarnejad et al., 2019<br>Liu, 2019<br>Ekanayake et al., 2021a<br>Ekanayake et al., 2021b |
| Stakeholder resilience management | Resilience metrics | Resilience metrics play a critical role in assessing resilience at organizational levels. The metrics were proposed to calculate the resilience score from two dimensions, namely, vulnerability and capability. | Bhamra et al., 2011<br>Pettit et al. 2013<br>Thome et al., 2016<br>Wood et al., 2019<br>Rahi and Bourgault, 2022 |
| | Resilience curves | The resilience curve shows how system performance varies in the resilience process with four statuses: prepare, absorb, recover and adapt. | McManus et al., 2008<br>Burnard et al., 2018<br>Kurth et al., 2019 |
| | Resilience maps | The resilience map connects stakeholder resilience management with the classical resilience curves by adopting four critical concepts: preparedness, absorption, recovery and adaptation. | Kurth et al., 2019 |
| | | Management strategies in the dangerous zone: the previous resilience studies suggest that the positive attitudes and proactive actions are essential for organizations to cope with the outbreak of dangers. | Vogus and Sutcliffe, 2007<br>Kantur and İşeri-Say, 2012<br>Iao-Jörgensen, 2023 |
| | | Management strategies in the challenging zone: the existing organization studies prove that stakeholders should keep learning how to deal with vulnerabilities during the difficult period of relationship recovery. | Lengnick-Hall et al., 2011<br>Burnard et al., 2018<br>Phillips and Chao, 2022 |
| | | Management strategies in the safe zone: management strategies aim to build stronger collaborative relationships amongst stakeholders compared with the status before the vulnerabilities' outbreak. | Lengnick-Hall et al., 2011<br>Ruiz-Martin et al., 2018 |
| | | Management strategies in the vigilant zone: the previous resilience studies highlight the importance of preparation capabilities for organizations facing unexpected crises | Kantur and İşeri-Say, 2012<br>Duchek, 2020 |

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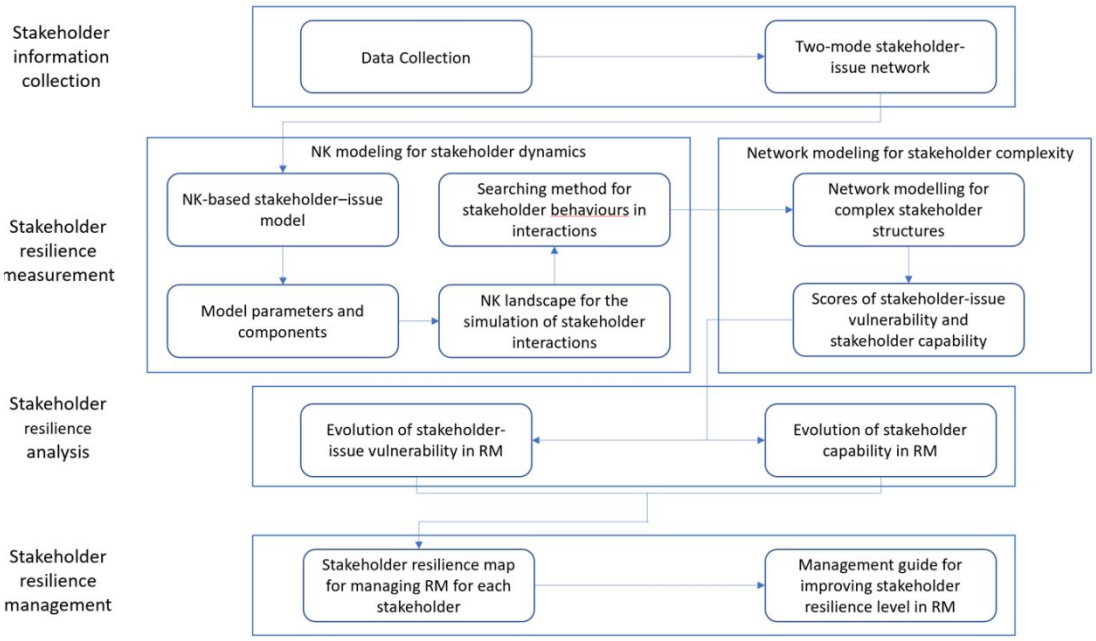
| C5: Include diagrams to explain better your methodology | R5: Following the comments, we drew the research method diagram in Figure 2, which matches each step in the following sub-sections of the method part.<br>  <br><br>**<Figure 2 Framework of the stakeholder resilience model in RM>** |
| C6: In your validation section, increase the paper's relevance by pointing out the potential biases and limitations. | R6: Following the comments, we added the demonstration of the potential biases and limitations at the end of the validation section. Line 528- Line 532.<br><br>"However, the model still has two limitations. First, it is time-consuming to build up the timestamped networks in data collection manually from large quantities of project documents, which may cause the missing of stakeholder information. Second, the simulation of the NK model requires the input of the capability distribution, which asks for prior relational empirical studies to provide numerical evidence. Thus, relational empirical research is a prerequisite which may constrain the model's accuracy." |
| C7: In your discussion section, include an explanation of the relevance of the scalability of the model and its adaptation to projects of various sizes or industries. | R7: Following the comments, we added one section to discuss the model's scalability and adaptation to projects of various sizes or industries at the end of the discussion section. Line 688- Line 696.<br><br>**5.4 The stakeholder resilience model's scalability and adaptation in RM**<br>The proposed stakeholder resilience model does not have project size and industry restrictions, The previous studies have proved that the Network models fit measurement of stakeholder involvement in both mega and conventional project size (Li et al., 2024, Ekanayake et al., 2021a). Meanwhile, the NK model has been widely used in organizational studies in multiple industries (Giannoccaro and Nair, 2016). Therefore, the integrated stakeholder resilience model enables to adapt to RM studies in various project sizes and industries. There are two elements of model inputs that require adjusting to the project context. First, the timestamped stakeholder-issue |

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| | networks are established based on the various stakeholder relationships identified in the project documents. Second, the RM capability distributions are set up according to the empirical stakeholder studies in the relevant industries. |
| C8: In your conclusions, add specific recommendations for future research and expand the different aspects of the model or indicate the possibility of applying it in other complex project environments. | R8: Following the comments, we added the recommendations for future research on model development and application in other complex project environments at the end of the conclusion section. Line 737-Line 746.<br><br>"Although the proposed stakeholder resilience model does not have regional restrictions, the case scenario is mainly in Hong Kong. The model's robustness can be tested further by applying it to many other regions. Other cases in multiple areas could be investigated in future studies to generalize and validate this study's proposed model. In addition, the automated text-mining method is waiting to be developed to replace the current manual approach for building up the timestamped stakeholder-issue networks more efficiently from the unstructured project documents. Meanwhile, the advanced Natural Language Processing (NLP) method is also expected to automatically set up the RM capability distributions under each relational strategy based on the relevant RM empirical literature in different regions. Furthermore, the model is expected to be applied to evaluate other complicated project issues (e.g., risk management and interface management) in megaprojects. Because the proposed model can analyse both the complex stakeholder structures and dynamic stakeholder interactions regarding various project issues in a changing project context." |
| C9: In your reference section, ensure that all cited works are up-to-date and relevant to research in project management and resilience theory. | R9: Following the comments, we checked the references and ensured them to be the state of the art from the leading journals, including but not limited to the IEEE Transactions on Engineering Management, International Journal of Project Management, Project Management Journal, Journal of Management in Engineering, and etc. |

| Reviewers' comments | Response with the revision |
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| Reviewer 3 | |
| C1: The manuscript can benefit from a more detailed and comprehensive introduction of the case project background. This would be very important for the potential readers who are not familiar with the project to understand the details in the measurement model as well as the validation, for example, Figure 7 in Section 4.1. Providing a thorough explanation of the figures with detail would enhance the reader's understanding and contextualize the subsequent analysis. | R1: Following the comments, we provided a thorough explanation of Figure 7 in Section 4.1 to enhance the reader's understanding of HZMB. Line 435- Line 442.<br><br>"Specifically, the figure clearly showed the development history of HZMB. Between 2003 and 2007, HZMB was at the conceptual planning stage so that the stakeholder relationships were relatively simple. In 2008, the stakeholder issues had the first outbreak due to the decisive moment when the National Congress passed the Project Bills. From 2010 to 2014, the stakeholder interactions were not intensively as the construction works were generally undergoing smoothly. The only outburst of stakeholder conflicts was in 2011 when the project faced serious challenges in environmental impact assessment. However, since 2015, HZMB had experienced a series of stakeholder intentions due to the time delay, cost overruns, safety incidents, quality issues, and operational arrangements, reflecting in the highly complicated stakeholder network structures." |
| C2: Figure 10 and Figure 11 are a bit hard to read clearly. The reviewer suggested arranging the three sections vertically | R2: Following the comments, we re-drew Figure 10 and Figure 11to clearly mark the trend in each figure. Each marked trend is discussed in the corresponding content (Sections 4.3&4.4) |

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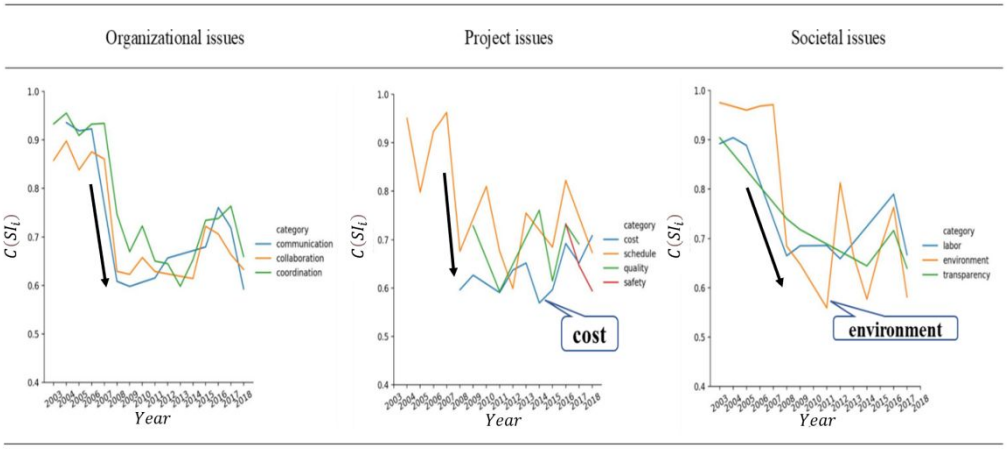
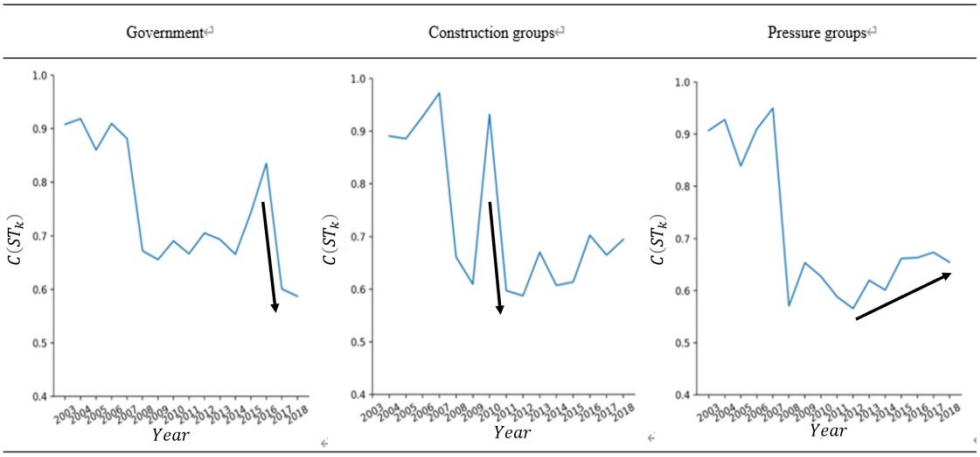
| so that readers can compare them more clearly. Improving the visual clarity of these figures, perhaps by reformatting or enlarging certain elements, would enhance their effectiveness in conveying the key findings to the readers. |  <br>**<Figure 10 Evolution of stakeholder issue vulnerability in HZMB>**<br>  <br>**<Figure 11 Evolution of stakeholder capabilities in HZMB>** |
| C3: The integration of NK model and network theory is a novel contribution to the field of project management. However, the case that this study focuses on is a megaproject located in China, and it is necessary for the authors to further discuss how the findings of this study can be further extended to | R3: Following the comments, we added a part to discuss how the findings can contribute to other regions in the world in the discussion section. Line 697- Line 702.<br><br>"The model's findings can be a valuable reference for different regions in the world, which share the similar context. For instance, the European megaprojects often require cooperation from different countries. The cross-border collaboration also faces the challenge of various regulation and culture systems in RM, which is quite like HZMB. The African megaprojects involve the contractors from different countries. The international collaboration increases the difficulties in RM to manage stakeholder complexities, which is also a big challenge in HZMB. Therefore, the case study of HZMB can provide useful implications to enhance stakeholder resilience in RM in multiple areas globally." |

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| construction projects in other regions of the world. Especially, discuss how to improve the broad applicability of the findings to benefit more construction projects of different scales and challenges, such as large-scale projects in the EU that require cooperation from different countries, or infrastructure projects in African countries involving different countries and contractors. Providing insights into the generalizability and transferability of the proposed framework to diverse project contexts would enhance the relevance and impact of the study for a broader audience of project management researchers and practitioners. | |
| C4: The introduction section is indeed well-written, | R4: Following the comments, we highlighted the research gap and purpose at the end of the introduction part. Line 132- Line 139.<br><br>"To fill the gap of lack of resilience studies in the stakeholder context to understand |

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| effectively introducing the concepts addressed in this manuscript alongside the recent research gap. However, it is suggested that the gap and the purpose of the research be highlighted with a brief summary at the end of the introduction. Such a summary would aid readers in recalling key points and maintaining focus on the research questions as they proceed through the manuscript. | the RM capability in stakeholder conflicts, this study introduces the concept of stakeholder resilience in RM and proposes a model for measuring, analysing, and managing stakeholder resilience in megaprojects. The model consists of three main components: a measurement function to evaluate stakeholder variations of RM in changeable environments, an analysis function to assess the evolution of stakeholder issue vulnerabilities and capabilities in RM, and a managerial map to classify stakeholder resilience and provide a management guide. To validate the proposed model, a real-project study of the Hong Kong-Zhuhai-Macao Bridge is conducted, providing empirical evidence on stakeholder resilience in RM in megaprojects.” |
| C5: In section 2.3, the HZMB project is introduced; however, considering the international readership, it is advisable to provide additional contextual information about the case, particularly regarding the unique political and administrative structure of "one country, two | R5: Following the comments, we added the additional contextual information about the unique political and administrative structure of "one country, two systems" and its relevance to HZMB in the background section. Line 240- Line 244.<br><br>“The project involves stakeholders from the regions under the “one country and two systems” scheme in the complex aspect. The scheme refers to the different regulation and culture systems between three regions, where Guangdong undertakes the mainland governance system while Hong Kong and Macao have their own administrative systems. The project stakeholders faced challenges in RM toward the collaboration among different systems.”<br><br>Moreover, we added a figure illustrating the timeframe progress of the project with the milestones, which benefits readers in understanding of project's chronology. Line 237- Line 240.<br><br>“The HZMB project is a globally recognized megaproject that links three significant regions in China, namely Hong Kong, Macao, and Guangdong Province. From a temporal standpoint, the project spans a duration of 16 years, encompassing the |

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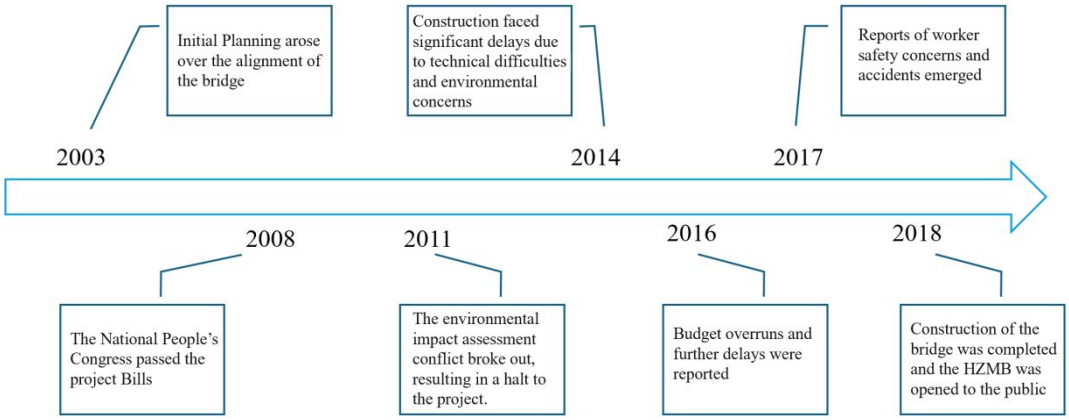
| systems" and its relevance to the project.<br>Incorporating details about this governance framework and its implications for the HZMB project would enrich the understanding of readers unfamiliar with the intricacies of the region. Moreover, including a visual representation, such as a figure illustrating the timeframe progress of the project, would enhance the visualization of its development stages. This addition would offer readers a clearer grasp of the project's chronology and milestones, thereby facilitating a deeper comprehension of its evolution and complexities. | planning phase (2003-2009), the construction phase (2010-2017), and the handover phase (2018), thus exhibiting dynamic characteristics (timeline shown in Appendix 3).”<br>**Appendix 3**<br>  <br><br>**Figure 13 Timeline in the development of HZMB** |
| C6: It might be helpful with new citations of up-to-date and high-quality papers on the subjects | R6: Following the comments, we updated the references and ensured them to be the state of the art from the leading journals, including but not limited to the IEEE Transactions on Engineering Management, International Journal of Project Management, Project Management Journal, Journal of Management in Engineering, and etc. |

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| covered in manuscript and engaged the previous literature in this journal. | |
| C7: Also, the author(s) should carefully format the manuscript following the guidance of the journal, such as the headers, references, and so on. There are mistakes in the citation (reference), such as missing volume, issue and page. | R7: Following the comments, we carefully checked the manuscript's format based on the journal's guidance. |