This is an Accepted Manuscript of an article published by Taylor & Francis in International Journal of Construction Management on 27 Jun 2016 (published online), available at: http://www.tandfonline.com/10.1080/15623599.2016.1187246.

A network theory-based analysis of stakeholder issues and their interrelationships in large construction projects: a case study

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Abstract

Large construction projects are characterized by numerous stakeholders and conflicting interests involved. Previous stakeholder management studies placed great emphasis on stakeholder identification and analysis based on individual stakeholder attributes, which are confined in completeness without taking into account stakeholder-related issues and their interrelationships. In real situations, a project environment is a network of interconnected stakeholder issues, where stakeholder perception and salience are affected by the propagating influences of these issue interactions. This paper conducts a network theory-based analysis to investigate the underlying network of stakeholder issues in large construction projects, as well as to identify key issues and relationships impacting project execution. Network analysis procedures are illustrated through a case study of a large building project. Recommendations and lessons learnt are drawn for future large public construction projects. This paper provides a network perspective to analyse stakeholder issues and interrelationships, eventually increasing the overall accuracy and effectiveness of project stakeholder management.

Keywords: stakeholder analysis; network analysis; stakeholder issues; project stakeholder management; stakeholder relationship; large construction project

Introduction

Large construction projects are described as massive investments of at least US$500 million, and are characterized by being highly complex, involving numerous and multidisciplinary project stakeholders, having huge workloads, and exerting long-lasting impacts on social, economic and environmental aspects (Hu et al. 2015). In this complex project environment, managing stakeholders is an essential task to engage their support and facilitate coalition, yet it has been a great challenge encountered by project teams. The difficulties and failures of stakeholder management in large construction projects have been extensively reported in previous studies (Flyvbjerg, Skamris Holm et al. 2003; Rose & Manley 2010). It can be observed that project participants are capable of affecting project decision-making to pursue their individual interests, and these stakeholder concerns are interconnected with complex and dynamic interdependencies.

Stakeholder issues refer to the concerns or vested interests of stakeholders in a project (Li et al. 2012). They are often conflicting and relate to different project aspects (such as cost, time, quality, social, environmental, economic, technological and ethical), due to the diverse stakeholder backgrounds and growing complexity of construction projects. Stakeholder issues emerging from the same project are connected with dynamic interdependencies instead of staying in a vacuum. The existence of an issue may trigger and control the occurrence of other issues under dependent or interdependent relationships, propagating to an influence network (Fang et al. 2012). This conception may be demonstrated by an example of three stakeholder issues. For example, environmental public authorities' concern about enforcing environmental protection legislation can trigger and affect a contractor's issue on implementing environmental mitigation measures during construction; simultaneously, this is also a consequence of the general public's concern regarding potential environmental disruption brought by construction activities. These three issues are interrelated and influence each other. A large construction project involves numerous stakeholder issues which are of high diversity and complexity; as such, it becomes vital to capture the network of stakeholder issue interdependencies, analyse its relational structures and understand their practical implications on project implementation. Failure to do so can result in inaccurate stakeholder analysis and uninformed decision-making, eventually affecting project performances in terms of time, cost and quality (Morris & Hough 1993).

Previous studies put considerable effort into stakeholder analysis in large construction projects from different perspectives. Olander (2007) assessed stakeholder influences on the implementation of large engineering projects based on individual stakeholder characteristics and attitudes. Li et al. (2012) identified stakeholder concerns during public participation of major construction projects and compared their importance across four stakeholder groups including the government, general public, pressure groups and project-affected groups. By integrating the traditional stakeholder analysis method and social network analysis, Linert et al. (2013) analysed interpersonal relationships among stakeholders and assessed their impact levels in infrastructure planning. These studies contributed to the construction management circle with empirical evidence on the importance and benefits of stakeholder analysis. However, existing stakeholder analysis approaches are inadequate to address the high complexity of large construction projects as they rely heavily upon individual stakeholder attributes and behaviours, while sacrificing the consideration of stakeholder issues and their interrelationships which can produce chain effects and practical implications for project delivery. In real situations, there is an underlying network of stakeholder-related issues in every construction project (Wambeke et al. 2012). Understanding this network is important for a project management team of large and complex undertakings to overcome stakeholder management challenges. Notwithstanding the theoretical and practical importance, research on the network of stakeholder-related issues and its implications for construction project delivery appears to be lacking.

Network analysis is a potential means to identify and analyse stakeholder issue interdependencies in large construction projects. Stakeholder-related issues are interconnected units embedded in intricate relationships; network analysis can help to visualize these relationship structures and decipher their impacts by quantitative analysis of their structural features (Tichy et al. 1979). With the aid of this technique, stakeholder issue analysis in large construction projects is expected to benefit the project team by capturing issue interactions, simulating project situations and enhancing stakeholder coordination. Network theory-based analyses have been conducted in the construction and engineering domain to examine social networks (Chinowsky et al. 2008; Park et al. 2011), project risk networks (Fang et al. 2012; R.J. Yang & Zou 2014) and networks of infrastructure systems (Sen et al. 2003; Eusgeld et al. 2009), yet research to recognize and analyse stakeholder issue networks using the network perspective has been lacking.

This study applies NetMiner, a network analysis program, to identify and investigate the underlying network of stakeholder issues in large construction projects. A case study of a US$645 million large building development in Hong Kong was undertaken to illustrate the application of network analysis and outline its analytical process. The results explain how stakeholder issues interact with and influence each other in the network. They also reveal the critical stakeholder issues and issue interrelationships which the project team should handle with high priority, due to their important roles in bridging other issues. This study is useful to both scholars and practitioners by illustrating a method to examine the underlying networks of stakeholder issues in large construction projects using network analysis. It is expected that this method can be repeated for stakeholder issue analysis in other types of construction projects as well.

Research background Analysing stakeholder issues from a network perspective

Conventional stakeholder impact analysis methods applied in large construction projects have been criticized as being 'linear and subjective' (J. Yang et al. 2011), as their impact assessment was built upon either dyadic organizationstakeholder relationships, or a discrete evaluation of individual stakeholder attributes and concerns. In the highly complex project environment, these linear approaches were confined in accuracy since they overlooked the sources of stakeholder concerns, as well as their interrelationships and propagating impacts.

To overcome the above challenges, a network perspective should be taken to accommodate these two essential aspects of effective stakeholder analysis methods. The first aspect is to identify the sources of stakeholder issues. The majority of concerns in large construction projects are connected with different stakeholders owing to their distinct interests and project expectations (R.J. Yang & Zou 2014). It becomes vital for a project team to recognize the right sources of stakeholder issues so as to develop proper engagement strategies. The second aspect considers the interdependencies between stakeholder-related issues in a project system. Concerning issues arising from the same construction project, the existence and occurrence of an issue can trigger other issues under influence relationships, thereby producing propagating impacts and affecting the stakeholder management process (Fang et al. 2012). Stakeholder issues in a project are subject to immediate, mediate or mutual influences from each other, and disregarding these interrelationships may result in an inaccurate and incomplete stakeholder influence evaluation. To bridge the gap, this study uses a network perspective to analyse stakeholder issues and their interactions in large construction projects.

Network theory-based analysis

Network theory-based analysis is a methodology to examine the formation and dynamics of relational structures among a defined set of actors, by giving graphical representations of these structures with sociograms and quantitatively evaluating the characteristics and patterns of these interdependencies (de Nooy et al. 2005). The origin of the network perspective can be traced back to the 1930s (Moreno 1960). Under network theory, the behaviours and robustness of a system are readily influenced by the interrelated elements embedding within the system, as well as how these elements are connected to each other (Wasserman & Faust 1994). In this regard, relational features and their causes and consequences, rather than individual attributes, of the network actors become the emphasis of network theory-based analysis.

Network analysis has been widely adopted in construction management research from two main aspects. One major aspect is the investigation of social networks, in which nodes usually refer to human entities that have a behaviour or decision-making ability such as organizations and individuals. For example, Loosemore (1998) investigated communication networks within a construction organization during crisis at the interpersonal level. Chinowsky et al. (2008) studied knowledge-sharing networks of project team members for achieving better team performance. Wambeke et al. (2012) deciphered the network of construction trades in a project based on spatial proximity and identified the key trades in project governance. At the inter-organizational level, Park et al. (2011) analysed collaboration networks in international joint venture projects and identified the network tendencies to achieve higher project profit. In the works of Linert et al. (2013) and J. Yang et al. (2011), network analysis was integrated with classical stakeholder analysis to assess stakeholder impacts based on collaboration and information exchange in infrastructure planning and green building projects, respectively.

Another major aspect of network analysis considers interrelated non-human objects of a system as nodes, and examines how their relational structures affect the system behaviours. For instance, Eusgeld et al. (2009) used network theory to identify key elements of a power transmission infrastructure system and measure its vulnerability by taking its substations as the nodes and overhead lines as the ties. Similarly, Sen et al. (2003) and Zhang et al. (2015) decipher the underlying network of railway infrastructure systems, by taking stations as nodes and tracks as ties, so as to determine the significance and protection priorities of infrastructure assets in the systems. In the works of Fang et al. (2012) and R.J. Yang and Zou (2014), construction project risks are considered as nodal elements to examine their underlying networks and influences on project implementation, under the conception that these risks are interconnected and produce propagating effects. Taking this network perspective, a construction project can be perceived as a system of interrelated stakeholder issues connected by a specific set of ties, and these relational structures are important in determining the influence level of issues on project delivery (Loosemore 1998). Built upon this research, this study considers the issues sourced from project stakeholders as the nodes, and adopts network theory-based analysis to investigate their underlying network in large construction projects.

In this study, the network theory-based analysis for exploring the stakeholder issue network will comprise five major steps: (1) identifying stakeholders issues (nodes) based on empirical knowledge of project stakeholders or snowballing; (2) assessing issue interrelationships (links) in terms of the impact between the issues and the possibility of the interaction to occur, and forming an adjacency matrix accordingly with these relational data; (3) visualizing the issue network; (4) analysing network structures by computerization of network indicators; and (5) recognizing key issues and interactions which influence project delivery, and suggesting measures to reduce network complexity (Scott 2000; Fang et al. 2012; Pryke 2012; R.J. Yang & Zou 2014).

Stakeholders and stakeholder issues in large construction projects

The perception of project success has altered from fulfilling the iron triangle (i.e. time, cost and quality) towards a humanbased perspective of accommodating stakeholder issues and achieving stakeholder satisfaction (Leung et al. 2005). It is crucial for a project team to fully understand stakeholders and their issues, in order to formulate proactive and effective engagement strategies. Table 1 summarizes stakeholder issues in large construction projects based on a literature review; these issues refer to the concerns/interests of multiple stakeholders during project design, construction and implementation.

Stakeholder issues in large construction projects are categorized in different manners in previous stakeholder management studies, such as: social, environmental, economic, financial, institutional and technical (Takayanagi et al. 2011); cost, safety, security, time, quality, collaboration and disputes (Toor & Ogunlana 2010); and internal/strategic and external/normative (Feige et al. 2011). In this study, stakeholder issues are classified into 10 groups. They are cost (regarding cost control and fluctuation), economic (regarding indirect cost/benefits brought by associated economic activities), environmental (regarding conservation of environment), ethical and reputational (such as corporate social responsibility and company image), political (such as political interference and morale of civil servants), project management and governance (regarding incentives, regulations and project administration structure), social (regarding habits, and social and cultural issues), technical (regarding quality and technical issues such as technical challenges and requirements, safety, resource availability and end-product quality), time (regarding time management) and others (such as democratic share of information and relations with developers). It is worth noting that the purpose of this issue classification is to assist practitioners during the issue identification process in the proposed network theory-based analysis method. Therefore, this classification is not intended to embody all issue categories in large construction projects.

Table 1.Stakeholder issues in large construction projects identified in previous publications.

Researchers	Issues/concerns	Related stakeholders	Issue category
Dooms et al. (2013)	Uneven subregional growth	General stakeholder	Social
	Stability and legitimacy of project governance structure	General stakeholder	Project management/ governance
El-Gohary et al. (2006)	Disturbance to nearby environment during construction	External stakeholders	Environmental
	Sustainability and reliability of project system over a long period of time	Internal stakeholders	Technical
Feige et al. (2011)	Sufficiency of existing laws, regulations and control to support the project	Investor; contractor; supplier; designer; government	Project management/ governance
	Possible access to and democratic dissemination of project-relevant information	NGOs; the general public; media	Others
Li et al. (2012, 2013)	Project adaptability to the changing needs	Government	Technical Economic

	New job opportunities created	Government; the general public; pressure groups	
	Project design in terms of aesthetics, density, height and visual permeability	Project-affected groups	Technical
Ng et al. (2012)	Disruption to local cultural and historical heritage	General stakeholder	Social
	Threats to availability of valuable natural resources	General stakeholder	Environmental
Nguyen et al. (2009)	Political interference to project planning and implementation	Government	Political
	Keeping stakeholders well informed of project progress	Contractor	Project management/ governance
Takayanagi et al. (2011)	Resettlement and compensation plan of projectaffected groups	Government; affected vicinity	Social
	Stability against construction price fluctuation	Internal stakeholders	Cost
	Encourage stakeholder participation in project planning and implementation	General stakeholder	Project management/ governance
	Use of new, efficient and innovative method or technology	Internal stakeholders	Technical

Toor and Ogunlana (2010)	On-time project completion	Internal stakeholders	Technical
	Safety	Internal stakeholders	Technical
	Minimized construction disputes and conflicts	Internal stakeholders	Project management/ governance

Note: "NGOs" refers to non-governmental organizations.

Identifying the right sources of stakeholder issues is an indispensable task for achieving stakeholder satisfaction. It is therefore beneficial to gain insights from the previous literature regarding stakeholder classification in large construction projects, where stakeholders can be described as individuals or organizations 'who can influence the project process and/ or final results, whose living environments are positively or negatively affected by the project, and who receive associated direct or indirect benefits and/or losses' (Li et al. 2012, p. 334).

El-Gohary et al. (2006) broadly classified stakeholders of major construction projects into six types. The first type includes developers and government agencies that undertake a certain level of decision-making authority in the project. The second type involves end users, the public and the affected vicinity, who are favourably or unfavourably impacted by the project. The third type refers to media and non-governmental organizations (NGOs), which are influential external stakeholders expressing the public voice. The fourth type comprises supply chain organizations and professional associations. They provide specialized advice which can serve as a guideline for project execution and administration. The fifth type comprises business leaders and politicians who give expert opinions from economic and political perspectives. Finally, the sixth type is public relations personnel who play facilitative roles in project communication and coordination. Zhai et al. (2009) and Turner and Zolin (2012) also compiled similar stakeholder lists for large construction projects, except that they included three more actors: investor, financial institution and insurer. Based on the above literature review, stakeholders are classified into 16 groups in this study, namely: client; contractor; project manager/supervisor; subcontractor and supplier; consultant; public authorities; financial institution; insurer; media; politician; NGOs; the general public and affected vicinity; end users; professional association; educational institution; and assessor. It should be noted that, instead of trying to cover all stakeholder groups, this stakeholder classification aims to develop a reference list of stakeholder categories for ease of use by construction practitioners during the stakeholder identification process in the network theory-based analysis method. Prior to the actual identification of stakeholders and issues, their classifications and reference lists should be double-checked with the key project stakeholders. Based on their professional and empirical project knowledge, the categories of stakeholders and issues could be added to or reduced.

Network indicators for investigating the stakeholder issue network

In this study, six network indicators are computed to investigate the structural characteristics and patterns embedded in the stakeholder issue network at both the network level and node/link level.

Network density

Density captures the overall connectivity of a network. It refers to the proportion of actual links presenting within a network to the maximum number of potential links if all network actors are interconnected with each other (Chinowsky et al. 2008). The density value varies between zero (all nodes are isolated) and one (a complete network with all nodes tied to everyone else), depending on the network size. More interactions between stakeholder issues would give a greater network density.

Network cohesion

Cohesion indicates network complexity by considering the reachability of stakeholder issues, where reachability is defined as the number of ties to approach nodes in a network according to the geodesic distance (Parise 2007). A great cohesion value indicates a complicated stakeholder issue network, as more walks are required from each node to reach everyone else.

Nodal degree

Nodal degree reflects the extent to which a stakeholder issue is tied to its immediate neighbours in a network, by measuring the weight sum of relations which are in direct incident with the node (Loosemore 1998). Nodal degree is further categorized as in-degree (incoming links received by the node) and out-degree (outgoing links emitted from the node) according to the direction of links. Degree difference is also calculated by subtracting the in-degree score from the out-degree score. A stakeholder issue with great degree difference can be interpreted as exerting stronger influences on its neighbours than accepting impacts. Considering node types, 'isolated' nodes are relatively easy to handle as these stakeholder issues are not linked to other nodes.

Betweenness centrality

Betweenness centrality calculates the occurrence in which a specific node/link is situated between other pairs of nodes/ links on the basis of the shortest path (Park et al. 2011). This measure identifies nodes/links which play an intermediary role to glue different parts of a network together, where 'weaknesses at these critical points can lead to disintegration' (Loosemore 1998). A node/link with a high betweenness centrality score possesses greater power in controlling the interactions or influences flowing through it.

Status centrality

Status centrality is a node measure to reflect the overall impact of a stakeholder issue within the entire network. This indicator calculates the number of a node's direct successors and predecessors, and also the secondary nodes which are linked indirectly to the focus node via its immediate neighbours (Katz 1953). Status centrality is further classified as in-status centrality (impact received) and out-status centrality (impact released). Nodes with greater out-status centrality scores are worth more attention as they are deemed more influential with a larger magnitude of impact.

Brokerage

Brokerage describes the role and capability of a particular node in bridging different subgroups within a network under a selected partition vector. In this study, the subgroups/partitions in the stakeholder issue network are the various stakeholder or issue categories identified in the stakeholder issue schedule. After choosing a partition vector, this node measure counts the frequency with which each of the five brokerage configurations (coordinator, representative, liaison, gatekeeper and itinerant) occurs on every node (Burt 2005). Nodes with high brokerage scores are worth high attention, since they play critical roles in producing propagating effects and increasing the overall network complexity.

Research methods

Case study and network analysis were applied as the primary research methods in this study to identify and investigate the underlying network of stakeholder issues in large construction projects. The questions to be answered in this research comprised: (1) what the important stakeholder issues and their interrelationships are in complex construction projects; and (2) to what extent these issues and interactions affect stakeholder management complexity.

Case study

Case study is a recognized tool to investigate a current phenomenon in depth within a real-life context under minimum interference of the researchers (Zainal 2007). According to Yin (1984), there are three approaches to a case study: exploratory, descriptive and explanatory. Exploratory case study was adopted here since the purpose of this research was to closely examine the causes behind the subject phenomenon, instead of generalizing and testing theories based on the collected data (McDonough & McDonough 1997). To address the research questions, a case study was conducted to apply network analysis in examining stakeholder issues and their relations. The case selection was based on information-oriented sampling strategy rather than being random (Flyvbjerg 2006). The current case was chosen because this project was considered atypical regarding its high project complexities, which brought stakeholder management challenges to the core project team and imposed an urgent need for an effective stakeholder issue analysis method. Despite the single case investigation, the researchers overcame the limitations of a small sample by ensuring a close and objective exploration, as 'objective setting of the research [is] far more important in case study method than a big sample size' (Zainal 2007, p. 5).

The case project is an iconic public office building development in Hong Kong, procured under a design-and-build (D&B) contract with a contract sum of US$645 million. The project scope embodies three office towers with a total gross floor area of 130,000 m^2 and an open space of nearly 20,000 m^2 for public enjoyment. The project management team encountered tremendous challenges in the project implementation, necessitating collaborative efforts among multiple stakeholders. For example, this development was the first project in Hong Kong adopting seismic-resistant measures for building structures. Without previous experiences and a relevant local code of practice, the client spent more time and resources than expected in developing the building standard and scrutinizing the detailed design. Accommodation and security requirements of the client and end users were also not clearly reflected in the employer's requirements (ER). Additionally, owing to public accountability and political interference, this public development attracted huge attention from the general public and pressure groups pertaining to project cost and value for money.

A network theory-based approach is used in the case project to examine the stakeholder issue network. Stakeholder concerns and their relationships are dynamic throughout the project life cycle, and so is the assessment of impacts of the issues on each other. Due to the constraints of resources and time, the network analysis in this study is only a one-off. The network in this case study only captures a snapshot of the stakeholder concerns and their interrelationships at a single point of time in the design-and-construction stage. The following sections explain the process and methods in network building and analysis.

Network building process and methods

Before defining the nodes and links of the stakeholder issue network, stakeholder identification is the initial task in data collection process as the origins of stakeholder-related issues are the stakeholders themselves. An empirical knowledgebased method and snowball method were applied to identify stakeholders in the case project (Biernacki & Waldorf 1981). Before the snowball process, five representatives from the project core (including client authority and client representative) were initially engaged. They were asked to comment on a reference list of stakeholder categories (which had been compiled using a literature review) based on their empirical knowledge about the case project. Correspondingly, the 16 stakeholder categories in the reference list were reduced to 10 categories: client, contractor, project manager, subcontractor, consultant, public authority, pressure groups, general public, end users, and professional institutions. This reference list was created to help respondents with comprehensive stakeholder identification in the snowball sampling process. In the snowball sampling, the five initially engaged respondents were invited to nominate other internal stakeholder entities in the supply chain; these identified parties were then asked to nominate external stakeholders who were deemed influential or being influenced in project execution. Accordingly, 18 stakeholder groups were identified and they were each assigned a numerical code S_n (where n D 1 to 18).

Node determination was the second task. Semi-structured interviews were conducted with comparable numbers of representatives from each of the 18 stakeholder groups. Respondents were invited to identify their issues in the project based on their empirical knowledge. A reference list of stakeholder issues and issue categorization, which had been developed based on desktop studies and literature review, was provided to respondents to facilitate their issue identification process. Similarly, feedbacks on the issue classification in the reference list had been sought from the five respondents of the project core prior to issue identification, and they agreed with the classification based on their empirical project knowledge. Accordingly, 253 issues associated with 18 stakeholders were identified. These 253 stakeholder-related issues (nodes) were each assigned a numerical code S_nI_j for systematic data processing, where j denotes the issue number sourced from a specific stakeholder. The internal stakeholders comprise the client authority (project proponent), main contractor, client representative (a government department working on behalf of the client), subcontractor and design consultants. More issues were sourced from internal stakeholders (150) than from external stakeholders (103). Technical, social, project management and cost were the top four issue categories in descending order, accounting for 70% of all identified issues. Tables 2 and 3 summarize the stakeholder groups and issue categories identified in the case project.

Respondents from the 18 stakeholder groups, who previously determined the nodes, were asked to identify and evaluate the links. In this study, when a stakeholder related issue influences another issue, a link is said to exist between these two nodes. The respondents then quantified each identified link by assigning two scores: the impact strength which one issue exerts on the other, and the possibility for this impact to occur, on a five-point scale (5 D 'the highest degree' and 1 D 'the lowest degree'). The influence level of each issue relation was calculated by multiplying the impact and possibility scores. Since links can be reciprocal, respondents were asked to make explicit the directions of the identified relations. In other words, the influence given by Issue A on Issue B is treated as a distinct relationship from the influence exerted by Issue B on Issue A. An adjacency matrix was therefore developed to indicate influence relationships among stakeholder related issues. In this matrix, stakeholder issues were listed at the top and along the left-hand side, and influence values of the links were inputted into the cells accordingly, with zero on the diagonal as an issue is not considered to exert impact on itself. These relational data were obtained from respondents using semi-structured interviews, in conjunction with a survey instrument in a matrix format to facilitate the link assessment process. Each interview lasted three to five hours. Interview was selected as the means to gather relational data because the researchers can provide clear explanations and Table 2. Summary of stakeholder groups and their issues in the case study.

Stakeholder category	No. of issues in each stakeholder category	Stakeholder	No. of issues of each stakeholder
Client	31	S1: The client authority (the government and project proponent)	31
Contractor	33	S2: The design-and-build contractor company	33
Project manager/administrator	30	S3: The client representative (a government department working on behalf of S1)	30
Subcontractor	14	S4: Subcontractor company	14
Consultant	18	S5: Lead designer	42
	6	S6: Quantity surveyor	
	5	S7: Lead structural designer	
	13	S8: Lead building services designer	
Public authority	7	S9: Municipal bureau	7
Pressure groups	16	S10: Media (newspaper)	32
	8	S11: Politician	
	4	S12: NGO (social welfare-related and rehabilitation services-related)	
	4	S13: NGO (environmental-related)	
General public	19	S14: The general public	19

End users	26	S15: End users of Office Tower A	38
	8	S16: End users of Office Tower B	
	4	S17: End users of Office Tower C (main tower)	
Professional institution	7	S18: Professional organization	7

Note: "NGOs" refers to non-governmental organizations.

Table 3.Summary of stakeholder issue categories in the case study.

Stakeholder issue category	Number of issues
Cost related	28
Economic related	18
Environmental related	22
Ethical and reputational related	11
Political related	11
Project management and governance related	30
Social related	45
Technical related	75
Time related	2
Others (including access to project-relevant information by the public and pressure groups; relation between the government and construction industry, etc.)	11
Total	253

instructions of the link assessment method to respondents, during which the respondents can give elaborations on the identified links and their scores. Finally, 1822 relations (links) connecting 253 nodes were identified. Although semi-structured interviews can facilitate a comprehensive link assessment, there are some drawbacks. First, the collection process of relational data is time-consuming. Secondly, it requires considerable human resources and efforts from the research team if there are many identified stakeholders to be interviewed. In practice, these limitations can be addressed by using online surveys in matrix format (with demonstration videos to avoid ambiguities in survey instructions). Workshops with the identified stakeholders may also be conducted for link assessment, during which the participants can identify and evaluate the links through online surveys.

Network visualization and investigation procedures

Among various network analysis software packages, NetMiner was applied for network visualization and investigation owing to its high capabilities in handling huge data sets and interactive network exploration (Furht 2010). The adjacency matrix and a profile list of nodes and links compose the input data that NetMiner requires to produce network graphs. As previously mentioned, six network indicators were chosen for network analysis. Two network level metrics, density and cohesion, were selected since they provide an overall picture of the stakeholder issue network by considering its structural characteristics. Four node/link level indicators, including nodal degree, betweenness centrality, status centrality and brokerages, were chosen because they help to identify important issues and relationships, taking into account particular roles and propagating impacts of individual nodes and links in the network.

Case study results and analysis Descriptive investigation of the stakeholder issue network

Figure 1 shows the stakeholder issue network of the case project, with the stakeholder and issue categories denoted by different node shapes and node colours, respectively. The network density and cohesion values were 0.27 and 0.082, respectively, while the average distance between stakeholder issues was 2.66 walks of length 1. These figures show that the current network was dense and complicated, and the issues were relatively proximate to each other in comparison with the network properties of previous network studies (Fang et al. 2012; R.J. Yang & Zou 2014).

Analysis of individual stakeholder issues and issue-interrelationships

This section investigates the roles of meaningful stakeholder issues and links in consideration of their positions and relationships in the network. Figure 2 visualizes the distribution of 20 stakeholder issues according to their out-degrees and degree differences. These 20 issues deserved considerable attention since they either had a great weighted sum of out-links or a high value of degree difference. S2I5 (‘Delivering the project within budget’ associated with the contractor) has the largest out-degree and in-degree simultaneously, with respective values of 528.96 and 546.12. S15I22 (‘Provision of tight

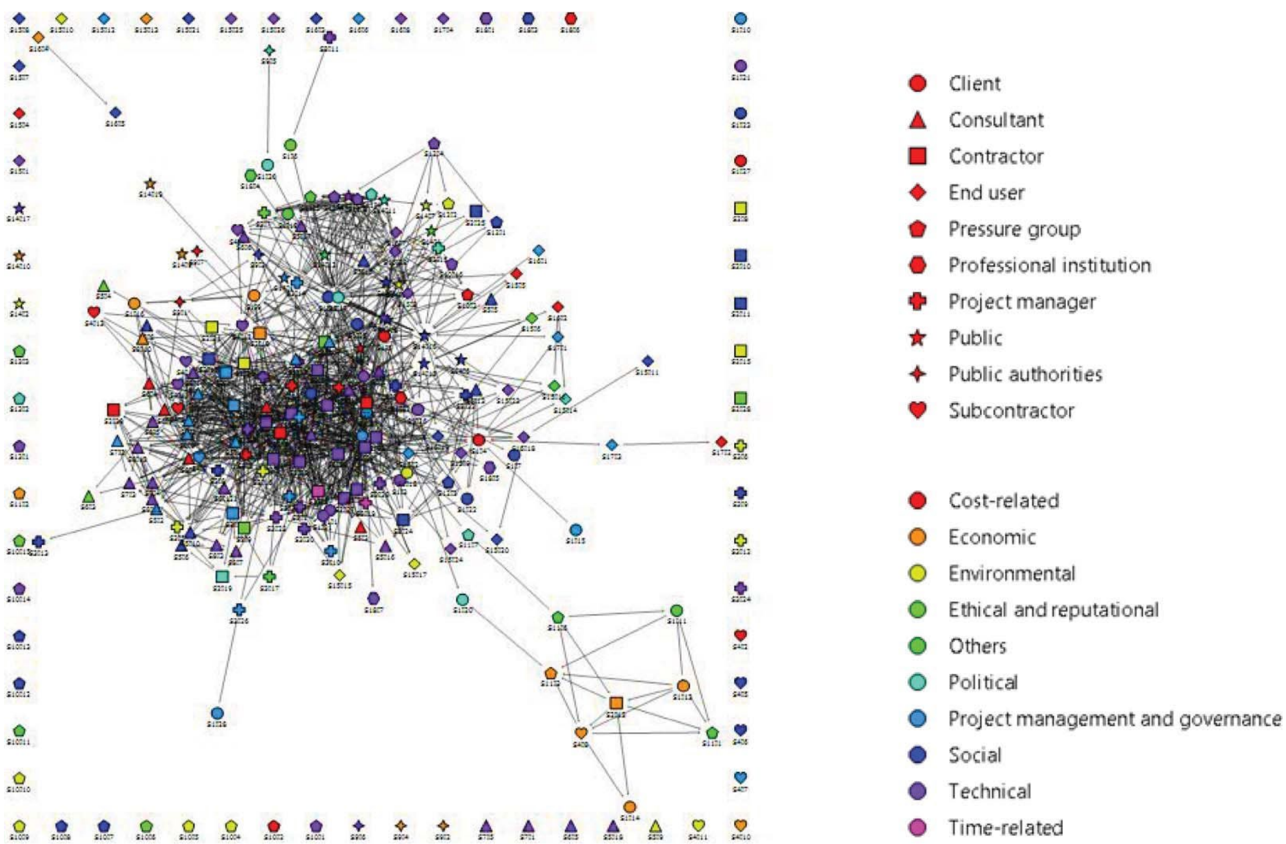

Figure 1.The network of stakeholder-associated issues in the case project.

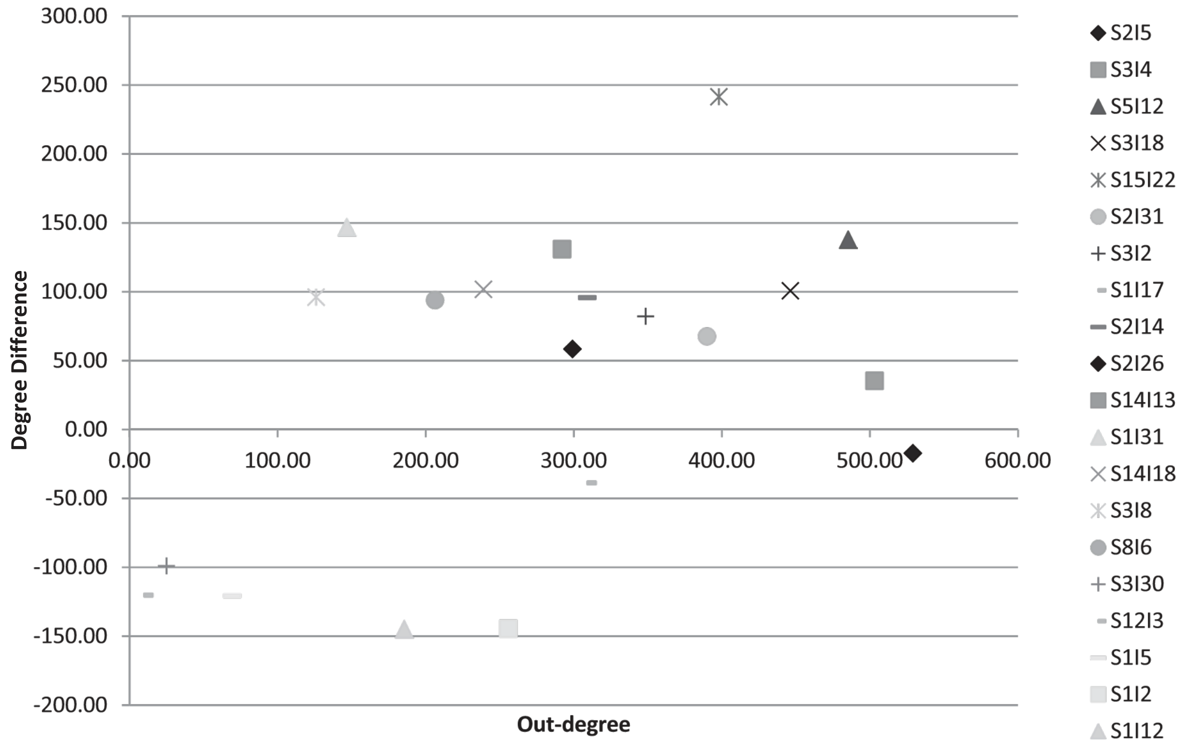

Figure 2.Distribution of stakeholder issues with high out-degrees and degree differences.

Table 4.Important stakeholder issues and links according to the betweenness centrality.

Rank	Issue ID	Issue betweenness centrality	Link ID	Link betweenness centrality
	S1I17	0.0392	S1I2 ! S2I5	433.30
1	S1I2	0.0360	S3I4 ! S17I3	318.00
2	S2I5	0.0355	S1I17 ! S3I27	251.91
3	S3I18	0.0295	S2I31 ! S1I5	250.57
4	S2I31	0.0286	S2I5 ! S1I17	200.45
5	S3I4	0.0268	S3I18 ! S1I29	192.53
6	S3I29	0.0260	S1I12 ! S2I14	191.79
7	S1I29	0.0215	S1I12 ! S3I18	183.39
8	S1I24	0.0206	S14I15 ! S1I17	182.86
	S1I5		!	

9	S14I16	0.0197	S3I18 ! S14I15	182.65
10	S1I12	0.0189	S14I6 ! S1I17	168.30
11	S14I15	0.0154	S16I1 ! S14I16	163.00
12	S2I14	0.0140	S3I30 ! S1I24	162.00
13	S3I27	0.0127	S15I3 ! S2I31	156.38
14		0.0115	S14I15 S3I29	147.73
15				

security measures and facilities' associated with end users of Office Tower A) has a high degree difference of 241.50, owing to its large number of immediate successors and comparatively slight direct impact from other stakeholder issues. The issue, S1I2 ('Accommodating the requirements of various end users' associated with the client authority), is most heavily impacted by direct predecessors in view of its high in-degree of 400.13.

The top 15 stakeholder issues and linkages according to their betweenness centrality scores are presented in Table 4. As shown, S1I17 ('Political interference to project implementation' associated with the client authority), S1I2, S2I5, S3I18 ('Project design in terms of design concept, aesthetics and visual permeability' associated with the client representative) and S2I31 ('Technical complexity in structural design and construction' associated with the contractor) are the top five issues with the highest betweenness centrality. The result indicates that these five issues are important junctions in bonding many issue pairs and in exerting a great degree of control over the interactions routed through it. Ten of the key relationships identified in Table 4 are routed through these five issues. Among these 10 key linkages, 'S1I2!S2I5' and 'S2I5!S1I17' should be heeded with alertness because both of their source and target nodes are the issues with the highest betweenness centrality. By comparing the stakeholder issues in Figure 2 and Table 4, six issues are recognized as significant due to their roles as major junctions in the network, notwithstanding their relatively low number of direct successors. These six issues include: S1I24 ('Provision of good incentives and clear instructions to support project implementation' associated with the client authority), S1I29 ('Sufficiency and effectiveness of public consultation' associated with the client authority), S3I27 ('Sufficiency and effectiveness of public consultation' associated with the client representative), S3I29 ('Using innovative and efficient construction methods and technology' associated with the client representative), S14I15 ('Provision of barrier-free facilities for the disabled' associated with the general public) and S14I16 ('Provision of public space and amenities' associated with the general public).

According to the out-status centrality analysis, S3I4 ('Delivering the project within budget' associated with the client representative), S2I5, S5I12 ('Project design in terms of design concept, aesthetics and visual permeability' associated with the lead designer) and S3I18 are the top four issues giving the greatest impact to other issues from a global view of network connection. The result is coherent with Figure 2 as these four issues are also at the highest four rankings based on the out-degree scores. The majority of the stakeholders issues with high out-status centrality values have already been pinpointed in the nodal degree and betweenness centrality analyses, except four important issues, namely S6I2 ('Exercising stringent cost control to ensure the project is delivered within budget' associated with the quantity surveyor), S3I25 ('Stability against fluctuation of construction labour and material prices' associated with the client representative), S16I7 ('Provision of tight security measures and facilities' associated with end users of Office Tower B) and S2I6 ('Availability or efficient allocation of workforce and resources' associated with the contractor).

Figure 3 shows the status centrality map of all stakeholder issues, giving an overall picture of the relative impact of every issue in the entire network. The stakeholder and issue categories are distinguished by different node shapes and colours, respectively. In this concentric map, the impact level of an issue reduces along the radial distance between the issue location and the centre, implying that issues with larger influence are positioned more proximately to the centre. As shown in Figure 3, most of the centrally positioned issues are associated with the contractor, client representative and the client

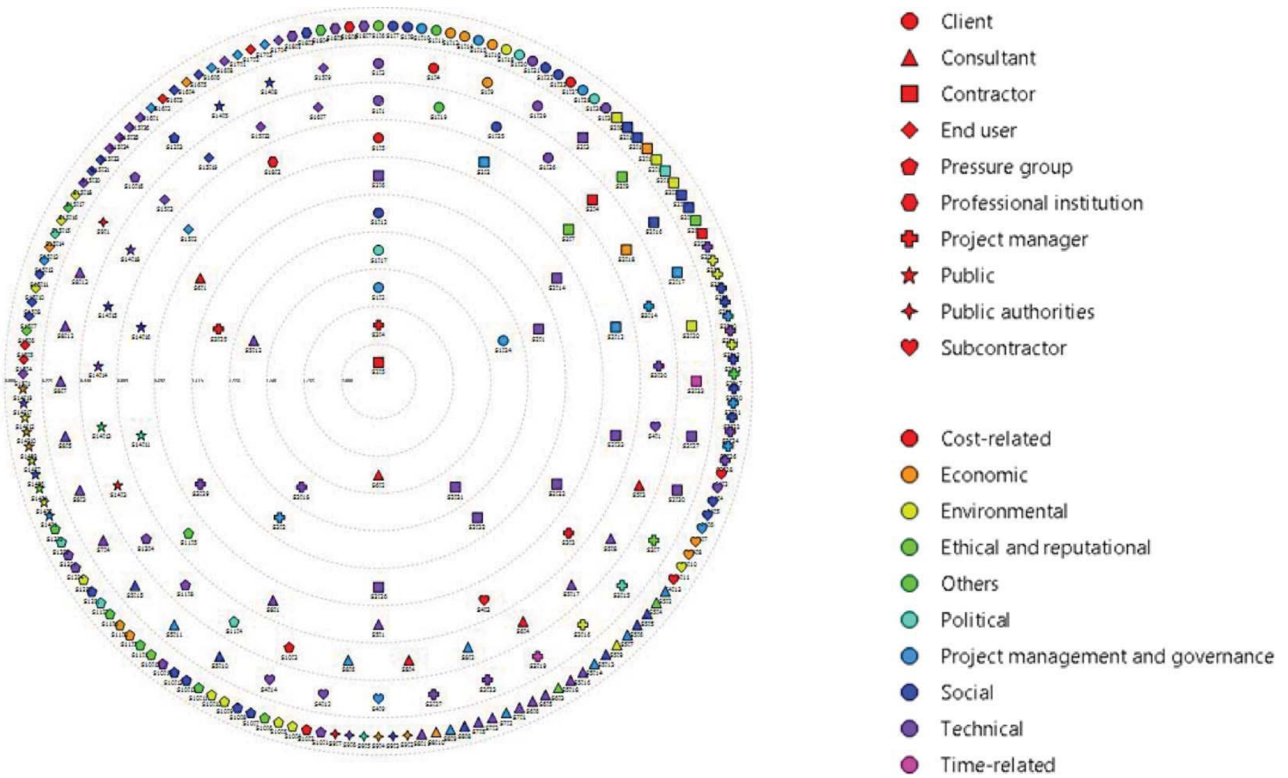

Figure 3.Distribution of stakeholder issues in the status centrality map.

authority, whereas the issues of pressure groups, professional institution, the general public and end users are situated more peripherally, implying that external stakeholders have limited impacts in the decision-making and implementation of public construction projects regardless of the emphasis on public consultation and participation by the government. Costrelated issues appear to be the most important issue category as reflected by their central positions. This finding is consistent with existing studies where cost overrun is the major pitfall of large construction projects arousing huge concerns from stakeholders (Flyvbjerg, Bruzelius et al. 2003; Flyvbjerg, Skamris Holm et al. 2003; Doloi 2013).

The top 15 stakeholder issues based on the brokerage scores are listed in Table 5. Stakeholder groups are chosen as the partition vector, in an attempt to investigate the different positions and functions of these issues in the interactions between

Table 5.Important stakeholder issues according to the brokerage scores.

Issue ID	Partition value	Coordinator	Gatekeeper	Representative	Itinerant	Liaison	Total

S2I5	Contractor	80	379	198	248	774	1679
S3I18	Project manager/supervisor	9	48	146	159	722	1084
S3I29	Project manager/supervisor	7	57	88	285	646	1083
S3I4	Project manager/supervisor	16	85	142	189	544	976
S2I31	Contractor	16	131	91	128	500	866
S1I2	Client	37	192	98	92	426	845
S2I7	Contractor	52	166	175	54	358	805
S2I26	Contractor	19	62	161	109	349	700
S1I24	Client	0	13	18	180	472	683
S3I2	Project manager/supervisor	20	66	131	87	357	661
S1I17	Client	15	164	38	47	348	612
S5I12	Consultant	7	46	72	75	331	531
S2I32	Contractor	12	60	72	84	288	516
S2I14	Contractor	19	57	73	54	182	385
S2I33	Contractor	0	12	0	156	212	380

various stakeholder groups. Attributed to its significant liaison and itinerant roles, S2I5 is determined as the most substantial issue with the highest brokerage value of 1679. By comparing Table 5 with the analyses of nodal degree, betweenness centrality and status centrality, three more critical issues are recognized, namely S2I7 (‘Enhancing company image and fulfilling corporate social responsibility’ associated with the contractor), S2I32 (‘Using innovative and efficient construction methods and technology’ associated with the contractor) and S2I33 (‘Vulnerability of the project end product to natural disaster such as earthquake' associated with the contractor). These issues serve as fulcrums in the interactions among different stakeholder categories; in the absence of these joints, the propagating effects evolved from these pairs of stakeholder groups can be eliminated. It is observed that most of the issues in Table 5 are related to the main contractor, suggesting its vital role in stakeholder engagement in pursuance of appropriate balance among diverse stakeholder interests.

Suggestions for stakeholder management measures

From the network perspective, a stakeholder issue is hard to address when it is interconnected with many other issues, because it can exert immediate and/or propagating impacts on its neighbouring issues, and cannot be handled as an independent problem. Therefore, network complexity, which can be indicated by network density and cohesion, helps to reflect the intricacy of stakeholder engagement and management process. In theory, network complexity can be reduced by weakening the propagating impacts between stakeholder issues that is, through addressing issues and eliminating relationships which play vital roles in connecting other issues. Consequently, developing stakeholder management measures which can alleviate key issues and remove critical issue interactions will help to decrease network complexity and facilitate the stakeholder management process. This section suggests stakeholder management measures for the said purpose on the basis of the previous network analysis results.

By consolidating the calculation results of nodal degree, node betweenness centrality, status centrality and brokerage, Table 6 compiles a list of 33 crucial stakeholder issues which ought to be paid particular attention. The core project team should treat these issues with high urgency and attempt to alleviate them, since they play important roles in connecting other issues and exert high immediate influences on many predecessors and successors. Among these issues, the majority are technical related (16); while others are mainly cost related (five) social related (five), project management and governance related (four political related (one) and ethical and reputational related (one). This result is consistent with the findings of Flyvbjerg (2014) who identified technical, economic, political and aesthetic sublimes as the four important drivers in the recent boom of large construction projects. Regarding stakeholder categories, most of the critical issues are associated with internal stakeholders, including eight from the main contractor, eight from the client representative, seven from the client authority and three from consultants. This observation explains why many previous studies on large construction projects have been conducted from the perspectives of internal stakeholders (Toor & Ogunlana 2009, 2010; Siva & London 2010; Memon & Rahman 2014). Seven issues are sourced from external stakeholders, in which the general public are the largest stakeholder group. This result is coherent with the findings of Manowong and Ogunlana (2008) and Li et al. (2013) where failure to accommodate the concerns of the public in large construction projects can lead to severe resistance and may eventually kill the project.

Based on the result of link betweenness centrality, a list of 15 critical links has been identified in Table 4, where enhancing collaborations between stakeholders associated with those source nodes and target nodes would help to remove these 15 key links. Accordingly, eliminating these relationships can disconnect a large number of issues, and disentangle the 'hairball' structure of the network into less complicated clusters. The project team should formulate stakeholder management strategies to alleviate the key issues (in Table 6) and to improve coordination between stakeholders relating to the main issue interactions (in Table 4). The development of these strategies should consider the identified key issues, together with the cause-and-effect relationships between particular issue pairs in the identified key links. Due to space limitations, only some of the suggested measures are listed in Table 7.

Simulating effectiveness of the suggested stakeholder management measures

Assuming all stakeholder management measures to alleviate key issues and eliminate main relationships are fully implemented, then the 33 issues and 15 links (as identified in Table 6 and 4) would be removed. This section illustrates an immediate simulation of the resultant stakeholder issue network, by removal of the identified key issues and links, and re-calculation of the network properties.

The simulation results can help the core project team to imitate the effectiveness of the suggested measures and to predict the potential of network complexity reduction.

In the simulation results, the resultant stakeholder issue network is diminished to a structure of 220 nodes and 624 interactions, as shown in Figure 4. In comparison to the initial network of Figure 1, three observations are found: (1) the network is less condensed, by reducing the linkages considerably; (2) the number of isolates increases, implying that more

Table6.Thecrucialstakeholderissuesinthecaseproject.

IssueID	Issue	Associatedstakeholder	Stakeholder category	Issuecategory
S1I2	Accommodatingtherequirementsofvariousendusers	Theclientauthority	Client	Projectmanagementandgovernancerelated
S1I5	Deliveringtheprojectwithinbudget	Theclientauthority	Client	Costrelated
S1I12	Enhancinginternationalreputationorimageofthecity	Theclientauthority	Client	Socialrelated
S1I17	Politicalinterferencetoprojectimplementation	Theclientauthority	Client	Politicalrelated
S1I24	Provisionofgoodincentivesandclearinstructionstosupportprojectimplementation	Theclientauthority	Client	Projectmanagementandgovernancerelated
S1I29	Sufficiencyandeffectivenessofpublicconsultation	Theclientauthority	Client	Technicalrelated
S1I31	Vulnerabilityoftheprojectendproducttonaturaldisastersuchasearthquake	Theclientauthority	Client	Technicalrelated
S2I5	Deliveringtheprojectwithinbudget	Thedesign-and-buildcontractor company	Contractor	Costrelated
S2I6	Availabilityorefficientallocationofworkforceandresources	Thedesign-and-buildcontractor company	Contractor	Technicalrelated
S2I7	Enhancingcompanyimageandfulfillingcorporatesocialresponsibility	Thedesign-and-buildcontractor company	Contractor	Ethicalandreputationalrelated
S2I14	Adoptinggreenandsustainabledesignandconstructionmethods	Thedesign-and-buildcontractor company	Contractor	Technicalrelated
S2I26	Achievingsatisfactoryconstructionsafetyperformance	Thedesign-and-buildcontractor company	Contractor	Technicalrelated
S2I31	Technicalcomplexityinstructuraldesignandconstruction	Thedesign-and-buildcontractor company	Contractor	Technicalrelated
S2I32	Usinginnovativeandefficientconstructionmethodsandtechnology	Thedesign-and-buildcontractor company	Contractor	Technicalrelated
S2I33	Vulnerabilityoftheprojectendproducttonaturaldisastersuchasearthquake	Thedesign-and-buildcontractor company	Contractor	Technicalrelated
S3I2	Accommodatingtherequirementsofvariousendusers	Theclientrepresentative	Projectmanager	Projectmanagementandgovernancerelated
S3I4	Deliveringtheprojectwithinbudget	Theclientrepresentative	Projectmanager	Costrelated
S3I8	Creationofaconvenientandcomfortablepedestriancirculationortransportnetwork	Theclientrepresentative	Projectmanager	Socialrelated
S3I18	Projectdesignintermsofdesignconcept,aestheticsandvisualpermeability	Theclientrepresentative	Projectmanager	Technicalrelated
S3I25	Stabilityagainstfluctuationofconstructionlaborandmaterialprices	Theclientrepresentative	Projectmanager	Costrelated
S3I27	Sufficiencyandeffectivenessofpublicconsultation	Theclientrepresentative	Projectmanager	Technicalrelated
S3I29	Usinginnovativeandefficientconstructionmethodsandtechnology	Theclientrepresentative	Projectmanager	Technicalrelated
S3I30	Vulnerabilityoftheprojectendproducttonaturaldisastersuchasearthquake	Theclientrepresentative	Projectmanager	Technicalrelated
S5I12	Projectdesignintermsofdesignconcept,aestheticsandvisualpermeability	Leaddesigner	Consultant	Technicalrelated
S6I2	Exercisingstringentcostcontroltoensuretheprojectisdeliveredwithinbudget	Quantitysurveyor	Consultant	Costrelated
S8I6	Formationofprojectcoalitionorcollaborativeeffortsamongprojectstakeholders	Leadbuildingservices designer	Consultant	Projectmanagementandgovernancerelated
S12I3	Provisionofbarrier-freefacilitiesforthedisabled	NGO(socialwelfare-related andrehabilitation services-related)	Pressuregroups	Socialrelated
S14I13	Possibilityandfreedomofaccesstoproject-relevantinformationbycivilsociety	Thegeneralpublic	Generalpublic	Others
S14I15	Provisionofbarrier-freefacilitiesforthedisabled	Thegeneralpublic	Generalpublic	Socialrelated
S14I16	Provisionofpublicspaceandamenities	Thegeneralpublic	Generalpublic	Socialrelated
S14I18	Sufficiencyandeffectivenessofpublicconsultation	Thegeneralpublic	Generalpublic	Technicalrelated
S15I22	Provisionoftightsecuritymeasuresandfacilities	EndusersofOfficeTowerA	Endusers	Technicalrelated
S16I7	Provisionoftightsecuritymeasuresandfacilities	EndusersofOfficeTowerB	Endusers	Technicalrelated

Note:“NGOs”referstonon-governmentalorganizations.

Table 7.Suggested measures to enhance stakeholder collaboration and eliminate the key issue relationships.

Critical links between issues	Corresponding stakeholder management measures
S1I2 ! S2I5	Contractor should actively and continuously communicate with client to fully understand the changing security and accommodation requirements of end users. In addition, contractor should consider potential cost increase caused by subsequent design changes before deciding whether to incorporate the changing requirements.
S2I31 ! S1I5	Client and contractor should communicate on potential additional cost items, particularly those caused by construction of technically complex building/structural elements.
S1I17 ! S3I27	The client representative, who acts as project manager/administrator, should maintain high transparency and effectiveness of public consultation so as to mitigate potential controversies and political interference encountered by the client.
S1I12 ! S2I14	Contractor should communicate more with the client to fully understand its expectations on green design and sustainability performance which eventually help to enhance project and city images.
S1I12 ! S3I18	The client representative (who acts as project manager/administrator) should improve its internal communication channels with the client to fully understand its expectations on project design (in terms of design concept and aesthetics) which eventually helps to enhance project and city images.

S15I3 !	S2I31	End users of Office Tower A highly concerned about the building adaptability for future expansion, so contractor should take this concern into its design and construction considerations.
S14I15 !	S3I29	The client representative should fully understand the general public's expectations on the provision of barrierfree facilities in its adoption of innovative construction methods and technologies.
S3I18 ! S16I1 !	S14I15 S14I16	The general public should actively participate in public consultation to reflect their expectations regarding the provision of barrier-free facilities and public space, so that the project team can maintain an appropriate balance between the public's expectations, the project design and the end users' requirements.
S2I5 !	S1I17	The client should mitigate potential controversies and political interference by imposing stringent cost control on contractor during the entire project life cycle.
S14I15 !	S1I17	The client should mitigate potential controversies and political interference by accommodating the general public's expectations on the provision of barrier-free facilities.
S14I6 !	S1I17	The client should mitigate potential controversies and political interference by minimizing possible disturbances to affected vicinity and the general public owing to project implementation.
S3I4 !	S17I3	The client representative and end users of Office Tower C should communicate more on issues regarding operational requirements and getting statutory approvals, and consider their subsequent cost implications.
S3I30 !	S1I24	The client should clearly reflect its expectations and requirements on seismic-resistant works in early project stages, so that the client representative (who acts

as project manager/administrator) can define clear implementation details and engage the right experts/professionals into the project team at the outset.

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stakeholder issues can be handled individually without propagating effects; and (3) dyadic interactions increase where the project team would find them easier to be managed by focusing on the particular cause-and-effect relationships. The reduced network complexity is also reflected by the figures of network properties. The density and cohesion of the resultant network in Figure 4 are 0.013 and 0.019. Compared with the original network density and cohesion of 0.029 and 0.082, they have declined by 55.17% and 76.83%, respectively. According to the simulation results, the suggested stakeholder management measures appear to be useful to decrease the network complexity and facilitate the stakeholder management process. In practice, to cope with the dynamic character of project environment and relationships, the stakeholder issue network should be continuously monitored and assessed, and the stakeholder management strategies should also be adjusted corresponding to the updated network assessment results.

Discussion and lessons learnt

This study aims to identify the underlying network of stakeholder-related issues, as well as the important stakeholder issues and issue interrelationships in large construction projects using network theory-based analysis. This paper demonstrates the method and procedures of the network approach through case study of a US$645 million office building development, and contributes to lessons learnt for future large public construction projects in Hong Kong.

The government is regarded as the most influential stakeholder in large public construction projects in Hong Kong since it often plays the simultaneous roles of project proponent and project administrator. As shown in the network analysis results, most of the critical issues and links were associated with the client and client representative. This can be explained by the project organizational structure in which the government (client) and its working department (client representative)

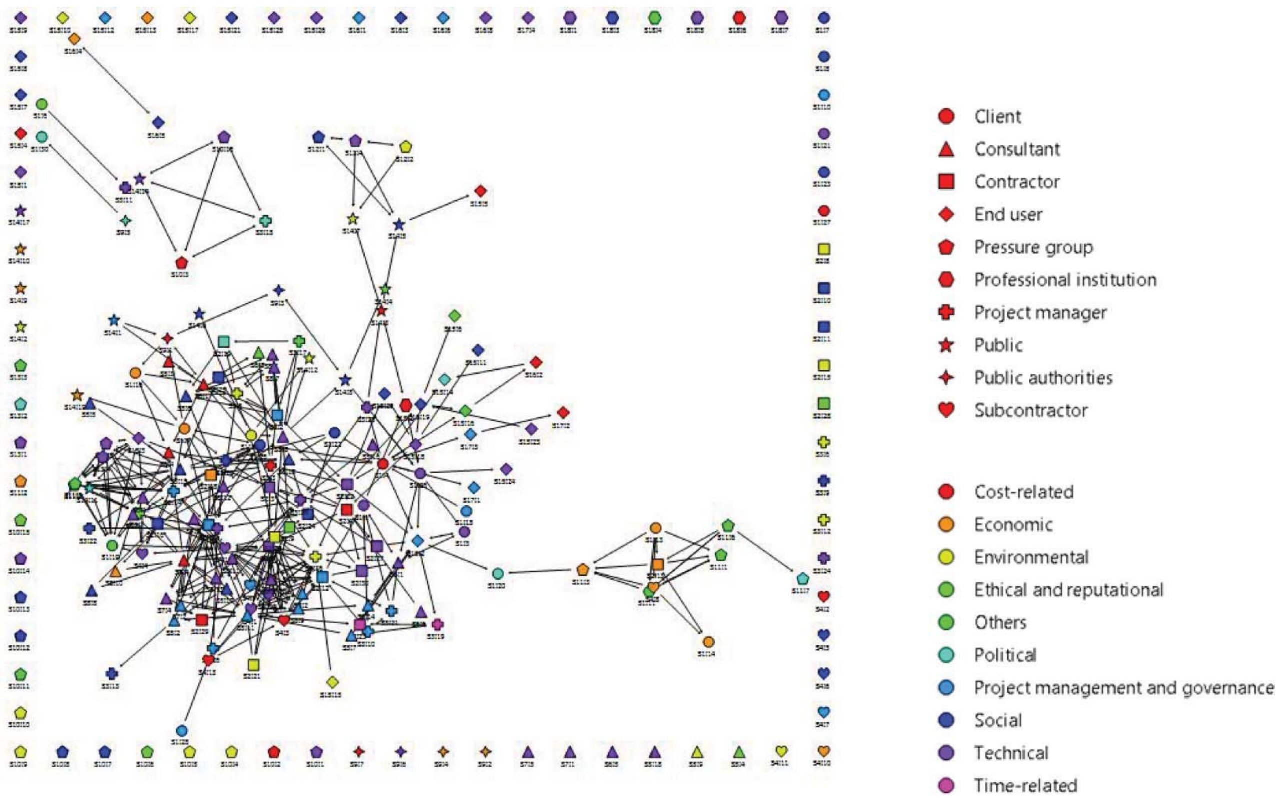

Figure 4. The resultant network assuming removal of key issues and links after full implementation of stakeholder management measures.

owned the authority and rights in establishing project goals; creating compulsory requirements for compliance of end users in developing the ER; and making final decisions on what to incorporate in the ER and design requirements. According to Lundrigan and Gil (2013), the contractor is considered a part of the supply chain located at the periphery of the project core who provides labour, technologies and specialized knowledge to construct, and exerts limited influence on the design. The situation is somehow different in our case study and the main contractor was the source of many important nodes and links. This can be attributed to the D&B procurement arrangement where the main contractor possessed the power and rights in developing the design and selecting his own supply chain members to produce project deliverables. In large construction projects procured under D&B, communications and coordination among the government and main contractor are particularly crucial as they are the major players in accommodating stakeholder interests and achieving stakeholder satisfaction.

Handling public controversies and political interference is a major challenge encountered by the core project team in recent large public developments in Hong Kong. In our case, notwithstanding that the general public is not a major end user, it was the source of many key nodes and links in the stakeholder issue network. The general public has paid considerable attention to issues on value for money, cost effectiveness, public consultation sufficiency, and democratic access to project information. This can be attributed to the public accountability of the government. As taxpayers and an indirect funder of large public developments, the general public places particular emphasis on proper utilization of the public treasury and the effectiveness of public engagement. Therefore, it is crucial for the government to ensure stringent cost control and maintain democratic dissemination of project knowledge to the public from time to time; failure in doing so can lead to unexpected resistance from the public and politicians on project execution.

In Hong Kong, it is a common phenomenon that the government borrows insights on new construction technologies/ innovations from overseas experience and puts them into practice in local large public projects. It is seen as a way to push forward technological advancement in the local construction industry as well as to strive for better project performance. The case project is an example as it is the first construction in Hong Kong adopting seismic-resistant measures in building structure. For successful delivery of a D&B project, it is crucial for the ER to reflect clearly the client's expectations. However, in our case, without relevant local building codes and previous experience, the government was not able to state precisely its requirements on seismic-resistant items in the ER. Consequently, the contractor underestimated the level of technical complexity did not engage the right expertise into the project supply chain at the outset, leading to extra time and resources and compromising quality in other work items. For similar projects in future, the government should put more effort into pre-project planning and the contractor should enhance communication with the client to gain full understanding on its expectations at the outset even if they are not clearly reflected in the ER.

Conclusions

The absence of a systematic method of analysis of stakeholder issues and their interrelations in large construction projects is a reason impeding the enhancement of collaborative working and informed decision-making between project team members in complex environments. This study contributes to the body of knowledge by merging the beauty of network theory and the classical stakeholder management approach. This paper explored the underlying network of stakeholder issues in large construction projects using network analysis, and identified key issues and issue interactions which exert high influences on other issues directly or indirectly. Network variables and analytical procedures were illustrated in detail, and were demonstrated through a case study of a large-scale office building project. Resolving stakeholder issues and eliminating relationships which play important roles in issue interconnection will help to reduce network complexity and ease the stakeholder management process. Some measures which would help to improve stakeholder coordination were suggested to address these main issues and interactions. Assuming an ideal case of the full implementation of these measures, the identified critical issues and links had been removed, while network density and cohesion were re-calculated to simulate the usefulness of the suggested measures. The use of network analysis in modelling and deciphering the stakeholder issue network can break the barriers of conventional stakeholder analysis. Applying this network approach in other major construction projects can enrich the understanding of the project team on stakeholder interests and shed insights into stakeholder management challenges.

In the case study, six network metrics were used to investigate structural characteristics of the stakeholder issue network. Among them, network density, nodal degree and betweenness centrality are considered the most useful to provide information other than what conventional stakeholder analysis could have revealed. Network density measures the number of issue relationships that are actually present in a network; it gives a straightforward indication of the connectivity of stakeholder concerns, and implies the complexity of the stakeholder management process. Nodal degree calculates the direct impacts that a stakeholder issue releases/receives, and categorizes issues into different types (e.g.

isolated, transmitter and receiver) based on their proportion of in-/out-links. This metric quickly highlights key issues to which the project team should pay high attention, and reveals issues that could be handled as stand-alone problems. Betweenness centrality calculates the extent to which an issue/link joins other network actors which would alternatively be separated. It is useful in revealing the potential 'cut-off' points of the network, so that the project team can develop measures to enhance stakeholder coordination, reduce network complexity and facilitate the stakeholder management process. In fact, every network indicator serves unique purposes and therefore no single metric can be considered the most useful. In practice, different projects may apply different combinations of network indicators, and this would be context-specific.

The case study results yielded some meaningful findings and lessons learnt for large public construction projects in Hong Kong. First, the government (as the project proponent and administrator) and the D&B contractor are the most influential stakeholders due to their high proximity to the project core, as well as their power and rights in establishing the design requirements. Many issues and links originating from the government and main contractor are closely interconnected; in particular the issues over end users' requirements, the application of new construction technologies and technical complexity. Therefore, communications and coordination among the government and contractor should be enhanced to facilitate their mutual understanding of stakeholder expectations and to clear ambiguities in the ER. Additionally, the general public is considered the most influential external stakeholder, where tremendous challenges have been encountered by the core project team in handling public controversies over concerns regarding value for money, public participation effectiveness and public access to project relevant information. The government, which plays a leading role in project governance and administration, should improve its performance in cost monitoring and public engagement, in an attempt to minimize potential resistance from the public and politicians.

This study is subject to several limitations which should inspire future research opportunities. First, despite the use of snowball sampling in the node identification process, it is unlikely to reach all stakeholders in reality. Engaging all stakeholders in the case project would be ideal to improve the quality and accuracy of stakeholder issue analysis. Second, the network in this case study only captures a snapshot of the stakeholder issues and issue relationships at a single point in time in the design-and-construction stage. Stakeholder communities, their concerns and propagating effects are constantly changing in construction projects. Therefore, periodical network analyses of stakeholder issues and relationships during the entire project life cycle would help to cope with the dynamics of the project environment and network. In practice, network analysis could be conducted regularly and periodically through updating network data, re-visualizing the issue network, re-computing network indicators and correspondingly adjusting the stakeholder management strategies, so as to monitor and manage the network dynamics. Finally, the findings on critical stakeholder issues and links in large construction projects were based on an individual case project. As no two projects are the same, case studies on different types of large-scale development, such as urban redevelopment and transport infrastructure, could be undertaken in future to compare and consolidate the research findings. It is expected that identification and structural investigation of stakeholder issue networks can help the core project team to better accommodate conflicting stakeholder interests and increase the overall effectiveness of stakeholder management in large construction projects.

Acknowledgements

The work described in this paper was supported by the Research Grants Council of the Hong Kong Special Administrative Region, China under Grant PolyU 5246/12E.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

Research Grants Council, University Grants Committee [grant number PolyU 5246/12E].

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