Integrating social network analysis with analytic network process for international development project selection

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Abstract

The social relationships between development agencies, non-governmental organizations, private companies, and other groups working on development projects play an important role in the overall success of projects. However, traditional project selection and prioritization processes ignore the organizational relationships. This paper proposes to integrate social network analysis into multi-criteria decision-making processes to enhance the effectiveness of project selection. A set of topological metrics of social network are used to quantitatively measure the organizational relationships and integrated into the analytic network process (ANP) to form a multi-criteria ANP project selection model. Utilizing empirical social network data of a water and food security research for development network in the Mekong River Basin, we investigate the effectiveness of the proposed model. The results show that it will offer companies, government agencies, and other donor organizations the opportunity to prioritize strategic network goals simultaneously with research and development priorities, and help companies and research organizations to increase their impact and reach within networks.

1. Introduction

Across the globe, there are roughly 850 million people who remain chronically hungry, 780 million people without access to clean drinking water, and 2.5 billion people without access to sanitation facilities (FAO, 2013; UNICEF and WHO, 2013). For decades, international development agencies have loaned, invested, and donated billions of dollars worldwide to combat poverty and work to provide everyone with these basic human rights such as food, water, shelter, and healthcare. The Official Development Assistance of $127 billion dollars in 2012 includes disbursements from the Organization for Economic Co-operation and Development’s Development Assistance Committee (DAC) (World Bank, 2014). In addition to government distributions there are billions of dollars more in expenditures from both private philanthropic and non-governmental organizations each year. The Bill and Melinda Gates Foundation alone spent $2.6 billion dollars on global grants and programs during the 2012 fiscal year (Gates Foundation, 2013). These massive resources are allocated through international aid, loans, investments, or a combination of these and other efforts. In the current economic climate, both public and private organizations are pushing for strong accountability of expenditures and proper utilization of funding. Often the associated projects fail to meet intended objectives, for any number of reasons including but not limited to a lack of local perspective from project implementers, trying to accomplish too much in a short timeframe, or not having social capital or support for continued project success after implementation. For example, a comprehensive external review of 133 completed World Bank projects showed that 50% of projects failed to meet the original objectives of the project (Marwanga, Nyangara, & Deleveaux, 2006). As a sector example, the percentage of water and wastewater treatment projects that fail to be sustained for long term use ranges from 10% to 75%, with commonly found estimates that state half of all water projects fail within 5 years (Elmendorf & Isely, 1981; Harvey & Reed, 2007; Whittington et al., 2009; World Bank, 2004).

Due to the ineffective development interventions, there is an increasing need to select and prioritize a project for funding that has the highest potential for long-term success. These multifaceted factors lead to choosing projects to allocate funds using a variety of complex multi-criteria decision-making techniques. There are many multi-criteria decision techniques for modeling decisions including optimizing and prioritizing project selection in various
settings. Some popular techniques include information system approaches such as the TOPSIS method (Boran, Genç, Kurt, & Akay, 2009; Ozurtokuğlu & Turker, 2013), the PROMETHEE method (Brans, Vincke, & Mareschal, 1986), the goal programming model (Santhanam & Kyparisis, 1995), non-linear integer programming (Yu, Wang, Wen, & Lai, 2012), and a number of others as described in several review papers (Figuera, Greco, & Ehrigott, 2005; Zavadskas & Turskis, 2011; and Stewart (1992). One decision-making technique that has previously been utilized for project selection of research and development programs is the analytic hierarchy process/analytic network process (AHP/APN) (e.g. Amir (2010; Aragonés-Beltrán, Chaparro-González, Pastor-Ferrando, & Rodríguez-Pozo, 2010; Archer & Ghasemzadeh, 1999; Habib, Khan, & Piracha, 2009). While other techniques have notable benefits, the AHP has been highly regarded because it can relate any element of a complex problem to a quantitative measurement even if the problem has difficulty to quantify components.

Classical project selection models focus more on the individual attributes of the candidate projects and therefore the decision-making criteria do not account for the interdependencies among alternative projects. Some project selection studies (e.g., Santhanam & Kyparisis, 1996) realized that interdependencies exist among alternative projects and proposed nonlinear programming formulations to address the resource, benefit and technical interdependencies among candidate projects. However, one type of project interdependencies, i.e., the inter-organizational communications and social relationships, has never been considered in existing multi-criteria project selection models. It should be noted that some studies (e.g., Abedini, Uhadi, & Modiri, 2013) have considered inter-organization factors in multi-criteria decision making models, although these models do not focus on project selection and inter-organizational social relationships.

Trust and communication between project coordinator and task manager are critical factors in successful development projects (Diallo & Thuillier, 2005). Another study of successful development project criteria in Southeast Asia suggests that using participatory planning and stakeholder participation will lead to more successful projects (Khang & Moe, 2008). The relationships between an organization and the broader network of entities working in the international development community have strong implications for the overall functioning of that organization. Global civil society, which refers to the large array of non-governmental organizations worldwide, has often been referred to as a highly networked and relational group (Anheier & Katz, 2004; Castells, 2000). Ozurtokuğlu and Turker (2013) sought to analyze stakeholder relations given relative power and interests, and found significant differences between public organizations, banks and financial institutions, universities, and non-governmental organizations in Turkey. The social relationships between development agencies, non-governmental organizations, private companies, and other groups working on development projects play an important role in the overall success of projects and the working community as a whole.

The inter-organizational communications and the social relationships between organizations can be considered as a new set of evaluation criteria in the project selection model. These communications and the social relationships criteria can be measured by applying metrics developed in social network analysis (SNA). SNA investigates the connections and relationships among social entities and draws patterns and implications from these relationships (Wasserman, 1994). Like all network analysis, it is based on the assumption that there is importance in the relationship among the interacting units. Investigating the network structure and properties is the most common method of analysis used in organizational network research (Provan, Fish, & Sydow, 2007). The metrics based on the network structural data can investigate the causes of structures or the consequences (Borgatti & Foster, 2003). Network analysis is well-suited for investigating the relationships of organization communities such as research for development groups that rely on research outputs being utilized by other groups as a sign of effective programs (Aberman, Johnson, & Doppelmann, 2012; Shrüm & Beggs, 1997).

Inter-organizational communications and the social relationships could be integrated into a variety of multi-criteria project selection methods. However, the ANP model was chosen because it allows for practical integration of social network data within its easy-to-comprehend formulation. This indicates ANP is an excellent choice for organizations in the development community interested in leveraging interdependencies with project selection procedures. Due to these factors, integrating social network analysis with the ANP could yield more successful outcomes and development interventions throughout the world.

This paper is motivated by real-world practical needs arising from the perspective of a donor organization in the water and food security research for development network in the Mekong River Basin. In the broader research for development community context, these needs can be characterized as follows. First, there is the need to select and fund project proposals that will succeed in meeting research or development goals. Second, a donor organization also seeks to increase its social capital by strengthening its standing in the network of organizations within the given field by connecting with the key players in the social network. While bridging these two important gaps in the current literature, this paper illustrates the application of a multi-criteria ANP model for international development project selection that integrates social network relationships into project selection, which can be applied to numerous disciplines. In addition to project selection outcomes, leveraging traditional applications of ANP in conjunction with traditional social network analyses can also serve to further and strengthen social network analyses. Empirical data from a social network of “research for development” organizations in the Mekong River Basin is used to analyze the proposed model. This model can be a systematic tool resource for development donors and grant recipients in the Mekong Basin and the larger research for development community worldwide. Building social network criteria into an AHP/APN model allows for the development of this model that can be applied in many project selection problems in multiple disciplines. However, to the best of our knowledge, none of the existing decision-making model approaches factor the inter-organization relationships in the project selection process.

2. Analytical formulation

Assume there are M (development) projects that are under consideration by a donor. The donor has a set of criteria, denoted by \{e_j| j = 1, \ldots, N\}, for project evaluation. Let each project be associated with a final numerical score \(r_i, i = 1, \ldots, M\). The project selection process is to determine the scores \(r_i\) based on the given criteria \(e_j\) through a multi-criteria decision-making model, such that the set of projects can be prioritized according to their scores \(r_i\) and the optimal alternative can be identified.

In this study, ANP is employed as the multi-criteria decision-making model to determine the scores \(r_i\) of candidate projects. In the rest of this section, a brief review of the ANP will be presented first, followed by the social network analysis and the proposed integrated model.

2.1. Analytic network process

ANP is a comprehensive model that is appropriate for making multi-objective, multi-criterion and multi-actor decision with and without certainty for any number of alternatives. As the ANP
is a generalization of the AHP, we first review AHP in this section. AHP was developed in order to quantify the importance of a set of criteria in a multi-criteria decision-making problem. Since AHP is based on easy to understand value rankings, it has been used and applied by companies and organizations in the real world whereas more mathematically complex models may not be easily transferred from advancing research theory into real world practice. Additionally, AHP models have been used effectively to optimize project selection in the research and development settings (Amiri, 2010).

A classical AHP can be constructed as follows. The goal, criteria, and alternatives form at least three levels of a linear hierarchy tree. After determining the overall goal and the criteria and alternatives for a particular decision, the pairwise comparison can be obtained. This pairwise comparison can be based on value choices from individuals involved in the decision-making and are often based on a 1–9 scale of importance (Saaty, 1996). Let \( a_{ij} \) denote the comparison of the strength of criterion \( i \) to criterion \( j \). Based on a priority vector \( w = (w_1, \ldots, w_n) \) for the overall goal, criteria, and alternatives determined by the decision-maker, the pairwise comparison of criterion \( i \) to criterion \( j \) is computed by \( a_{ij} = w_i / w_j \). Similarly, \( a_{ji} = w_j / w_i \). And thus, \( a_{ij} = 1 / a_{ji} \). Then, for the set of decision criteria \( e = \{e_j|j = 1, 2, \ldots, n\} \), the pairwise comparison of \( n \) criteria can be summarized in the matrix:

\[
A = \begin{bmatrix}
a_{11} & \cdots & a_{1n} \\
\vdots & \ddots & \vdots \\
a_{n1} & \cdots & a_{nn}
\end{bmatrix}
\]

\( \alpha_{ii} = 1 / a_{i}, a_{ij} = 0 \) (1)

where every element \( a_{ij}(i, j = 1, 2, \ldots, n) \) is the quotient of weights of the criteria. The priority vector, or relative weights, of the set of criteria are determined by the right eigenvector \( w \) of matrix \( A \) which corresponds to the largest eigenvalue \( \lambda_{\text{max}} \), i.e., \( Aw = \lambda_{\text{max}}w \). This is necessary because the matrix is formed based on human value judgments which are intrinsically inconsistent and this method can provide validity of the priorities of a decision (Saaty, 2003). A pairwise comparison and subsequent eigenvalue calculation is completed by the decision-maker for each criteria and set of subcriteria. The final score of \( t_r, r = 1, \ldots, M \) for each alternative is obtained by summing each alternative’s relative weight with respect to each criteria multiplied by the criteria’s priority with respect to the goal.

The ANP, which is a derivative of AHP based on the benefits, opportunities, costs, and risk values, has also been used in many applications multi-criteria decision-making (Saaty, 1996, 2004) including project selection (Habib et al., 2009). Both ANP and AHP utilize pairwise comparisons to determine weights of the criteria used in order to make a decision. These weights can then be used to determine which alternative or option, within a selection of potential decision outcomes, is the most optimal based on criteria weights. Alternatively, the weights derived from the AHP process can also be applied to other multi-criteria decision models (Amiri, 2010). Unlike AHP, the ANP has the ability to allow the decision criteria to interact and for the criteria to be affected by the alternatives. Thereby, while ANP is more involved mathematically, it provides a broader, more realistic approach to multi-criteria decision-making.

Both the AHP and ANP models are based on a comparative judgment of the alternatives and criteria. Since ANP dismisses the hierarchical structure associated with AHP it allows criteria to interact with each other. After creating the local priority matrix for the criteria, which consists of deriving matrix \( A \) as previously described for each criteria, a supermatrix is formed:

\[
\begin{bmatrix}
C_1 & C_2 & \cdots & C_n \\
C_1e_1 & e_1 & \cdots & e_n \\
\vdots & \vdots & \ddots & \vdots \\
C_ne_m & e_m & \cdots & e_m
\end{bmatrix}
\]

where \( C_i \) is the \( n \)th cluster with criteria or element \( e_n \), and each \( A_{ij} \) is the local priority matrix as described in the AHP formulation evaluating the relative priority between cluster \( i \) and cluster \( j \). Although this supermatrix allows for influence of every element on every other element, if two clusters have no influence on one-another, then \( A_{ij} = 0 \). While criteria can be grouped into clusters, a cluster could also contain only one criterion. After determining the local weights using the eigenvector value, the global weights are calculated by raising the supermatrix to limiting powers:

\[
\lim_{k \to \infty} \mathbf{B}^k
\]

Raising the supermatrix to compute the limiting priorities allows for the determination of whether the supermatrix is reducible or not. This permits for normalization and allows the control criteria to not be dependent on the alternatives. Unlike AHP, the ANP supermatrix allows for interdependence between all of the elements (criteria and alternatives).

In classical AHP applications for project selection, all criteria considered in the model are related to the attributes of individual project or grantee. The inter-organizational communications and the social relationships between organizations can be considered as an additional cluster of evaluation criteria \( C_0 \) in the model. In the next section, we introduce a set of metrics developed in social network analysis to evaluate the inter-organizational communications and the social relationships that are used in the integrated model.

2.2. Social network analysis

In a social network, entities (e.g., people, organizations, countries, etc.) are connected in various ways with various levels of interaction. The entity is referred to as a node while the connections between entities are known as links. For this empirical example, the nodes include organizations in the research for development network and the links represent three different types of connections. Two common topological metrics in a social network are degree centrality (denoted by \( C_d \)) and betweenness centrality (denoted by \( C_b \)). Given a network \( G := (S, L) \) with \( |S| \) nodes and \( |L| \) links, Eqs. (4) and (5) represent these two metrics for any node \( s \in S \):

\[
C_d(s) = \deg(s) = \sum_j X_{sj}
\]

\[
C_b(s) = \sum_{i=r \rightarrow j \in s} \frac{\sigma_{ij}(s)}{\sigma_{ij}}
\]

where \( X_{sj} \) and \( \sigma_{ij} \) represent the number of links and the shortest distance of links connecting a pair of nodes \( (i, j) \), respectively, and \( \sigma_{ij}(s) \)
represents the number of shortest paths that pass through node \( s \).

Centrality measures can provide useful information about the functioning of the social network. For example, if an organization (node) has a low betweenness value and a high degree value, this organization’s connections are repetitive and communication can potentially bypass them with no adverse consequences. Conversely, if an organization or node has a low degree but high betweenness value, that organization’s ties, while few, are critical to the overall functioning of the network.

Network analyses can be used to identify the organizations or actors in a network that serve as integral links to that network, also known as a key player(s). The key player problem consists of two subproblems: (i) node disruption: determining the node or set of nodes that, if removed, would maximally disrupt communication among the remaining actors, and (ii) node reach: determining the node or set of nodes that is maximally connected to all the other nodes (Borgatti, 2003). Given this problem, the network analysis results could be used by an organization to increase its reach within a network by becoming associated with the key player(s).

Identifying the key player in a social network is not computationally straightforward (Borgatti, 2003). While the key player problem in social network analysis can refer to both node disruption in the network and node reach in the network, for the purpose of this study we are only concerned in organizational reach and therefore the latter of the two key player problems. Utilizing this measure has multiple applications. For example, an organization could use this in order to identify a small group of other organizations to use as seeds for diffusing new work practices effectively within the network. Distance weighted reach \( (R) \), the value of reach capital that one node holds, can be defined as the sum of the reciprocals of distances from the key player \( S \) to all nodes \( (Borgatti, 2003) \). This distance from a set to a node outside, for our purposes, is the minimum distance from any member of the set to the outside node:

\[
R = \frac{1}{n} \sum_{j} \frac{1}{d_{sj}} \tag{6}
\]

In Eq. (6), the distance from a node \( S \) to node \( j \) is represented by \( d_{sj} \). The summation includes all nodes, and the distance from the node or set of nodes evaluated to a node within the set is defined to be 1. If there is no path connecting node \( S \) and node \( j \), then the distance \( d_{sj} \) is infinite, and the reciprocal of an infinite distance is 0. In this setting, \( R \) is the proportion of all nodes reached by the set, where nodes are weighted by their distance from the set and only nodes at distance 1 are given full weight. \( R \) gives us the quantitative value of reach used to determine the “key player” according to this metric.

The centrality measures \( (C_{d} \) and \( C_{b} \)) as well as the distance weighted reach \( (R) \) are important attributes of candidate projects which help companies and research organizations in evaluating the candidate projects, such that the key players in the social network are identified and the long-term success of the development project can be enhanced. The next sub-section illustrates the multi-criteria ANP project selection model that integrates the project selection criteria from SNA.

2.3. The multi-criteria ANP project selection model

This study provides two important advances to the literature on project selection with ANP models. First, unlike any previous work, this paper utilizes the ANP model within a research for development case study. Second, this paper serves as the first example of integrating SNA results to an ANP model through creating nontraditional criteria. In order to allow for SNA results to aid development work we propose three basic stages: (1) identify the criteria to be used in the model, (2) SNA computations, and (3) ANP computations, evaluation of the alternatives, and determination of final rank (Fig. 1).

In the first stage of Fig. 1, the decision-making team (donor organization) determines the criteria for which the alternatives (project proposals) will be evaluated (Amiri, 2010). In a traditional ANP model, the decision-making team would proceed directly to ANP calculations (stage 3) after determining the criteria and decision hierarchy (Saaty, 2004). In this model, stage 2 represents the application of SNA computations which is not included in previous ANP models. According to the literature, international development program success is tied to social relational aspects including communication, trust, interorganizational collaboration, and stakeholder participation (Anheier & Katz, 2004; Castells, 2000; Dallio & Thuillier, 2005; Khang & Moe, 2008; and others). This articulates the need for stage 2 which strengthens the traditional project selection techniques utilized in stage 1 and stage 3. Finally, stage 3 represents the convergence of SNA results with ANP calculations which allows for the determination of the final rank.

In this empirical study, the ANP model represented by the supermatrix \( B \), i.e., Eq. (2) is modified to include both traditional ANP criteria \( (A) \) and SNA criteria \( (D) \):

\[
B = \begin{bmatrix} A & 0 \\ 0 & D \end{bmatrix} \tag{7}
\]

where the matrix \( D \) includes all the social relationship attributes presented in the previous section. Since both \( A \) and \( D \) represent criteria, they are still compared utilizing pair-wise decisions. In order to articulate the differences between these criteria and stages, four decision hierarchy trees, described in Section 2.4, were used. In this study, as described by Eq. (7), we assume that the various criteria (represented by \( A \) and \( D \)) do not interact with each other. However, it is important to note that in a broader multi-criteria decision model, it would be conceivable for decision makers to choose to allow for criteria interaction.

2.4. Identification and hierarchy of criteria in proposed model

Criteria to be considered in the selection of projects are determined by previous literature for project selection as well as new SNA criteria summarized into Table 1. Eleven criteria and ten alternatives were evaluated in the evaluation process calculated by using the ANP method.

Criteria C1–C5 are generic project selection criteria selected to represent traditional project criteria used in previous literature (Amiri, 2010; Wu & Lee, 2007). Criteria C6, C7, C8, C9 are social network criteria calculated based on SNA related to the social network structure or link attributes. Criteria C10 and C11 are related to the organization properties or node attributes of the social network. The alternatives are different organizations from an actual international development social network. These organizations represent project proposals submitted to a donor organization decision making team for international development funding. In order to determine the benefit of introducing additional SNA criteria, four different hierarchy trees were evaluated (Fig. 2). In addition, all 11 criteria are categorized into benefit, opportunity, cost, and risk categories. Although these criteria were categorized according to the types listed in Table 1, different decision makers may choose to categorize criteria in other ways. For example, organization experience and author track record could be categorized as opportunity criteria if the decision making team viewed them as a positive benefit instead of a potential risk. This traditional
benefit, cost, opportunity and risk model (BCOR) allows for the development of two different hierarchy trees utilizing all 11 criteria (Fig. 2B and C). Fig. 2 represents multiple scenarios created in stage one, the group working stage, of the proposed model.

Four decision networks are constructed in order to model likely scenarios for the priorities of a hypothetical donor organization. In the first case, the donor organization determines that only social network criteria for each alternative organization should be utilized in evaluating the project proposals (Fig. 2A). This articulates a case where a donor organization project selection team believes that the network relationships of the recipient organization are the only important factors in the overall success of the project. In the second (Fig. 2B) and third cases (Fig. 2C) all eleven criteria were used. The shaded boxes in the second case (Fig. 2B) were weighted at a ratio of $\alpha$ to the unshaded boxes $\beta$ and $\alpha + \beta = 1$. This is a commonly used weight where a donor organization project selection team ranked the benefits and opportunities (shaded criteria boxes) as more important than the costs and risks (white criteria boxes). Case three (Fig. 2B) utilizes all criteria with equal weight. The cases 2B and 2C articulate two typical implementation strategies for the proposed model. In the final case, the decision network included traditional project selection criteria only (Fig. 2D). This represents the current status of AHP/ANP modeling for project selection which does not integrate any social network analysis criteria. To evaluate the benefit of introducing additional SNA criteria to ANP model, the proposed model is evaluated using data collected from a Mekong Basin International Development Network in the next section.

Fig. 1. Schematic diagram of the proposed model for project selection.
3. Empirical study and results

3.1. Mekong basin international development social network

In order to complete stage 2 of the proposed model, a Mekong Basin International Development Social Network was created. The Mekong River, located in Southeast Asia, is the 10th largest river in the world with a length of 4909 km (Liu, Lu, Liu, & Jin, 2007). This transboundary river spans six different countries with headwaters that originate in China’s Yunnan province, then flow south into Burma (Myanmar), Lao PDR, Thailand, Cambodia and ultimately outflow from Viet Nam into the South China Sea. The Lower Mekong Basin, comprised of the basin sections within Burma, Thailand, Laos, Cambodia, and Viet Nam, is the most populous and well-studied region within the Mekong River Basin and is home to over 60 million people (Mekong River Commission, 2010). This region is in a transitional period of development as several countries within the basin are pursuing large scale hydropower dam projects. These infrastructure projects will change the natural water flows of the Mekong and could potentially present challenges to water and food security for Mekong Basin citizens.

Due to the environmental complexity, research for development activities has been highly regarded by many large international development organizations.

The network model of the organizations in the Mekong River Basin working in research for development related to water and food security was created using a survey. This survey was sent to 101 known organizations whose contact information was provided by a large international research organization. A list of these organizations was used to create a structured format for survey questions. Because a list of over 100 organizations may overwhelm a survey respondent, a subset of that list was used for the survey. 62 organizations that appeared to be most involved with the Mekong River Basin according to their webpages, along with 8 spots where fill-in-the-blank organizations could be written, for a total of 70 selection choices, were used in the online survey sent to organizations involved in research for development activities in the region. The 8 open-ended spots were stratified by sector: government ministries (Viet Nam, Thailand, Lao PDR, Cambodia), non-profit/non-governmental organizations, private companies, universities, and other government organizations.

The survey respondents were asked to explain the level/strength of linkage between their organization and the partner organization(s): (i) formal: other organizations that you formally report to, collaborate with, or work with on watershed management in the Mekong; (ii) informal: other organizations that you have an informal professional relationship with (i.e. which organization has professionals that you would call if you had a Mekong Basin management question); and, (iii) familiar: other organizations that you are familiar with but have had no formal or informal interactions with. The three options enable the building of a network with different linkage levels between nodes.

An overall survey response rate of 59% was obtained. As shown through Fig. 3, the network produced included 109 unique organizations and 901 different organizational links of varying levels.

Within Fig. 3, the nodes are shaded according to the organization type (e.g., private company, university, government agency, etc.), and the size of the node is associated with the size or scope of the organization (e.g. global, regional, or local). Additionally, the strength of linkage is associated with the darkness of the line. The labels of each organization have been removed in order to provide anonymity to survey respondents. In order to complete the project selection model, ten alternatives were selected from this social network (Table 2). These alternatives represent real organizations within the Mekong River Basin research for development social network. These organizations were chosen to represent a wide array of organization type, scope, and location in the network that are likely candidates for submitting a project proposal for development funding.

Utilizing the key player approach, the social network results for each of the 10 alternatives are articulated in Table 3. Reach, degree, and betweenness were calculated using Eqs. (4)–(6). Since the actual values of these metrics are relative to the social network under examination, the rank of each value according to the overall network of 109 organizations is displayed for easy comparison between organizations. The reach and degree rankings only vary slightly from one another. This implies that these centrality measures are correlated with one another. However, there is variation in the rankings for degree centrality and betweenness centrality. For example, alternative A8 has a degree rank of 8, which is high, but a betweenness rank of 21. This implies that although alternative A8 is highly connected, the connections are not unique and therefore may not be as important to the overall functioning of the network as an organization that has a high degree and a high betweenness ranking.

A donor organization, such as the World Bank, US Agency for International Development, or the Bill and Melinda Gates Foundation may utilize this information in order to garner further connections within the network of organizations. The actual values of reach (R), degree (C_d), and betweenness (C_b) were utilized in the ANP model but since these values are relative to each different
social network, the ranks provide a more clear illustration of the influences each alternative may have on the overall ANP outcome. Furthermore, as shown next through the project ranking analysis, the proposed multi-criteria ANP project selection model combines these SNA results with ANP in order to evaluate the differences between traditional ANP applications (stage 1 and stage 3) and the addition of stage 2 in the proposed model.

3.2. ANP results

In order to complete stage 3 of the proposed model, the SuperDecisions Software (Creative Decisions Foundation., 2014) was utilized for the criteria network and the pairwise comparison of criteria. Fig. 4 shows the theoretical network structure of the ANP model in SuperDecisions.

As shown through the figure, the social network criteria are designated in black while the traditional project selection criteria are designated in white. This represents two of the four cases analyzed for comparison between criteria. In the SuperDecisions software, each primary factor was created with a subnetwork of those influential criteria. Traditionally, the pairwise comparison of criteria can be derived from a survey of the decision-makers values but for the purpose of this empirical example, random pairwise comparisons are made for the four hierarchy cases previously articulated (Table 4).

The cases in Table 4 show only one application of the potential pairwise comparison. The criteria were compared on a 9-point scale which is commonly utilized in questionnaire procedures if actual decision makers were contributing to the model formulation. Since decision makers were not involved, a random
A number generator from the R statistical software was used to choose the 1–9 ranking of each criterion comparatively. In practice, these pairwise comparisons would be formed by the decision makers, but here they are randomly generated to show four specific cases among potentially unlimited combinations of methods.

For prioritizing the set of projects in addition to ranking the criteria, each alternative was scored from 1–9 with respect to the specific criterion (Table 5). The weights of the criteria, derived from the final limit matrix were then used to calculate each project final score (Table 6). These scores are for demonstration purposes only and were not derived from real data as previously described.

Tables 5 and 6 further articulate how the alternatives for funding an organization project vary with the different cases illustrated in Fig. 2. When only SNA criteria are analyzed (case 1), as an organization might do in order to increase its reach within the network, the results indicate the best organization to fund would be organization 26 (A1), then organization 5 (A5), and so on. If the donor organization was only concerned with increasing its reach within their social network by utilizing project selection, it would choose to fund alternative A1 using case 1. Cases 2 and 3 show that when SNA is integrated with traditional project selection criteria, the results can vary. As shown in case 2, the top five alternatives still have high SNA scores because most of the benefit and opportunity criteria, which has a higher weight, are related to the SNA criteria. Case 3 articulates the model which most evenly prioritizes the dual goals of selecting the best project while also increasing the donor reach. In a traditional ANP project selection model a donor organization would select a project to fund without considering the social network criteria (case 4). The results show that the donor would fund the project proposal from alternative organization 71 (A8), then organization 68 (A6) and so on. Since the top alternative (A8) does not have an important role in the social network for the Mekong Basin, the donor organization would be funding an organization without key social connections that lead to program success. Hence, using a traditional ANP model (case 4) would produce significantly different results than modeling a project selection process with SNA criteria (cases 1–3).

### Table 2: Alternatives for Mekong project selection.

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Organization number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Organization 26</td>
</tr>
<tr>
<td>A2</td>
<td>Organization 42</td>
</tr>
<tr>
<td>A3</td>
<td>Organization 69</td>
</tr>
<tr>
<td>A4</td>
<td>Organization 22</td>
</tr>
<tr>
<td>A5</td>
<td>Organization 5</td>
</tr>
<tr>
<td>A6</td>
<td>Organization 68</td>
</tr>
<tr>
<td>A7</td>
<td>Organization 15</td>
</tr>
<tr>
<td>A8</td>
<td>Organization 71</td>
</tr>
<tr>
<td>A9</td>
<td>Organization 14</td>
</tr>
<tr>
<td>A10</td>
<td>Organization 45</td>
</tr>
</tbody>
</table>

### Table 3: Centrality metric rankings for Mekong social network.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Organization ID</th>
<th>Degree ($C_d$)</th>
<th>Betweenness ($C_b$)</th>
<th>Reach ($R$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>26</td>
<td>3</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>A2</td>
<td>42</td>
<td>4</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>A3</td>
<td>69</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>A4</td>
<td>22</td>
<td>6</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>A5</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>A6</td>
<td>68</td>
<td>14</td>
<td>27</td>
<td>12</td>
</tr>
<tr>
<td>A7</td>
<td>15</td>
<td>10</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>A8</td>
<td>71</td>
<td>8</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>A9</td>
<td>14</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>A10</td>
<td>45</td>
<td>7</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>

![Fig. 3. Social network of organizations working on research for development in the Mekong.](image-url)
4. Discussion and conclusion

This study proposes a multi-criteria ANP project selection model for combining social network topological measurements with traditional project selection criteria in order to maximize the outcome for the donor organization. Combining two nontraditional fields allows for the opportunity to fund and deploy development projects that are more successful than many underway today. Reducing the failure of development work will strengthen the opportunities to bring millions of people out of poverty worldwide. As shown through the empirical study, the proposed model can incorporate social network metrics in order to aid complex decision-making processes such as project selection for donor organizations. From the evaluation of results, we are able to derive which grantee organization would increase the donor organization connections within the network while optimizing project selection criteria. The study also articulates the influence of various social network topological measures such as reach, degree and betweenness.

The study approach illustrates several unique features which contribute to the depth of knowledge in social network analysis and multi-criteria decision-making with ANP models. First, integrating social network analysis in this way allows for including both link data, traditionally captured in topological social network analysis, as well as node data, about the organizations themselves which is not often captured and is independent of the link connections. Second, articulating social network features as criteria in an ANP model allows for optimizing two traditionally separate goals, project selection and organizational connections, within a real network. Finally, this work provides an approach to integrate two analytical techniques, which increases complexity yet still

<table>
<thead>
<tr>
<th>Case number</th>
<th>Fig.</th>
<th>Theoretical general pairwise comparisons</th>
<th>Project ranking of first 5 alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2A</td>
<td>Pairwise comparisons of social network components only, prioritizing C9&gt;C11&gt;C10 &gt; C7 &gt; C8 &gt; C6</td>
<td>A1 &gt; A5 &gt; A2 &gt; A3 &gt; A9</td>
</tr>
<tr>
<td>2</td>
<td>2B</td>
<td>Pairwise comparisons with random values chosen for project criteria with benefits weighted at $\alpha = 0.80$ and cost weighted at $\beta = .20$</td>
<td>A3 &gt; A5 &gt; A1 &gt; A4 &gt; A9</td>
</tr>
<tr>
<td>3</td>
<td>2C</td>
<td>Pairwise comparisons with random values chosen for project criteria with overall benefits and cost with equal weight $\alpha = \beta$</td>
<td>A5 &gt; A3 &gt; A8 &gt; A2 &gt; A4</td>
</tr>
<tr>
<td>4</td>
<td>2D</td>
<td>Pairwise comparison of project selection criteria only, prioritizing technical C3 &gt; C1 &gt; C2 &gt; C4 &gt; C5</td>
<td>A8 &gt; A6 &gt; A4 &gt; A9 &gt; A3</td>
</tr>
</tbody>
</table>

Table 4
Application of combined ANP with SNA criteria.
remains accessible to managers and researchers in organizations worldwide.

In a real world project selection process decision-makers would provide value judgments that indicate how the pairwise comparisons of criteria should be done in order to achieve the weights of criteria. This project selection model utilized random values for the information about the proposed project (e.g. budget, overhead costs, technical qualities, etc) as well as the pairwise comparisons of criteria. However, in reality, there would be data for the project alternatives being evaluated. Additionally, the social survey construction can only be as complete as the response rate allows. The achieved response rate of 57% is considered acceptable for an online survey since it is representative of the overall sample (Cook, Heath, & Thompson, 2000; Nulty, 2008). Despite these issues, we show how utilizing a traditional ANP project selection model, without the SNA completed in stage 2, could lead to a decision-making team selecting an organization without the proper social connections that lead to successful development interventions.

This study presents a framework and an example model of how employing nontraditional social network criteria could be accomplished. Another methodological approach could include integrating fuzzy logic into the final ranking procedures of ANP (Amiri, 2010 and Boran et al., 2009). Despite these issues, we show how utilizing a traditional ANP project selection model, without the SNA completed in stage 2, could lead to a decision-making team selecting an organization without the proper social connections that lead to successful development interventions.

Table 5
Final prioritization of ten projects.

<table>
<thead>
<tr>
<th>Weight case 1</th>
<th>Weight case 2</th>
<th>Weight case 3</th>
<th>Weight case 4</th>
<th>Project score for each criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>A1</td>
</tr>
<tr>
<td>C1</td>
<td>–</td>
<td>0.06</td>
<td>0.15</td>
<td>0.233</td>
</tr>
<tr>
<td>C2</td>
<td>–</td>
<td>0.04</td>
<td>0.1</td>
<td>0.095</td>
</tr>
<tr>
<td>C3</td>
<td>–</td>
<td>0.24</td>
<td>0.15</td>
<td>0.42</td>
</tr>
<tr>
<td>C4</td>
<td>–</td>
<td>0.05</td>
<td>0.125</td>
<td>0.163</td>
</tr>
<tr>
<td>C5</td>
<td>–</td>
<td>0.05</td>
<td>0.125</td>
<td>0.088</td>
</tr>
<tr>
<td>C6</td>
<td>0.086</td>
<td>0.0676</td>
<td>0.04225</td>
<td>–</td>
</tr>
<tr>
<td>C7</td>
<td>0.094</td>
<td>0.0784</td>
<td>0.049</td>
<td>–</td>
</tr>
<tr>
<td>C8</td>
<td>0.12</td>
<td>0.1072</td>
<td>0.067</td>
<td>–</td>
</tr>
<tr>
<td>C9</td>
<td>0.26</td>
<td>0.1464</td>
<td>0.0915</td>
<td>–</td>
</tr>
<tr>
<td>C10</td>
<td>0.21</td>
<td>0.08</td>
<td>0.05</td>
<td>–</td>
</tr>
<tr>
<td>C11</td>
<td>0.23</td>
<td>0.08</td>
<td>0.05</td>
<td>–</td>
</tr>
</tbody>
</table>

Note: The weight column is the final limit matrix.

Table 6
Project score and outcome for the four cases.

<table>
<thead>
<tr>
<th>Case</th>
<th>Score</th>
<th>Rank</th>
<th>Score</th>
<th>Rank</th>
<th>Score</th>
<th>Rank</th>
<th>Score</th>
<th>Rank</th>
<th>Score</th>
<th>Rank</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>7.47</td>
<td>1</td>
<td>6.08</td>
<td>3</td>
<td>5.38</td>
<td>4</td>
<td>4.67</td>
<td>6</td>
<td>6.15</td>
<td>27</td>
</tr>
<tr>
<td>2</td>
<td>6.19</td>
<td>2</td>
<td>5.49</td>
<td>3</td>
<td>6.31</td>
<td>4</td>
<td>5.71</td>
<td>4</td>
<td>6.22</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>5.09</td>
<td>3</td>
<td>5.44</td>
<td>4</td>
<td>5.57</td>
<td>5</td>
<td>5.41</td>
<td>4</td>
<td>5.91</td>
<td>48</td>
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<tr>
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<td>6.72</td>
<td>5</td>
<td>5.53</td>
<td>71</td>
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References


