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Investigating key challenges in major public engineering projects by a network-theory based analysis of stakeholder concerns: A case study

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Abstract

The diversities of stakeholder concerns and intricate interdependencies between stakeholder concerns are important factors adding complexities to major public engineering projects (MEPs). Using case study and network-theory based analysis in a large reclamation project, this paper investigated the key stakeholder concerns and concern interdependencies of MEPs, and how they bring major challenges confronted by stakeholders. The network analysis identifies five major challenges of the case: "applying highly advanced and complex construction technology", "mitigating project disruptions to the environment and marine ecology", "conducting public and community consultation during construction phase", "site constraints due to nearby air and marine traffic", and "meeting government standard on the quality of new materials and equipment". Recommendations are provided to alleviate these problems for future MEPs. This paper contributes to a new angle, the network perspective, of analyzing stakeholder concern interdependencies and their practical implications on MEPs. The findings provide useful insights on common pitfalls of MEPs.

Keywords: Stakeholder concern; Stakeholder analysis; Network analysis; Major engineering project

1. Introduction

Major public engineering projects (MEPs) are substantial investment, which are initiated and funded by the government, to provide communal facilities essential for boosting economic growth as well as enhancing the environment and societal quality of life (Zeng et al., 2015). MEPs are characterized by being dimensionally huge and human-oriented (Yeo, 1995); having extreme complexity, high risks and long lead time (Fiori and Kovaka, 2005); involving multiple stakeholders at different levels; and producing considerable impacts to the society, economy and natural environment (Zhai et al., 2009). The cost of MEP is huge where the governments and researchers worldwide have accepted the range of US$500 million–1 billion as the cost threshold per project (FHA, 2005; Hu et al., 2015). Failures of MEPs have been discussed in many studies, where the complexities of stakeholders, stakeholder issues and their interrelationships are highlighted as major factors adding difficulties to MEP management (Olander and Landin, 2005).

MEPs involve a wide range of stakeholders who come from diverse backgrounds and raise various issues that are at stake in the project. These concerns might be favorably or unfavorably affected owing to the achievement of project objectives (PMI, 1996). Although they are often conflicting and relate to diverse topics, stakeholder concerns springing from a MEP are bonded with strong and dynamic interdependencies. The presence of a concern can evoke or govern the existence as well as incidence of other directly or indirectly related concerns in the same project environment (Fang et al., 2012). The interactions and chain effects between stakeholder concerns increase uncertainties in stakeholder behaviors and project decision making, therefore posing great challenges to both stakeholder management and the delivery of MEPs. In fact, a MEP can be considered as a network of interrelated stakeholder concerns. A network perspective to analyze stakeholder concerns, their interrelationships and proliferating impacts on the project is essential; without which the stakeholder analysis process might compromise in completeness and accuracy,leading to poor stakeholder satisfaction, uninformed project decision making and unsatisfactory MEP performance.

In recent decades, researchers have developed various stakeholder analysis processes and tools in an attempt to cope with stakeholder complexities in MEPs. Mitchell et al. (1997) established stakeholder salience model to determine the classes of stakeholders based on their possession of three attributes: power, urgency, and legitimacy. The power/interest matrix is another broadly used method to classify stakeholders based on their power and interest levels (Olander and Landin, 2008). Rowley (1997) proposed a relational approach to evaluate stakeholder influences, and predict their behaviors and levels of demands towards focal company by investigating stakeholder relationships. These traditional methods are useful in classifying stakeholders and evaluating their impacts according to stakeholder attributes, attitudes and interdependencies; nonetheless, they are insufficient to address complexities brought by stakeholder concerns, concern relationships and their chain effects on the project. The existing methods view stakeholder concerns as being independent and stationary in vacuum. Consequently, they may not be able to help in answering the following questions: (1) What stakeholder concerns are at stake in a project and how are these concerns interconnected? (2) What are the practical implications of these concern interdependencies on stakeholder management and project implementation? To bridge these research gaps, a network perspective to investigate concern interdependencies in MEPs is of theoretical and practical importance.

Network-theory based analysis is a potential method to investigate stakeholder concern interdependencies in MEPs by visualizing the relationship fabrics and examining quantitatively their structural properties (Wasserman and Faust, 1994). Stakeholder concerns exist in a form of network in each MEP; however, the existing stakeholder analysis methods have overlooked concern interdependencies and their proliferating impacts. Using a network approach can help project team to capture the cause and-effect relationships among stakeholder concerns, identify key concerns and interactions, as well as understand the key challenges encountered by project stakeholders based on the network analysis results. Researchers of the construction management field have applied network analysis to examine various interdependencies, such as human relationships of project participants (Dogan et al., 2015; Solis et al., 2013), project risk interactions (Fang et al., 2012; Yang and Zou, 2014), and interconnections between elements of an infrastructure system (Eusgeld et al., 2009; Zhang et al., 2015). Despite the need of usinga network approach for concerninterdependencyanalysis in MEPs, such empirical studies appear tobe lacking. Therefore,this paper demonstrates the use of network-theory based analysis for identifying key stakeholder concerns and concern relationships in MEPs through a case study, as well as identifies major challenges in the case project based on the network analysis results.

This paper starts with a review of the major stakeholders and concerns in MEPs, followed by an overview of the network theory and usage of network analysis in construction management field. The research methodology section explains the case study method, as well as the network development and analytical process. A MEP of large-scale reclamation is presented as case study to illustrate the identification of key stakeholder concerns and interdependencies using a network approach, and show how the network analysis results help to identify major challenges confronted by project stakeholders. After determining the key challenges, the discussion section provides an in-depth investigation on their root causes and includes recommendations to tackle these problems in future MEPs.

2. Literature review

2.1. The concepts of stakeholder and stakeholder concerns in MEPs

The stakeholder theory was originated from strategic management in 1963 when the Stanford Research Institute primarily defined stakeholders as individuals whose existences are vital to organizational survival (Freeman, 1984). The stakeholder concept was given wider recognition since Freeman (1984) elaborated on stakeholder definition as any entities "who can affect or is affected by the achievement of the firm's objectives" in his classic: Strategic Management: a Stakeholder Approach. Thereafter, scholars enriched the stakeholder theory to enhance its position. For example, Donaldson and Preston (1995) proposed three approaches to look into stakeholder theory: (1) descriptive, which explores stakeholder management process and develops methods; (2) instrumental, which investigates how stakeholder management influences the accomplishment of organizational goals; and (3) normative, which considers moral guidelines to manage stakeholders. McElroy and Mills (2000) categorized stakeholders into five types based on their individual attitudes regarding a project, including "active opposition", "passive opposition", "not committed", "passive support" and "active support". Bourne (2005) developed Stakeholder Circle tool to visualize stakeholder influences and prioritize their importance by considering stakeholder "power" and "urgency" (from Mitchell et al.'s model) and another attribute: "proximity". Following the advancement of stakeholder theory, scholars have realized its potential to be implemented in other domains including construction management. In project management context, the Project Management Institute (PMI) (1996)describes project stakeholders as any "individuals and organizations who are actively involved in the project, or whose interests may be positively or negatively affected as a result of project execution or successful project completion". In this study, PMI's definition is used to conceptualize stakeholders in MEPs.

MEPs comprise a wide range of stakeholders, while various methods are available to identify who they are. Classifying stakeholders into groups is a popular approach to stakeholder identification; while stakeholders' contractual relationships with the project, their degree of engagement in project decision making, and their position in project environment are some broadly adopted basis for stakeholder classification (Nguyen et al., 2009). In the study of Tuman (2006), project stakeholders include four groups: (1) project champion, who make the project come into existence (e.g. project proponents, developers, financiers, and end users); (2) project participants, who have responsibilities in project planning, execution and management; (3) community participants, whose stakes are directly influenced by project implementation (e.g. the local community and natural environment in the vicinity of project); and (4) parasitic participants, who bring about challenges or controversies even they do not possess any direct interests in the project (e.g. the media and pressure groups). Based on stakeholders' legal relationships with the project, Charkham (1992) and Li et al. (2012) categorized MEP stakeholders into two types: (1) internal stakeholders, who are engaged contractually with the client for the demand/supply of resources, services and/or end products in project delivery (e.g. contractors, engineers, suppliers, consultants and end-users); and (2) external stakeholders, who do not have contractual relationships but are collaborated in the project as owning a stake (e.g. local community, environmentalists, public authorities). There are many other ways to classify stakeholders, such as internal/external interests

(Huang and Kung, 2010), direct/indirect environmental impacts (Darnall et al., 2010), as well as the direction of stakeholder influence on the project and its outcome (Bourne, 2011). Generally, MEP stakeholders include: publicly-funded project proponent, contractors, designers, consultants, suppliers and subcontractors, regulatory agencies, financers, media, environmentalists, politicians, local community, the public, end users, and professional institutions. It is worth noting that this list does not aim to cover all stakeholder entities in MEPs. This stakeholder classification has two purposes: (1) to provide initial insights regarding which stakeholder groups will be focused in this study; (2) to serve as a reference and assist practitioners in the stakeholder identification task during the network development process.

In this study, the authors conceptualized stakeholder concerns based on previous research, extended their idea and developed a definition of this term. According to early literature, stakeholders are individuals or groups who have a 'stake' in the project; these stakes can be favorably or unfavorably affected due to the project, and the stakeholders would try to influence project implementation or decision making, so as to prevent their stakes from being jeopardized (Olander and Landin, 2005). As such, this paper defines stakeholder concerns as the issues or vested interests of stakeholders in a project, which could be positively or negatively affected due to project execution or completion (Li et al., 2012; PMI, 1996). They are the interests that a stakeholder attempts to safeguard by increasing its salience level in the eyes of other powerful stakeholders and influencing their decision making. They are also the important considerations of a stakeholder whenever it makes decisions or takes actions in a project. These concerns are often multidimensional and conflicting because stakeholder backgrounds, expectations and objectives are diverse (Mok et al., 2015). Additionally, stakeholder concerns in a project are interdependent—the occurrence of a concern can bring about the other related ones. The interactions and propagating effects of stakeholder concerns can increase uncertainties in stakeholders' behaviors and project decision making. When these concerns are not properly addressed, they can become the causes or consequences of various challenges and problems confronted by stakeholders in project implementation. Previous project management studies classified stakeholder concerns into different groups such as: cost, time, safety, relationships, social, environmental, and economics (Guo et al., 2013); investment, resources allocation, responsibility, and coordination (Zeng et al., 2015); system performance, environmental, safety, social, economic, political, and travel (El-Gohary et al., 2006); time, cost, quality, technical, safety, and disputes (Toor and Ogunlana, 2010); also social, economic, environmental, technical, and institutional (Takayanagi et al., 2011). In fact, there is no universal categorization of stakeholder concerns, yet this paper attempts to classify stakeholder concerns in MEPs into thirteen types, namely: cost (project cost control); economic (indirect cost/benefits due to associated economic activities); environmental (environmental protection); ethical (e.g. corporate reputation); legal (legislation compliance and enforcement); organizational (e.g. organizational members, structures and relationships); political (e.g. political interference); procurement and contractual (e.g. labor productivity and resources allocation); quality (e.g. quality standards and tests); safety (occupational health and safety); social (social and cultural issues); technological (technological systems, processes and diversity); and time (project time management). Similarly, this concern classification does not intend to include all concern groups in MEPs.
Instead, this list of concern categories is developed to facilitate construction practitioners in identifying their concerns during the network building process. Since these stakeholder and concern classifications are derived based on literature review, they should be checked with practitioners before the actual stakeholder and concern identification, and the categories could be revised by practitioners according to their empirical project knowledge.

2.2. Network-theory based analysis

Evolving from the network theory, network analysis is a quantitative tool to identify the interdependencies between a group of elements, and analyze the features and implications of these relational fabrics, by integrating mathematical and computational applications (Dogan et al., 2015). As defined by Wasserman and Faust (1994), elements (nodes) of a system can be joined by different kinds of relationships (links) (e.g. influence or resources sharing) invarious manners(e.g.directlyorindirectly in a loop), forming unique network structures. This method accentuates network and relational measures instead of the elements' individual attributes, due to the conception that: (1) the existence of an element can influence the presence of other interrelated elements in the same system; and (2) the system's strength and behaviors can be readily affected by how its elements are interconnected (Fang et al., 2012).

Following its earlier use in sociometry (Moreno, 1960), network analysis has been applied in other research domains including construction and engineering management. These studies can be broadly divided into two types. The first type primarily analyzes interpersonal, intra- or inter-organizational ties in project contexts, considering human actors as nodal elements of the network. Previous research topics comprise the investigation of command transmission (Lin, 2015), spatial proximity between construction trades (Wambeke et al., 2012), communication (Dogan et al., 2015), and integrating network analysis with jobs-to-be-done tool to increase team performance (Solis et al., 2013). These studies show the capability of network analysis for interpreting human relationships to improve project performance.

The second type of network studies in the construction and engineering field considers the interconnected but non-human objects in a project as nodal elements, and analyzes their interdependencies. Eusgeld et al. (2009) and Sen et al. (2003) studied the underlying networks of infrastructure systems (power transmission and railway systems respectively), its vulnerability and structural properties, by taking power/railway stations as nodes and power/railway lines between stations as links. Zhang et al. (2015) investigated the salience and protection arrangement of railway infrastructure by modeling the network of their train stations (nodes) and railway lines (links) according to the strength of passenger flow. Fang et al. (2012) analyzed the risk network in a large engineering project to identify the key risks and risk interactions affecting the project objectives. They surveyed members of the risk management process to determine the project risks (nodes) and their influence relationships (links). Similarly, Yang and Zou (2014) investigated stakeholder risks (nodes) and their relationships in green building projects to facilitate risk management. These research show the methodological viability of network-theory based analysis in exploring relational structures of interrelated non-human objects, and giving insights into the central network components. However, the potential of using this network perspective in analyzing stakeholder concerns of MEPs has not yet been thoroughly explored, presenting a need to conduct relevant research.

The application of network-theory based analysis in investigating stakeholder concern network contains five general steps (Wasserman and Faust, 1994), namely: (1) identification of the network boundary, (2) mapping of meaningful relationships, (3) network visualization, (4) quantitative analysis of network data, and (5) demonstration of the analysis results. Owing to space limitation, the network metrics, their theoretical definitions and interpretations when applied to the stakeholder concern network are summarized in Table 1.

Table 1
Network metrics and their interpretations for stakeholder concern network.

Level	network metrics	Theoretical definitions	Interpretations for stakeholder concern network
Network	Density	The proportion of existing relationships in the entire network to the largest number of possible links if all nodes are joined together	The overall network connectedness; dense network implies that many stakeholder concerns are interrelated to each other
	Cohesion	The length of path, or the number of ties, to approach nodes in a network based on the geodesic distance	The overall network complexity; high cohesion implies a more complicated network
Node	Nodal out-degree	The weight sum of outgoing relationships radiated from a specified node	The impact given by a stakeholder concern on others; stakeholder concerns with high out-degree worth more attention
	Nodal degree difference	The magnitude of difference between out-degree and in-degree scores of a particular node (Note: In-degree is the weight sum of incoming relationships transmitted to a particular node)	The net influence level of a stakeholder concern; high degree difference implies that a stakeholder concern can readily impact or be impacted by others
	Ego network size	The number of nodes located in the direct neighborhood of a focal node	The number of immediate successors or predecessors of a stakeholder concern; large egonet size implies a great extent of influence of a stakeholder concern
	Betweenness centrality	The extent to which a particularnode is locatedupon the geodesic distance between all combinations of other pairs of nodes	The power of a stakeholder concern in controlling the influence along a link; addressing central concerns can reduce the complexity of stakeholder concerns
	Out-status centrality	The number of nodes adjacent to or from a focal node, plus the number of secondary nodes which indirectly connect to the focal node through its direct neighbors	The relative out-going impact given by a stakeholder concern; central stakeholder concerns worth more attention
	Brokerage	The occurrence of which a specified node acts as coordinator/ liaison/itinerant/representative/gatekeeper in linking different subgroups under a chosen node partition	The role and ability of a stakeholder concern in bridging different stakeholder entities (Note: partition vector asstakeholderentities); stakeholder concerns with high brokerage worth more attention
Link	Betweenness centrality	The extent to which a specific link is situated upon the geodesic distance between all combinations of other pairs of links	The power of an concern interaction in controlling the influence along a link; addressing central interactions can reduce the complexity of stakeholder concerns

3. Research methodology and process

Four primary research methods including a case study, interviews, survey and network-theory based analysis were used in this study to address the research questions: (1) What are the main stakeholder concerns and concern interdependencies in MEPs? (2) How do these key concerns and links help to identify the major project challenges in MEPs?

3.1. Case study

Case study is an appropriate method to look into the complexity and uniqueness of a real life phenomenon from 'why' and 'how' aspects; when the subject phenomenon could not be examined meaningfully without considering its embedded contextual conditions, and when the researchers placed minimum interference on the occurrence (Thomas, 2011; Yin, 2003). Since the current research question is of 'how' type, case study method is considered suitable.

There are various case study approaches such as intrinsic, instrumental and collective (Stake, 1995), or a-single-case and multiple-cases (Yin, 2003). This research conducts a single instrumental case study, since the intent is to analyze stakeholder concern complexities in MEPs where the insights could be transferred to other large engineering projects of similar context; and a more holistic understanding of the phenomenon could be gained through in-depth investigation of a unique project setting (Baxter and Jack, 2008). The case was not chosen randomly but on the basis of information-oriented sampling (Flyvbjerg, 2006). Four criteria were set for case selection: (1) only MEP which involves a wide range of stakeholders (preferably including stakeholder groups identified in the literature review) was chosen, as it poses great challenges to the project stakeholder management; (2) only MEP which generates substantial impacts to the society, economy and environment was selected, since it makes the stakeholder concern analysis more meaningful when the concerns of these kinds are in stake; (3) only MEP with a contract sumof overUS$500millionwasconsidered, as it is a cost threshold broadly accepted by the governments and scholars to define a MEP; and (4) the authors only considered ongoing MEP and excluded the completed ones, because it is less insightful to study past cases when their major concerns and challenges were known. The selected case fulfills these four criteria. Desktop studies were then conducted to understand the project background. Documents reviewed include two main types. The first type is publicly accessible government documents, such as project profile and progress reports prepared by the project proponent, environmental monitoring and auditing reports prepared by the environmental protection bureau, as well as discuss papers submitted to legislative authority for funding approval, etc. The second type is non-government documents, including project profile provided by the contractor, articles by green groups regarding potential project environmental impacts, and discussion papers by professional institutions on technical features of the project. These documents were analyzed under six themes: cost, time, scope of works, stakeholders, concerns of each stakeholder, and project impacts; in order to summarize and synthesize the obtained project information. The authors also conducted a site visit to better understand the project progress and site situation.

After case selection and desktop studies, the case boundary was well determined to ensure a reasonable research scope, and this was done by considering definition, context and time (Baxter and Jack, 2008). The definition on MEPs previously mentioned is adopted as the threshold in the case study; that is, the selected case should fall within this definition. In view of the dynamism of stakeholder concerns and their relationships, a definite time span should be defined. The selected case is an ongoing project, and roughly three-fifth of the contract period of its main contract works had passed when the research was conducted. This case analysis solely focuses on stakeholder concerns which are related to or arise during construction phase, and the concern network herein only reflects a screen-shot in the construction period. The findings of desktop studies and site visit helped the authors in two tasks: (1) to fine-tune the stakeholder and concern classifications previously obtained through literature review, and (2) to derive the tentative lists of stakeholder entities and concerns in the case, which would be used as reference lists to assist practitioners in the network development process.

The case project is the construction of a 150 ha artificial island, under a contract sum of over US$900 million, to create land for developing passenger clearance facilities and transport infrastructures in a metropolitan city X. The project scope was to construct a seawall ofabout 6 km long and toreclaim an area of 150 ha for the island, using a new non-dredge method and stone columns (toexpedite settlement). Thehighproject complexitiesin this case made its project stakeholder management a challenging task. For example, the non-dredge method, developed by the project proponent and resident engineer, has never been adopted for reclamation in city X until this case project. Unlike traditional reclamation, the non-dredge method intends to prevent dredging of marine mud, to minimize disturbance to seabed and to lessen the backfilling materials needed. It was considered more environmental friendly but technologically complex. The construction site was proximate to an airport, and marine traffic near the site was heavy. Marine ecology in diversified species was found at and near the site including Chinese white dolphins (CWD). Four construction projects including superstructures were in close interface with the case project. The project schedule was extremely tight and any time overruns (in phase or in whole) would delay the progress of interfacing projects.

3.2. The process of network-theory based analysis

3.2.1. Network development process

In the network building process, the first step was to identify the stakeholders who were sources of the nodes (i.e. stakeholder concerns) of the network. This study used chain referral sampling for the said task (Berg, 1988), in an attempt to fully recognize stakeholders and their related concerns in the case. To start the referral process, three representatives from the contractor company and subcontractor were reached. These representatives were selected because they were situated at or higher than the senior management level, and have directly involved in the construction stage since contract commencement. They were invited to appoint internal stakeholder groups. Then, the nominated parties were invited to provide referrals of external stakeholders who may impact orbe impacted bythe project.After that, these designated parties were required to appoint any conceivably impacting or impacted groups who were still absent in the list. A provisional stakeholder roster (which had been developed by literature review and desktop studies) was given for reference in the chain referral process, while feedbacks on this reference list had been sought from the three initially engaged representatives prior to the actual stakeholder identification. Finally, 18 stakeholder groups were identified and coded numerically as S_a (where a = 1 to 18). Table 2 summarizes the stakeholder profiles.

The second step was to determine the nodes, i.e. stakeholderrelated concerns of the case project. Semi-structured interviews and empirical identification were the primary means for the said purpose. This method was used because a large amount of information could be elicited from targeted samples according to the predetermined orders but without sacrificing flexibility (Longhurst, 2003), and the interview findings can be used to triangulate the network analysis results. Interviews were carried out with representatives from the 18 stakeholder groups. The interviewees (except S16 to S18) all had direct involvement in the construction stage, also they were situated at or higher than the senior management level and with 10+ years work experience in their profession. These sampling criteria help to make certain that the collected data were reliable and representative. Based on their experience and project knowledge, the interviewees were asked to give opinions on three main questions: (1) What are their key concerns in the project? (2) What major challenges do they encounter in the project? (3) How do these identified concerns relate to the major challenges? Similar to stakeholder identification step, a provisional list of stakeholder concerns and concern groups (which had been compiled by literature review and desktop studies) was provided as reference to assist the concern identification task; while feedbacks on this reference list had been obtained from the three initially engaged stakeholder representatives in the stakeholder identification process. Most interviews lasted 1–2 h and two interviews lasted 2.5–3 h. The information obtained from interviews were analyzed under four main themes: (1) roles/duties of stakeholders, (2) issues concerned by stakeholders, (3) challenges confronted by stakeholders, and (4) recommendations to tackle these challenges. All interviews were properly documented, the transcripts were sent back to interviewees for feedbacks. Finally, 247 concerns sourced from 18 stakeholder groups were identified. Table 2 shows the number of concerns of each stakeholder group. For network data processing, these nodes were coded numerically as S_eC_f, where f represents the concern number of a particular stakeholder. This study attempts to identify a complete list of stakeholder concerns in the case rather than focusing on a specific category of issues due to two reasons: (1) stakeholder concerns arising from the same project are interconnected; and (2) the researchers aim to analyze the overall picture of concern interdependencies and its implications in the project. It should be noted that the same concern identified by different stakeholders was distinguished as different concerns, and was assigned with different numerical codes. This is because the nodes in this network analysis refer to stakeholder-related concerns, i.e. issues concerned by or sourced from a particular stakeholder. If stakeholders tell contradicting

Table 2
Stakeholders identified in the case project.

Stakeholder	Stakeholder description	Concern no.
S1: Project proponent	A public agency who initiates and funds the proposed reclamation works	40
S2: Resident engineer	A private engineering consultancy (appointed by S1) who undertakes site investigation and Environmental Impact Assessment; designs the reclamation method and supervises the works of S3	25
S3: Contractor	A private contractor company (employed by S1) to construct an artificial island by reclamation	48
S4: Subcontractor and supplier	Subcontractor and supplier companies including backfilling; supplying and manufacturing of steel for seawall construction	15
S5: Independent environmental checker	An independent unit (employed by S2 under statutory requirements) to review the environmental monitoring and auditing works done by S6; and to report to S11	16
S6: Environmental team	An independent unit (hired by S3 under statutory requirements) to undertake environmental monitoring and auditing on the works of S3; and to report to S5	9
S7: Maritime engineering consultant	A private consultancy (hired by S3) to assist S3 in developing marine traffic schedules; and addressing marine safety and regulatory issues	7
S8: Environmental specialists in marine ecology	Independent and qualified specialists (hired by S6) to conduct impact monitoring on ecology in the nearby waters, in particular Chinese White Dolphins	7
S9: Marine Bureau	A government bureau in charge of port control; shipping register and licensing; navigational issues	5
S10: Civil Aviation Bureau	A government bureau in charge of air traffic flow control; managing aviation safety; setting and implementing relevant statutory regulations	5
S11: Environmental Protection Bureau	A government bureauin charge of environmental protection and environmental legislationenforcement	13
S12: District Board	Local authority to advise the government on district administration and affairs	3
S13: Green groups	–	9
S14: Transport trades	Transport operators who provide public transport services in the water or air near the construction site	7
S15: Contractors of interfacing projects	Contractor companies of interfacing construction projects undertaken concurrently with the case project in or nearby the construction site	10
S16: Local residents	Residents who live in the vicinity of the construction site	12
S17: Fishermen groups	Fishermen whose habitual fishing grounds or fish culture zones are located near the construction site	3
S18: General public	–	13

stories about a concern, the contradictions should be studied and sorted out, e.g. by seeking opinions from relevant stakeholders on the contradictions and raising questions about these issues from different angles, in an attempt to reaching consensus. Workshop with key project participants and stakeholder representatives is a potential method to resolve contradictions. Based on literature review, the identified 247 concerns were classified into thirteen categories as previously mentioned. The top three groups were “environmental” (55), “technological” (30) and “social” (28), making up 45% of the nodes.

The last step was link identification and assessment. In this study, a link refers to the influence that a stakeholder concern exerts on another concern. Accordingly, a questionnaire survey was designed to obtain responses from representatives of the 18 stakeholder groups who had previously participated in node determination. A sample survey can be viewed in the Website: https://drive.google.com/file/d/0B_B0TjAak2LRSUJ3 YnFuV2I2VzA/view?pli=1. At the beginning, the researchers verbally explained (face-to-face or on phone) the survey purpose, instructions and questions to all respondents in an attempt to avoid their confusions. In the survey, respondents were asked to consider all possible combinations of node pairs, and to decide whether a link exists in each pair based on their empirical knowledge. Since relationships can be reciprocal, respondents shouldclearly define the link direction. For example, an influence exerted by S_gC_h on S_eC_f is distinguished from an influence that S_eC_f has on S_gC_h, and they are considered as two different ties. Next, the respondents quantified each identified link by giving two scores, namely the intensity of impact given by a concern on the other, and the likeliness for this impact to happen; with a five-point scale (“1” indicates the lowest level and “5” denotes the highest level). Multiplying the impact intensity and likeliness serves as a basis for evaluating the influence level of a pair of stakeholder concerns. If no influence presents between two concerns, the influence level becomes nil. At last, according to the survey results, 1660 links connecting 247 nodes were determined. An adjacency matrix was created to represent the influence network G(247,1660) of stakeholder concerns; where the 247 nodes were shown in the head row and first column, with influence levels of the 1660 ties inputted into the respective cells.

3.2.2. Network visualization and analysis process

This study used NetMiner 4 for network visualization and analysis because this software package has high competence in the processing and exploratory analysis of huge networks (Furht, 2010). The node list, link list and adjacency matrix are the required input data and were therefore imported into NetMiner. In the network graph G(247,1660), nodes represent stakeholder concerns, and node colors and shapes indicate their concern categories and stakeholder types respectively. The edges are the influence relationships between two concerns, where a thicker edge indicates a higher influence level.

The network analysis process can be further divided into four stages. It starts with a visual examination to have initial understanding about the key concerns and their distribution in the network. A descriptive analysis follows by calculating the network densityandcohesion. Thesetwo network-level indicators were selected as they are useful for measuring the overall network properties from the perspectives of network connectedness and complexity.

Next, six node-level metrics were computed to investigate the roles, characteristics and functions of individual nodes; and to identify key stakeholder concerns in the network. These six indicators include nodal out-degree, degree difference magnitude, ego network size, betweenness centrality, out-status centrality and brokerage. Their theoretical definitions and interpretations when applied to the stakeholder concern network were explained in Table 1. The outcome of this stage is a list of key stakeholder concerns of the case project.

Following the node-level analysis, link betweenness centrality was calculated to assess the significance of concern interactions and identify the key relationships. It should be noted that, this link-level analysis focused on the ties radiating from or emitting to the key stakeholder concerns identified in the nodelevel results; in an endeavor to explore the cause-and-effect relationships behind these important issues. A plot of the link betweenness centrality scores of all 1660 ties was created to observe the trend and determine the cut-off point. The intent was to identify all key concern interactions in the network, and to spot any links which score higher than the cut-off point but are not radiating from or emitting to the critical nodes. These interactions should also be considered critical so as to make certain that the link-level investigation is inclusive. This stage yields a comprehensive list of key concern interactions of the case project.

The final stage is to investigate the key challenges faced by stakeholders in the case project. There are two fundamental questions to be considered in performing this task:

(1) How to determine the major challenges from the understanding on stakeholder concerns and concern interdependencies?

The prior interview findings and the SNA results on key concerns and interactions form the primary basis for determining the major stakeholder challenges. Interviews had provided the authors initial insights regarding the problems that stakeholders have been tackling in the project. However, many problems/challenges have been mentioned by the stakeholders, it would not be objective enough to determine which challenges are ‘major’ and worth particular attention by solely synthesizing the qualitative interview findings. As such, SNA was applied to identify the main stakeholder concerns and the key links associated to these nodes. Then, these network analysis results were complemented with the interview findings to interpret the cause-and-effect relationships between the key concerns, classify the related links into groups, and determine the major challenges confronted by stakeholders in the project. Stakeholder concerns in a project are interrelated. If an issue is not addressed properly, it may trigger the occurrence of other related issues. The interactions and chain effects of these issues can bring about challenges faced by stakeholders. Therefore, understanding the key concerns and their interdependencies can help to recognize the major stakeholder challenges in the project.

Solely synthesizing the interview findings is not objective enough to identify the major challenges, yet solely relying on the SNA results (of key issues and links) may also not be adequate enough to draw conclusions. In this study, SNA is applied in conjunction with interviews, so that the qualitative data can be complemented with the quantitative results to make conclusions. Some isolated concerns may also be important enough to bring about problems, yet they are discussed relatively less in the paper because this study focuses more on the concern interdependency analysis. Also, it can reasonably be assumed that isolated concerns are less complicated to handle since they have no interactions with other concerns. It is crucial for the project management team to possess sufficient knowledge about the project and stakeholders when they group the key links and determine the major stakeholder challenges. One cannot draw meaningful conclusions without adequate understanding on the project. A potential method is to conduct workshops with all stakeholder representatives after the SNA, so that stakeholders can discuss and evaluate theSNA results, reach consensus, and effectivelydetermine the major challenges.

(2) What are the criteria in determining challenges from the key concerns and relationships?

In this study, the determination of major challenges is based on the identification of key concerns and interactions, complemented with the interviewing findings. In addition, there are four criteria in which the identification of key concerns and links is based on: (a) the concerns' scores in the node-level results, (b) what links are radiated from or emitting to the identified key nodes, (c) the link betweenness centrality values, and (d) the cut-off points of node-level and link betweenness centrality results. It should be noted that the way of cutting off the node- and link-level results could affect the identification of key concerns and interactions. In addition, the cut-off points are case-specific and depend on how much risks the core leadership team can take in the project. If the project team can only take a low risk, then a lower threshold should be set for the cut-off points, so as to cover more concerns and links as important and to provide a wider lens in determining the major challenges.

4. Results of data analysis

4.1. Network level results

Fig. 1 captures the influence network, composing of 247 stakeholder concerns linked by 1660 ties, in the case project. The node colors and shapes denote the concern categories and stakeholder groups respectively. An edge joining two adjacent nodes represents the presence of an influence relationship between the two concerns. The centre of network is occupied by the highly connected nodes, while nodes at the periphery are those with fewer linkages. It can be observed that almost all concerns were interconnected except one isolated node, reflecting that the project stakeholder management process was highly complex. Social and economic concerns are located at the periphery, suggesting that many concerns of these types were given lower attention from the stakeholder perspective.

Network-level indicators provide a quantitative means to unravel the network structure. Network density was equal to 0.321 and the average distance of nodes was 3.383 walks, showing that the concerns are situated closely in a dense network. The network cohesion was 0.682. A greater cohesion than the density indicates that the network configuration is complicated in terms of node reachability.

4.2. Node level results

This part determines the key stakeholder concerns of the case by examining the direct and/or propagating impacts of nodes, as well as their functions and properties in the influence network. Six node-level metrics were computed namely out-degree, degree difference, ego network size, betweenness centrality, out-status centrality and brokerage. As previously mentioned, their definitions and interpretations when applied to stakeholder concern network are shown in Table 1.

Table 3 presents the top ten ranking in each of the out-degree, degree difference, ego network size, betweenness centrality, outstatus centrality and brokerage results. Nodes ranked at the top three in each of these six node-level results are highlighted in bold; accordingly, these nodes are identified as important stakeholder concerns of the case project. As shown in Table 3, these six key stakeholder concerns include: S1C1 ("Unforeseen situations delay project completion and the commencement of interfacing superstructure projects" sourced from project proponent); S1C21 ("Encountering political pressure and subsequently affecting public sentiment towards the government" sourced from project proponent); S1C22 ("Public pressure and controversies in case of public dissatisfaction on the project progress and performance" sourced from project proponent); S3C10 ("Adopting construction methodology and systems which are experimental and leading-edge technology in the local construction industry" sourced from contractor); S3C17 ("Fully implementing environmental mitigation measures throughout the construction course and making necessary revisions to suit the changing conditions" sourced from contractor); and S1C32 ("Achieving goals and objectives at project, managerial and functional levels" sourced from project proponent). These critical nodes are worth high attention from the project team because they exerted great direct and/or chain effects to many adjacent nodes. In the next part, these key stakeholder concerns are further investigated by identifying the important concern interactions which were sourcing from or targeting to these six nodes; in an attempt to eventually identify the key challenges of stakeholders in the project.

Table 3
The top ten stakeholder concerns in the node-level results.

4.3. Link level results

Link betweenness centralitymeasures the extentthat a concern interaction plays a gatekeeper role in governing the influences passing through it. A greater centrality value implies a more critical tie. A plot of the link betweenness centrality results (not shown herein owing to space limitation) was generated to determine the cut-off point for recognizing the main interactions. A sharp decline was observed at centrality score of 400 in the L-shaped curve, thus it was set

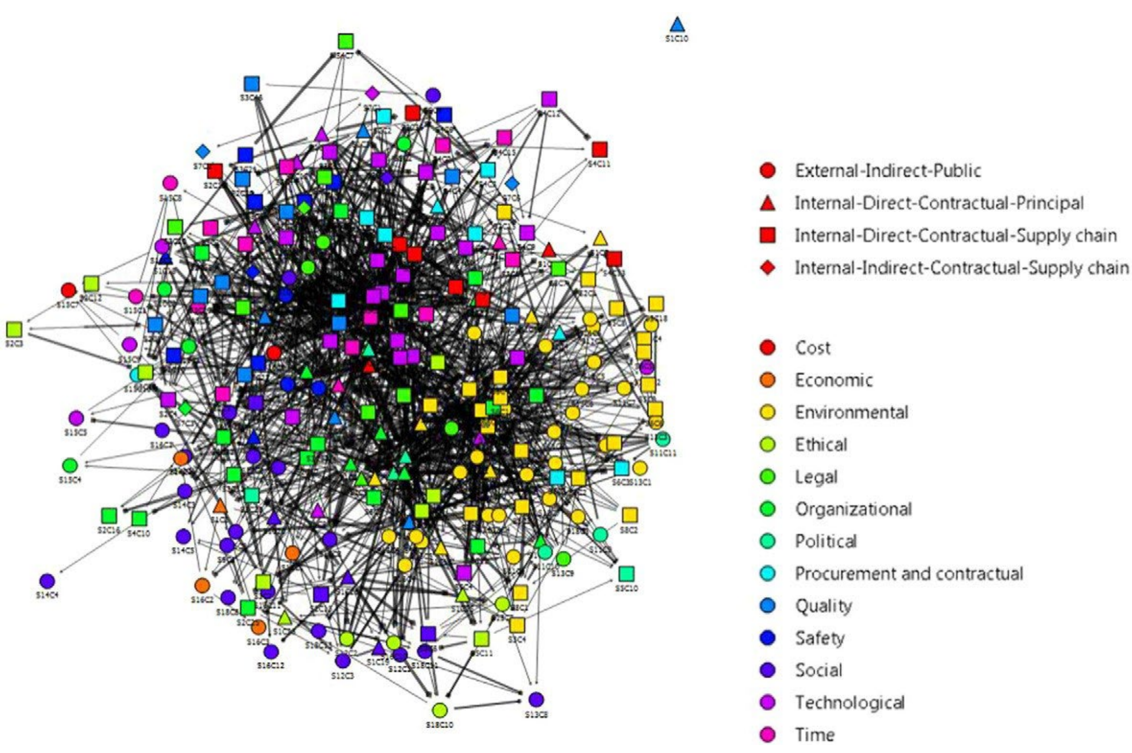

Fig. 1. Stakeholder concern network in the case project based on influence relationships. Note: (1) Node shapes and colors denote stakeholder and concern categor respectively; (2) Stakeholders (S1–S18) are categorized from four aspects to reflect their positions in the stakeholder community: (i) internal/external interests; direct/indirect impacts on environmental management; (iii) contractual/public in considering formal contractual relationships; and (iv) principal/supply chain further classifying the contractual parties.

as the cut-off point. Among all the 1660 interactions, 18 ties were recognized as radiating from or emitting to the six identified key concerns, and scoring ≥400 in the betweenness centrality result. These eighteen links, as shown in Table 4, were recognized as the key concern interactions of the case project since they indicated the main causes and/or likely consequences of the critical stakeholder issues. Links ranked at the top ten in the link betweenness centrality results of all 1660 ties could also be found in Table 4, showing that the identification of key relationships was inclusive. To facilitate understanding of the link-level results, the list of neighboring nodes in these eighteen key interactions can be viewed in the Website: https://drive.google.com/file/d/0B_B0TjAak2LRRHFsUndZaHlCNkU/ view?pli=1.

4.4. Identification of major stakeholder challenges in the case

The network analysis helps to recognize the main stakeholder concerns in the case, and a list of key links sourcing from or targeting tothese importantnodes. Thenextsteps aretounderstand the actual meanings of these key concerns and cause-and-effect relationships based on the SNA and interview findings, and to identify the key challenges of stakeholders in the case project from these interpretations. As shown in Table 5, it can be accomplished by grouping the eighteen key interdependencies according to their actual meanings.

For example, according to Table 5, eight key relationships (including "S5C1➔S1C1", "S1C36➔S1C21", "S1C22➔S1C36","S1C36➔S3C17", "S17C1➔S3C17","S3C17➔S3C39", "S3C17➔S1C16", and "S8C4➔S3C17") described issues about

Rank	Concern code	Out-degree	Concern code	Degree difference magnitude	Concern code	Ego network size	Concern code	Node Betweenness centrality	Concern code	Out-status centrality	Concern code	Brokerage
1	S3C17	646.50	S1C22	806.25	S3C17	94	S3C17	0.1616	S3C17	2.4010	S3C17	2727
2	S1C1	458.35	S1C21	307.50	S1C22	59	S1C22	0.0959	S1C1	1.9755	S3C10	656
3	S3C10	434.47	S1C1	304.85	S3C10	48	S3C10	0.0891	S1C21	1.8837	S1C32	573
4	S1C32	389.25	S3C41	283.25	S1C32	46	S3C39	0.0532	S3C10	1.7589	S3C8	384
5	S1C21	384.50	S1C11	258.50	S3C8	40	S1C1	0.0509	S3C34	1.5313	S5C1	374
6	S3C34	359.78	S8C4	258.30	S1C1	39	S1C32	0.0493	S1C32	1.5192	S3C39	361
7	S3C8	338.25	S1C28	243.30	S3C9	38	S1C21	0.0488	S5C1	1.4592	S3C9	348
8	S1C11	299.50	S10C3	219.00	S5C1	37	S3C47	0.0485	S3C8	1.4388	S11C13	333
9	S3C41	299.25	S2C23	200.00	S11C13; S3C39	36	S3C12	0.0479	S3C41	1.2354	S3C12	327
10	S5C1	291.22	S3C10	192.97	–	–	S1C26	0.0468	S11C13	1.1997	S1C1	315

Note: Bold values indicate the top three important stakeholder concerns.

Table 4

The key concern interactions in the case project.

Link code & betweenness centrality			Link description
S5C1	➔ S1C1	462.12	Ineffective environmental mitigation implementation and monitoring works checked by IEC could cause unexpected delays to the works and interfacing projects as concerned by the project proponent.
S3C10	➔ S1C1	411.97	Unexpected situations and subsequent delays may occur when the contractor adopts an experimental and leading-edge construction methodology.
S3C14	➔ S1C1	402.68	Unclear technological specification and work instructions received by the contractor could cause unforeseen delays to the works and interfacing projects as concerned by the project proponent.
S1C1	➔ S1C32	356.63*	Delays to the project and interfacing developments could affect the project proponent in achieving its goals and objectives at project, managerial and function levels.
S16C10	➔ S1C21	1078.88	Inadequately informing the local residents of the latest project impacts and addressing their subsequent needs could bring the project proponent political pressure and public discontent.
S1C36	➔ S1C21	696.25	Incompliance with environmental legislations during project execution could bring the project proponent political pressure and public discontent about the government.
S1C21	➔ S5C11	354.69*	The project proponent's concerns on potential political pressure and public discontent about the government are important drivers for IEC to ensure adequate and effective public information disclosure.
S1C22	➔ S1C36	2003.17	Public pressure acts as an important driver for the project proponent to ensure legal compliance with environmental protection related regulations throughout project implementation.
S1C22	➔ S1C26	1905.50	Public pressure is an important driving force for the project proponent to conduct sufficient and effective public and community consultation throughout the construction course.
S1C22	➔ S16C10	612.88	Public pressure is an important driver for the project proponent to continuously inform the local residents of the project impacts and to address their subsequent needs during the construction course.
S13C7	➔ S1C22	338.56*	The pressure groups' dissatisfaction in case of insufficient and ineffective public and community consultation could lead to public pressure and controversies as concerned by the project proponent.
S9C5	➔ S1C32	371.55*	Marine Bureau's concerns on compliance with marine navigation related legislations might affect the project proponent in achieving its goals and objectives at project, managerial and function levels.

S2C23	➔ S3C10	1275.04	Sufficient specialized knowledge and relevant experience from resident engineer are essential for successful application of highly complex and experimental construction methodology by the contractor in the project.
S3C47	➔ S3C10	731.67	Passing laboratory tests for new materials could be a technical challenge to the contractor in his application of leading-edge and complex methodology.
S10C4	➔ S3C10	713.86	The contractor encounters technical challenges in accommodating site constraints and mitigating Civil Aviation Bureau's concerns on potential disruption to existing aviation traffic activities.
S1C24	➔ S3C10	547.80	Stringent cost control by the project proponent increases the contractor's technical challenges in applying the experimental and highly complex construction methodology.
S3C10	➔ S3C12	538.79	The use of high complex and leading-edge technology could pose challenges to the contractor in procuring appropriate materials and equipment with a sufficient quantity.
S18C5	➔ S3C10	345.45*	The general public's concerns on the environmental intact of future generations is a driving force for the contractor to adopt leading-edge and experimental construction methodology.
S1C36	➔ S3C17	910.87	The project proponent's emphasis on legal compliance with environmental regulations is an important driver for the contractor to properly implement the agreed environmental mitigation measures.
S17C1	➔ S3C17	684.97	The contractor's effective implementation of environmental mitigation measures is important for minimizing disruption to habitual fishing operations near the site.
S3C17	➔ S3C39	624.02	Revisions of environmental mitigation measures during construction stage could cause the contractor to make subsequent changes to its construction methods and programme.
S3C17	➔ S1C16	511.05	Effective implementation of environmental mitigation measures by the contractor could alleviate the project proponent's concerns on waste generation and chemical spillage by construction vessels.
S8C4	➔ S3C17	464.48	Environmental specialists' concerns on ecological impacts (e.g. CWD) are an important driving force for the contractor to properly implement the agreed environmental mitigation measures.
S3C17	➔ S18C5	315.78*	Ineffective environmental mitigation implementation by the contractor could deprive the environmental intact of future generations as concerned by the general public.

Note:

(1) The cut-off point of link betweenness centrality (BC) is 400.Concern interactions with link BC greater than 400 are considered as important and are further investigated;

(2) Concern interactions are shown in descending order based on their link BC. "*" denotes interactions with link BC less than 400 and they will not be further investigated. Interactions following those denoted with "*" are not shown in the table due to limitation of space.

(3) After plotting a graph of the link BC results, a sharp change was observed at 400, thus 400 was considered as the cut-off point.

environmental impacts and mitigation implementation in the project. "S8C4➔S3C17" and "S3C17➔S1C16" shed lights on project disruptions to the marine ecology. "S1C22➔S1C36" and "S1C36➔S3C17" reveal the drivers of proper environmental mitigations and compliance; while "S5C1➔S1C1", "S1C36➔S1C21" and "S3C17➔S3C39" describe the potential consequences of ineffective mitigation implementation. Consequently, these eight links were put under one category in which a major stakeholder challenge was determined: "mitigating project disruptions to the environment and marine ecology".

Using this principle, five key challenges confronted by stakeholders in the case were determined, namely: (1) applying

Table 5
Main challenges confronted by stakeholders and key concern interactions related to these challenges.

Major challenges	Related links	Links description
1. Applying highly advanced and complex construction technology	S3C10➔S1C1	Unexpected situations and subsequent delays may occur when the contractor adopts an experimental and leading-edge construction methodology.
	S3C14➔S1C1	Unclear technological specification and work instructions received by the contractor could cause unforeseen delays to the works and interfacing projects as concerned by the project proponent.
	S2C23➔S3C10	Sufficient specialized knowledge and relevant experience from resident engineer are essential for successful application of highly complex and experimental construction methodology by the contractor in the project.
	S1C24➔S3C10	Stringent cost control by the project proponent increases the contractor's technical challenges in applying the experimental and highly complex construction methodology.
	S3C10➔S3C12	The use of high complex and leading-edge technology could pose challenges to the contractor in procuring appropriate materials and equipment with a sufficient quantity.
2. Mitigating project disruptions to the environment and marine ecology	S5C1➔S1C1	Ineffective environmental mitigation implementation and monitoring works checked by IEC could cause unexpected delays to the works and interfacing projects as concerned by the project proponent.
	S1C36➔S1C21	Incompliance with environmental legislations during project execution could bring the project proponent political pressure and public discontent about the government.
	S1C22➔S1C36	Public pressure acts as an important driver for the project proponent to ensure legal compliance with environmental protection related regulations throughout project implementation.
	S1C36➔S3C17	The project proponent's emphasis on legal compliance with environmental regulations is an important driver for the contractor to properly implement the agreed environmental mitigation measures.
	S17C1➔S3C17	The contractor's effective implementation of environmental mitigation measures is important for minimizing disruption to habitual fishing operations near the site.
	S3C17➔S3C39	Revisions of environmental mitigation measures during construction stage could cause the contractor to make subsequent changes to its construction methods and programme.
	S3C17➔S1C16	Effective implementation of environmental mitigation measures by the contractor could alleviate the project proponent's concerns on waste generation and chemical spillage by construction vessels.
	S8C4➔S3C17	Environmental specialists' concerns on ecological impacts (e.g. CWD) are an important driving force for the contractor to properly implement the agreed environmental mitigation measures.
3. Conducting public and community consultation during construction phase	S16C10➔S1C21	Inadequately informing the local residents of the latest project impacts and addressing their subsequent needs could bring the project proponent political pressure and public discontent.
	S1C22➔S1C26	Public pressure is an important driving force for the project proponent to conduct sufficient and effective public and community consultation throughout the construction course.
	S1C22➔S16C10	Public pressure is an important driver for the project proponent to continuously inform the local residents of the project impacts and to address their subsequent needs during the construction course.
4. Site constraints due to nearby air and marine traffic	S10C4➔S3C10	The contractor encounters technical challenges in accommodating site constraints and mitigating Civil Aviation Bureau's concerns on potential disruption to existing aviation traffic activities.
5. New materials and equipment meeting the government standard	S3C14➔S1C1	Unclear technological specification and work instructions received by the contractor could cause unforeseen delays to the reclamation works and interfacing projects as concerned by the project proponent.
	S3C47➔S3C10	Passing laboratory tests for new materials could be a technical challenge to the contractor in his application of leading-edge and complex methodology.
	S1C24➔S3C10	Stringent cost control by the project proponent increases the contractor's technical challenges in applying the experimental and highly complex construction methodology.
	S3C10➔S3C12	The use of high complex and leading-edge technology could pose challenges to the contractor in procuring appropriate materials and equipment with a sufficient quantity.

highly advanced and complex construction technology; (2) mitigating project disruptions to the environment and marine ecology;(3) conductingpublic and community consultation(PCC) during construction phase; (4) site constraints due to nearby air and marine traffic; and (5) new materials and equipment meeting the government standard. In the next section, these five challenges will be discussed according to the network analysis results, together with the interview findings obtained beforehand.

5. Interpretation of results—major challenges in the case project

5.1. Applying highly advanced and complex constructiontechnology

The network analysis results show that adopting complex and experimental construction technology (S3C10) was a major challenge in this case. Sufficiency of construction expertise in the design team (S2C23), clarity in work instructions and specifications (S3C14), and cost control (S1C24) can be influential factors; while problems such as unexpected delays (S1C1) and unavailability of resources (S3C12) may arise if the new construction methodology is not well applied. With the consolidation of network analysis and interview findings, this challenge was mainly due tothe inadequate expertise ofdesigners in this new technology, as well as late involvement of contractors and specialists in design and procurement under the design-bidbuild arrangement, leading to major design deficiencies. For example, this project applied non-dredge reclamation method for both the seawall and main reclamation, which was the first attempt ever in the local construction industry. This method required installation of a large amount of huge stone columns at the front of and inside the steel cellular structures, to give additional strength and enhance properties of surrounding soft soil. However, the resident engineer (i.e. the designer) overestimated the availability of this stone column in the current market; leading to material shortage which required changes of construction material after project commencement. As such, the contractor spent extra time and resources to investigate the use of alternative materials (eventually stone columns were substituted by concrete blocks). The interviewee also indicated that another design deficiency came onto surface after project began. The contractor identified a mismatch of tolerance requirement on the acceptable settlement for reclaimed land between the designer (e.g. the designer's requirement stated not more than 500 mm) and the government (e.g. the general specification for public works only allowed less than 300 mm). This mismatch incurred extra time for clearing such ambiguity. Early integrating the construction expertise of contractors and specialists in the project design (e.g. using design-and-build procurement method) would increase the design quality and improve material supply. A number of researchers also obtained similar findings and stated that joint collaboration between client, designers and contractors in the design and procurement stages can largely enhance the design quality and constructability of large engineering projects, in particular when new technology is adopted (Jergeas and Put, 2001; Mosey, 2009; Song et al., 2009).

5.2. Mitigating project disruptions to the environment andmarine ecology

Environmental issues accounted for about one-fifth of stakeholder concerns in the case; such a great number has shed light on the substantial environmental impacts broughtby the project. Among these, mitigation of disturbance to marine ecology was an immense challenge faced by stakeholders. Public pressure (S1C2) along with potential environmental and ecological disruptions (S8C4, S17C1 and S1C16) is an important driver to effective environmental mitigation, monitoring and auditing. If it is not performed well, problems such as public discontent (S1C21), construction method and programme changes (S3C39) and delays may occur. As shown in the network analysis results, keyenvironmental stakeholders (e.g.S1, S3, S5,S8 andS11)have realized the command-and-control based environmental impact assessment (EIA) follow-up approach during the construction stage (Morrison-Saunders et al., 2003), such as enforcement of agreed mitigation measures through environmental permits, and continuous environmental monitoring and auditing (EM&A) to control environmental performance. Despite such robust mechanism, as indicated by the green group interviewees, they have observed an alarming decline of 90% in dolphin population (who has been habituated in the waters near the reclamation site) since construction began. According to the interview findings, this significant ecological disturbance could be attributed to three reasons:

(a) Unclear "baseline" and end goals. As declared by the green group interviewees, neither the definitions of "baseline" nor the detailed requirements of baseline surveys were clearly described in EIA. Baseline studies should be undertaken before commencement to determine pre-construction states, but they discovered an absence of baseline figures on CWD population after project began. As there was no clear baseline, EPB has ascribed the sharp decrease of dolphins to natural fluctuation instead of project disruptions in his response to the pressure groups' environmental complaints, and denied to order temporary suspension for investigation and remedial actions. The interviewees opined that this might be related to the substantial social and economic benefits brought by the development. Since this project was considered as part of a political achievement of the government, completing the project within deadline might take priority over environmental concerns. As such, project parties might exploit loopholes in the EM&A process, without violating environmental legislations and EM&A requirements. In addition, the end goals of ecological mitigation measures were not clearly defined in EIA (e.g. targeting at zero net loss). Without clear baseline and targets, EM&A in construction phase would have lost its actual meaning.
(b) Vague obligations in mitigation implementation. Some interviewees pointed out that the responsibilities in many mitigation implementations were only indicated as "should be" instead of "will be" (e.g. following predefined routes and parking areas of working vessels to minimize disturbance to CWD), such gray areas could increase uncertainties in mitigation implementation and lower its effectiveness.
(c) Questionable impartiality of EM&A parties. In the EIA mechanism, contractor was obliged to employ an Environmental Team (ET) to undertake the EM&A activities, while resident engineer was required to appoint an IEC to validate the EM&A works performed by ET. Despite an indication of ET's and IEC's independences in the EM&A requirements, the interviewees opined that potential conflict of interests exists between these EM&A parties and their employers. In the occasions that mitigation implementation was not indicated compulsory, the EM&A parties would make judgment or decisions which are in favor of their employers, ceding the priorities of environmental protection.

The above findings were consistent with a number of previous studies, pointing out that environmental performance of major developments can be enhanced by setting clear baseline and end goals (Drayson and Thompson, 2013); giving clear indications on the responsibilities of mitigation implementation (Drayson and Thompson, 2013); and improving the practiceofEIA verifiersand construction practitioners (Morrison-Saunders and Retief, 2012).

5.3. Conducting PCC during construction phase

Conducting sufficient and effective PCC in construction phase (S1C26 and S16C10) was another major challenge encountered by stakeholders in this case, while political pressure (S1C21) and public controversies (S1C22) are its driving forces and potential consequences (in case of ineffective PCC during construction) at the same time. According to the network analysis and interview findings, there were three main causes of this challenge:
(1) project proponent disregarding the importance of PCC after the development reached its construction stage; (2) indirect means and channel of communication between project core and the community; and (3) potential distortion of PCC results due to political interference. Consequently, these led to dissatisfied voices from pressure groups and the community in a view that their concerns and grievances were not adequately addressed and understood. In this case, the main mechanism of PCC during construction was regular meetings hosted by project proponent, with the involvement of contractors, district board and rural committee representatives. The district board interviewees remarked that these meetings were effective PCC tools to understand the current project progress and reflect the community views in decision making. Also, the interviewees added that dedicated website has been created by the government to disseminate relevant information for public access throughout the construction course. However, diverse opinions were obtained from pressure groups and the public. The interviewees from environmental group doubted the sincerity of the government in having real communications as PCC was more like procedural requirement in pre-construction phase, and their dialog has ceased once the construction period started. They opined that some enduring concerns could extend their effects to construction stage, and new concerns often emerge when project influences become increasingly apparent; however, in this stage, they have limited opportunities to make their voices heard or even to propose potential solutions (e.g. the concern about an unexpected sharp decrease of CWD population once reclamation started). In addition, some interviewees from the community asserted that their actual needs and opinions might be misinterpreted or inadequately reflected by district councilors and rural committee in the meetings. Instead, direct involvement can improve communication and mutual understanding between project parties and the community. Some interviewees concerned about political interference as councilors with political background might misrepresent the PCC result for their political interests. These findings are consistent with several previous studies, pointing out that PCC and direct involvement in construction period should be strengthened to resolve conflicts and enhance public satisfaction (Close and Loosemore, 2014; Ng et al., 2014).

5.4. Site constraints due to nearby air and marine traffic

In this case, overcoming site constraints caused by nearby air and marine traffic was another main challenge of stakeholders. It can be seen from two aspects: (1) minimizing disruption to existing air and marine traffic activities; (2) safeguarding aviation and marine navigational safety, throughout the entire construction period. The network analysis and interview findings reveal that the use of complex and experimental technology (S3C10) has increased stakeholders' difficulties in achieving the above goals (S10C4); leading to changes in construction equipment and operations, and requiring close collaboration between contractor, government departments and interfacing projects. For example, the reclamation site was located close to the airport (in front of the runway); therefore, operations of tall and huge machines in seawall construction might pose a threat to aviation safety. Despite contractor's knowledge to airport height restriction (AHR), the interviewees from civil aviation bureau (CAB) stated that many equipment initially proposed by contractor had exceeded AHR and were prohibited from use; resulting in extra time and resources from contractor, resident engineer and CAB to revise and reassess construction methods and procedures. They commented that this situation would have been improved if contractor has more experience in using the non-dredge method and higher awareness of aviation safety. In case of necessary use of tall machines, contractor was required to get temporary height exemption (THE) permit from CAB. However, some interviewees indicated that THE might not be granted for certain daytime (e.g. peak hours of air traffic), leading to more nightworks of contractor to accelerate project progress. In some occasions (e.g. urgency), contractor could not undertake their works unless other contractors of interfacing projects shared THE permit with him, as THE could only be granted to a single party for a specific location and duration. Therefore, some interviewees opined that good relationships between contractor and interfacing projects were essential to facilitate each other's works. Similar views were obtained from the interviewees of marine bureau (MB), indicating that close and continuous collaboration was needed between contractor and MB to revise marine impact assessment and establish temporary traffic arrangement in construction stage. These findings echo a number of previous research on the importance of stakeholder collaboration in successful project delivery (Bouchlaghem, 2011; Xue et al., 2010).

5.5. New materials and equipment meeting the government standard

In this case, the contractor and subcontractors faced challenges in recognizing and seeking compliance with the government standard on material and equipment quality (S3C47). On the basis of the network analysis and interview findings, this challenge was attributed to three reasons: (1) insufficient experience in using the leading-edge construction method (S3C10 and S2C23); (2) a lack of clear quality standard, testing methods and acceptance criteria for new materials and equipment established by the government (S3C47 and S3C14); and (3) ineffective coordination between contractors, consultants and relevant government departments; leading to delay in contractor's progress (S1C1). For example, as indicated by the steel supplier interviewees, since there have been no track records of non-dredge reclamation, no relevant testing methods and assessment criteria could be ascertained for the newly adopted materials in legislative requirements or the government's general specification for civil engineering works. As such, they were failed in the government laboratory test on their flat steel plates and arc units for building cellular structures of steel cofferdam. The steel supplier spent extra resources to collaborate with universities and overseas technical experts to explore possible testing methods, in an attempt to verify the satisfactory material quality. Similar situations also occurred in the licensing of construction vessels. A large number of huge vessels wasusedfor steel cofferdam installation. Since noexisting local vessels of the required size and type were available, the contractor has hired overseas vessels and modified them for the said purpose in construction stage. The MB interviewees stated that no existing licensing and control regulations could be applied for the modified vessels; resulting in extra resources from MB to fine-tune licensing requirements, also incurring time and cost overruns of the project. As opined by the interviewees, these problems could have been alleviated by proper planning and effective coordination between the government and project parties; eventually facilitating the establishment of testing methods and acceptance criteria for new materials and plants before project commencement. Consistent with Chew's (2010) findings, the government plays a leading role in driving the adoption of pioneering technology at both project and industry levels through legislative and regulatory controls.

6. Features of the network-theory based stakeholder concern analysis method

This study applies network-theory based analysis to assess stakeholder concerns and concern interdependencies in the context of MEPs. Prior studies on stakeholder analysis have taken the perspectives of empiricism (e.g. Stakeholder Salience model (Mitchell et al., 1997), power/interest matrix (Olander and

Main steps	Methods/sub-steps	Outcomes
1. Identify stakeholders	Chain referral sampling	Stakeholder list (e.g. S1,S2,S3)
2. Define stakeholder concerns (nodes)	Interview; empirical identification	Stakeholder-related concern list (e.g. S1C1,S1C2,S2C1,S2C2,S3C1,S3C2)
3. Define stakeholder concern interdependencies (links)	Questionnaire survey a. Identify links b. Assess links (by rating impact intensity and likeliness)	Adjacency matrix
4. Visualize network	SNA software	Stakeholder concern network
5. Analyze network	a. Visual examination b. Descriptive analysis c. Node-level analysis d. Link-level analysis · *Calculate link betweenness centrality (link BC)* · *Plot a graph, determine link BC cut-off value* · *Identify links which are associated to key nodes and score ≥ cut-off value* · *Identify links which are not associated to key nodes but score ≥ cut-off value*	Initial understanding Network connectivity analyzed Key nodes identified Key links identified
6. Identify key stakeholder challenges	a. Complement key nodes and links results with interview findings b. Interpret cause-and-effect relationships between key concerns c. Classify related key links into groups	Key stakeholder challenges identified

	S1C1	S1C2	S2C1	S2C2	S3C1	S3C2
S1C1	0	0	(2,5)	(2,2)	(2,2)	(5,3)
S1C2	0	0	(4,3)	(1,5)	(3,4)	(4,2)
S2C1	(1,3)	(2,0)	0	0	(1,2)	(3,3)
S2C2	(1,2)	(2,1)	0	0	(2,5)	(1,5)
S3C1	(4,3)	(2,2)	(1,3)	(2,2)	0	0
S3C2	(1,5)	(2,3)	(3,3)	(4,5)	0	0

	S1C1	S1C2	S2C1	S2C2	S3C1	S3C2
S1C1	0	0	10	4	4	15
S1C2	0	0	12	5	12	8
S2C1	3	0	0	0	2	9
S2C2	2	2	0	0	10	5
S3C1	12	4	3	4	0	0
S3C2	5	6	9	20	0	0

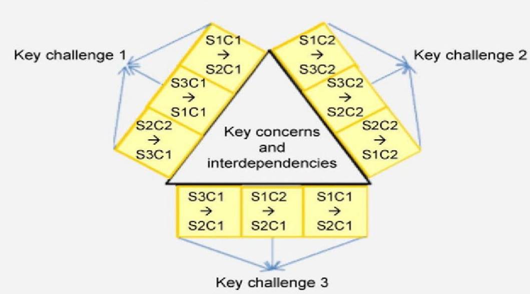

Fig. 2. An illustrative example of the network development and interpretation process.

Landin, 2005), and Stakeholder Circle methodology (Bourne, 2005)) and rationalism (e.g. social network theory (Rowley, 1997)) to identify and prioritize stakeholders (Yang, 2014). Existing methods in the former perspective evaluate stakeholder influences based on empirical knowledge and subjective assessment by core stakeholders on stakeholder attributes, while those in the later perspective analyze stakeholder roles and predict their behaviors by engaging all stakeholders and modeling their actual relationships.Nonetheless, stakeholder impacts and behaviors are dependent on more factors (other than stakeholder attributes and relationships) — stakeholder concerns and concern interdependencies. Overlooking the analysis of concern interdependencies and their propagating impacts on project implementation can compromise the accuracy of stakeholder analysis and the quality of project performance.

To improve the current stakeholder analysis practice, the network theory is applied in this study to assess stakeholder concerns and their interrelationships in complex project environment. This network approach identifies completely the involved stakeholders and the concerns specified by each stakeholder in a project, models the interdependencies among stakeholder-related concerns, analyzes structural patterns of the overall concern network, and identifies important concerns and links which play central roles in influencing and/or connecting other concerns. These analysis results indicate critical concerns and interactions which give rise to the high stakeholder and project complexities, and help yielding insights on what major challenges are faced by the stakeholders. Such methodology extends beyond conventional emphases on the attributes and relationships of individual stakeholders, and

Table 6

provides a new angle to address stakeholder complexitiesin project environment.

In addition, this methodology does not draw conclusions based on just one stakeholder perspective. Instead, it considers all stakeholders' perspectives from the outset as the network building process is to identify thoroughly all stakeholder groups by chain referral sampling, and to specify concerns sourcing from each identified stakeholder. This approach defines one node as one concern raised by one stakeholder, in an attempt to capture a complete picture of all concerns specified by all stakeholders. There are occasions that the same concern is raised by different stakeholders, but it is differentiated into different concerns and coded differently during the concern identification process. The link identification and evaluation process is also comprehensive by taking into account all impacts existing between every stakeholder's particular concerns and their impacted/impacting concerns. As such, this methodology provides the benefit of considering all stakeholders' perspectives.

Fig. 2 shows an illustrative example of the network development and interpretation process, while Table 6 presents some possible stakeholder-related concerns in MEPs and their positions in network. They provide a clear explanation of the network analysis method and enable its application to be repeatable for future research. Despite its analytical capabilities, using the network approach in isolation is not the best way to analyze stakeholder concerns and interdependencies, and to identify major challenges in MEPs. Applying network-theory based analysis along with other methods (e.g. chain referral sampling, interviews), as adopted in this case study, can bring the benefits of complementing quantitative network results with qualitative data to gain a richer understanding and make better decisions about stakeholder management in MEPs.

An illustrative example of stakeholder-related concerns and their positions in network.

Stakeholder	Stakeholder-related concern	Concern category	Network position			
			Direct influencer	Global influencer	Gatekeeper	The impacted
Client	Public pressure and controversies on project progress and performance	Social				

7. Conclusions

Network-theory based analysis offers a new angle to better understand the major challenges of MEPs confronted by stakeholders through a thorough analysis of key stakeholder concerns and concern interdependencies. Stakeholder concerns arising from the same MEP are interconnected. When a concern is not properly addressed, its presence can be the source of occurrences of other interrelated concerns in the same project environment, producing chain effects of more stakeholder issues which can further lead to conflicts and project resisting forces. Stakeholder concerns have been viewed as independent units in previous studies, but their great diversities and complex interrelationships are important factors causing challenges of MEPs. Therefore, this paper mainly focuses on using a network approach to examine key stakeholder concerns and their interdependencies of MEPs, and how these bring about various challenges in MEPs.

A large-scale reclamation project was presented as case study to illustrate the stakeholder concern network building and analysis process. The case study results revealed five key challenges of stakeholders, including: (1) applying highly advanced and complex construction technology; (2) mitigating project disruptions to the environment and marine ecology; (3) conducting consultation of the public and community during construction; (4) the difficulties in overcoming site constraints due to nearby air and marine traffic; and (5) the challenges in meeting the government standard on the quality for new materials or equipment. Recommendations are provided to alleviate these problems for similar MEPs in future. These recommendations include: (1) encouraging early contractor involvement to integrate their construction expertise in design and procurement; (2) improving the implementation and monitoring of environmental mitigation by establishing explicit commitment, clear goals and ecological baselines, along with improving the practice of EIA verifiers; and (3) encouraging more sufficient and effective PCC in construction phase by changing the practitioners' mindsets that PCC is not important after project commencement.

Four limitations in this study should be noted with attention. First, notwithstanding the use of chain referral sampling in the network development process, it is practically and ethically challenging to engage all stakeholders, where some of them might concern the confidentiality and anonymity issues and are disinclined to provide data. A higher precision of concern interdependency analysis can be yielded if all stakeholder entities are ideally reached. Secondly, this paper analyses only a screen-shot of the stakeholder concern network at a point in time during the construction phase. Longitudinal network studies are needed in future to explore the dynamics of stakeholder concern relationships throughout the whole MEP lifecycle. Thirdly, although the findings presented here offer practical insights on key concerns and challenges of stakeholders in MEPs, they are derived from a single case. In future,morecasestudieson similar type of MEPs should be carried out to complement and reinforce the findings. Future empirical studies, using the same network approach, can also be undertaken in other types and contexts of MEPs to compare the findings and develop more comprehensive stakeholder management strategies. Finally, owing to the limited context of single case study, this paper lacks a generalization on the thresholds of network metrics for extracting the most critical stakeholder concerns. It should be noted that the importance level of stakeholder concerns and the identification of major challenges faced by stakeholders are not solely related to the network analysis result of concern interdependencies. In practice, these can also be affected by a set of external (e.g. political climate of the society) and internal factors (e.g. the expertise of the project management team in stakeholder management). To increase practicality of the network approach, future endeavor should attempt to establish a method to define and generalize the thresholds of network metrics; which can simultaneously take into consideration the internal and external influential factors, and integrate the network analysis results from previous case studies.

Despite the above limitations, this study contributes theoretically to the body of knowledge by using a network perspective to analyze stakeholder concerns and concern interdependencies in MEPs. The network approach presented here can help identifying a complete boundary of project stakeholders and their concerns, mapping the concern interdependencies, visualizing the overall concern network, and identifying the important concerns and linksin theproject. Such information offer useful insights onwhat major challenges the stakeholders encounter in project execution. Compared to the traditional stakeholder analysis practice, the network-theory based analysis brings higher accuracy and a richer understanding on the propagating effects between stakeholder concerns. It can be applied in other complex project systems for modeling concern interdependencies and serving as basis to develop stakeholder management strategies as well. Notwithstanding the limited context of single case, the project challenges reported in this empirical study can provide practical insights on some common pitfalls of MEPs, the findings and recommendations are expected to benefit construction practitioners when they handle similar problems in future MEPs.

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