ANALYZING THE IMPACT OF FIRM’S EMBEDDEDNESS IN A CENTRALIZED SUPPLY NETWORK STRUCTURE ON RELATIONAL CAPITAL OUTCOMES

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Abstract: This research looks at the different effects of firms’ network structural positions in an upstream supply network upon the firms’ level of relational capital outcomes. Previous research largely focused on the context of decentralized network structure. However, the supply network is a centralized network because of the existence of the focal firm. The existence of the focal firm may influence the impact of relational capital outcomes. Hence, the objective of this research is to determine the type of network structural positions required to obtain a reasonable relational capital outcome in upstream supply network. This study found that network structural positions, i.e. degree centrality contributed to firms’ level of relational capital trust. Hence, a firm embedded in upstream supply network benefits differently in terms of relational capital through different degree of embeddedness. The firm resources should be re-aligned to match the benefits of the different network structural positions.

Keywords: Supply Chain Management, Network Studies, Inter-Organizational Relations

JEL Classification:

1 INTRODUCTION

The last decades have seen an increase in managerial concern regarding the complexity of the supply chain, more specifically the upstream supply network. The upstream supply network refers to the firms that reside in the upstream flow of the supply network. The upstream supply network has become more complex due

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to the increased interactions and interrelations among the suppliers’ firms as well as the number of the firms. These firms which are the suppliers of materials and services to the focal firms are connected or deal with each other directly or indirectly through the supply of materials to the focal firms or manufacturer.

The traditional reductionist arguments state that supply chain firms opted for the removal from the complex upstream supply chain of partners who are not meeting the performance requirements of the supply chain in an attempt to manage the complexity arising from extensive inter-firm relationships (Choi and Kim, 2008). These strategies may prove to be effective in the short term, but may negatively impact the focal firms in the long run. These negative effects may emerge as firms’ involvement in a network of inter-firm relation, creates an important element of intangible capital, which is the relational social capital. This involvement among the firms in the upstream supply network is essentially the firm embeddedness in the upstream supply network structure. However, recent arguments suggest that simply removing these underperforming firms may not be the best way, as firms may remove partners who are resourceful or more influential, but these characteristics are not visible through good accounting measures. Cockburn and Henderson (1998) in addition to Putnam (1993; 2000) posited the approaches that value and appreciate these complex inter-firm relations may be better alternatives. This is because, firms have been found to benefit through embeddedness with other firms in a network structure.

Network embeddedness constitutes an important element that Putnam (1992) identifies as being the relational capital (Cousins et al. 2001). Cousins et al. (2006) stated that relational capital was the configuration of relationships within the network structure, as well as with the broader network structure of the firm. It has been documented that the level of embeddedness increases relational capital such as trust and motivation from the interactions (Cousins et al., 2006). More specifically, organizational researchers have confirmed that organizational involvement in a decentralized network structure impacts on organizational relational capital outcomes such as the level of trust (Gulati and Gargiulo, 1999; Podolny and Page, 1998). Thus, a firm’s embeddedness in the network structure may produce relational capital such as trust that may then have the potential to generate other benefits such as reduced costs and greater flexibility (Reagans, Zuckerman and McEvily, 2004). Nevertheless, in the decentralized and horizontal communication structure of networks causes opportunistic acts to become an imminent threat. Opportunism may emerge when parties in the network relationship have issues of goal incongruence. In addition, connectivity may have its costs too, as a firm may lose some control of its operations and administrations.
Naturally, in a supply network context, to guard against the instability of the network structure and threat of opportunism, while at the same time acquiring high levels of integration among firms in the supply network structure, stakeholders in the network structure often introduce a focal or central firm to administer and manage the activities in the network structure (Huang, 2007). This is the case that the study is investigating.

The upstream supply network is essentially a centralized network structure. It is a centralized structure through the existence of the focal firm that monitors and administers transactions in the upstream supply chain for the production of the finished goods and services. This centralized coordination often involves a focal firm or manufacturer, typically operating in the center of the transformation process (Choi and Krause, 2006). Since relational capital outcomes emerge through interactions in a free flow, decentralized, network structure application (Gulati and Gargiulo, 1999; Podolny and Page, 1998) of the integrated network to the issues of centralized upstream supply network complexity may require deeper understanding of the impact of the centralized network structure. This study raised this concern following the argument of Putnam (1992) which posited that relational capital emerged largely in a decentralized network structure. This is because; a centralized coordination such as the focal firm in the upstream supply network may introduce effects unknown, or remove potential benefits to the firms in the upstream supply network. For example, since the central coordinator (i.e. the focal firm), is often the most powerful firm in the supply base having arms-length control that monitors actions of the network member, it is also a profit-driven entity with the most investment in the supply network. Occasionally albeit unintended, a Machiavellian portrayal may affect the level of relational capital among the firms in the centralized network structure. In addition, the centralized nature of network governance has been found to reduce the horizontal connection which is prominent for the creation of relational capital in a network structure (Poppo and Zenger, 2002). Since these horizontal connections are significant for generating the relational capital mentioned by Putnam (1992), a key question would be: will firm involvement or embeddedness in the centralized upstream supply network produce the same relational capital outcomes?

2 Literature Review

“...firms are no longer structured like a medieval kingdom, walled off and protected from hostile outside forces...but....involved in an intricate lattice work of collaborative ventures with other firms, most of whom are ostensibly competitors” (Powell, 2003, p. 113)
Powell’s statement described the overall transition of organization form over the years as follows: The adoption of network firms in the upstream supply network structure relates to the assertion of network forms of organization in an inter-organizational or inter-firm relationship as conducted by an organizational study researcher. Integrated network refers to the notable structure of the inter-firm relationship. Globalization has made the study of inter-firm relations increasingly important, as the resources needed to undertake the task of organizational management have grown in scale. Hence, this limits the potential of independent action by any single organization (Kauffman, 1993). A holistic understanding of the inter-firm relationship would catapult organizations into providing better service as well as cost reduction (Faems, Van Looy and Debackere, 2005; Krauss, Mueller and Luke, 2004; Lawson et al., 2009; Stuart, Hoang and Hybels, 1999). This situation arises because a network, argued Powell (1990), facilitates the exchange of efficient and reliable information. This is due to the relational capital developed through the firms’ level of embeddedness in the network structure.

2.1 Embeddedness

Granovetter (1985) advanced the concept of embeddedness as an effort by which to explain economic behaviour of an organization. According to Granovetter (1985), embeddedness refers to the level of involvement of a firm in the network of inter-relations. A firm’s levels of involvement have an impact upon its actions or behaviour in the network. Granovetter (1985) posited that transactions between actors in a network are embedded in a social context economic decisions and outcomes are affected not only by the actor’s isolated relations with other individuals or firms in the network but also by the structure of the overall network of relations within which the actor resides. Economic behaviors are embedded in the network of relations that provide the context for economic processes (Granovetter, 1985). As every behaviour materializes through some form of outcome, almost all economic processes are presumed to be embedded in the networks of relations.

Thus organizational performance is influenced by the pattern of embeddedness of the organization in the network. Since in the upstream supply network, firm embeddedness relates to the degree of the interaction that a firm may has with other firms in the network which are a direct reflection of the firm degree of inter connectivity with others in a network. Hence, one may conclude that organization performance in the supply network may also be influenced by the organization embeddedness pattern such as its centrality and connection (Scott, 1998) with other organizations in the supply network (Mueller, 2000).
Structurally, supply network is virtually formed by the connectivity or links between firms where the integration progressively forms the ultimate structure, which is the supply network itself. The relationship is also known in the literature as the buyer-supplier relationship (Beamon, 1999). According to Choi and Kim (2010), a buyer–supplier relationship represents a dyad, or two nodes and one link, in network terms. Each node can be conceptualized as an actor performing activities for generating value (Choi, 2008). The firms need resources from its supplier organization, and the supplier needs contracts and payments from the buyer. On top of that the firms also interact with each other to share information regarding market opportunities and new threats (Choi, 2008). As a consequence, these phenomena create a link and form a dyad or a buyer–supplier relationship. Because a firm in the supply network often has links to other firms, the firm is then impliedly linked to the new indirectly connected organizations. Similarly, with the supplier organization, this will also bring to the dyad their links with other organizations either directly or indirectly (Lamming et al., 2000). Conclusively, a buyer–supplier relationship is not only a dyad. It is also part of a network that has come to bear on individual nodes to the relationship through each other’s extended business relationships. This form of inter-firm relations or connectivity created the complexity in the supply network structure.

Research applying the embeddedness theory lens to supply chain relationship is beginning to appear since the last decade. Recent studies have emphasized the impact of embeddedness in driving improve supply chain performance. For instance, the embeddedness in social interaction between firms in the supply network were found to be an important factor in solving problems and reducing total costs (Stuart, 1997). Choi and Kim (2001) present the initial platform for operations and supply chain management researchers to adopt the embeddedness concept into the supply of supply input in the supply network. Using the Social Network approach, the authors present the embeddedness concept from the perspective of the supply chain. The authors posit the importance of framing organizations in the supply network (i.e. suppliers) as being embedded in a larger supply network than in isolation. Such framing provides organizations in the supply network with better basis in developing policies and long-term strategies. The authors went on to posit that the embeddedness of organizations in the supply network influence its performance, a statement in tandem with previous network research findings that found the configuration of network of relations can facilitate or impede an organization’s behaviors and performance (Granovetter, 1985; Burt, 1992; Nohria, 1992). Krause, Handfield and Tyler (2007) also documented that embeddedness in the supply network of information sharing is an important means
for transferring appropriate practice. The findings on embeddedness and relational capital are not particularly new. Nevertheless, the theoretical elements' underlying firm’s embeddedness and relational capital in the supply network have little theoretical underpinnings. A more systematic study into the extent to which embeddedness of the different inter-firms relationships network contributes to the creation of relational capital is warranted.

Although there has been an increase in research regarding firm’s embeddedness in network, the literature is silent about the relationship between organizational embeddedness and organizational social capital in a centrally governed supply network that is a network governed by a strong focal organization which enforces and monitors the supply and demand of materials by other sub organizations in the network. Network scholars have found a strong relationship between organizational embeddedness in network structure and organizational social capital in a decentralized network form of organization (Wasserman and Galaskiewicz, 1994, Ter Wal and Boschma, 2009, Chang, 2003a, McEvily and Zaheer, 1999, Ahuja, 2000, Anderson et al., 1994, Provan et al., 2007, Galaskiewicz and Marsden, 1978, Johnson and Mareva, 2002, Haibin, 2004, Breschi and Lissoni, 2005, Hite et al., 2005).

In this study, although undoubtedly the organizational social capital emerged in network forms of organizations, we argue that the presence of a central actor of or dominant power such as the focal organization in a supply network, may change the pattern of inter connectivity and ties among organizations in the network hence influencing the organizational social performance. At the minimum, the flow of information has to go through the central actors before it can be disseminated to other actors in the network. Furthermore, the formal power of the central organization may add new perspectives to the informal, social control mechanism operating in the network.

2.2 Relational capital outcomes and supply network structure

Trust increases connectivity among the organizations in the network. For example, Uzzi (1997) shows how firms have embedded ties with each other in addition to the arms’ length relationship. Uzzi (1997) refers to the arms’ length relationship as an opportunistic relationship; while embedded ties induce cooperation, and coordination among network organizations. The author further emphasized three features of embedded ties, which include: fine grained information exchange, joint problem-solving and trust (Uzzi, 1997). The findings of Powell (2003) and Uzzi (1997) all point to the competitive advantage for organizations in a network form of relationships.
Trust also plays an important role in franchising for outlets of a retail chain. Ou, Abratt and Dion (2006) conducted a survey among 356 grocery store shoppers to study the effects of individual retailer reputation on their store choice patterns. Using the Structural Equation Modeling (SEM) approach, the authors found that retailer reputation affects purchase frequency, travel time and expenditure levels. Podolny (1993) added that visible network ties to a highly reputable firm are a sign of quality. Consequently, bestows status upon an organization.

The author found that reference to trust through ties to other prominent actors in the network allows for the provision of higher products and service's prices. Trust capital is posited to contribute to reduced costs, ease of recruitment as well as increased employee loyalty (Carmeli and Tishler, 2005; Fombrun, 2008; Helm and Salminen, 2010; Luoma-aho, 2007).

Goins and Gruca (2008), Yu and Lester (2008) applied social network analysis to give a theoretical perspective to elucidate how the spill overs effects can take place in a network structure. Based on a study that adopted industry as a network, the authors investigated how both proximity and structural equivalence impact upon spill over effects on firms in the network. The authors (using social network analysis terminology) noted that actors in a network who interact frequently with each other in a network have a tendency to occupy similar network positions and types of network ties between these organizations. These conditions, according to Goins and Gruca (2008), increase the likelihood of the actors to resemble one another and share common perceptions of reputation from stakeholders. Thus, interdependence in the network would depend on the organizational network position.

In social network analysis, network positions with other organizations with high network centrality not only provide peripheral organizations with access to capital, these ties also provide other organizations with relational capital spill-over benefits. For example, network centrality refers to an organization's position in the network relative to others (Scott, 1988). As one of the most important properties of network structure, network centrality evaluates an actor's status, prominence and power (Knoke and Kuklinski, 1982). Knoke and Kuklinski (1982) further stated that actors who are the most important or prominent in the network are usually located in the most central positions within the network. Being central means the actors or organizations are connected to almost all other actors in the network. The connections can be in the form of informal ties, such as information-sharing and referrals, as well as formal ties, which include contractual relationships. Exchange of resources occurs between actors who are tied together either formally or informally.
Thus, extensive contacts or associations with the central organizations in the network increase the availability of information and inflate the reputational spill over benefits (Luoma-aho, 2007). Hence, the embeddedness in the exchange network not only begets tangible returns, it also warrants the accumulation of other intangible ones such as the relational capital outcomes.

It is instructive to know that, scholars have argued that as organizational performance information is difficult to obtain, relational capital becomes an important element for the survival of the organizations (Ferris et al., 1998; Kramer, 1999). Relational capital is generated in the network of inter-firm relations. This argument can be promptly adapted to the upstream supply network. Because of the difficulties involved in analyzing the profiles or intentions of firms in the network, relational capital items such as trust is often applied by the stakeholders in order to make resource allocation/partnership decisions (Poppo and Zenger, 2002). One implication of this dependency on relational capital is that a firm’s high level of involvement may result in increased relational capital outcomes upon it.

However, despite the various impacts of embeddedness found in the literature, many of these inter-organizational network outcomes studies have been focusing on the decentralized network structure. Little to no research has paid attention to firms’ embeddedness in centralized networks with focal firms, such as in the upstream supply network. In the upstream supply network, Choi and Krause (2008) argued that an upstream supply network is likely to be a centralized network structure. What affects firms’ embeddedness in such a centralized network structure has upon network relational capital outcome as per a decentralized network structure is not certain. One important element that may result in diverse relational capital effects is the nature of the network governance between a decentralized network and a centralized network structure.

Even though an integrated network of services and flows may be the best solution to the problem of complexity driven by inter-firm relationships in the upstream supply network, the question remains, will the effects of a firm’s embeddedness on reputation, trust and influence be similar when firms are embedded in a centralized network such as the upstream supply network? This question is valid because the existence of a powerful focal firm in the upstream supply network may introduce an unknown impact on relational capital outcomes in the context of the upstream supply network structure. This is because the introduction of the focal firm may alter the overall network positions of the network members. Thus, the first main research question for this research seeks to investigate the relationship between firms’ embeddedness in the centralized upstream supply network and firms’ relational capital outcomes and reads:
Is the embeddedness of firms in the centralized upstream supply network related to the firms’ relational capital outcomes?

2.3 Research hypothesis

Extensive interactions generate trust among firms. For example, Uzzi (1997) found that, in order to obtain information regarding a potential partner before collaboration activities can be carried out; firms resort to trusted firms for information. The trust between the firms, argued (Uzzi (1997) is the result of multiple exchanges in the past. In the same vein, Gulati (1995) highlighted that years of inter-firm relationships generate trust among them. In addition to that, Gulati and Gargiulo (1999) found that negative gossip by third parties about another party’s uncooperative behaviour significantly reduces the likelihood of direct relations; whereas positive gossip strengthens the likelihood of direct relations among firms in the network. What this literature shows is that, in a network relationship, a firm will sometimes refer to its partner’s previous experience and information with potential partners before agreeing to short-term or long-term business commitments. Extensive interactions are a catalyst for trust in networks of inter-firm relations. Similarly, Eccles (1981) found that extensive interactions among a network of homebuilder firms also create trust among network members. The authors found that exchanges of information among the contractors regarding materials prices create stronger inter-firm relationships and thereby facilitate the creation of trust.

Trust also materializes in the long run through the contract relations among firms. For example, Brown and Troutt (2004) found that trust emerged through extensive contracts and social relations between government organizations and non-profit organizations. McEvily, Perrone and Zaheer (2003) found that an important structural condition in a network of inter-firm relationship is trust. A firm that loses the trust of its network members may see that some of its ties are removed and the firm itself is pushed into the periphery from the core network position. Consequently, this will create a new firm that will take the central figure and become the core firm in the inter-firm network. Thus, the literature indicates that firms in a network having an extensive relationship with other firms in the network may be perceived as trustworthy by others. Since extensive relationships in network analysis can be pictured based on the level of firms’ coreness in the network structure, this research hypothesizes that:

Research Hypothesis: Firm’s embeddedness following their centrality position in the upstream supply network through different inter firm relations impact the level of trust that the firms may acquire from other network members.
3. METHODOLOGY

Align with the objectives of this study; the design and methodology of are based on the theoretical and analytical framework of the Social Network Analysis (SNA). In SNA, the relationships or ties between the actors in the network are the primary data collected while the actor attributes or characteristics serve as the secondary data. Graphically, an actor of the social network is represented in the network diagram by a node or a point. Given a collection of actors, social network analysis can be used to study the structural variables measured on actors in the set. The relational structure of a group or large social system consists of the pattern of relationships among the collection of actors. The concept of a network emphasizes the fact that each individual has ties to other individuals, each of whom in turn is tied to a few, some, or many others, and so on. The phrase “social network” refers to the set of actors and the ties between them. The network analyst would seek to model these relationships to depict the structure of a group. One could then study the impact of this structure on the functioning of the group and/or the influence of this structure on individuals within the group.

There are several key concepts at the heart of network analysis that are fundamental to the discussion of social networks. These concepts are: actor, relational tie, dyad, triad, subgroup, group, relation, and network. The definition and descriptions of these concepts are given in the table in Appendix 1.

For this study, an upstream supply network of a small maritime industry seems to be an ideal setting. A supply network in the maritime industry is a material-intensive enterprise. Much of the activities and activities are highly dynamics and are widely dispersed throughout the network. Materials and information flow are transferred through interactions among different firms. Since firms in supply network operate in an environment of high degree of complexity (Bozarth et al., 2009) and uncertainty (Wilding, 1998a), firms seek an edge through connections or interactions with the members of the network. Lambert and Cooper (2000) stated that the key to these issues is the on-going relationship with the other partners. They stressed on the importance of investigating the relationships that suppliers and customers have. Johnston et al. (2004) suggested that on-going relationship among members increases efficiency and effectiveness of the supply network.

The site of this study is located in the country Malaysia. The researcher profiles different supply networks critically to determine the most suitable network for study. One of the networks, here labelled as APMMHQ-1 supply network, was found to be the appropriate site for this exploration. APMMHQ-1 supply network was found to have good performance indicator, and considered one of the best
supply system in the region through its Integrated Logistic Support (ILS) programs. Accordingly, these signs were assumed to be good pointers for the suitability of the site. The top level managements were approached for possible participations in the study. After several communication about the goal of this study and the potentials benefits for the APMMHQ-1 supply network, positive commitments were received from the top managements to participate and granting participations to this study.

The first step of social network analysis is to determine the population of the study to be surveyed. There are two sampling units in this study: the firms that occupy the APMMHQ-1 upstream supply network for the product RHIB and the ties or relationship between them. The sampling frames for the firms and for the connections between them are nested. In network studies, the method used to sample relations is part of the survey instrument.

In network studies, all the actors that are located within the naturally occurring boundaries are included for analysis. Consequently, network studies do not use samples as in the conventional sense, rather, it seek to include all of the actors in some population or populations (Hanneman and Riddle, 2005). The research population for this study consists of the firms in the upstream supply network of APMMHQ-1. More specifically this study investigates the firms operating in the upstream supply network of APMMHQ-1 for the supply of parts and materials for the production of Rigid Hull Inflatable Boat (RHIB) to the APMMHQ-1. In APMMHQ-1 production, the RHIB is the small fast craft that received highest demand from the market. It contributes to up to 43% of the company return in 2010, 2009, and 2008.

As mentioned in network studies, all the actors that are located within the naturally occurring boundaries are included for analysis. Consequently, network studies do not use samples as in the conventional sense, rather, it seek to include all of the actors in some population or populations (Hanneman and Riddle, 2005). Defining and locating the boundaries of a network is utmost important in a network study. To identify and define the target population within the APMMHQ-1 upstream supply network for RHIB, the author combines the realist and the nominalist approach.

A survey instrument was used to collect majority of the information needed for this study. Surveys and questionnaire are traditional tools to help network researchers to obtain data on inter-organisational relationships (Wasserman and Faust, 1994). Leading network researcher such as Galaskiewicz and Marsden (1978), Knoke and Kuklinski (1982), Burt (2004), and Borgatti and Li (2009a) established the credibility of this technique for the collection of network data on inter-organisational transactions such as information transfer, resource transfer and...
joint activities. Survey is suitable for this type of study because it allows the researcher to tap into the participants’ subjective perceptions of interactions rather than objective measure of interactions, which many situations are hard to get access to for confidentiality reasons (Diani, 2002).

The survey instrument in this study followed standard survey design features such as asking general information questions at the beginning, followed by more specific questions, and lastly the most probing questions at the end. The survey questionnaire consisted of closed ended questions and open ended questions. In general, the questionnaire were framed following the standard of Choi and Hong (2002), Provan and Milward (1995), Stone (2001), Corteville and Sun (2009) and Cross and Parker (2004).

### 3.1 Network Ties Questions

The first category of questions seeks demographic information of the network actors. The second category investigates the network ties between the organisation/unit in the MMEA supply network. In this section, the respondents were given a grid with each of the buyer-supplier organisations in sample on the vertical axis. Respondents were asked to go through the list and indicate (with a check) which buyer-supplier organisations that the respondents’ organisations have been involved with for each of the four types of relationship listed. These four types of ties are important to understand both formal and informal relationships among organisations (Provan and Milward, 1995, Choi and Hong, 2002a, Corteville and Sun, 2009). The four types of ties investigated, which were contracts, information sharing, referral made and received ties. The contractual questions shows how formally linked an organisation/unit is with another in the supply network. The survey instrument asked the key informants to indicate on the roster the list of organisations that they have formal service contracts with (Choi and Hong, 2002a, Provan and Milward, 1995). The shared information category illustrates the norm of collaboration and cooperation between the organisation/unit that is asserted on formal links or ties. Network data on information and communication ties reveal collaboration in a network. Information sharing was assessed in the network survey by asking key informants to indicate on the rosters which the buyer-supplier organisations listed below that might have exchange of information to accomplish their work (Cross & Parker, 2004). Referral made and received illustrates the patterning of service links or ties and the overlap with the other two links as referral links can be either formal or informal. Respondents were asked to indicate with a check on the rosters the list of buyer-supplier organisations to which they made referrals. Similar actions were asked from respondent for referral received ties. Key informants from each buyer-supplier organisations were asked to select organisations...
to which they received referrals. Referral made and referral received ties followed the work of Corteville and Sun (2009).

Another important source of network ties data were gathered indirectly during the surveys. For example, key informants were likely to mention existing information, contract, or referral relationships that they had formed outside of the known boundary. The researcher also invites the respondents to name other organisations that may have participate in the MMEA supply system but is not listed as one of the 37 buyer-supplier organisations. The researcher, however, did not receive any additional named to be included into the network data.

3.2 Definitions and Operationalization

There are two types of variables that are included in the network data of this study. First is the embeddedness variable. Embeddedness variables are the main independent variables of the social network data set. The second set of variables is the relational capital performance variables which form the outcome variables of this study. Degree centrality measures the number of other actors in the network to which the focal organisation or ego is tied to. In a directional graph degree centrality is recognized by adding the number of connections flowing to the focal organisation or the ego to the number of connection flowing from ego and subtracting the overlap. In the case of non-directional graph, the degree centrality of an actor or organisation is defined as,

\[ \text{DEGREE CENTRALITY} = d(ni) \]

where \( d(ni) \) refers to the degree of the node \( i \). An actor or organisation degree centrality score is bound by the number of actors in a network other than ego (n-1) (Wasserman and Faust, 1994).

3.3 Relational Capital Performance Variables

There are many forms of trust that can exist in an organization from what is referred to as blanket trust which translates to a trust of another individual in any action they take to a focused trust on a specific topic. In the context of the Social Network Model, trust is considered when an individual believes that another individual will take actions that are mutually beneficial and not solely to one’s own advantage.

Trust measures the quality of relationship between two organisations. In this study, although respondents were asked to report their multiples types of relationship with other organisations, a global measure of relationship quality is adopted to measure the overall quality of the relationships between two organisations or actors. Operationally, the actor’s ratings of relationship quality
with other buyer-supplier organizations are organized in a matrix of reported relationship quality. The horizontal and vertical axes represent each buyer-supplier organization. The respondents were listed on the vertical axis and the target buyer-supplier organizations for reported relationship quality were listed on the horizontal axis. This places each response along the rows of each matrix. The rating given by the respondent buyer-supplier organizations (1-4, 1 = poor relationship to 4 = excellent relationship) was recorded in the appropriate column of the relationship matrix. The trustworthiness of buyer-supplier organizations is calculated by the ratio of the column total of the matrix (the sums of all reported relationship quality rating of a target actor of organisation) to the number of organisations which reported a quality rating.

3.4 Analysis Method

The analysis was divided according to the types of analysis technique applied. First, the researcher performed exploratory social network analysis (visual analysis) of buyer-supplier organisations network by exploring the network maps and the network structural measures. For this purpose, this study adopted a spring-embedding visualization method in the UCINET program whereby a network layout is computed using force directed algorithm. More specifically, the algorithm place nodes based on node repulsion and equal edge length bias. When so configured, the placement of nodes in the sociogram is based on forcing the nodes apart and tending to select placements that lead to equal edge lengths (i.e., equal length lines between nodes). This particular layout has the advantage of detecting network centrality patterning (Polites and Watson, 2008). For these routines, this study applied the network imaging software within the UCINET (Borgatti et al., 2002) i.e. the NetDraw, which is equipped with sophisticated visualization techniques. Visual representation of supply networks can provide useful direction for researchers, and starting point to developed subsequent quantitative analyses (Choi and Hong, 2002b).

Then, the researcher tested the research hypotheses using innovative statistical network modeling known as the Exponential Random Graph Modeling (ERGM, or p* model; Robins et al., 2007b). Robins, Elliott et al. (2001) suggested that in social network analysis, the network structure need to be searched not assume from previous other related literature.

In general, the exponential random graph models (ERGM) have the following form:

$$P_r (Y = y) \left( \frac{1}{k} \right) \exp (\sum nA(g) A(y))$$

(2)

where:

(i) The summation is over all configurations A;
(ii) \( \eta_A \) is the parameter corresponding to the configuration A (and is nonzero only if all pairs of variables in A are assumed to be conditionally dependent).

(iii) \( g_A(y) \) is the network statistic corresponding to configuration A; \( g_A(y) = 1 \) if the configuration is observed in the network \( y \), and is 0 otherwise.

All ERGM models are of the form of equation (1), which describes a general probability distribution of graphs on \( n \) nodes. The probability of observing any particular graph \( y \) in this distribution is given by the equation, and this probability is dependent both on the statistics \( g_A(y) \) in the network \( y \) and on the various non-zero parameters \( \eta_A \) for all configurations A in the model.

Consequently, different network analysis routines were applied to explore patterns of connectivity among the buyer-supplier organisations that are embedded in the MMEA supply network and examine the structural characteristics of these entities. These analyses were performed using the software package UCINET (Borgatti et al., 2002).

Scholars of social network have consistently confirmed that the fundamental theoretical insight of the social network analysis rest on the importance of the ties between actors (Lusher, 2011, Lusher and Ackland, 2010, Lusher et al., 2012, Carrington et al., 2005, Nahapiet and Ghoshal, 1998). In social network, the embedded nodes or actors are interdependent, making them related unit of analysis (Lusher et al., 2012, Snijders et al., 2006). Consequently, it is not best assessing network member’s relations in a quantitative manner through the normal series of traditional statistical analysis (Shumate and Palazzolo, 2010). One chief reason for this argument is that as the normal series of traditional statistical techniques consider each node or actors of a network to be unrelated or independent (Robins et al., 2012, Igarashi et al., 2006). Many leading network scholars claimed that traditional statistical analysis disregard the possibility of relations between the individual nodes or actors through the assumption of independence of observation (Bamber et al., 2010, Lusher et al., 2012, Robins et al., 2009, Shumate and Palazzolo, 2010), when in fact, in social network node and actor are an interdependent, related, unit of analysis (Knoke and Kuklinski, 1982). It is for this interdependency and relatedness argument that a special class of statistical models is preferred when investigating social relations phenomena, in particular the Exponential Random Graph Model (ERGM) (Shumate and Palazzolo, 2010).

4 RESULTS

4.1 Exploratory Network Analysis: Visual Analysis of Social Network Trust Network Map and Degree Centrality

From Figure 1, there are several sub-groups or cliques of trust relationship in the network structure. In addition in the almost all sub-groups or cliques, there
exists one firm that has high trust attribute compared to other nodes. Furthermore, nodes that are periphery in the network are mostly low in their trust score. This network map implies that nodes that are embedded in the core position may experience high level of trust while nodes on the periphery have mostly low trust level. Together, the positioning of the nodes of the trust network indicates the tendency towards a degree based core-periphery structure. Borgatti and Everett (2000) stated that the core periphery structures imply the existence of two distinct regions in the network, i.e. one that includes dense and cohesive subsets of nodes, and another where connections are looser and sparse. Borgatti and Everett (2000) posited that these particular structure may form in two ways, i.e. one as a result of high centralization process, indicated by the presence of hubs and spokes nodes, for example when prominent firms attracts most of the other firms, and another, due to high triangulation, which suggest the presence of large number of overlapping cliques.

Figure 1: Trust network with color on the nodes representing high and low trust score.
Source: Author
4.2 ERGM Analysis of Trust Network and Embeddedness Based on Degree Centrality

To test the effects of nodes embeddedness attribute in a more systematic way, this study performed a series of ERGM analysis, which allow the researcher to determine statistically the effects of organizations measures of network embeddedness upon trust network (Snijders et al., 2006, Robins et al., 2009). For the ERGM analysis this study adopted Shumate and Palazzolo (2010) Pure Structural Effects and Pure Attribute Effects model analysis. In the initial analysis, the researcher conducted the Pure Structural Parameter Effects model ERGM analysis to determine the relevant structural formation of the trust network. Following this, the researcher conducted another ERGM analysis with the buyer-supplier organizations measures of network embeddedness or node attributes included into the model. This model is called the Pure Attribute Based Network Effect model. The outcome of this model will enable the researcher to see the impact of the attribute upon the ties structural formation propensity inside the relevant network and more importantly upon the node attribute parameters. The relevant node attribute parameter to test for these effects is the Sum of Continuous Attribute and supplemented by the Difference of Continuous Attribute parameters. Using these parameters the researcher will be able to tell the individual effects of the attributes upon the buyer-supplier organizations in the network. Following Robins et al. (2007a), the researcher analysed the MLE (Maximum Likelihood Estimate), and the standard error. The parameter is significant when absolute value of estimates exceed twice the standard error outcomes of each models. The sign of the MLE ("+") or "-"") provides an indication of whether the particular network structure occurs more or less likely than predicted by chance. For a model to be considered well converged the parameters t-ratio must be less than 0.1 is absolute value. All of the parameters included in this study models are under the convergence threshold, indicating that the models fit the data well. In the following section this study discuss the analysis results of ERG model for trust network and embeddedness attributes measured based on degree centrality in the formal contract tie, information sharing tie, referral made tie, and referral received tie.

4.3 MMEA Trust Network with Organization Network Embeddedness Degree Centrality (ONEDC)

In this section, the researcher discussed the ERGM analysis results involving embeddedness of firms measured based on the ONEDC across four supply ties. For reason of constraints place on this study report, the researcher will only discuss the
Pure Structural Effects model results followed by the model effects of the embeddedness attributed as represented by the Sum of Continuous Attribute and the Difference of Continuous Attribute parameter of each supply ties. The parameter estimates (MLE), and standard error are presented in Table 1.

Table 1: ERGM Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ML Estimates</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trust Network Pure Structural Effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arc</td>
<td>-1.101</td>
<td>0.082*</td>
</tr>
<tr>
<td>Reciprocity</td>
<td>1.478</td>
<td>0.401*</td>
</tr>
<tr>
<td>A-in-S</td>
<td>-1.350</td>
<td>0.429*</td>
</tr>
<tr>
<td>A-out-S</td>
<td>0.128</td>
<td>0.399</td>
</tr>
<tr>
<td>AT-T</td>
<td>1.096</td>
<td>0.259*</td>
</tr>
<tr>
<td>AT-C</td>
<td>-0.273</td>
<td>0.109*</td>
</tr>
<tr>
<td>AT-D</td>
<td>0.469</td>
<td>0.212*</td>
</tr>
<tr>
<td>AT-U</td>
<td>-0.089</td>
<td>0.131</td>
</tr>
<tr>
<td>A2P-T</td>
<td>-0.163</td>
<td>0.045*</td>
</tr>
<tr>
<td>A2P-D</td>
<td>-0.124</td>
<td>0.075</td>
</tr>
<tr>
<td>A2P-U</td>
<td>0.084</td>
<td>0.027*</td>
</tr>
</tbody>
</table>

| **Trust Network Pure Attribute Effects** | | |
| **Section 1: ONEDC in Contract tie** | | |
| Sum of continuous attributes | 0.071 | 0.026* |
| Difference of continuous attributes | -0.036 | 0.017* |
| **Section 2: ONEDC in Information sharing tie** | | |
| Sum of continuous attributes | - | 0.017* |
| Difference of continuous attributes | 0.064 | 0.014* |
| **Section 3: ONEDC in Referral Made tie** | | |
| Sum of continuous attributes | 0.028 | |
| Difference of continuous attributes | | |
| **Section 4: ONEDC in Referral Received tie** | | |
| Sum of continuous attributes | 0.017 | |
| Difference of continuous attributes | -0.027 | |
| Difference of continuous attributes | 0.031 | 0.012* |
| Difference of continuous attributes | 0.046 | 0.022* |

* Asterisk indicate effects where absolute value of estimates exceed twice the standard error

In Table 1, to obtain a converged Pure Structural Effects model for trust network, the structural parameters are included conditionally until the model is converged i.e. until the t-ratio of each relevant parameter is less than 0.1. Consequently, the parameters that are included in the Pure Structural Effects model of the trust network are as follow: Reciprocity, A-in-S, A-out-S, AT-T, AT-D, AT-
Analyzing the Impact of Firm’s Embeddedness in a Centralized Supply Network Structure…

U, AT-C, A2P-T, A2P-U, and A2P-D. Structurally these parameters reflect certain form of ties structural formations in the trust network. These parameters reflect density (arc), reciprocation (reciprocity), degree based or centralization (A-in-S, A-out-S), and multiple transitivity (AT-T, AT-D, AT-U, AT-C, A2P-T, A2P-U, and A2P-D) (Robins et al., 2009, Wang et al., 2006b).

First, in the structural effects section, the Arc ML estimate is a significant and negative parameter, suggesting fewer trust relationships are expected if the MMEA supply system are observed than would have been expected by chance. In other words, firms of the MMEA supply network forge trust relationships to only a few of the potential other firms in the network. This phenomenon is expected as trust relationships are build overtime and relies on other endogenous variables such as size of the participating firms and the length of the relationships (Jiang et al., 2011, Laaksonen et al., 2009, Doney and Cannon, 1997). Firms’ size encompasses the firm’s overall size and its market share position. Firms’ size provides a signal to other firm its level of trustworthiness. Overall size and market share indicate that many other businesses trust this firm enough to do business with it. This suggests that the firms consistently deliver on its promises to others or it would not have been able to maintain its position in the industry.

Second, there is a significant and positive effect of reciprocity for trust network model. This indicate that firms are likely to nominate each other in trust relation i.e. if Organizations APMMHQ1 trust WILSEL4 there is also a high likelihood that WILSEL4 trust APMMHQ1 in return. Reciprocity is an important feature of many other social networks studies, and it is expected in trust relationships (Lusher, 2011, Lusher and Ackland, 2010, Lusher et al., 2010, Lusher et al., 2012, Bamber et al., 2010, Robins et al., 2012, Robins et al., 2009).

Third, the model shows that the A-in-S parameter is significant but negative A-in-S parameter is an indication of the presence of highly nominated firms within the trust network. What can be taken from this parameter estimates is that in the trust network, controlling for other effects, although there is a significant parameter estimates for A-in-S, the negative MLE score indicate that it is unlikely that trust ties relationship will be forge based on the degree based structural formation. On top of the structural parameters, Table 1 also shows the effects of the continuous attributes upon the ties formation propensity between the embedded buyer-supplier organizations in the trust network in the attribute effects sections. The first section shows the results for ONEDC in contract tie. The Sum of Continuous Attributes is significant and positive. This shows that in the trust network, firms that have high ONEDC in contract tie forge trust ties with others with similar high embeddedness level and with low embeddedness level more frequently. Because the
embeddedness score is related to the number of connections that firms has in the network, we could also relate this parameters to the location of these firms in the network structure. Structurally, we would find these firms to be located in the center of the network, as there are the nodes that has the most connections or ties to other nodes in the network. The Difference of Continuous Attribute is significant and negative suggest that the firms with differing level of embeddedness levels are less likely to forge ties together. What can be taken from the findings of the ERGM analysis outcome is that, ONEDC in contract tie influences the propensity for trust ties to be forged between the embedded firms. Thus, firms with high ONEDC may appear more trustworthy to the other network members.

In the second section, there is a negative and significant Sum of Continuous Attribute parameter indicating that firms with high ONEDC in the information sharing tie have low tendency to trust others with high or low ONEDC firms. A significant and positive Differences of Continuous Attribute shows that there is a strong tendency for firms in the observed network to forge ties or trust other network members when their ONEDC differences are small. When compared to the attribute effects in contract ties, the Sum of Continuous Attribute effects are non-significant but Difference of Continuous Attribute effects are positive and significant. The distinctions in the attribute effects may relate to the type of type of ties in question. A formal tie such as the contract tie is governed by terms and regulation. Such condition may lead to focal organizations becoming dominant in the network. For example, Toyota is the focal organization in the Toyota supply chain with few tier one organizations also considered focal, as they functions as the main supplier to the Toyota production facility. The flow of supplier between upstream suppliers to the focal suppliers and subsequently to the manufacturer itself is governed by agreed rules and regulations with the contracted organizations are bounded to the demands and needs of the ordering authority (i.e. focal organizations). This phenomenon may create a few focal organizations that become core nodes as indicated by the positive Sum of Continuous Attribute effects in the model. On the other hand, positive and significant Difference Continuous Attributes may be attributed to the informal nature of the information sharing tie whereby in such network, communication is not based and bounded by any official regulatory. The third section of trust network model in shows the attributes effects results for ONEDC in referral made tie. There is a significant and positive Sum of Continuous Attribute effects for the observed network indicating that firms with high ONEDC in the referral made tie tend to forge ties with others. The negative and significant Differences of Continuous Attribute show that when the difference
in their ONEDC is small, there is low tendency for the firms of the observed network to forged trust ties with other firms.

Finally, the fourth section shows the result of attributes effects, ONEDC in referral received tie. The Sum of Continuous Attribute is found to be positive and significant. This is an indication that firms that possessed high ONEDC in referral received tie are likely to form ties with other network members. However, the positive and significant Difference of Continuous Attribute shows that trust relationship are more likely to be forged between network nodes when the difference in ONEDC in referral received tie is small.

5 DISCUSSIONS

The exploratory analysis and the ERGM analysis revealed that there were significant, positive effects of firm’s embeddedness based on centrality network positions and trust. For example, firms that are highly embedded in the information-sharing tie network, based on their degree centrality network structural position, have a high likelihood of being perceived as trustworthy by other network members. The results are similar in the referral made ties, and the referral received ties. This also indicates that, as firms are more embedded in the centralized upstream supply network based on the degree centrality network structural position, their level of trustworthiness as well improves. However, the Maximum Likelihood Estimate (MLE) is significant but negative when firms are highly embedded in the contract tie. What this means is that the more embedded a firm is in the upstream supply network based on the formal contract tie, the less is the likelihood that it will be perceived as trustworthy by other network members.

This suggests that the study hypothesis can be accepted. As a firm becomes more embedded in the upstream supply network structure, it will experience varying levels of relational capital depending on the type of activity that the firm is involved in. Thus, the more embedded a firm is in the supply network based on degree centrality network position, the more likelihood there is that the firm will be perceived as trustworthy by other firms embedded in a similar network structure. This implies that firms in an upstream supply network relationship trust the firms that occupy the central position in the supply network structure; alternatively, by definition, the firms that receive the most ties or connections from other firms.

Overall, it appears that firm’s embeddedness in the supply network structure contributes to the level of trust that one firm may receive from other network members. Moreover, the trustworthiness level that a firm receives from other colleagues may be helpful in the collaborative development of a new-product innovation or services. The level of trust can also influence the development and
training of personnel; for example, to qualify them to deal with the partners’ or customers’ technology or system. The results of the parameter estimations are in line with the results of the trust network visual analysis (Figures 1). In this case, this study also found that, in the sociogram of trust network (Figures 1), firms that have a high level of embeddedness based on degree centrality are also the central firms in the trust network structure.

This finding is consistent with Uzzi (1997). Uzzi (1997) found that, in inter-firm relationships, active relational governance such as information-sharing is associated with trust. Further, it was found that firms resort to trusted firms in the network with whom they have dealt multiple times in the past to obtain information regarding a potential partner before collaboration activities can be carried out. More importantly, Zaheer et al., (1998) confirm that this leads to improved performance of inter-firm exchanges. An important implication of this study is that the findings provide support that firm’s commitment into information-sharing activities enhances the perception of trust that the firm may receive from other network members. In addition, referral relationships are regarded as being a firm’s high level of goodwill (Anderson, 1998). Referral relationships often involve sending human resources, or participating in programs to make certain of issues regarding clients or processes. As receiving referrals can be interpreted as receiving resources from other network members, others may regard the act of sending referrals to other firms as an act of goodwill. Consequently, firms that receive a high number of referrals will also be perceived as highly trustworthy by other firms in the network structure. Thus, the findings of ERGM analysis for the hypothesis lend support to the argument that firms are more embedded in the centralized upstream supply network.

6 CONTRIBUTION

Achieving success in a supply network is essential. Understanding how and why some business relationships succeed and why others fail is perhaps among the most critical issues facing firms in the supply network. Thus, from a manager’s standpoint, it is important to know how to improve firms’ overall performance. Based on the findings of this research, the following implications are highlighted. First, the researcher could demonstrate that firm network involvement, or its embeddedness in the centralized upstream supply network or supply base, is extensively related to the firm’s key relational capital resources (ERGM analysis of Table 1). More specifically, it is beneficial to know that firms which become aware of, and are involved in the centralized upstream supply network relations, will widely experience increased levels of trust. Even though it is not the goal of this
study to explore the impact of network involvement on accounting or financial indicators, it is, however, important to note that Reagans et al. (2004) argued that relational capital such as trust facilitates transactions. As a result, it could reduce costs, as well as increase performance and innovativeness of the related parties. What this means for managers of the supply network is the ability to identify and capitalize on the important network structural position that can contribute to increase relational capital outcomes. The findings of this study have indicated the relevant position or degree of involvement for the generation of trust; it is the initiative of managers to determine their respective positions in the centralized upstream supply network structure and make the necessary adjustments.

In addition, the findings of this study also showed that the relationship between network involvement and relational capital is reasonably high, even in the highly centralized upstream supply network structure. Thus, managers of firms in the supply network should not be discouraged from involving themselves with other firms in the supply network structure. The relational capital resources still flow to other firms despite the existence of a central focal firm managing and administering transactions between firms in the network structure. This highlights the needs for managers and firms to have the ability to examine and understand other firms’ patterns of embeddedness as this may be the key to capturing the dynamics of inter-firm relationships that might be beneficial or lead to future concerns. As firms are able to understand this concept, it might help the firm to avoid the danger of dismissing a certain firm based solely on poor accounting measures, when, in fact, this firm is connected to other highly powerful or resourceful ones. The quantitative analysis results of this study may shed light on the type of relations that may have influence upon firms’ relational capital and become the knowledge needed for managers to comprehend the dynamics. In addition, the findings of this study may shed light on the ‘myth of downsizing’ in the context of inter-organizations. Choi (2011) described the upstream supply chain complexity or supply base complexity as being a ‘beast’ that requires understanding in order to tame it. Rather than by harsh actions such as removal of a part or elements that formed the whole network. This study attempted and succeeded to investigate and provide others with an additional lens through which to comprehend the complexity and consequently, bring new means to tame the beast. Since it has been a known empirical fact that downsizing does not improve performance of intra-organizations, the findings of this study may prove similar effects. It may also explain in part why, in the context of inter-organizations, a ‘reductionist’ approach (based on accounting measures) to suppliers’ management may not be the answer. It follows that it seems ill-guided reductionist may remove
the influential, resourceful firms that do not appear on the firms’ radar of good accounting measures (Choi et al., 2006).

This study also indicates the importance for firms and more specifically, managers of the firm operating the supply chain management functions to be able to understand and analyze the embeddedness of other firms in the supply network structure, as well as their own. To understand the nature of other firm’s embeddedness in the supply network structure, managers need to have the ability to determine the direct and indirect ties that the firms have with other network members. Thus, firms must possess potent network awareness in order to manage the complexity resulting from multiple direct and indirect ties. For example, a firm with heightened network awareness ability should not simply cut ties with low performing partners in the network merely assuming low accounting returns, as these partners may actually be connected to a more influential network of members. Network theorists refer to this phenomenon as the strength of weak ties (Granovetter, 1973; Ruef, 2002). This study also contributes to the resource allocation and management strategy in the supply chain. Resource allocation problems in supply chain management may take place during portfolio management optimization. Owing to the complexity inherent in these systems, the search for optimal solutions can be a difficult task. Since sharing of information is central to the resource allocation activities in supply chain management, understanding the pattern of the resulting network structure can help managers to use this preliminary finding to channel the resources for relationship management based on the type of both organizations and relationships. More focused relationship management would ultimately improve cost savings and performance of the supply chain. Thus, overall, on top of the normal accounting measures commonly applied to the management of the supply network structure, results from this study can add to the much needed tacit, intangible knowledge of complexity arising from inter-firm relations. Accordingly, the knowledge of embeddedness of firms in the upstream supply network structure can be another strategic tool for managers when dealing with the complexity in the supply network that arises from inter-firm relations. The researcher posited that by understanding and knowing firms’ patterns of embeddedness in the different network ties, managers will be equipped with an additional tool when evaluating current and potential partners, as well as determining optimum resource’s allocation strategy and forecasting purposes.
7 Future Research

As for future research opportunities, the framework of this study could also be tested in other industries, i.e. in a more dynamic, fast cycle industry such as the electronics industry. The heightened degree of uncertainty and rate of innovation in the electronics industry may influence the pattern of strategic behaviour of the embedded organizations and the appropriate network configurations. Firms embedded in rapidly changing networks may achieve competitive advantage through different forms of network embeddedness from firms in a more stable environment such as the shipping industry. In the volatile, rapidly changing environment, the level of uncertainty will also be higher compared to the more stable industry. With this increased volatility and uncertainty, organizations are expected to make decisions that are based less on economic parameters but more on relationships and resources at hand. Hence to see if the findings of this study would also hold in different industry, it would be an interesting undertaking and would add to the generalizability of this study.

8 Conclusion

This study has presented a view of the supply network as a social system and has pointed out that network embeddedness plays a prominent role. Our results suggest that embeddedness impact upon the organizational level of social capital. This implies that the supply management function can, to some extent, shape the supply network structure around particular organizations. More research is needed to determine the extent, to which embeddedness of an organization can control, or more likely influence, the development of networks and how much leverage the supply network has in this process. The results also suggest that supply network embeddedness may have much to contribute towards strategy development. In conclusion, by considering the overall implications of the study, it may conclude that complexity is not all bad. Managers need to consider their firm’s existing embeddedness in order to exploit the competitive advantage of supply network inter-organizational relationships. Firms that fail to understand the underpinnings of these relationships stand to face more difficulties within the network itself. For this reason, managers that intend to obtain competitive advantage from the network must engage with other partners more effectively. No doubt some firms are at an adequate standing, while others are struggling in some areas. The framework of this study can be applied by managers who are committed in engaging other network members.
REFERENCES

APPENDIX

<table>
<thead>
<tr>
<th>Concept</th>
<th>Description/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actor</td>
<td>Social entities of the network. Actors are discrete individual, corporate, or collective social units</td>
</tr>
</tbody>
</table>
| Tie     | A linkage between a pair of actors. Actors are linked to one another by social ties. Common examples of ties employed in network analysis are:  
  - Evaluation of one person by another (for example shared values)  
  - Transfer of resources (such as communications, giving information and receiving information)  
  - Behavioural interaction (such as knowledge exchange) |
<table>
<thead>
<tr>
<th>Concept</th>
<th>Description/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyad</td>
<td>A tie between two actors. A dyad consists of a pair of actors and the (possible) tie(s) between them. Dyad is frequently the basic unit for the statistical analysis of social networks.</td>
</tr>
<tr>
<td>Triad</td>
<td>A subset of three actors and the (possible) tie(s) among them</td>
</tr>
<tr>
<td>Network Data</td>
<td>Network data consists of at least one structural variable measured on a set of actors</td>
</tr>
<tr>
<td>Graph</td>
<td>Graph theory has been useful in social network analysis for many reasons.</td>
</tr>
<tr>
<td></td>
<td>• provides a vocabulary to label and denote social structural properties</td>
</tr>
<tr>
<td></td>
<td>• gives mathematical operations with which many of these properties can be quantified and measured</td>
</tr>
<tr>
<td></td>
<td>• gives us the ability to prove</td>
</tr>
<tr>
<td></td>
<td>• gives theorems about graphs, and hence, about representations of social structure</td>
</tr>
<tr>
<td></td>
<td>• gives a representation of a social network as a model of a social system consisting of a set of actors and the arcs between them</td>
</tr>
</tbody>
</table>