
Creative Construction Conference 2016

# A Network-Theory Based Model for Stakeholder Analysis in Major Construction Projects

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**Abstract**

The high complexity and uncertainty of major construction projects (MCPs) call for a rigorous approach to manage the relationships and conflicting needs of stakeholders who act a pivotal role in project success. During the past decades, there has been an unsatisfactory stakeholder management record in the construction industry. Despite a rapid advancement of stakeholder analysis methods, project teams still face challenges in completely identifying stakeholders and their concerns, and accurately evaluating their relationships and impacts. These obstacles are attributed to the weaknesses of the current stakeholder analysis practice, in which project teams categorize and prioritize stakeholders by assessing their individual attributes based on empirical knowledge of team members. The weaknesses are threefold. First, 'hidden' stakeholders are often missed out in the identification process due to cognitive limitation. Second, the accuracy of assessment is limited due to subjectivity. Third, the basis for evaluation relies heavily on the dyadic relationships between project teams and stakeholders; neglecting both the actual stakeholder interrelationships and stakeholder issue interdependencies.

In reality, a project environment can be perceived as network systems composed of interconnected stakeholders, as well as of interrelated stakeholder issues. The characteristics of and propagating effects produced by these network structures determine the perceptions, salience and impacts of project stakeholders. To overcome the limitations of current practice, this paper proposes an innovative stakeholder analysis approach based on the network theory. In this paper, the sources of stakeholder complexities in MCPs are firstly discussed. The existing stakeholder analysis methods are reviewed with their limitations highlighted. A network-theory based stakeholder analysis approach for MCPs is proposed. Its process and network analysis techniques are introduced. Taking a network perspective to analyze both stakeholders and their interests can benefit researchers and industry practitioners by improving the accuracy, completeness and effectiveness of the stakeholder management practice in construction.

**Keywords:** stakeholder analysis; network analysis; network theory; major construction project

## 1. Introduction

Managing stakeholder relationships and interests has been increasingly regarded as a critical yet challenging task in the successful delivery of major construction projects (MCPs). MCPs involve numerous stakeholder groups who have discrepant concerns and expectations, and are interrelated by multiple kinds of social interactions in the project. MCP development can readily produce positive and negative impacts to the vested interests of stakeholders; who are making their best endeavor, in different ways, to increase the project team's salience in avoiding their interests from being put in peril [7]. Stakeholders can even be allied to build a stronger resistive force in safeguarding their interests. Ineffectively addressing stakeholder needs often harms the project and leads to failures.

Stakeholder analysis is an essential element of MCP management to understand the stakeholder environment; conventionally, it comprises four main parts: (1) identification of stakeholders and issues; (2) stakeholder classification based on individual attributes; (3) examination of stakeholder relationships, and (4) evaluation of stakeholder influences [9]. Notwithstanding the recent growth of project stakeholder analysis theories and practical

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approaches, the record of stakeholder management in MCPs has still been criticized as unsatisfactory. There are limitations in the existing stakeholder analysis practice, which have put obstacles on project teams to fully identifying stakeholders and their issues, and accurately evaluating their relationships and impacts [11]. This paper aims to improve stakeholder analysis practice in MCPs by proposing a network-theory based model. The paper firstly reviews the existing stakeholder analysis methods and highlights their weaknesses, a network perspective is then suggested to tackle the problems. Lastly, a network-theory based model for stakeholder analysis in MCPs is proposed, with its process and network measures discussed.

## 2. Stakeholder complexities in MCPs

Stakeholders refer to any groups or individuals "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 and indirect benefits and/or loss" [5]. In MCPs, the complexity of stakeholders can be analyzed from three aspects: (1) stakeholder issues and their interdependencies, referring to what stakeholders concern about in the project and how these stakes are interrelated; (2) relationships and interactions of stakeholders, referring to the social interactions of these entities; and (3) dynamics of stakeholders and issues, referring to how the stakeholder community and stakeholders' interests change over time as the project proceeds. This section discusses stakeholder complexities in MCPs in detail.

### 2.1. *Stakeholder issues and their interdependencies*

The development of MCPs can readily attract and influence the vested interests of various stakeholder groups. Stakeholder issues, being described as the vested interests or concerns of project stakeholders, are often discrepant and dynamic owing to the disparate stakeholder backgrounds in the changing project circumstances. New stakeholders and issues often emerge in response to the changing environment; priorities of issues may also vary among different stakeholder groups. The conflicting stakeholder interests may result in project threats and failures if they are insufficiently accommodated. Comprehensive identification and prioritization of stakeholder interests have attracted attentions in previous studies. Li et al. [5] identified the main stakeholder concerns in the planning and design of large public infrastructure projects and investigated their different priorities among the government, general public, pressure groups and the affected vicinity. Zeng et al. [13] identified the key stakeholder issues in major engineering projects which relate to the fulfillment of project social responsibility. Existing publications have enriched our understanding about stakeholder concerns in MCPs. However, the evaluation and prioritization of issue importance have relied heavily upon the subjective judgment of individual stakeholders; disregarding the actual interdependencies between stakeholder issues and the propagating impacts produced by the issue network. As such, a rigorous method is in need to analyze stakeholder issue interdependencies and assess their impacts on each other.

### 2.2. *Relationships and interactions of stakeholders*

In MCPs, stakeholders are connected directly or indirectly by many kinds of relationships across functional and organizational borders, so they are embedded in various social networks instead of being isolated in vacuum. Earlier studies paid much attentions on formal relationships of stakeholders; for instance the contractual relationships between project organizations concerning resources sharing and supply of construction services [8], and the hierarchical relationships between intra-organizational project participants. Recent studies shift the focus towards informal relationships of stakeholders, and pay considerable efforts on improving the strategies of relationship management towards project success. In the studies of Cross and Parker [3], informal stakeholder relationships are classified into four kinds; including collaborative relationships, information/knowledge exchange relationships, power/influence relationships, and interpersonal relationships (e.g. emotional support, trust). Chinowsky et al. [2] also stated that communication and information/knowledge sharing are important social networks to be analyzed for achieving high performance in MCPs. Stakeholders do not exist independently in a project environment. The relationships and interactions of stakeholders are major factors determining stakeholders' behaviors and strategies to safeguard their vested interests. Accordingly, a systematic method is needed to examine the interactions of stakeholders and their roles in these relational structures.

### 2.3. *Dynamics of stakeholders and issues*

The composition of stakeholder community is changing over time in response to the dynamic project environment, so as stakeholder relationships, their issues and issue interdependencies. To cope with such dynamics, continuous monitoring and updating are necessary for the entire stakeholder analysis process regardless of the methods adopted.

## 3. Existing project stakeholder analysis methods and their limitations

Due to the highly uncertain, volatile and complex nature of MCPs, the stakeholder environment in MCPs is also highly complicated, requiring a set of systematic methods and procedures to manage stakeholder relationships and issues. Stakeholder analysis is essential in stakeholder management process as it allows project teams to understand the stakeholder environment and develop appropriate engagement strategies. This section reviewed some traditional stakeholder analysis methods in previous studies and highlighted their limitations.

### 3.1. *Attribute-based stakeholder classification*

Stakeholder Salience Model is an attribute-based classification method widely used in the construction management domain [6]. Power, legitimacy and urgency are three key attributes forming the basis of classification. Power is described as the capability of stakeholders through relationship dependency and resources occupation [12]. Legitimacy describes how appropriate the stakeholder claims or behaviors are according to the norms and core values of social organizations. Urgency refers to the level in which a stakeholder claim requires instant response or awareness, depending on the time sensitivity of the issue and its necessity to the stakeholder [12]. By considering stakeholders' possession of these attributes, project management teams can perform stakeholder categorization, determine the degree of salience paid on stakeholders, and assess their impacts. This method is time-efficient as data can be easily obtained via focus groups or interviews. However, the attribute assessment and classification of stakeholders are perception-driven and may result in bias; for example, the same stakeholder may be put into different classes by different respondents.

### 3.2. *Impact-probability matrices*

In impact-probability matrices, project teams assess stakeholder influences and predict their likely behaviors by categorizing stakeholders in terms of two aspects [7]: (1) the level that a stakeholder can impact the project; and (2) the probability for this impact to occur. There are many variations of this method in the project stakeholder management domain, e.g. stakeholder vested-interest impact index, power/interest or power/predictability matrices.

### 3.3. *The Stakeholder Circle tool*

Stakeholder Circle methodology covers the stakeholder management process more completely by including ways for stakeholder visualization, engagement, and evaluation of communication effectiveness [1]. Comparing with the above methods, this tool prioritizes stakeholders and assesses their impacts in a more structured way. For instance, Bourne [1] modified the stakeholder salience model and replaced legitimacy with another key attribute, proximity; which describes the extent that a stakeholder is directly engaged in the project. This method also illustrates the nature of stakeholder influences by indicating the directions of stakeholder impacts to the project team, as well as the scope and degree of impacts. In certain extent, this tool considers the dyadic relationships between stakeholders and focal organization in its assessment. However, in reality, stakeholders are connected by many social interactions and embedded in relationship networks. This tool, building upon dyadic stakeholder relationships, are thus inadequate to address stakeholder complexities in MCPs.

This section reviews some important existing stakeholder analysis approaches developed in previous studies. It indicates that the current stakeholder analysis methods in MCPs are linear and subjective. They have disregarded some important aspects of stakeholder complexities, such as *stakeholder interactions*, *stakeholder issue interdependencies*, and *propagating impacts produced by these network systems* (i.e. stakeholder network and issue network); resulting in limited accuracy and effectiveness in project stakeholder analysis. The next section discusses the potential of applying a network perspective for addressing stakeholder complexities in complex project environment.

## 4. Potential of using a network perspective for stakeholder analysis in MCPs

### 4.1. *Network-theory based analysis*

The network theory was firstly introduced in 1930s, this methodology systematically analyzes the relational structures of a definite set of actors, by visualizing the structures using sociographs and quantitatively deciphering the structural pattern with network indices [4]. According to Wasserman and Faust [10], the performance and robustness of a network system are readily affected by the interconnected elements within this system, as well as the ways that these elements are linked together. As such, using network-theory based approach for stakeholder analysis can help to understand interactions of stakeholders, cause-and-effect relationships between stakeholder issues, as well as the resultant impacts of these on project delivery. There are five general steps of the network methodology, namely (1) defining the network boundary (i.e. which stakeholders/issues to be included); (2) identifying and assessing the interdependencies of network actors ; (3) visualizing the networks; (4) examining the network structures using network indices; and (5) developing management actions and strategies in response to the analysis results [12].

### 4.2. *Why using a network perspective*

To improve the conventional stakeholder analysis practice, a network perspective can be used to analyze two key aspects of stakeholder complexities, namely (1) *stakeholder interactions* and (2) *stakeholder issue interdependencies*. In MCPs, stakeholders are connected by many different kinds of social interactions, e.g. trust and communication [8]. In this study, we focus on knowledge exchange between stakeholders among the various kinds, as it is an essential type of social interactions for collaboration of project participants. Herein, knowledge exchange refers to the transfer of skills/expertise to explain the ways of doing something and to explore ways for improvement [2]. Stakeholder issue interdependencies in the project is another key aspect to be analyzed because issues emerging from a MCP are interrelated. The presence and incidence of an issue can trigger the other issues to occur and affect their perceived importance under chain effects. The issues of a project are under direct, indirect or mutual impacts from each other. Neglecting these interdependencies will reduce the accuracy and completeness of stakeholder impact assessment. The following section introduces a network-theory based approach for analyze stakeholder interactions and stakeholder issue interdependencies in MCPs.

## 5. The network-theory based model for stakeholder analysis in MCPs

Figure 1 shows the proposed network-theory based stakeholder analysis model for application in MCPs. This model aims to analyze stakeholder relationships and interests from a network perspective, identify key stakeholders and issues, and develop appropriate management strategies to engage stakeholders and accommodate their concerns.

This model comprise four major steps and two parts of network analysis: (1) *establish the context and stakeholder analysis planning* – this is to create an initial understanding of the project environment (e.g. project goals, objectives, constraints, organizational structures, etc.) and the context in which project stakeholder analysis will be undertaken; (2a) *a network-theory based analysis of stakeholder-related issues* – this analysis helps to identify critical issues and issue-interdependencies which exert great direct/propagating impacts on other issues/links; (2b) *a social network analysis of stakeholders* – in this model, the knowledge exchange relationships between stakeholders are analyzed based on three relationship attributes (frequency, quality of knowledge, and timeliness of access). In other occasions, social interactions of various kinds (e.g. information flow, communication) can be studied. This analysis helps to identify key stakeholders (e.g. central connectors, boundary spanners, knowledge brokers) and also peripheral ones. It should be noted that Step (2a) and (2b) should be conducted in parallel, as their results complement each other. The network measures used in analyzing stakeholder knowledge network and issue network are introduced in Table 1; (3) *consolidate the network analysis results* – the outcomes of this step are the lists of key stakeholders (with their roles/positons in project knowledge exchange), and the critical issues and interdependencies which worth project team's attention; and (4) *develop and simulate stakeholder management strategies* – this is to formulate proper management measures for improving stakeholder engagement (e.g. decentralizing the network for long term knowledge sharing, protecting the weak ties, exploring innovative knowledge from peripheral stakeholders) and accommodating critical stakeholder issues. Quick simulation of the proposed measures can be carried out by re-calculating the network measures. Since the stakeholder community, their social interactions and issues are changing in response to project environment, the whole process of the model require continuous recording, monitoring and updating; as well as continuous communication and consultations with the stakeholders involved.

Table 1: Network measures and their explanation in the network-theory based stakeholder analysis model.

| Network measures | Theoretical meaning | Practical meaning for: Stakeholder knowledge network | Practical meaning for: Stakeholder issue network |
|---|---|---|---|
| Network density | The ratio of current links to the greatest number of ties if all nodes are interlinked | Denser network → more occurrence of knowledge exchange | Denser network → more issues are interconnected |
| Network cohesion | The average distance of path to meet nodes of a network | Higher cohesion → longer knowledge flow time | Higher cohesion → more complex network |
| Degree centrality | The number of immediate links directed to (in-degree) or given off by (out-degree) a node | Higher degree → more knowledge flow to/from a stakeholder | Higher degree → larger immediate impact to/from an issue |
| Betweenness centrality | How often a node falls between two non-adjacent nodes based on shortest path | Higher betweenness → greater control by a stakeholder on its two neighbours | Higher betweenness → greater control by an issue on its two neighbours |
| Closeness centrality | How far is a node to meet every other else in the network | Higher closeness → harder for stakeholder to act alone | Pay more attention to issues with higher closeness |
| Brokerage | The role of a node (e.g. representative, gatekeeper) when bridging subgroups | Higher brokerage → easier to discover new knowledge in other subgroups | Pay more attention to issues with higher brokerage |

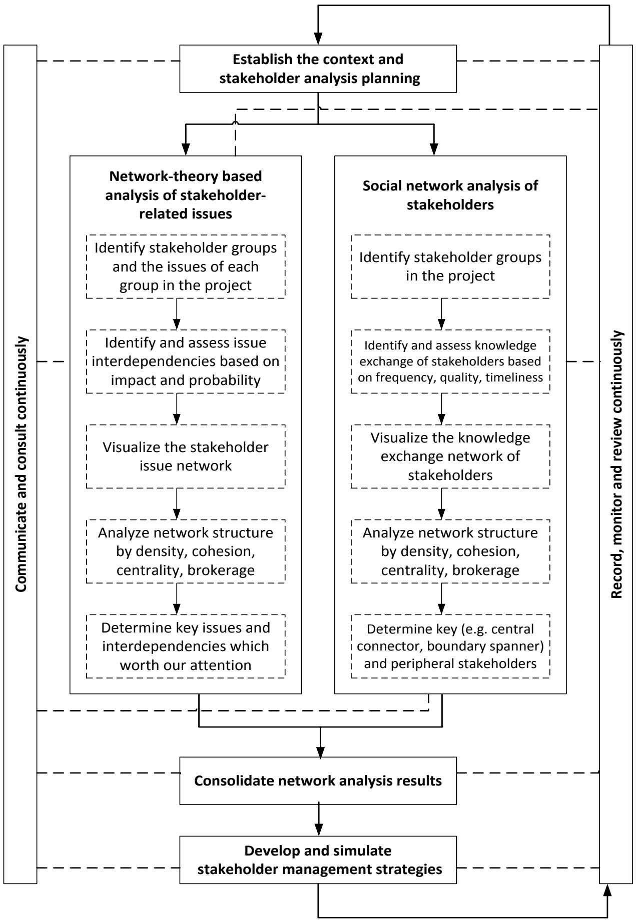


Figure 1: The conceptual network-theory based model for stakeholder analysis in MCPs.

## 6. A hypothetical case study

This section presents a hypothetical case study to illustrate the use of the proposed network-theory based approach. Due to the limitation of space, only part of the network analysis results are shown.

### 6.1. *Drawing the network boundary*

In this case study, two networks are built and analyzed: (1) stakeholder knowledge exchange network, and (2) stakeholder issue network. Drawing network boundaries is the first task to be done, which involves the identification of stakeholders, knowledge exchange relationships of stakeholders, stakeholder issues, and issue interdependencies. Snowball rolling method is a suitable means for stakeholder identification because it helps to recognize nearly all stakeholder entities; while desktop studies on project documents, interviews and workshops with core project team members can be conducted to identify stakeholder issues in the project. Questionnaire surveys, in matrix form, can be used to define and assess stakeholder knowledge exchange interactions (based on the frequency) and issue interdependencies (based on the impact exerted by an issue on others and the probability of such impact). Table 2 shows the stakeholder groups and the issues of each group in this hypothetical case. In this case, the six stakeholders are linked by 28 knowledge exchange relationships, resulting in a stakeholder network N(6,28). Besides, the issues of stakeholders are related by 72 interdependencies, resulting in an issue network N'(19,72).

Table 2: Stakeholders and their issues identified in the case project.

| Stakeholder | Stakeholder code | Issues of each stakeholder | Issue code | Issue category |
|---|---|---|---|---|
| Client | S1 | Delivering the project within budget | S1C1 | Cost |
| | | Time overrun | S1C2 | Time |
| | | Performance of contractors | S1C3 | Quality |
| | | Company image and reputation | S1C4 | Ethical |
| Executive project manager | S2 | Sequencing of construction activities | S2C1 | Time |
| | | Communication and collaboration of the project team | S2C2 | Project management |
| | | Pollution and environmental mitigation | S2C3 | Environmental |
| Lead design consultant | S3 | Building aesthetics | S3C1 | Quality |
| | | Meeting the requirements of client and end users | S3C2 | Quality |
| | | Green design | S3C3 | Technical |
| Contractor | S4 | Construction safety | S4C1 | Safety |
| | | Contractual dispute and claims | S4C2 | Contractual |
| | | Inflation of material and labour cost | S4C3 | Cost |
| | | Site logistics | S4C4 | Technical |
| | | Technical complexity | S4C5 | Technical |
| Quantity surveyor | S5 | Project cost control | S5C1 | Cost |
| | | Contract administration | S5C2 | Contractual |
| Subcontractor team | S6 | Construction safety | S6C1 | Safety |
| | | Material and labour supply | S6C2 | Technical |

### 6.2. *Visualizing the networks*

This case study applies NetMiner for network visualization as it is capable in exploratory network data processing. Basically, the main node sets and link matrices are the primary inputs for this software. The stakeholder knowledge exchange network and the issue network are shown in Figure 2(a) and 2(b) accordingly. In both figures, node shapes represent the stakeholders; while a more central stakeholder is denoted by a bigger node. In Figure 2(b), node colors indicate the issue categories.

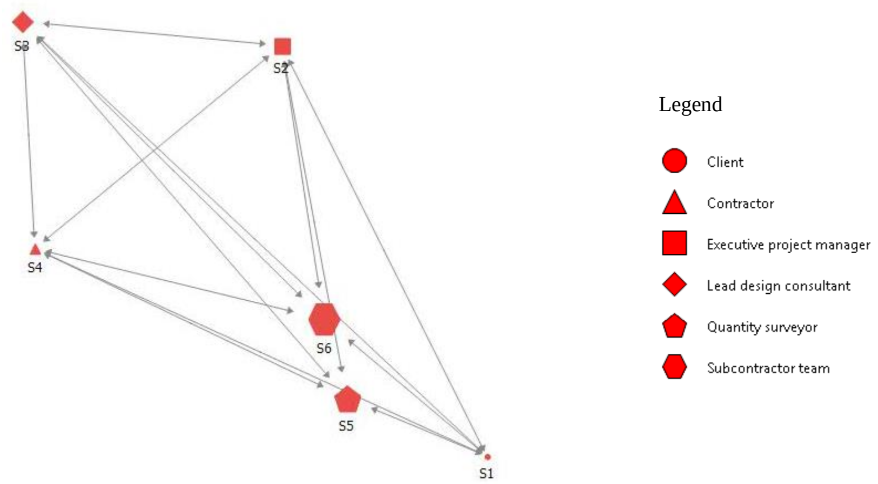


Figure 2(a): Stakeholder knowledge exchange network in the case project.

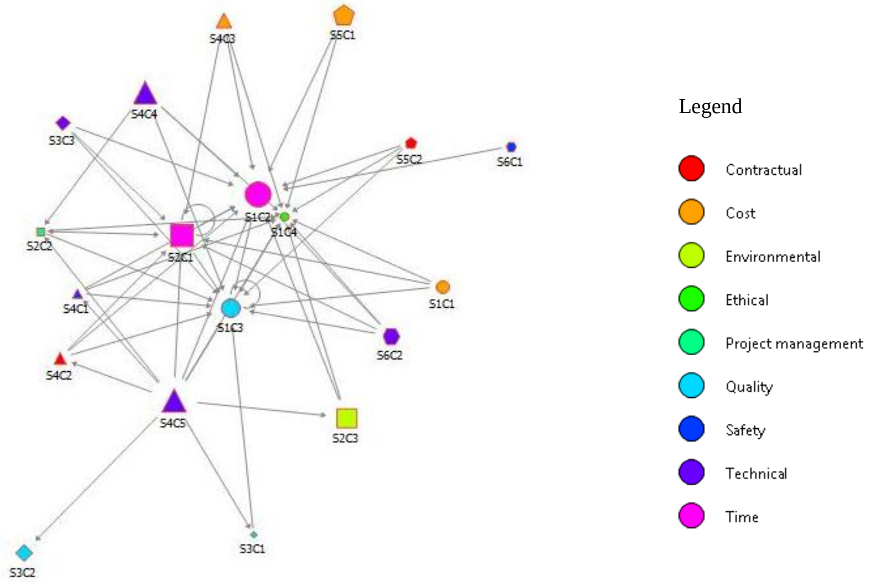


Figure 2(b): Stakeholder issue network in the case project.

### 6.3. *Preliminary network analysis results*

Degree centrality refers to the number of immediate links directed to (in-degree) or given off by (out-degree) a node. Figure 3(a) and 3(b) shows the out-degree centrality maps of stakeholders and stakeholder issues in the case. According to Figure 3(a), S1 (client), S2 (executive project manager), S3 (lead design consultant) and S4 (contractor) occupy the central position of the concentric map. All these four stakeholders have the maximum out-degree value of 1, indicating that they transfer knowledge to each of the other stakeholders very frequently. According to Figure 3(b), three concerns of the client, namely S1C2 ('Time overrun'), S1C3 ('Performance of contractors'), and S1C4 ('Company image and reputation') are the most central issues in the concentric map. They are ranked top three in the out-degree result, with the values of 0.56, 0.22 and 0.22 respectively; indicating that they are the issues giving the greatest direct impact to other immediate neighbours in the case.

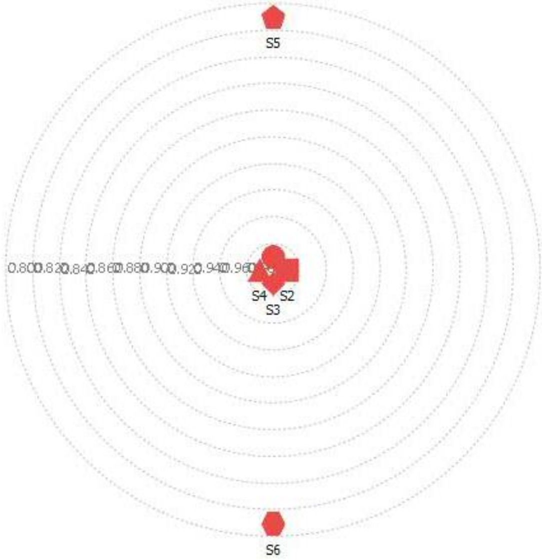


Figure 3(a): The concentric out-degree centrality map of stakeholders

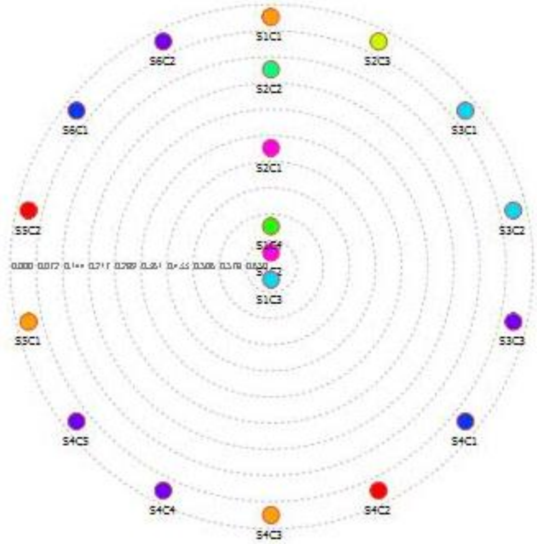


Figure 3(b): The concentric out-degree centrality map of stakeholder issues

## 7. Conclusions

The existing stakeholder analysis practice in MCPs has been criticized as linear and intuitive. These methods often omit the 'hidden' stakeholders and issues, overlook stakeholder interrelationships and issue interdependencies, thereby become insufficient to address stakeholder complexities in MCPs. This paper suggests a network perspective to tackle these problems, and proposes a conceptual network-theory based model for stakeholder analysis in MCPs. By using network analysis, the model helps to: (1) recognize as complete as possible the project stakeholders and their concerns, (2) assess social interactions (e.g. knowledge exchange) of stakeholders and the cause-and-effect relationships of issues, (3) mathematically analyze these network structures, (4) identify the key stakeholders and issues based on their network roles and positions, and (5) develop corresponding actions to engage stakeholders and accommodate their needs. In future, empirical case studies of MCPs in different types and contexts can be carried out to put the conceptual model into real application. The model can help to increase the overall accuracy and effectiveness of stakeholder analysis in construction, and its application can provide practical insights concerning stakeholder relational structures and issues in MCPs.

## Acknowledgements

The authors wish to express their sincere gratitude to the Research Grants Council of the Hong Kong Special Administrative Region, China (PolyU 5246/12E) and the Hong Kong Polytechnic University for the funding support to the research projects on which this paper is based.

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