# SOCIAL NETWORK ANALYSIS OF CONSTRUCTION COMPANIES OPERATING IN INTERNATIONAL MARKETS: THE CASE OF TURKISH CONTRACTORS

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**I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.**

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# ABSTRACT

## SOCIAL NETWORK ANALYSIS OF CONSTRUCTION COMPANIES OPERATING IN INTERNATIONAL MARKETS: THE CASE OF TURKISH CONTRACTORS


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The nature of the construction sector makes the management in this field very complex. Therefore, the executives are pressurized to explore new techniques with the purpose of increasing the efficiency of management of the companies. Although it is originally developed to study the topics related to the social sciences, the applicability of the Social Network Analysis (SNA) to various fields gave rise to its utilization in the construction industry in the recent years. In this manner, the administrative bodies could make managerial improvements by creating a new point of view with the help of SNA. However, these kind of studies are relatively unrecognized in the Turkish construction sector. Therefore, it is aimed to overcome this situation by making a contribution with a case study which deals with the collaborative behaviors of Turkish contractors in the international projects. The data were obtained from Turkish Ministry of Economy and they were used to analyze the partnerships of the Turkish contractors. Moreover, the attitudes of the companies in various types of project networks were also examined. Obtained international projects were classified based on their budgets and the related markets of these projects. In this way, the general and individual performances of Turkish

contractors in these networks were investigated and various comments were drawn. Finally, these outcomes were interrogated by experts to check their validity.

Keywords: Construction management, Social Network Analysis, Collaborative project networks, Turkish construction industry, Company relationships

# ÖZ

## YURT DIŞI PAZARLARINDA ÇALIŞAN İNŞAAT ŞİRKETLERİNİN SOSYAL AĞ ANALİZİ: TÜRK MÜTEAHHİTLERİNİN DURUMU

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Yapım sektörünün doğası sebebiyle bu sektörde yönetim çok karmaşık bir haldedir. Bu nedenle, yöneticiler şirket yönetiminin etkinliğini artırmak hedefiyle yeni teknikler araştırma baskısında kalır. Sosyal bilimlerle ilgili konuları çalışma amacıyla geliştirilmiş olmasına rağmen, çeşitli alanlara uygulanabilirliği sosyal ağ analizinden son yıllarda inşaat endüstrisinde de faydalanılmasına sebep olmuştur. Bu şekilde, idari birimler sosyal ağ analizinin yardımıyla yaratacakları yeni bakış açıları sayesinde yönetimsel gelişimler yapabilir. Bununla birlikte, bu tip çalışmalar Türk yapım sektöründe görece olarak fark edilmemiştir. Bu sebeple, bu durumun üstesinden gelebilmek amacıyla Türk müteahhitlerinin uluslararası projelerde göstermiş olduğu işbirliği davranışlarıyla ilgilenen bir alan çalışması ile katkı yapılması hedeflenmiştir. Veriler T.C. Ekonomi Bakanlığından elde edilmiş ve Türk müteahhitlerinin ortaklıklarını analiz etmek amacıyla kullanılmıştır. Buna ek olarak, şirketlerin çeşitli tipte projelerin ağlarına olan yaklaşımları da incelenmiştir. Elde edilen uluslararası projeler bütçelerine ve ilgili marketlerine göre sınıflandırılmıştır. Bu yolla, Türk müteahhitlerin bu ağlardaki genel ve bireysel performansları araştırılmış ve çeşitli yorumlar çıkarılmıştır. Son olarak, geçerliliğinin kontrol edilmesi amacıyla, sonuçlar uzmanlar tarafından sorgulanmıştır.

Anahtar Kelimeler: Yapım yönetimi, Sosyal Ağ Analizi, İşbirliği proje ağları, Türk yapım endüstrisi, Şirket ilişkileri

*To the Headmaster and Founder of Turkish Republic Mustafa Kemal ATATÜRK*

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| | |
|---|---|
| CDM | Clean Development Mechanism |
| CIS | Commonwealth of Independent States |
| ENR | Engineering News Record Magazine |
| LSPN | Large Scale Project Network |
| MSPN | Medium Scale Project Network |
| SNA | Social Network Analysis |
| SSPN | Small Scale Project Network |
| TCA | Turkish Contractors Association |
| UAE | United Arab Emirates |
| USA | United States of America |

# CHAPTER 1

# INTRODUCTION

In this chapter brief introduction about the research will be provided. The concern of this study is to use social network theory for the construction sector at firm level. Although this theory is developed for studying the interactions among people, it has been implemented in many different fields due to its adaptability in various relationships. Therefore, the construction industry can be regarded as one of these fields where the application of Social Network Analysis (SNA) is possible. Despite the fact that SNA has been come into use in construction industry in recent years, these studies are mainly at individual level. However, undertaking firm level studies are possible with the use of SNA.

The objective of this study is to implement SNA to construction industry in order to understand the strategies of the Turkish contractors for the collaborative international projects. The data which includes these projects were obtained from the Turkish Contracting and Engineering Services unit of Turkish Republic Ministry of Economy and analyzed by a SNA software program. In this way, the significances of the Turkish contractors could be explained and the opportunities for both the incoming and residual members can be displayed.

In addition to the general network, the projects of the data were classified according to various projects budgets and project areas to detect how the contractors change their strategy according to scale and market. Thus, the strong and important Turkish contractors in various networks were determined. Moreover, common collaboration practices in these networks were identified based on the results.

The thesis begin with the explanations of social network theory and SNA. A brief review of the previous work on SNA is presented. In Chapter 3, the overview of Turkish construction sector is described. It is followed by a review of SNA in construction industry and brief information about collaboration practice. In Chapter 4, the case study is explained and the results are presented. The results and comments about the general network is given in this chapter. Moreover, three project scale networks and four market networks are evaluated in the same manner. In the last chapter, the study is concluded with the summary.

# CHAPTER 2

# LITERATURE REVIEW ON SOCIAL NETWORK ANALYSIS

In this chapter, the fundamentals of social network analysis are represented based on what is taken from the literature review. It is started with the explanations of what is social network and then continued with what is social network analysis. The measures of social networks analysis are depicted and the information for the commonly used software is mentioned. The previous works on the social network analysis are explicated in the end of the chapter.

## 2.1 What is Social Network?

A network is a graphical representation of a group of nodes which are connected by edges (Kim et al., 2011). Social network can simply be explained as the network of actors who have some kind of relationship between them. The concept is originated from sociology. After the First World War, sociometry is developed to study the human societies in the sense of different characteristics (Moreno, 1937). It is started by classifying people according to various age levels, working areas, communities, etc. (Moreno, 1937). Besides, since the rules and properties are not rigid, it can be modified to implement any kind of relationship between a set of actors.

Some examples of these relationships are friendship, blood kinship, partnership, co-working, information exchange etc. These kinds of relationships are defined by the links in the network. If there is a relationship between two actors, then a link between them is present. Meltzer et al. (2010) described social network as the ties in between the group of social players. These social players could be living creatures, objects, organizations etc. Interactions of these social players can be comprehended with the network approach (Kilduff & Tsai, 2003). Tang (2012) pointed out that, individuals are shown by a node and the connected ones are grouped to produce networks.

Actors in social networks behave under the influence of the relationships that construct the network (Ling & Li, 2012). Kilduff and Tsai (2003) stated that human beings are clubbable creatures and their personalities are affected by these social relationships. With growth of technology, the accessibility of people caused the social networks to become much wider than as it in the past. Recently, social networks have become a part of daily life with the increasing interest on social network sites on the internet world. Facebook, Linkedin and Twitter are examples of these social network sites. In these sites a person creates his/her own network by being friends, following someone or adding to the professional network. The number of registered users to the social network sites is getting increased in each and every day. Therefore, most of the people of whom have access to the internet make use of social networks either by being aware or unaware.

## 2.2 What is Social Network Analysis?

The interest and focus on the social networks, opened an exploratory to go deeper of these networks. The need for a tool and technique to discover these networks led to Social Network Analysis (Chinowsky et al., 2008).

Social Network Analysis (SNA) is a method which is used to identify, express and evaluate the social networks. Pryke (2004) asserted that SNA is technique which helps to show the position of actors and the links between them. By mathematically expressing the networks and providing measures, SNA helps to visualize and compare various networks. It is a quantitative approach which can be explained as the combination of sociometrics, graph theory and algebra (Kang&Park, 2013). Loosemore (1998) proposed that, SNA is founded on graph theory and not interested in causality but the interpretation and comprehension of the networks. Li et al. (2011) argued that quantification of data and turning it to visual graphs are the main features of SNA. Kilduff & Tsai (2003) asserted that the major difference of social network approach originated from its ability to combine the qualitative, quantitative and graphical data while concentrating on the connections of the social players. SNA approach complements the qualitative data with numerical values. Kim et al. (2011) asserted that SNA's ability to introduce quantitative measures, result in persuasive numerical values. In this way, SNA provides ability to assay the social networks' chemistry. SNA analyze the constitutional properties to seek after the details of the relationships in the social networks (Kang & Park, 2013). By using complicated methods, SNA expedites the comprehension of the connections between the social actors (M'Chirgui, 2007).

By analyzing various networks and relationships, SNA provide opportunity to make remarkable comparisons between different networks (Pryke, 2004). The main reason behind this feature is that SNA uses the same criterion to analyze the networks. Therefore, these measures enable the users to contrast separate networks. In this manner, different networks can be interpreted in the same vein.

SNA make use of social network data to produce sociograms (Meese & McMahon, 2012). Sociograms are the representations of social networks, in which the social actors are demonstrated as nodes (Figure 2.1). These nodes can be various geometrical shapes such as; triangle, circle, square, etc. The relationships are shown by the links (or ties) between the social actors. Therefore, it is a very successful way to represent the relationships in a simple manner (Li et al. 2011). Originally, the sociograms were used to search the configuration of the interpersonal connections in the networks and show them graphically (Chinowsky et al., 2008). Kim et al. (2011) proclaimed that the sociograms are very conducive in objectifying the networks and getting a demonstration of these networks. In sociograms the interrelated nodes are tried to be located close to each other (Meltzer et al., 2010). Because of the fact that the sociograms are utilized to display the networks, a part of the network can be worked on comprehensively (Moreno, 1937).

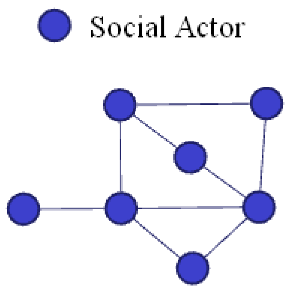


Figure 2.1: A Simple Sociogram

In SNA, the goal is to delineate the social connections between the social actors by using sociograms (Li et al. 2011). Moreover, SNA intends to explore the structure of the networks by using these sociograms. The SNA technique has various unique conceptions which helps the networks to be presented and examined by just focusing the relations (Kilduff & Tsai, 2003). The positions and properties of the actors in the network are disclosed with the help of this technique. These characteristics are the diagnostic part of SNA (Moreno, 1937). The position of the actor in the network could provide some occasions. On the other hand, it could restrict the actor to behave independently from the rest of the network. Moreno (1937) stated that the research for the group set up in the network is a part of the sociometric approach. The groups which are formed by the actors in the network are also a topic that SNA is interested in. Meltzer et al. (2010) emphasized that SNA considers the location of groups in the network and the position of both individual actors and groups in the larger picture. Kilduff and Tsai (2003) remarked that how these groups were formed together and the results of this formation are also concerns of SNA. The adjustment of these groups and individuals in the network is the alterative capability of SNA (Moreno, 1937). In SNA, the aim is placing the actors in the networks and understanding how the connections are established between them by considering the effects of their relationships (Kilduff & Tsai, 2003). In his study, Moreno (1937) summarized SNA as a combination of procedures which are representation, recognition and treatment.

### 2.3 Structure of Social Networks

As it is previously stated, social networks are formed by nodes and ties between them. They are the fundamental constituents of the SNA (Li et al., 2011).

#### 2.3.1 Nodes

The nodes in the social networks are the demonstrations of the social players. They can be used to identify multifarious kind of actors. Originally, the people were represented as nodes to work on human societies (Moreno, 1937). However, in recent years the nodes have been used to represent other types of actors. The most common actor types in the literature are the organizations, firms, teams, tasks, etc.

#### 2.3.2 Ties

The other element of the social networks is the tie which is the link between the nodes that demonstrates the relationship. As mentioned earlier, they can be used to exhibit various relationship types. Friendship, kinship, flow of knowledge, flow of information, f1ow of illness, flow of narcotics, communication, partnership, cooperation, collaboration, etc. are the examples of these relationship types. Regardless of the tie and the node type, the progress and comprehension of the networks are in the scope of SNA (Kilduff & Tsai, 2003). Loosemore (1998) interpreted that the usage of these ties in various manners, lead SNA to be adaptable to diversified amount of fields. The ties are placed between the nodes according to the existence of a relationship between them.

There have been some attributes of the ties in the SNA. Firstly, the relationship in the network does not necessarily to be reciprocal. In that case, the ties might have directions. If a tie has a direction, it is shown by an arrow towards the recipient node. Directed ties can also be denominated as asymmetrical ties (Meese & McMahon, 2012). These ties are commonly used to represent the relationships which involve flows from one actor to the other one. Information flow in a company, infection flow for a disease and drug flow in a drug cartel can be given as the examples of networks for the use of directed ties. In some cases, the ties do not have a direction since the connections between the actors are bilateral. In literature these ties are denominated as undirected or symmetrical ties (Meese & McMahon, 2012).  The networks which are constituted by directed and undirected ties are shown in the figure below (Figure 2.2).

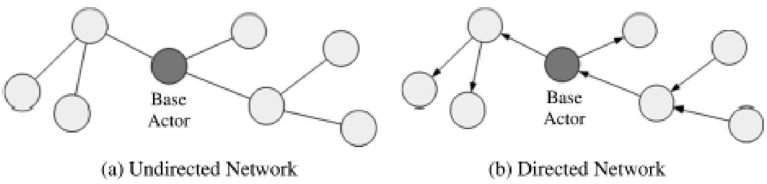


Figure 2.2: Undirected and Directed Networks (adapted from Park et al., 2011)

In the second place, the ties might have weights which are assigned on them. These weights refer to the frequency of the relationships (Meese & McMahon, 2012). For example, in a network of a company, the ties may be used to represent the number of telephone calls between the personnel with indicating the frequency. On the contrary, in a network where the SNA only deals with the existence of relationship between the social actors, the weight assignment to the ties is not needed. In sociograms these weights are represented by the thickness of the ties in accordance with the frequency.

### 2.3.3 Adjacency Matrix

In order to establish the social networks, the adjacency matrix is used for the transformation of the data. In mathematics, the term implies a matrix which shows the vertices that have neighboring between them (Wambeke et al., 2012). Loosemore (1998) asserted that the data of interactions in a network can be projected to the matrix format. Being a part of graph theory, adjacency matrices are utilized to convert these data to graphs. The numerical values in the adjacency matrix are a depiction of the relationship between the actors (Loosemore, 1998). The matrix may have two different formats. In first one, the matrix can be symmetrical. As in algebra, the values which represent the interactions in the matrix are symmetric with respect to the main diagonal. The symmetrical adjacency matrices are used to construct the undirected networks. In these cases, the relationship between the actors is not directed and the only matter is the existence of the relationship. In other words, the interrelation is bilateral and the link between the nodes do not have arrow. For example, if a large family is considered to construct a network and ties represent the existence of the kinship, the adjacency matrix of the data will be symmetrical. Secondly, the matrix can be asymmetrical which comes to mean that the relationships have directions. In that case, the asymmetrical matrices are used to constitute the directed networks. In these matrices, the upper part of the matrix is not the same as the lower part and the values show the number of directed links between the nodes. To give an example, if a network is constituted from a company’s staff by using their email data considering the direction of the communication, asymmetrical adjacency matrix can be used to identify sender and recipient. Generally in these matrices, the values for the senders are written in the rows while recipients are written in the columns.

The figure (Figure 2.3) demonstrates the adjacency matrices for different ties attributes and their sociogram representations. The simplest data, which involves reciprocal relationship without weights are defined as undirected binary data

(Meese & McMahon, 2012). The search for only the existence of the relationship and the symmetric relationship causes the simplicity. However, when the frequency of the relationship is important and the relationship is not bilateral the data becomes the most complex one.

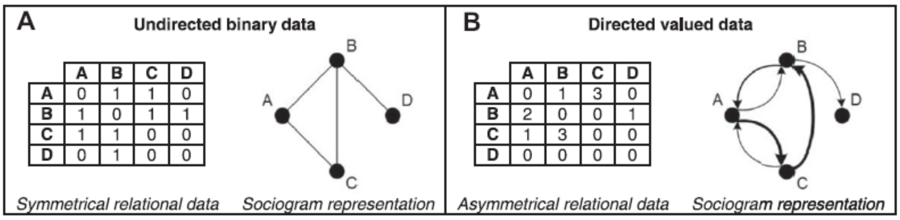


Figure 2.3: Adjacency Matrices and Their Sociograms (adapted from Meese & McMahon, 2012)

The relationships of various networks in diverse fields can be illustrated by sociograms when the data is entered to an adjacency matrix. SNA use this data to both visualize and analyze it by applying its measures on the network.

### 2.4 Social Network Analysis Terms

In Social Network Analysis, there are some terms which are commonly used for identifying or defining a situation. The explanations of these terms are provided in this section.

- ✓ <u>Dyad:</u> Dyad is constituted by a pair of points (Loosemore, 1998). The term dyad can be used to represent each tie in the network, since all the ties are connecting two nodes in the network. However, the importance of the term comes from its ability to distinguish the particular nodes in the network. For example, if two nodes are only connected to each other but no one else in the whole network, the dyadic tie between them is crucial for their existence.

- ✓ Triad: Triad is a sub network which is comprised of three nodes (Park et al., 2011). As in the case of dyads, the triads can be observed both under larger groups and alone in the general network.
- ✓ Clique: Cliques are the sub groups in the network. These nodes in the cliques are tightly connected to each other. Li et al. (2011) argues that as the relationship between the members becomes closer, the progressive formation of cliques occurs. The term cluster can be substituted for the term clique. In the literature, the cluster analysis is used to examine these sub groups. Kilduff & Tsai (2003) asserted that the members of the cliques have interactions inside the group but they do not have common connections with the rest of the group. However, the term can also be used to identify the sub groups where the interactions between the members are very strong with each other, in the meanwhile these members could have a couple of ties with other nodes in the network that are not part of this sub group. In this sense, Tang (2012) stressed that even if a team is condensed, cliques come into view inside the team.

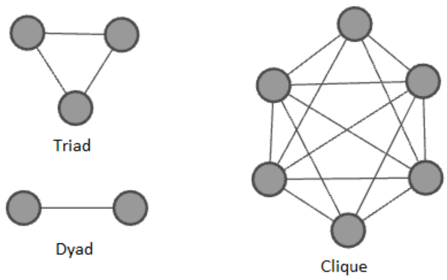


Figure 2.4: Dyad, Triad and Clique

- ✓ Co-membership: Co-membership is being a part of more than one clusters at the same time. The higher the co-membership means the higher the essentiality of that member in the network (Tang, 2012).
- ✓ Equivalence: According to the pattern of the ties that the nodes have in the network, the behaviors of the nodes could have resemblance. Loosemore (1998) classified the equivalence into two: Structurally Equivalent and Regularly Equivalent. Structural Equivalence term is used to identify the nodes whose contact

arrangements are same. On the other hand the Regular Equivalence term is used when nodes are linked to the same nodes with the same manner (Loosemore, 1998).

- ✓ Reachability: The term reachability is typically used for the networks where the relationship type deals with the information flow, communication patterns, disease spread etc. In the networks whose reachability is considered to be high, the efficiency of the network is high and the transmission of the information, disease or messages are easier (Kilduff & Tsai, 2003). In high-reachability networks, some nodes have the capability to contact more people which is the main reason behind the easier diffusion.
- ✓ Balance Theory: A theory for social networks which includes reciprocity and transitivity. The theory signifies that the especially networks that are formed by people, have tendency to constitute cliques with the effect of the intention to have balance in the relationships (Kilduff & Tsai, 2003).
- ✓ Reciprocity: As stated earlier the relationship in the social networks could be directed and undirected. In the undirected networks, the relationships between the nodes are mutual which means there is reciprocity. In directed networks, there said to be reciprocity for the relationships that are shown with two headed arrows.
- ✓ Transitivity: According to balance theory, if a node is connected with two nodes, the two other nodes are also expected to be connected to each other. The three actors complete their connections to form a triad. As the transitivity gets higher, the potential for the network to form cliques gets higher (Kilduff & Tsai, 2003).
- ✓ Multiplexity: The ties could be used to work on more than one relationship at the same network. In this case the relationship between the actors who have more than one relationship is termed as multiplex relationship (Kilduff & Tsai, 2003). For instance, if two nodes are both friends and relatives, their relationship is multiplex.
- ✓ Homophily: Kilduff & Tsai (2003) stated that according to the homophily theory the nodes in networks are prone to make connections with other nodes which can be said as similar.

- ✓ Heterophily: The heterophily theory proposes that member of other networks or cliques who can be considered as strangers provide new information and unfamiliar resources (Kilduff & Tsai, 2003).
- ✓ Structural Hole: The term is used to explain the lack of relation between two groups or nodes. As claimed by Ruan et al. (2012), if the network deals with information flow, the existence of a structural hole between the nodes means that these nodes cannot make any exchange of information. Kang & Park (2013) defined structural hole as a gap between actors who are connected to others in the network. The term is used to concentrate on the importance of joining ties (Kilduff & Tsai, 2003). On the other hand, in the literature the term is also used for the nodes that connect these gaps. The role of the actors who connects the structural holes is very crucial since they act like bridge for the network. Structural holes provide benefits to the networks by producing the links for the flow between separate parts of the networks (Ruan et al., 2012). The main reason behind why the actors should search for structural holes in a network is that they increase the performance and reachability of the network. In particular, for the knowledge sharing networks the structural holes help to reach new and unfamiliar information and resources (Kilduff & Tsai, 2003).

### 2.5 Social Network Analysis Measures

SNA deals with social networks to make inference and to interpret the results. In order to have this ability, SNA uses various measures which analyze the networks comprehensively. Although the SNA metrics are applicable to all kinds of networks, Meese & McMahon (2012) stated that they are most particularly efficient in the analysis of complex networks.

The SNA metrics can be considered in two different levels: node and network. At node level, SNA evaluate the actor's position and role in the whole network. Kim et al. (2011) stated that this level shows how the actor is inserted in the network by the actor's viewpoint. At network level, SNA evaluates networks as a whole and interprets the overall structure.  This characteristic makes SNA a beneficial technique to realize some features of the networks which are not distinctly visible. Focusing to the problem is enabled by this characteristic of SNA. In other words, by considering the network level measures, SNA clearly shows the problematic place in the network and makes easy to develop a solution for the problem. For example, if the network of information flow within a management staff is considered, the reason for inefficient relationship can easily be discovered by applying SNA. In the same vein, SNA helps to develop solution for this type of problems by highlighting the problematic flow sources of the network. On the other hand, by using node level measures, the reason behind the success or failure of individual actors in the network can be comprehended. For example, if a network formed by the students in a primary school and the class is investigated in SNA by defining the relationship as being playmate, then the reason behind the sadness of an isolated child can be understood. Besides, SNA helps to find out the most popular child in the network whom the isolated one should become friends with to overcome his or her problem. The most commonly used measures of the SNA are explained in the following sections.

### 2.5.1 Density

Density is one of the most important SNA measures that gives general idea about networks' situation. Density is social network measure that is originated from the interrelationship between the social actors and can be utilized to comprehend the comportments of the social actors (Kilduff & Tsai, 2003). It is a gauge to work out the amount of interaction between the social players in the network (Chinowsky et al., 2008). The connectedness of the network is explained by the density (M'Chirgui, 2007; Farshchi & Brown, 2011).

While measuring the density of the network, the importance of the non-existing ties becomes evident. The density is calculated by dividing the number of actual ties in the network to the number of possible ties that could exist in between all nodes in the network (Dimitros, 2010; Farshchi & Brown, 2011; Kilduff & Tsai, 2003; Kim et al., 2011; Li et al., 2011; M'Chirgui, 2007; Ruan et al., 2012). All the nodes are assumed to be connected in the network while calculating the number of possible ties (Chinowsky et al., 2008). The weights of the ties are neglected and the values are taken binary in calculation of the density. The value of the density changes between 0 and 1. A density value of 1 means that all the actors in the network are connected to the all the others which means the interconnectedness is maximum. On the other hand, a density value of 0 signifies that the network does not have any connection and all the nodes are isolated (Pryke, 2005; M'Chirgui, 2007). In other words, the values which are closer to 0 reflect the network is scattered while the values which are closer to 1 are indication of a condensed network (M'Chirgui, 2007).

In dense networks the relationships between the actors force the team members to follow the expected moves and create hesitation from the possible record for an irregularity by their fellows (Meltzer et al., 2010). On the other side, the individuals in sparse networks could behave independently from rest of the networks since the interactions are limited in the network.

Meltzer et al. (2010) proposed that in order a network or a part of network to have relatively high density values, the connections between large portions of the actors should exist in the network. However, a part of the network could make an impact on the overall density of the whole network if this part is very dense where rest of the network is sparse. With the effect of the denser portion overall density of the network could be relatively high. Therefore, this measure may have shortcomings. In some situations the value that is gathered from the network may mislead the interpreter. For example, if there are cliques inside the network whose members are tightly connected to each other but not connected with the other cliques, the density value may end up being high. However, the overall productivity may not be as high as the density implies since there is no interaction among the different cliques. Furthermore, as the size of the network gets higher, the number of the possible relationship increases intensely. Therefore, comparison of different networks can only be reasonable if the sizes of the networks are close to each other (Kilduff & Tsai, 2003). Park et al. (2011) stated that in order to compare the networks with different scales according to their density value, normalization process should be followed to have a fair outcome.

Consequently, the density is a frequently used measure for social networks and calculated by taking ratio of existent ties to the probable ties that can be formed between the nodes in the network. Despite the fact that density is not a perfect gauge to compare multiple networks with different sizes, it provides information for the networks' features. Therefore, density is an initial point for beginning to the comprehension of a social network.

### 2.5.2 Degree

Unlike the density which gives information about the whole network, degree is a measure that provides information about the nodes. Degree of a node is the number of connections that a node has with other nodes in the network (Farshchi & Brown, 2011). In undirected networks, the measurement of degree is very simple and straightforward. Basically, it is found by calculating the number of links of the node.

The degree of a node directly influences the role of node in the network. Nodes, whose degrees are high, have the significant positions in the network and have high possibility to affect the connected nodes. When the network map is considered, it can be easily observed that these nodes have the chance to concatenate numerous other social actors. Park et al. (2011) claimed that, these nodes have ability to play the determiner role for the network and has more capability to activate the resources than the less degree nodes.

On the other side, in directed networks the sub-concept of indegree and outdegree come into the picture. The underlying reason is that the degree is directly related to the relationships. Thus, if the connections have directions, they should be considered while measuring the degree of the nodes (Dimitros, 2010).

In the calculation of these sub-concepts, the same procedure is applied only by paying attention to the direction of the connections. Indegree of a node is found by calculating the number of the links incoming to the node whilst outdegree of a node is found by the emanating links from the node (Park et al., 2011).

Indegree is an indicator of acceptance capability of nodes. High indegree means that the node plays the receiver role in the relationship. For example, in a knowledge sharing network the nodes with high indegree are the actors that accumulate the information. Conversely, outdegree reveals the sending capacity of the nodes. The nodes with high outdegree are the senders of the networks. If the previous example is considered, the nodes with high outdegree are the actors who have the most information in the networks and feed the other actors.

Although the fact that degree is an important measure to apprehend the position of the nodes in the network, it is not functional to compare the nodes from different networks as in the case of the density. This is because various networks may have various sizes which may evidently affect the total number of connections. Therefore an attempt to standardize the degree values could be made while comparing networks with unequal sizes. This attempt is executed by dividing the degree of the nodes to the number of possible connections in the network and it is named as normalized degree (Ruan et al., 2012). The normalized degrees are denoted as percentages and they can be used to compare the nodes from different networks.

For example, in a network which is undirected and where self-connection is not allowed, the degree of the nodes should be divided to (n-1) where n is the number of nodes in the network.

Degree will also be considered in the subsequent heading according to its relevance to centrality.

### 2.5.3 Centrality

Centrality is the widest concept among the SNA measures. As the name implies basically this measure tries to find the core of the network and the essential transactions (Wambeke et al., 2012). Centrality is a very important measure to locate the social players in the network. Ruan et al. (2012) stated that since the position of the nodes are key characteristic of the networks, centrality helps to make estimation about the significance and power of the nodes.

The organization of the connections is shown by the centrality measure (Chinowsky et al., 2008). The networks which have high centrality values do not have distributed configurations and a small fraction of the nodes have most of the relationships in the network (Chinowsky et al., 2008; Zhang et al., 2013). In a network in order a node to be more central, its neighborhood should have plentiful connections (Hossain, 2009). In high centrality networks, the most of the nodes are connected to these central individuals (Farshchi & Brown, 2011). In other words, majority of the nodes in the network is aligned to the periphery of some specific nodes. Therefore these nodes connect many other nodes by being located strategically (Hossain, 2009). This situation creates a power of controlling and coordination to these nodes in the center. Therefore, actors who have high centrality are more prone to have this power and accordingly the ability to influence the others (Hossain, 2009; Pryke, 2005). The centrality of a node is more related with the coordination than the organizational position of a node (Hossain, 2009).

In order a node to be more powerful, the number of connections of its neighbors should not be high. Although the explanations of centrality and power seem to be conflicting, the logic behind them are parallel. Being in a central position does not reflect power on by itself, if the other nodes in the neighborhood have numerously connections. An example is illustrated in Figure 2.5. Two neighborhoods with same number of connections are constructed. In N1 the degree of node B is relatively high when compared to the other nodes in the network. On the contrary, in N2 the degree of nodes A and C are closer to the degree of node B. Although the structures of these networks are similar, the power of central node is not identical.

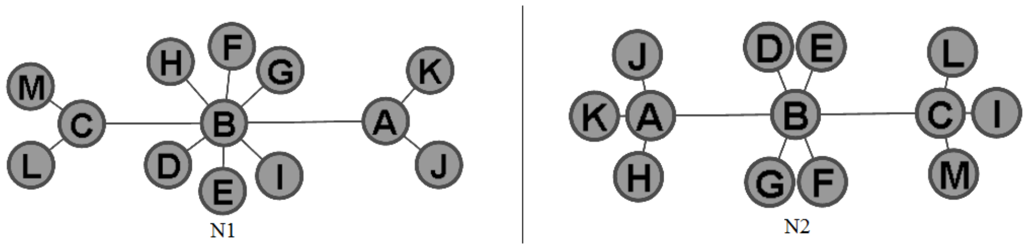


Figure 2.5: Two Sample Networks with Same Number of Connections

As the number of high degree individual increases, the ability to influence the others, the power, decreases. Therefore it can be said that centrality can be seen as an indicator of informal power, but not only one (Hossain, 2009). Park et al. (2011) confirmed this statement by saying that centrality is an imprecise signal of social dominance.

On the other hand, in low centrality networks the relationships are evenly distributed in the network (Chinowsky et al., 2008). Therefore the distribution of the nodes in the network is more scattered and the nodes in these networks are not capable of dominating the others. The lowest centralization occurs in the networks where the number of connections of all nodes is same (Kim et al., 2011).

In SNA, the centrality seeks for the positional attributes of the nodes in the network but not the actors' characteristics (Hossain, 2009). Therefore this measure deals with the nodes. In this case the node level centrality is named as point centrality. In SNA, the point centralities are assessed to find an outcome for the whole network (Kim et al., 2011). M'Chirgui (2007) explained that the distribution of the centralities of the nodes in the network is examined by using point centralities and named as centralization of the network. Kilduff & Tsai (2003) proposed that network centralization helps to realize the unanticipated inside story of the network mechanism. For example the extent to the networks' dependence on one or few actors can be seen by the help of centralization (Kilduff & Tsai, 2003).

The centralization measure varies in between 0 and 1 where higher values mean that the network is gathered around a few central individuals (Kilduff & Tsai, 2003). Highest centralization is seen in star type of networks where a node is in the middle and all the others are connected to this node but not to each other (Kim et al., 2011). In full networks, where all the nodes are connected to each other, the centralization is lowest. The centralization in segmented networks may differ according to the structure of the networks. The type of networks and the relationship between centralization and segmentation are summarized in Figure 2.6.

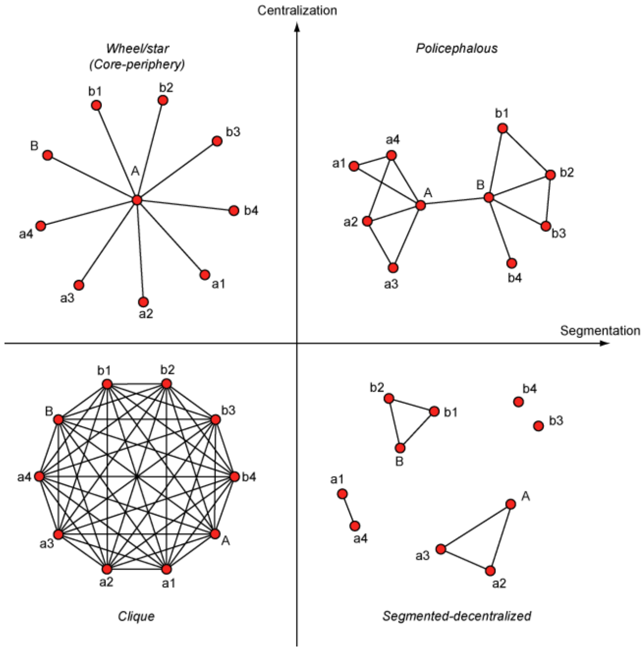

Figure 2.6: Network Types (Diani, 2003 cited in Ernstson et al., 2008)

The placement of a node in the network is dependent on different features of the connections. The centralities of nodes are mainly evaluated in terms of 3 sub concepts: closeness, degree or betweenness (Hossain, 2009). The importance of the nodes is recognized by looking from different perspectives with the help of these centrality metrics (Kim et al., 2011). These metrics are explained below:

#### 2.5.3.1 Degree Centrality

Degree centrality is the most commonly used and simple one among the other centrality metrics. It is a computation which represents the topology of the networks (Wambeke et al., 2012). Loosemore (1998) and Pryke (2005) described that the degree centrality evaluates the node's binding ability to all the other nodes in the network. It investigates the direct relationship amount of the nodes in the network by simply searching for the number of nodes' connections (Farshchi & Brown, 2011; Wambeke et al., 2012). In other words, degree centrality is the application of degree concept to all nodes in the network at the same time to find centrality. In this way, the importance of a node is assessed by finding its position in the network (Farshchi & Brown, 2011).

Being connected to high amount of individuals results in high degree centrality (Kim et al., 2011; Li et al. 2010). As mentioned earlier, high degree centrality is an indicator of power in the network. Moreover, the opportunities and restrictions of nodes are directly influenced by their degree centrality (Kilduff & Tsai, 2003). In the directed networks, centrality values for the indegree and outdegree are considered separately. Indegree centrality is an indicator of the node's reachability to information. The nodes whose indegree centrality is high are the most popular or prestigious ones in the network (Farshchi & Brown, 2011). On the other hand, outdegree centrality indicates the node's ability to control the network. Directed networks have dependence on the nodes whose outdegree centrality is high (Loosemore, 1998). Farshchi & Brown (2011) described that the action takes place around the high out degree centrality actors.

#### 2.5.3.2 Betweenness Centrality

Another sub concept for the centrality is the betweenness. The importance of a node does not only arise from high amount of degree. Although a node does not have high number of connections, it could be located in a critical position. A low degree node could be significant for the network as long as it plays a mediator role between the others (M'Chirgui, 2007). Betweenness centrality is interested in this ability of node's to link the other nodes in the network (Loosemore, 1998). As the betweenness centrality gets higher, the talent of a node to join others becomes more powerful (Li et al., 2010). As a consequence of this, the connective nodes are located in more central positions in the network (Kim et al., 2011).

Shortest path between a pair of actors is defined as geodesic (M'Chirgui, 2007). All the geodesics in the network are considered while measuring the betweenness centrality. Freeman (1979) described that in order to find a betweenness centrality value for a node, at first the number of geodesic between two other nodes that pass through the searched node is determined and divided to the number of all geodesics between the two nodes. This process is repeated for each and every pair in the network and the ratios are summed up to find the betweenness centrality of the searched node. In other words, it is a proportion of the shortest paths which goes through a node to the all shortest paths in the network (Park et al., 2011). Therefore, betweenness centrality measures the frequency of a node to reside in between all the geodesic combinations among the network (Farshchi & Brown, 2011; Kim et al., 2011).

As it is previously stated, the actors whose betweenness centrality is high are the bridges in between the other nodes (Li et al., 2010; M'Chirgui, 2007). Loosemore (1998) liken these actors as valves of the networks. They can be seen as the doors which are opening to the rest of the network. For this reason, these nodes have ability to control the relationships of the others. Zhang et al. (2013) emphasized that in knowledge flow networks, high betweenness centrality nodes restrains the reachability. They take part in most of the communications and in this way influence the route of the discussions (Chinowsky et al., 2010). Meltzer et al. (2010) clarified that for spreading information all over the network and, the betweenness centrality helps to find the best options. Hence, the betweenness of an actor is very important to assess the social influence (Meltzer et al., 2010).

To conclude, betweenness centrality is useful in identifying the powerful nodes in the network by looking their ability to connect the other ones. High betweenness implies high connectivity which signals ability to control and power.

#### 2.5.3.3 Closeness Centrality

In previous centrality measures, the number of connections and the ability of spanning is considered to find how a node is centrally placed in the network. Besides, the node's distance to other nodes is an important factor for its position. A node could be located in the middle of the network even if its betweenness and degree centrality are not very high. Closeness centrality is another measure to find the location of the nodes. Kim et al. (2011) described that how much a node is closer to the other nodes is measured by the closeness centrality.

The shortest paths from a node to all the other nodes are aggregated to find the closeness centrality (M'Chirgui, 2007). Farshchi & Brown (2011) described the closeness centrality as a representation of total distance to reach the other nodes. Kim et al. (2011) remarked that while calculating the closeness centrality for a node all the other nodes are considered apart from the ones that are connected directly. The total value gathered by the distances is not the closeness centrality. In order to find the closeness centrality value, the reciprocal of the total distance should be calculated (Freeman, 1979). Otherwise, it measures the farness not the closeness. Higher closeness centrality denotes that the actor is in short distance to the other actors in the network (Loosemore, 1998). In other words, as the closeness centrality gets higher, the node becomes more centrally placed and closer to the other nodes (Kilduff & Tsai, 2003; Li et al., 2010).

The ability to achieve other nodes is related with the closeness centrality. Park et al., (2011) stated that this ability is important in knowledge sharing networks. The information can be easily reached by high closeness centrality nodes. Loosemore (1998) pronounced that behaving independently without the awareness of others is not easy for these nodes. On the other hand, the monitoring and controlling capacity of these nodes are very high and their ideas rapidly scatter around the network (Loosemore, 1998).

In case of directed networks, closeness can be considered as in inward and outward level. The out-closeness focuses how an actor is capable to reach the other actors while producing relationship. High out-closeness means ties emanated by the actor are in short distance to others.  In other words, out-closeness measures the productivity (Farshchi & Brown, 2011). On the other side, the in-closeness focuses how a node is reachable to the other actors by considering the ties oriented to it.

### 2.5.4 Average Shortest Path

As mentioned earlier, the path lengths of the nodes are used to calculate some centrality types. The measure can also be used in network level to describe the effectiveness of the networks. Average shortest path looks for a value for the network which shows a typical number of steps to go between any two nodes along the network. The shortest path term sometimes replaced with distance or geodesic.

The distances between nodes are found by looking the paths which connect them. The average shortest path is found by taking the medium of all distances in the network (Dimitros, 2010). In other words, the number of links that should be passed to get a node from another is calculated to find the average distance (Chinowsky et al., 2008).

Especially in knowledge sharing networks, it is expected that the efficiency and the reachability of the networks decreases as the average shortest path increases. Tang (2012) commented that when the distance is large, it is more costly to transfer information. Besides, improving the general condition by constructing new ties is very difficult for the networks whose average shortest path is relatively high.

### 2.5.5 Clustering Coefficient

As previously stated, clique is among the SNA terms used to identify the small groups in networks. The members in these groups are highly dependent on each other (Pryke, 2004). In literature the term cluster is also used as a substitute for clique. The sub groups in networks are examined in SNA under the heading of cluster analysis.

Clustering coefficient is the measure related to these sub groups. There are two types of clustering coefficients in the literature: global and local. The former one is dealing with the triplets in the network. The number of closed triplets in which all the nodes are connected is determined. It is the same as three times of the triangles in the network. After that, it is divided to the total number of triplets which is calculated by considering both open and closed triplets (Opsahl & Panzarasa, 2009). The global clustering coefficient is also called the transitivity ratio since it calculates the triangles which have transitivity. On the other hand, the latter one is the proportion of actual links between neighbors to the maximum possible ones (Hardiman & Katzir, 2013). The local one has the ability to show how the nodes are socially embedded and the effects of this situation in their characters (Opsahl & Panzarasa, 2009). The average clustering coefficient for the network is calculated by using the local one. It is the average of all local clustering coefficients in the network. Originally, clustering coefficient cannot be applied to the directed networks. Moreover, although there are some attempts, the weights on the ties are not taken into account while calculating the clustering coefficient (Opsahl & Panzarasa, 2009).

Consequently, the clustering coefficient is used to understand the ability of network to form cliques. The neighbors are prone to form highly linked cliques as the clustering coefficient of the actor increases (Dimitros, 2010). Kang & Park (2013) stated that in the networks with high average clustering coefficient the clusters formed around a few actors. The expectancy increases when the density of the network is relatively low.

### 2.6 Social Network Analysis Software

Both the developments in the computer science and the increasing interest on social networks are the main factors behind the production of a software package to analyze the social networks. As a consequence of that there is numerous software available for social networks and they are increasing from day to day. Some of these programs are commercially available while some of them are free to use.

Although there are programs which are only capable of either visualizing or analyzing the networks, there are also programs which could be used for both at the same time (Huisman & Van Duijn, 2005). All these programs have various limitations and restrictions with their various strengths (Hanneman & Riddle, 2005). The most commonly used ones in the literature are Pajek (Batagelj & Mrvar, 1998) and UCINET (Borgatti et al., 2002). In this section, brief information about these two programs are given with an additional alternative Gephi (Bastian et al., 2009).

- ✓ Pajek: This program is prepared to examine the networks with great amount of nodes and ties. The name of the program means spider in Slovenian language. It is available on the internet and can be used freely for noncommercial use. The main aims of the program are: analyzing large networks effectively, visualizing networks powerfully and decomposing them to smaller ones (Batagelj & Mrvar, 1998). It can be used for various types of networks: directed, undirected, mixed and more complex ones. The data could be added to the program with various ways such as matrix format, writing the notepads, etc.

- ✓ UCINET: This program is also another alternative which is commonly used in the literature. It also has the ability to provide various analysis measures. As in the case of Pajek, UCINET is also capable of providing visual representations of networks (Kim et al., 2011). The program can be gathered from the internet but only with a trial version. In order to use the program after the trial period, the license should be acquired (Borgatti et al., 2002). The data is introduced to the program within matrix format and program can also be used for various types of networks.
- ✓ Gephi: Gephi is relatively new program which helps working elaborately on networks. It provides the users the ability to draw the map of the network, to make filtering and manipulating data. Moreover, data import and export is a feature of Gephi and in this way it can cooperate with different programs (Bastian et al., 2009). The program can deal with large networks which could be in various types as in Pajek and UCINET. Gephi is an open source network software and freely available on its website. In this program, the customization of the networks reaches an advanced level with the application of various algorithms.

As mentioned earlier, there is a high amount of software prepared for social network analysis. Since it is very hard to conceive their strengths and weaknesses without allocating time to work with them, the most recognized ones are discussed with a newer alternative which does not require any specialization on software language. Ultimately, even though Pajek and UCINET are the most popular ones for examining social networks, Gephi is used in this study because of its properties like user-friendly interface and better visual performance.

## 2.7 Previous Work on Social Network Analysis

As it is stated earlier, SNA is originated for the sociology and anthropology sciences, nevertheless used to work on various fields to apprehend the social networks. In this section, previous studies which use SNA to analyze the networks in some fields which are other than the natives are presented. However, the studies in construction sector will be introduced in the prospective sections.

There are many studies about the measures and structural components of SNA. Borgatti et al. (2006) made an analysis about the centrality measures to search their robustness. The aim of the study was to understand how the accuracy of the centrality behaves according to various amounts of errors in the data set. Moreover, the effects of basic network characteristics on the robustness were also considered. Large number of sample networks was investigated with inserting controlled amount of errors and statistical approach was done for the calculation of the centrality robustness. The results of the study unsurprisingly showed that the accuracy decreases as the amount of error increases. Borgatti et al. (2006) suggested that the confidence intervals should be constructed for the centrality measures in the networks constructed with imperfect data.

Levin & Cross (2004) investigated the strength of the ties and its effect on the knowledge transmission. A theoretical model was prepared for knowledge exchange, combined with trustworthiness and tested with three different companies. The attention of the study was to compare whether strong or weak ties have higher capability on transferring beneficial knowledge and the reason behind this situation. The study focused the transfer which improves the results of the knowledge seeker's view. The ability of weak ties to transfer non-redundant information and the ability of trust to play a mediator role in between stronger ties were demonstrated. Moreover, Levin & Cross (2004) discussed the influence of competence and benevolence based trust on tacit and explicit knowledge in their study.

Health sector is another field that SNA has been used frequently. Meltzer et al. (2010) applied SNA to obtain the design principles for clinical team constitution. The study was based on the idea that the interactions are important for enhancing the information flow and acquiring the intended results. Meltzer et al. (2010) tried to show that the SNA could make contribution for improving the quality of team design. The SNA measures were used to establish the principles for the construction of quality improvement teams. Moreover, the execution of these principles was investigated with the participating physicians of a medical center.

Similarly, SNA can be used in educational field to understand the performance of the students. Li et al. (2010) studied an online course to comprehend the knowledge generation process of the students. In the study, the posts of the students were examined to construct a discussion network of the course by using SNA. The aim of the study was to consider the effectiveness of the cooperation in a virtual learning group. Based on the results, Li et al. (2010) proposed that SNA can be used as an approach in interactive education to find out the problems and to open new ways to improve the efficiency.

In their study, Korkmaz & Singh (2012) researched the team success in an undergraduate level engineering course by various methods of analysis. The integrity of the teams generated by the students was examined through SNA and the results were compared with the outcomes of their projects. The results of the study certified the authors' proposition that the teams who have higher communication density are susceptible to produce better outputs. Korkmaz & Singh (2012) also demonstrated that the leadership, shared values and trust are also important factors for the team success.

Di Marco et al. (2010) investigated the role of the member who acts like a bridge in design project teams. In the study, two teams were formed identically by Indian and Americans with only one difference which was that in one team there is an Indian member who lived in United States. It is expected from this member to connect the culturally dissimilar parts. By using SNA, the communication patterns of these two teams were examined and the effect of this bridge member was explained. In this way, Di Marco et al. (2010) displayed that the national-cultural conflicts can be solved rapidly by the help of the cultural boundary spanner. Therefore, it is shown that the performance of the project team can be enhanced with the existence of culturally connecting members.

As mentioned earlier, the nodes in the SNA can be used for various type of actors. Kang & Park (2013) worked on Clean Development Mechanism (CDM) projects to determine the dynamics of the cooperative activities by taking the host countries as the social actors. The collaboration dependence, roles and positions of the host countries in CDM network were perceived by applying SNA. Kang & Park (2013) asserted that the status of a country in the network is a signal of its power in the entire network. Based on the results of the study, participant organizations could decide which countries are more attractive for making investments in CDM market.

Divjak et al. (2010) used SNA to obtain the network of projects which were nominated as successful by the EUREKA which is a research initiative. In the study, the projects were considered as the relationships between the member countries. The aim of the study was to draw the map of the successful projects and determine the countries that performed best in the years between 2002 and 2009. According to the outcomes, the authors' certified their hypotheses that the developed countries are the centrally located ones in the network and the most of the successful project are bilateral.

## 2.8 SNA and Organizations

### 2.8.1 Use of SNA in Organizational Level

The structure of the company could be an obstacle for all the organizations (Javernick-Will, 2011). As shown earlier, the organizational arrangement could be comprehended by applying the SNA to the companies by considering the staff as the social players. Li et al. (2011) stressed that SNA frequently used for examining the existence of the ties between the staff of companies.

On the other hand, the networking approach could be seen in every part of professional actions (Chinowsky et al., 2008). As mentioned earlier, the ability of SNA to be used for various fields comes from the flexibility of the types of nodes and ties. Although originally invented for people, the nodes usability for other type of actors allow SNA to be used for defining the relationship of the organizations. Therefore, the companies could also form networks with their relationships among each other. Li et al. (2011) explained that the SNA brings a new point of view for searching the organizational behaviors. As in the case of individual people in the networks, firms also seek for having significant positions in their networks to increase their benefit (Chinowsky et al., 2011). The application of SNA on organizational level is a favored topic in recent years.

In today's world the complexity of the projects gets higher each and every day. All the firms make plans to develop their benefits and have competing interests in particular with the firms in their industry (Chinowsky et al., 2008). Park & Han (2012) confirmed that firms should be seen as dependent to each other. Son et al. (2010) supported this idea by stating that the economic behaviors of the firms are restricted by their social interactivity. This dependence leads to increase the importance of the relationships among the involved firms. The relationships between the firms affect their ability to get strategic roles in the sector. In this point SNA can be seen as a new and influential methodology to study the connections of the firms (Li et al., 2011).

Park et al. (2011) asserted that a firm's performance and characteristics could be extracted from its situation in the inter-firm network. Firms which occupy central positions in the networks indicate their power among the industry. Son et al. (2010) described that having diversified relations raise the probability of firms to reach precious information and to increase profitability. SNA helps the identification of these firms in the sector. Moreover, the structural holes in the networks and the opportunities in the industry can easily be seen by using SNA.

In these networks where the nodes are the firms, the ties could be used to identify doing business in the same country, making collaboration, having flows of supply, etc. In this manner, SNA can be used for constructing diversified networks which investigates the interrelationships of firms.

### 2.8.2 Previous Work in Organizations

In organizational basis, SNA was used to understand the structure of the firms and to find the reasons behind the problems in the firm. For example, Hossain (2009) used SNA to approach a company's email data set to comprehend the coordination dynamics of multi-million dollar complex projects. The Enron data set is analyzed to investigate the consequences of the member's position in the network and in the organization on coordination. The aim in this study was to measure the correlation between the network centrality and coordinative capability of the actors by applying SNA. Hossain (2009) showed that an actor's centrality in a network is more correlated with the coordination than his/her organizational position. In the study, it is corroborated that the actors who are well connected and centrally positioned have ability to coordinate the others.

As mentioned in the previous section, taking companies as the social actors provides the advantage to study industrial sectors with SNA. In this manner, M'Chirgui (2007) utilized SNA to investigate the associations among the firms of the smart card industry in the years 1997-2003. In the study, the partnership network of the firms were constructed and analyzed with SNA. The aim was to comprehend the strategic importance of the cooperation among the firms in this industry with the help of social network approach. For this reason, the fluctuant collaboration models were explored by taking different time intervals over the mentioned period. M’Chirgui (2007) exhibited the power of specific firms in the market based on the results of SNA measures.

Similarly, Kim et al. (2011) benefited from the SNA to understand the features of three different automotive supply networks which are reported in a previous analysis by Choi & Hong (2002). The contractual relationships and the material flow among the firms were analyzed in this study. The aim was to propose SNA to examine supply networks, to deduct inferences from this kind of analysis and compare the results with previous analysis. SNA metrics were used to discuss the role and behaviors of the firms according to the position of the network. Kim et al. (2011) put forward that the SNA integrates the qualitative approaches while seizing the structure of the networks in an impartial way.

# CHAPTER 3

# OVERVIEW OF CONSTRUCTION SECTOR AND ITS COLLABORATION

## 3.1 General Situation of Turkish Construction Industry

As in many other developing countries, construction sector plays an important role in the economy of Turkey. According to the statistics from the Turkish Contractors Association (TCA), which is a non-profit organization, construction sector constitutes approximately 6% of Turkish gross national product. Among all Turkish contractors, the ones that are the members of TCA carried out 70% of national and 90% of international projects (Turkish Contractors Association, 2014).

Since the foundation of the Turkish Republic, investments on this sector help the contractors to become powerful in the industry with passing years. According to the TCA, the history of the Turkish contractors can be divided into 5 period: preparation, action in the domestic market, going to international market, diversification in market and product and global competition (Turkish Contractors Association, 2014).

Following the foundation in the year 1923, the Turkish construction industry needed architects and engineers from foreign countries to educate and initiate the construction works. In 1930s the engineers who will be the leaders of the domestic and international projects had started to be trained. In 1950s the native engineers had started to establish their firms and found huge opportunities to develop in the construction sector with the crunch time for the country. Between the years 1950s and 1970s the Turkish contractors had completed many infrastructure projects and upgraded their capabilities on various construction fields. Beginning from 1970s Turkish contractors started to turn their attention to international markets and become significant players of the industry progressively (Turkish Contractors Association, 2014).

The factors that provide competitive advantages to the Turkish contractors can be seen as:

- The position of the country,
- More affordable prices with high quality,
- High customer satisfaction,
- Being dependable business partners,
- High experience in various projects,
- High risk taking capacity,
- Familiarity to peripheral countries,
- High number of skilled neighbor.

### 3.2 Turkish Contractors in the International Construction Sector

According to the data of TCA, the activities of Turkish contractor in the international market are classified with ten-year periods. These periods are explained in the following sections.

#### 3.2.1 Activities in the International Market in between 1972-1979

Turkish Contractors firstly take part in international market in the year 1972. Libya was the first country for opening the international market and in these years the required technology had been imported from the European countries. In this period, Turkish Contractors orientated to the other countries in Middle Asia. However, Libya took place on top of the market. The countries where the projects undertaken in this period were: Libya (72.53%), Saudi Arabia (15.44%), Iraq (7.25%), Kuwait (4.71%), Greece (0.06%) and Iran (0.01%). Moreover, residential buildings (32.1%), harbors (18.1%) and industrial buildings (15.6%) were the most common job types in this period (Turkish Contractors Association, 2014).

### 3.2.2 Activities in the International Market in between 1980-1989

In this period, Turkish Contractors started to turn their attention to the Soviet Union market with the changes in the politics of East Europe. Although its share decreased, Libya (55.2%) had retained its position for Turkish Contractors. In addition to that, Saudi Arabia (23.4%) and Iraq (11.5%) had protected their positions on the ranking together with increasing their shares. The other countries that on the list were Yemen, Jordan, Iran, the USA, Tunisia, the United Arab Emirates (the UAE) and Kuwait. Furthermore, residential buildings (36.7%) and urban infrastructure (17.2%) were the project types on top of the share distribution during this period (Turkish Contractors Association, 2014).

### 3.2.3 Activities in the International Market in between 1990-1999

In this period due to the economic and politic crisis in Middle East countries and Libya, Turkish Contractors directed their attention to closer regions. Therefore, the trend in the international market changed. The biggest effect of this period can be seen as the diversification of the international market for Turkish Contractors. Commonwealth of Independent States (CIS) gained high importance during these years. Russian Federation (34.5%) became the leading country, Libya (13.7%) and Saudi Arabia 3.1%) had sharp falls in the market share. In addition to that Kazakhstan (7.8%), Turkmenistan (6.7%) and Pakistan (6.6%) were the other countries on top of the ranking. Uzbekistan (3.9%), Azerbaijan (2.6%), Bulgaria (2.6%), The USA (2.5%), Croatia (2.2%), Kuwait (2.0%), Germany (1.8%), Belarus (1.1%) and Israel (1.0%) were other countries which emerged in this period. Moreover, there were many other countries which in total constitute 6.2% of the share (Turkish Contractors Association, 2014).

Turkish Contractors Association (2014) claimed that the increase in diversity of markets triggered the variety of project types. In this way, the share of residential buildings (24.9%) dropped. Other than the previous project types business centers, tourism centers, social and cultural buildings, administrative buildings, petrochemical facilities, etc. were added the portfolio of the Turkish Contractors in the international market.

### 3.2.4 Activities in the International Market in between 2000-2012

After the economic crisis in 2001, the international contracting has been increased rapidly. The sector had a big leap from 2002 to 2006 by increasing total business volume from 2.6 billion $ to 24.3 billion $ for these years respectively. After the reaching the top values in 2007, the business volume had a slight decrease and little fluctuations in the following years. The volume reached the highest value of the history with 26.6 billion $ in the year 2012 (Turkish Contractors Association, 2014).

Turkish Contractors Association (2014) stated that the decrease in the domestic investments, enhanced abilities due to previous collaborations with foreign firms and enrichment of the close countries due to the oil prices are main reasons in the growth of the international business volume of Turkish Contractors.

The number of countries that Turkish Contractors conduct business increased considerably. Accordingly, the share of the countries decreased relatively. Another progress in this period was that after the war in Afghanistan and Iraq, the reconstruction works in these countries opened high opportunities (Turkish Contractors Association, 2014).

In recent years, Turkmenistan, Russian Federation and Iraq are the countries where the most of the activities took place. After the Arab Spring, the market of northern Africa countries goes into recession. Not only ongoing projects started to have problems but also it is become very difficult to undertake new projects in these countries (Turkish Contractors Association, 2014).

### 3.2.5 Activities in the International Market General Overview

According to Turkish Contractors Association (2014), when the period between 1972 and 2012 considered the 90 % of the project were undertaken in Commonwealth of Independent States (CIS) (42.9%), Middle East (27.6) and Africa (19.4%).

In this period, the projects changed from labor intensive types to specialization required types. Moreover, the project scopes and sizes are in an increasing trend in recent years. Consequently, Turkish Contractors started to become world's leading brand in various project types (Turkish Contractors Association, 2014).

According to Turkish Contractors Association (2014), making investments in the closer countries and collaborating with both national and international firms are the strengthened trends in the Turkish construction industry in recent times.

### 3.2.6 Current Situation of Turkish Contracting Services

According to Turkish Contracting and Engineering Services unit of Turkish Republic Ministry of Economy (2014), the number of projects that Turkish contractors had undertaken is approximately over seven thousand. These projects were executed in 102 countries. With respect to the data of Turkish Contracting and Engineering Services, the total worth of these projects is approximately 260 billion $ as the date of September 2013.

The average project value for the international market had an increasing momentum. These values increased to the level of 40 million $ from the beginning of the year 2006. After having a peak average in the year 2012 with approximately 55 million $, in the first 9 months of the year 2013 the average has reached to approximately 100 million $ (Turkish Republic Ministry of Economy, 2014).

According to the Engineering News Record (ENR), which is the world's leading engineering magazine, Turkish Contractors is in the second place after the Chinese Contractors in the Top International Contractors list. In preparation of this list, the total revenues of the firms based on the undertaken international projects were considered. Being in this list is a clear indication of success in the international market. The number of Turkish firms which entered this list is in a gradually increasing form. As claimed by Turkish Contracting and Engineering Services, in the year 2003 there were only 8 firms on the ENR's list of top 225 International Contractors. Since then, this figure increased every year and beginning from 2009 each year more than 30 Turkish Contractors have appeared. In the year 2013, the list is enlarged to 250 firms and 38 Turkish firms is ranked in that list. Therefore, it can be said that the Turkish Contractors' condition in the international market is very strong and constantly developing.

From the perspective of Turkish Contracting and Engineering Services (2014), the aim of the sector is to maintain and to increase the efficiency of Turkish Contractors in the international market. The yearly volume of the projects is targeted to be increased to 100 billion $ in the year 2023. Taking projects in the sub-Saharan Africa countries, which are open for improvement with their natural resources, is another goal of the Turkish Contracting and Engineering Services. Besides, enlargement of the firms' scale, increasing the consciousness of collaboration and undertaking prestigious projects are other goals for the Turkish Construction sector.

### 3.3 Social Network and Management

In project management the main focus is the utilization of tools to plan tasks and to generate schedules in an elaborative way (Li et al., 2011). Nevertheless, there are many components of projects. Therefore, in order to manage efficiently, all the components of the project should be considered. Li et al. (2011) stated that human, technological and natural actors are among these components. Social network approach considers the firms as a structure which inherently includes much type of relationships between people, groups and organizations (Loosemore, 1998).

Traditional methods are not capable of providing enough strategies for effective management. Social network approach can be used to improve innovative management strategies. Farshchi & Brown (2011) stated that in particular multi-disciplinary projects are very sensitive since all the components should work well to ensure success. SNA could be seen as a step to develop the management point of view since it helps the understanding of the structure. The consistency in organizations can be secured; the problems in the structure can be determined and solved with proper execution of SNA. Wambeke et al. (2012) stated that SNA could be used as an efficient method for the analysis of the organizations by the project management teams.

To conclude, because of the interconnected nature of the organizations, many application areas in their management can be found for SNA. The application of SNA provides the ability to highlight the dark spots which are not comprehended by traditional management perspective.

#### 3.3.1 Social Network and Construction Management

In this section, the relationship between social network approach and construction management is considered. In most of developed and developing countries construction industry is among the leading sectors of economy (Farshchi & Brown, 2011). The importance of construction management arises from the remarkable features of construction projects such as uniqueness, various components, limited resources, etc. Korkmaz & Singh (2012) confirmed that the fragmented nature is the reason of many problems of the construction industry. Because of these characteristics, management of construction projects and acquiring of desired results become a real challenge. If there is a failure in reaching the desired level of productivity in construction industry, it can be interpreted that the development of the economy is restricted (Farshchi & Brown, 2011).

Chinowsky et al. (2008) stated that focus in construction is turned to high performance projects. Besides, as the construction industry develops, the projects become more complex (Park & Han, 2012). Ignoring the computational methods in construction management of these projects seems to be unreasonable since the need for unfamiliar techniques is obvious (Loosemore, 1998).

Pryke (2004) stated that the structures of construction projects are complicated, non-linear and interactive. The traditional approaches and flow charts are not enough to analyze all features of these projects (Pryke, 2004). In order to overcome this situation, different perspectives could be very helpful for the management of construction projects. Unusual approaches help the management teams to generate these perspectives. In this way, the management teams concentrate on the projects from several angles. Social network concept could be seen as one of these various approaches.

The construction projects can be regarded as a network of relationships and the prosperity of the projects is dependent on the effectiveness of these relationships (Pryke, 2004). Moreover, the attention to social network concept in construction sector has increased recently (Loosemore, 1998). Therefore, the management of networks in this sector should be relied on the social network approach to attain improvement in the performance (Chinowsky et al., 2008). Consequently, the identification and analysis of the networks become an integral part of construction industry (Pryke, 2004).

Visualization of the relationships and comparison between successful projects and unproductive ones are the main contributions of SNA to construction management field (Chinowsky et al., 2008). Pryke (2004) also endorsed that the SNA provides ability to make comparative analyses in construction projects. Moreover, SNA provides management teams the capability to study projects in many different aspects with the help of its quantitative and qualitative outcomes. Therefore by utilization of SNA, the administration of the projects could be done in a more efficient way with the interpretation of its outcomes and taking precautions accordingly. In conclusion, complex construction projects could be handled more easily and the performance of the projects could increase by use of SNA.

### 3.3.2 Previous Work on Construction Management

Larsen (2011) asserted that there are some exponents of SNA in construction management literature who benefit from SNA in various ways. Usability of SNA in management of construction projects comes from its applicability on various types of social actors and relationships. Projects, host countries, information flow, supply flow, activities, activity place and time, etc. can be taken as ties between the actors of construction projects. In the same way companies, countries, staff members, projects, etc. are the examples of the social actors which are taken as the nodes in SNA of construction management.

The most common application of the SNA is to consider the information flow between the staff members of the construction companies. Javernick-Will (2011) investigated the knowledge exchange patterns of a firm which conducts business in architecture, engineering and construction industry globally. In this research, qualitative and quantitative methods combined to examine the knowledge sharing connections between the employees of that firm. The social network approach is applied with making questionnaires and evaluation of them. In preparing the questionnaires the technique of Chinowsky et al. (2008) was performed. The focus of the paper was to enlarge the comprehension of the connections in an intra-firm network which involves knowledge sharing.

In the same manner, Tang (2012) examined the knowledge transferring characteristics of construction project team with implementation of SNA. In the research, a case study was examined to find the features of a construction project team which is formed for the construction of a bridge in China. According to the social network measures the characteristics of the team is deduced.

Meese & McMahon (2012) explored the information flow about sustainable development inside a civil engineering consultancy firm. The aim was to study the organization on the basis of knowledge sharing, to determine which factors could affect its performance and to identify the key members. In their study, SNA is used to certify the findings of a previous study on knowledge sharing barriers. Meese & McMahon (2012) proclaimed that their study can be seen as the first one in civil engineering sector on its class.

Teams in the construction projects could be investigated by adopting SNA. Farshchi & Brown (2011) benefited from the SNA in order to explore the communication process among the team members in the construction sector. The aim of the research was to present the essential points of knowledge formation and transferring in construction sector. In other words, Farshchi & Brown (2011) focused to show how the general situation of construction project teams can be improved with the help of SNA. In the research, a case study was conducted to demonstrate the role of SNA for the knowledge creation in construction industry.

Loosemore (1998) utilized SNA to show that the both qualitative and quantitative approaches should be used to comprehend the construction crises. The social roles, positions and actions of the people are variable. Loosemore (1998) examined these changing human behaviors during the construction crises with a case study. The project in the study was divided into three phases and the communication networks between the staff in the project were investigated. The behaviors of these people were interpreted according to the results of SNA.

Zhang et al. (2013) investigated the flexibility of integrated project team characteristics and its importance in construction projects. The main focus of the paper was to explore the history of flexibility concept in construction field which is very dynamic and changing. In the study, the relationship between tacit knowledge sharing and team flexibility was also considered. Zhang et al. (2013) conducted a case study to reveal this relevance. The enhancement ways of the integrated team efficiency was presented according to the results of this study. Therefore, the cooperation and harmony inside the team increased with the actions based on the findings of the study.

Li et al. (2011) utilized SNA to understand the social network relations in a complex project environment. The aim was to enhance the organizational and team performance in controlling of complex projects. In the study, the social network approach was applied to find various policies for constructing an organizational control mechanism. Li et al. (2011) analyzed the construction projects of EXPO 2010 Shanghai as a case study. Consequently, social network was proposed as a method to establish strategies for the organizational control in construction projects.

Lin (2012) established a social network model for construction project organizations and analyzed this model quantitatively. In this study, the organization of structural elements was determined and their relationships were defined with the connections among these elements. Subsequently, social network between the organizational elements were constructed based on the frequency of these relationships. In this way, Lin (2012) tried to prove that there is reasoning behind the interactions among these elements in construction industry.

As mentioned earlier the construction activities were taken as the nodes in the networks. Wambeke et al. (2012) benefited from the SNA to identification of the key construction trades of a construction project. In the study, construction trades are considered as the actors of the networks and the ties are placed between the trades which are physically carried out in the same area. The main aim was to comprehend the trades which have high importance in the construction site. A 50 million-$-construction project is examined in the case study.

There are studies which investigated not the SNA but the applications of the social network approach in construction management. For example, Ling & Li (2012) aimed to search the relevance of the social network practices in management of construction projects. In their study, architectural, engineering or construction firms which conduct business in China were considered to discover this relevance. A structured questionnaire was conducted among the firms and analyzed statistically to understand the managerial behavior of local and foreign firms in China. Moreover, how relationships are formed between these firms and their competition capacity were also investigated. Consequently, Ling & Li (2012) showed that the social network strategy should be adopted in management of the construction projects while working in China.

### 3.4 Social Network and Collaboration

This section presents a brief summary on collaboration and its relation with construction industry. Moreover, the implementation of social network approach to collaboration and the previous work on the construction industry are mentioned.

### 3.4.1 Brief Summary of Collaboration?

Collaboration simply means working together of more than one actor to finish a task. The wording can be considered not only for people but also for organizations and etc. For example, three students may come together and form a team to make a design project. In their work, they are collaborated and in a way the results of their product will affect each of the participants. In the same manner, two or more firms could make a partnership to complete a project. The shared aim and cooperation are the basis of collaboration.

Collaboration is used to increase the efficiency and the success of the works by taking advantage of the resources of the participants. In this study the collaboration practice is mainly considered among large industries rather than individual level. It enhances the communication, knowledge transfer and trust level among the firms to achieve higher performance (Chinowsky et al., 2010; Ruan et al., 2012). Chinowsky et al. (2008) stated that the collaboration practice should be used to have better results than the traditional anticipations. The reason behind this situation is explained by the positive influence of collaboration to innovation (Kang & Park, 2013). In other words, establishing collaborations among firms with different abilities sets free new ideas and result in novelty.

Although, collaboration is applied in many industries, M'Chirgui (2007) asserted that the number of strategic partnerships increased notably in last three decades and most of them are in the knowledge based industries. Ruan et al. (2012) claimed that collaboration could be an effective way to develop the performance in knowledge based networks. The trust and shared values among the participants play important roles and because of this the collaboration practice is very efficient in these industries (Chinowsky et al., 2010).

On the other hand, collaboration is also useful in other type of industries where the interaction is directly related with product or service. Construction, automotive, manufacturing can be given as example fields where collaboration is highly utilized. In these sectors, the organizations become tightly connected when they jointly participated to the projects or products (Ruan et al., 2012).

### 3.4.2 Collaboration in Construction Industry

As stated earlier, construction is among the industries in which the collaboration between the companies is seen frequently (Dimitros, 2010). The main reason behind this situation is the complexity of the construction projects. The need for additional resources gets higher as the projects get complicated. Accordingly the risks also increase with complexity. Since the risks are higher, the budgets and the profits of complex projects are very high relative to the ordinary projects. Construction companies prefer to make partnerships in order to compete in these projects. In particular, collaboration practice is widely used for international projects (Son et al., 2010). With the help of collaboration, the firms gain the ability to mitigate the risks of the projects and to complete projects which are not capable to do on their own. In addition to that, in some projects there are instructions that force the participants to make collaboration. For example, being partner with a local company or a company with special abilities can be requested from all the tenderers.

In this manner, for the completion of the construction projects two or more firms may come together and make collaboration. The most common types are joint ventures and consortiums. In general, joint ventures can be defined as single entities that are formed by two or more firms which are all jointly and severally liable. In other words, a new entity is generated and it has its own assets and management staff. On the other hand, consortiums are becoming together of the firms to form an association. The firms in these associations are responsible for the completion of parts of the projects which are under their responsibility. In particular, this type of partnership is used for the projects which need various areas of expertise. The definitions and characteristics of the partnerships are highly variable according to the laws and their formation agreements.

The management of collaborative partnerships is a difficult task by nature (Park & Han, 2012). The execution of a project could turn to a big problem with an unskillful partner. Therefore, the selection of partners is a crucial point for collaboration. All the firms should be sensitive in this point in order not to have undesired outcomes. Competency of the partners should be controlled in detail since the success of project is directly related with the right choice of partners (Son et al., 2010). SNA could be very helpful to the firms for the determination of the correct partners. Moreover, the analyzing of the collaboration networks is worthwhile since there is a great potential of firm relationships in construction industry (Park et al., 2011).

### 3.4.3 Social Network Application to Collaboration

As mentioned earlier, collaboration is a very common action among the various industries. This situation makes collaboration is an important part of the industries and creates a need for understanding its dynamics. Social network approach could be used to understand the coalition networks. Pryke (2004) explained that the adaptability of SNA is the reason behind its applicability on collaboration. When the firms work together, a relationship between them is formed. In SNA, ties are used to represent these relationships among the firms. In other words, the collaborated projects constitute the ties between the nodes in the networks. In this way, the interactions among the firms can be demonstrated visually and graphically by using SNA (Wambeke et al., 2012). Therefore, the mechanism of collaboration networks could be studied elaborately.

Son et al. (2010) described that social capital is one of the important factors for a firm’s partner selection and project performance. The application of SNA provides the ability to investigate the positioning of the firms and to determine the reasons behind the performance of firms and networks. Kilduff & Tsai (2003) supported that the attraction of SNA comes from its ability to seize the embodiment of the investigated system. The formation of collaboration networks helps the comprehension of the partnership attitudes by applying SNA.

The relationships in their industry are valuable information for all the firms. The ones which are located at the center of the collaboration networks have high probability to get new opportunities, to be more powerful in the network and to select correct partners (Park & Han, 2012). According to the state of the network, firms could determine their prospective actions. At this point, SNA can be considered as a beneficial approach to highlight the features of the collaboration networks. Kilduff & Tsai (2003) stated that with the help of SNA, how the organizations form, improve and utilize relationships is studied by various levels of analysis. Moreover, how the firms are restricted by their relationships can also be comprehended.

### 3.4.4 Previous Work on Construction Collaboration

In previous sections, the collaboration among the firm in various sectors was exemplified by the studies from the literature. In the same manner, the collaboration studies from the literature are mentioned in this section. Park et al. (2011) stated that in the literature there is a little research on collaboration of construction firms. Nevertheless, with the increasing interest on social network concept, an increase on these studies can be expected.

By virtue of the knowledge flow being the most common practice in SNA, its applications in construction collaboration is not surprising. Ruan et al. (2012) used SNA to study the knowledge integration patterns for collaborative construction projects. An empirical research was provided to examine the knowledge management between organizational boundaries. The authors aimed to investigate the effect of collaborative system of procurement to the management of knowledge in construction. In the study, SNA was applied for measurement and visualization of the information and knowledge flow between the organizational structures in the projects. Consequentially, the difference between knowledge integration patterns of collaborative and non-collaborative projects was showed in this research.

The usefulness of SNA in construction collaboration mainly comes from its ability to focus on the partnership between the firms. Taking firms as the social actors in the networks, collaboration can be examined to understand its dynamics. In their study, Park et al. (2011) aimed to form the social networks of collaboration which is constituted by internationally performing construction firms. In this manner, collaboration network of Korean firms was investigated by the help of SNA. The focus of the study was to understand the collaborative strategies of the construction companies. In the study, the firms were classified as large and small-to-medium companies, and then some hypotheses about their behaviors were proposed. The real collaboration patterns were compared with these hypotheses by applying a case study. Park et al. (2011) also discussed the effect of the collaborative actions to performance of the firms in this study. In this way, guidelines for the construction companies to establish collaboration strategies for future projects were presented.

In the same manner, Dimitros (2010) investigated the collaboration patterns of large Greek construction firms. In the study, the projects that were performed in Greece for three-year period were considered. The networks were constructed with various time intervals to discuss all the possible networks in that time interval. These networks were analyzed with 8 different SNA measures. Moreover, Dimitros (2010) reduced the nodes with only one connection in the networks and reanalyzed them to search for permanency. In the end, the results of all these networks were commented and compared with the predictions of previous studies.

Park & Han (2012) made an investigation about the evolution of the collaboration networks by using the data of international projects. These data were constituted by the projects that Korean firms took part for a ten-year period. Moreover, the network characteristics which have the most influence on the performance of the firms were also explored in the study. By using the results of various networks which were constituted in two-year time intervals, the performances of the firms were commented and compared with next years. In this way, Park & Han (2012) claimed that review of the other firms' social relationships can play an important role for decision support in partner selection. Therefore, the authors asserted that social network approach can be utilized for earning success in collaborative construction sector.

Another study on collaborative construction projects was done by Son et al. (2010). In this study, the collaborative projects were examined to search the firms for being embedded both the structurally and relationally in inter-firm networks. The results of SNA used to reveal that the firms are dependent to each other and their behaviors are affected by this situation. In their study, Son et al. (2010) researched the motives of large and small-to-medium size firms to enter the collaborative market by making questionnaires. Then, the social network of Korean firms were formed and analyzed by using previous data of a-eighteen-year period. The results were combined with various statistical approaches to investigate the embeddedness of firms in the network.

# CHAPTER 4

# COLLABORATION NETWORKS OF TURKISH CONTRACTORS

In this chapter, the gap in the literature is explained and the application of social network practice to Turkish Contractors' is presented with a case study. General network for the whole international projects will be visualized and its results will be displayed. Moreover, budget-based and market-based networks will be also analyzed in the same manner.

## 4.1 Gap in the Literature

As mentioned earlier, SNA can be used as a complementary tool in various fields. It provides ability to look from different perspectives and hence enables advanced understanding. Its use in management science is to find what is needed for being more efficient by this ability of SNA. Therefore, the implementation of SNA to management science has become a current issue in the literature in recent years.

Construction management is one these fields which utilizes SNA to increase the performance of the projects. As it is stated in the previous chapter, applications of SNA with various conditions can be seen in the literature. In addition to activity, organization and human based networks, there are researches at company level. The behavior and success of the companies in construction sector could be comprehended more effectively with the help of SNA. In other words, SNA provides widespread perception of the reasons behind the companies' project performances and their relations with the status of companies in the sector. However, the number of researches on company based networks is not as high as the other types of networks both in construction management and in other fields. Therefore, it can be said that the adaptability of SNA is not well benefited and literature is not strong in the firm level networks.

Another gap is that Turkish construction industry is not familiar with SNA. There is not any research on the applicability of SNA to construction management in Turkey. In this study, these two gaps are filled by making a case study to analyze the Turkish Contractors' collaboration network in the international projects. In this way, contribution to the literature of firm level networks in construction management and to the literature of the Turkish construction industry will be provided. Moreover, the usability of SNA in the understanding of collaboration networks of construction sector will be demonstrated.

## 4.2 Methodology

Data collection is the first step for the establishment of the network. As a matter of fact, the hearth of SNA is having proper and enough data. Therefore, without availability of convenient data, SNA could not be performed.

In this study, it is aimed to constitute the collaboration network of Turkish Contractors which is formed according to the data of international projects. In order to establish this network, the data should include the collaborated construction projects which are executed by Turkish Contractors in abroad.

### 4.2.1 Data Collection

In this research, the data of outland construction projects were collected from the Turkish Contracting and Engineering Services unit of Turkish Republic Ministry of Economy. These data were formed by Turkish Contracting and Engineering Services based on the declarations of Turkish Contractors. The name of the company, host country, contract date, job name, region, category and activity-area of each project are included in the data. The exact contract amount of the projects were not given with the data. Nevertheless, some sort of information about the project budget is provided by defining various ranges about the budgets of these projects. In total 7272 projects were received through given data set. The contract dates of these projects changes between the years of 1972 and 2013. The projects that Turkish Contractors collaborated with foreign contractors were also included in the data.

### 4.2.2 Classification

Since the provided data include the projects done by single entities, consultancy works and other services, the collaborated projects should be identified from the given data. In order to make this identification the names of the projects and companies were investigated. Thereafter, the projects other than the collaborated construction works were eliminated. In this way, the remained projects are the ones with the names of joint ventures and consortiums. In other words, the consultancy and service works removed from the data in addition to contract works with single entity.

For the remaining projects two important situations are paid attention:

- ✓ The projects which are done by different companies of same group is marked to be taken under only one heading for that group in entering the software.
- ✓ If there is a newly formed single entity by coming together of more than one companies while each of these companies also continue their business life, the projects which are done by these new entities were taken as collaborations among these companies.

At this point, there were 501 projects left in the data. However, there were still projects which should be excluded to have coherence. The removal of these projects is related to available information in the data. The reasons for the projects to be eliminated as follows:

- ✓ In the project the collaborated companies are group companies,
- ✓ The project is repeated with all the same properties,
- ✓ The collaboration name does not imply the individual companies and information about the collaboration name is not publicly available,
- ✓ The information about the existence of the companies which are implied in the collaboration name is not publicly available.

Therefore, the remaining projects were searched and the ones with above mentioned conditions were also eliminated from the data. The total project amount decreased to 449 projects. By this way, more consistent and more dependable data were obtained to use for SNA.

### 4.3 Case Study

The final shape of the data is used to construct the collaboration network of Turkish Contractors in the international projects. In the formation of the network, the construction companies were taken as the nodes and the projects were taken as the relationship between these collaborated companies. Accordingly, all the data were entered the software Gephi (Bastian et al., 2009) to obtain the general network for the international projects of Turkish Contractors.

The collaborated projects were also analyzed based on the project budgets. In this way, it is aimed to make comprehensive comparison between the behaviors of the companies based on the project sizes. Therefore, the projects were classified in 3 different ranges to construct 3 different networks.

These ranges were listed below and the details will be given in the related section:

- ✓ Small
- ✓ Medium
- ✓ Large

In addition to these networks, market-based networks were also considered in the case study since the data have the information about the host country of the projects. When this information is examined, the host countries were decided to be classified according to the market that they belong.

In this way, the data were divided into 4 sub-groups and all the existent countries were classified under one market except the USA. These sub-groups are listed below:

- ✓ Commonwealth of Independent States (CIS) Market
- ✓ Middle East Market
- ✓ Africa Market
- ✓ Europe Market

The data for these markets were determined and entered into the Gephi. Therefore, market-based networks were also analyzed in the case study. The detailed information for the analyzed networks will be provided in the following sections.

### 4.3.1 Constitution of Networks in Gephi

The nodes and edges were entered to the Gephi from different panels. A sample data entry panel for nodes is shown in Figure 4.1. The label name is entered to the program and it generates an id number and label for each node. As mentioned earlier, foreign firms that collaborated with Turkish Contractors also considered in the network formation. A node is created for each of the companies that exist in the data. However, the names and labels of the companies will not be provided in this study since they are confidential information. Therefore, the companies will be identified by their assigned ID by the software. In the software, the ID of the nodes are not editable. Moreover, if a node is incorrectly entered to the software and then removed, its ID is also removed and will not be given any other node. There are 254 different companies in the data. Their ID's are given by the software by 51 to 309 and they will remain same throughout the study. There are five ID's which were removed from the software: 99, 181, 217, 233 and 239. These ID's are not existent in the case study and do not represent any company.

In the same manner the edges were entered into Gephi. However, entering the edges has additional procedures. As stated earlier, whether the edges have directions or not are a very important parameter while entering the data. Since collaboration is a reciprocal process, it is not reasonable to mention directions. The edges show the existence of cooperated projects between the companies. Therefore, all the edges in the network are undirected. The edges are entered by selecting the type, the source and the target nodes. In order an edge to be registered, the nodes of this edge should have been defined in the node panel. These defined nodes are seen in the edge addition interface and the selection can be done easily. A sample edge entry panel is shown in Figure 4.2. Moreover, the software provides ability to assign various characteristics to these edges. Assigning weights to the edges is a standard ability provided by the software. The weights can be assigned for each edge after definition.

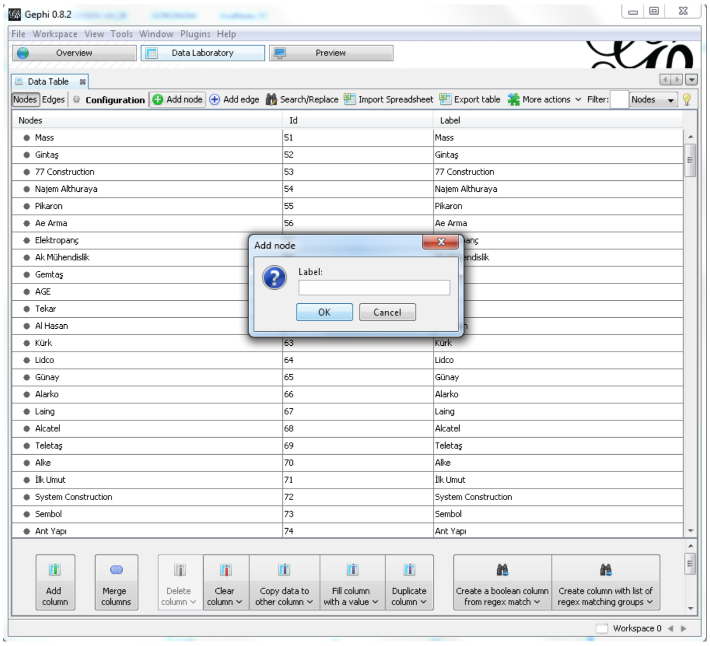


Figure 4.1: Node Entry Panel in Gephi

In the case study the followed procedure for entering the edges are summarized below:

- ✓ Each project is examined and an edge is defined between the collaborated companies,
- ✓ If there are more than two collaborated companies in a project, an edge is defined for each pair.
- ✓ If two companies had collaborated on more than one project, then the feature of assigning weights to the edges is used. The weight of the edge is arranged to represent total number of collaborated projects. Additional contracts were also counted for these relationship weights.

In this way, all the data were entered for the case study networks and the visualizations were obtained from the software.

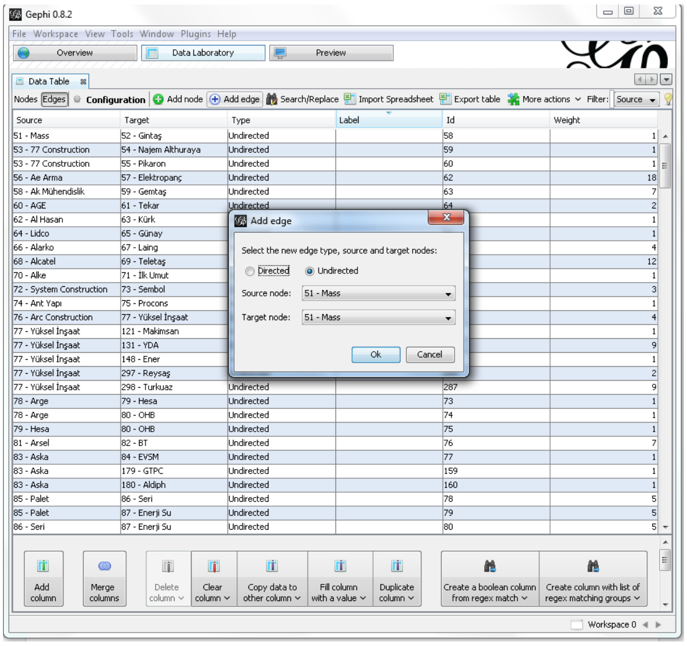


Figure 4.2: Edge Entry Panel in Gephi

### 4.3.2 Output of Gephi

The measures of SNA can be provided by Gephi, after the data are entered and the analysis is run. As mentioned earlier, node level and network level measures are supplied. The previously mentioned network level results which are calculated by Gephi are listed as:

- ✓ Average Degree
- ✓ Average Clustering Coefficient
- ✓ Graph Density
- ✓ Average Path Length (Average Shortest Path)

According to Bastian et al. (2009) previously unmentioned network level measures which are also calculated by Gephi are introduced below:

- ✓ Average Weighted Degree: In the weighted networks, this measure is used to take into consideration the effect of the weighted ties on the average degree for the network. This measure is affected by both the number of projects indicated by the ties weight and the number of projects which have more than two partners.

- ✓ Network Diameter: Used to define maximum distance among the all pairs in the network. In other words, it is the largest distance between the farthest nodes in the network.
- ✓ Connected Components: In undirected graphs, this measure shows the number of groups in the network, in which the nodes are only connected to the nodes in the same group. Therefore, this measure gives the total number of sub groups in the network.
- ✓ Modularity: This measure is an indication of the network's disintegration into communities. It helps to identify and to visualize the cliques in the network. Various cliques may be formed by the nodes from the same connected component. A modularity class number is assigned for each sub group in the network.

On the other hand, the node level measures which are also among the output of Gephi are as follows:

- ✓ Degree
- ✓ Closeness Centrality
- ✓ Betweenness Centrality

In the same manner, the unmentioned node level measures are described below according to Bastian et al. (2009):

- ✓ Weighted Degree: As previously stated in the Average Weighted Degree, the ties between the companies may refer collaboration of more than one project since the network is a weighted network. Therefore, calculating only the number of nodes that a node connected to is not enough in weighted networks. The ties which show more than one collaborated projects between the companies should be considered in the average degree calculation.

However, this measure does not directly show the total number of projects that a company participated in since a project with collaboration of more than two firms also affects this measure. Therefore, it can be seen as an indicative of total number of relationships in the network. If a company have involved in partnerships with only one company in all its projects, than the weighted degree directly shows the total number of projects.

- ✓ Eigenvector Centrality: This measure indicates the importance of a node based on the nodes that it is connected to. Therefore, it can be seen as a measure of connectivity based on a node's connections in a broader extent. In other words, the centralities of linked nodes are considered in the calculation of a node's eigenvector centrality (Wambeke et al., 2012). The measure assigns each node in the network a value between 0 and 1. The company with highest importance is given the eigenvector centrality of 1.
- ✓ Component ID: This measure shows which component in the network that a node belongs to. These components are isolated from each other.
- ✓ Eccentricity: This measure is related with the network level measure of diameter. It shows the node's maximum distance to farthest one in its component. When the members in its connected component get higher, the eccentricity of a node increases since the number of ties to reach farthest one in the component also increases. However, if a company is in an isolated dyad or triad, then there is only one tie to reach farthest node in that component. Therefore, this measure calculates the number of ties to reach farthest member in the component of each node.
- ✓ Modularity Class: This measure shows the cliques which each node belongs to in the network. Since there may be more than one clique in a connected component, this measure assign each sub-group in the network to a different modularity class.

## 4.4 General Collaboration Network of Turkish Contractors in International Projects

The general collaboration network is drawn by using all the remaining reliable data. The summary of the case projects are given in Table 4.1.

Table 4.1: Summary of the Data

| | |
|---|---|
| Total Number of Collaborated Projects | 449 |
| Total Number of Companies | 254 |
| Total Number of Host Countries | 46 |
| Total Number of Edges | 232 |

Figure 4.3 shows the sociogram of the general network.

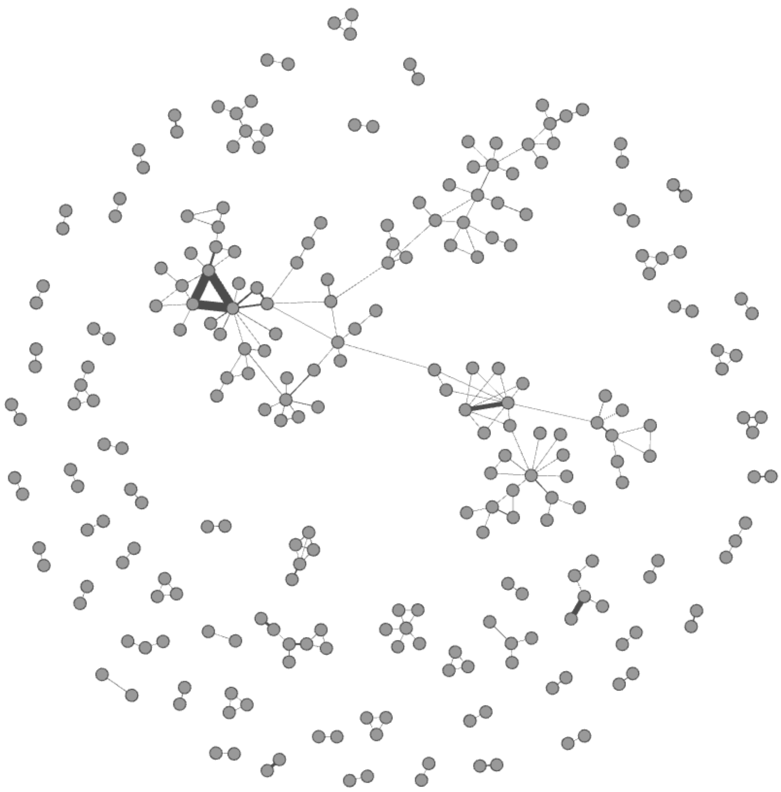

Figure 4.3 International Collaboration Network of Turkish Contractors

As it can be forecasted, the map of the Turkish Contractor's collaboration network is relatively dispersed. However, there is a structure in the network which is constituted by considerably large portion of the nodes. Other than this highly connected structure, there are many dyads and triads in the network. Moreover, a small number of cliques can also be seen in the network.

### 4.4.1 Discussion of the Results for the General Network

The results of general network and their discussions are given in this section. The node and network measures will be handled separately.

Network Measures:

The results of the SNA measures for the network are given below:

Table 4.2: Network Measures of General Network

| | |
|---|---|
| Density | 0.007 |
| Average Degree | 1.827 |
| Average Weighted Degree | 5.220 |
| Network Diameter | 16 |
| Modularity | 0.848 |
| Weakly Connected Components | 61 |
| Average Clustering Coefficient | 0.592 |
| Average Path Length | 6.507 |

These metrics represent the features of the whole network. The density of the network is very low. The reason behind is that the projects were carried out by many different companies. Total number of node is very high compared to the project number. Therefore, there is a very large number of possible relationships in the network but the most of them are not existent. Since the situation of Turkish construction industry is advanced, many firms look for winning the tenders of the international projects. This situation results in variety of companies and very low density.

In the same manner, the average degree value for the network is low. It shows that a node in the network in average has connection with only 1.827 other nodes in the network. However, the weights of the ties should be taken into account since the ties in the network are weighted. In this case, the average degree of the nodes is almost tripled. It can be interpreted from this result that the companies prefer to make collaboration with the previously interrelated companies in the network. According to these numbers, in average a company has involved in approximately 3 projects with approximately 2 other companies. However this is not true, since the number of ties whose weights are more than 1 is only 70. Therefore, only 30.17 % of the relationships between the companies shows that they had collaborated on more than one project. When these ties are considered in the network by removing the ties with weight of 1, the network with remaining ties are shown in Figure 4.4. As it can be seen from this figure, many nodes in the network become unconnected from the rest of the network. There are only two small structures in the network. The interpretations that can be made for this situation are:

- There are many dyads in the network, in which two companies collaborated in only one international project and have not involved in any other collaborative activity with any other company in the international market.
- There are important projects which are the only ones that hold the companies together and constitute the main structure. In the absence of the ties which represents only one collaborative action, the main structure disappeared.

- There are high numbers of projects in the data which connect more than two partners and increase the weights of the nodes in the network. Therefore, the average weighted degree is increased by the effect of these projects.

The value of network diameter shows the distance between two farthest nodes in the network. Average shortest path value represents the standard path length between all possible pairs in the network. In other words, it provides information about proximity of the nodes in the network. The node level metrics are used to calculate the average shortest path of the node. In this network, every node can reach another one by help of other 6.507 nodes.

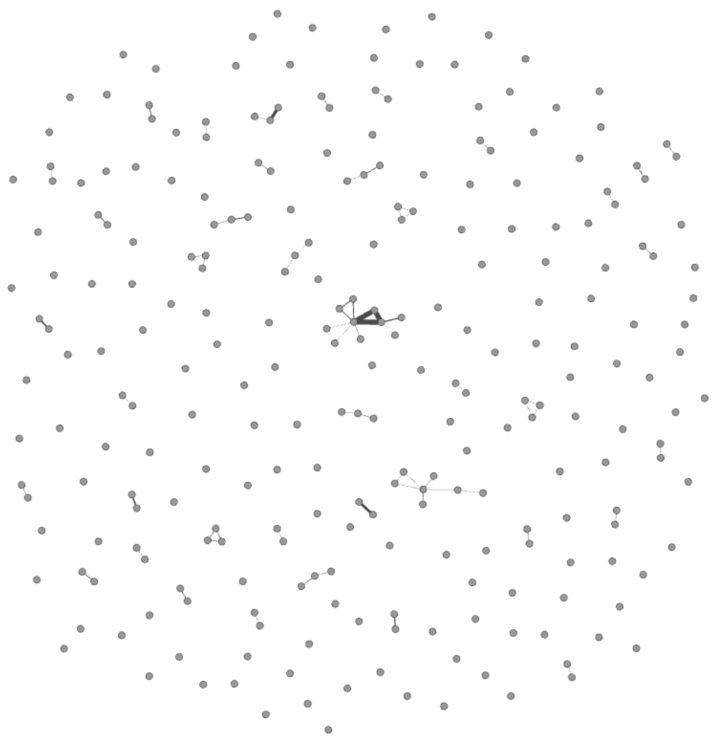

Figure 4.4: Filtered Network with Ties Weighted more than One Projects

As previously mentioned, the average clustering coefficient is calculated by using the local clustering coefficients of the nodes which are based on the triplets in the network. The average value for the network is 0.592 and can be seen as considerably high. The reasons behind this situation are:

- There are notable numbers of dyads in the network which are not considered in the computation.
- There are notable numbers of triads in the network which increase the average clustering coefficient since all the companies in these triads have a value of 1.
- In the network there are considerable amount of projects which connect more than two companies from the main structure and have impact on the clustering coefficient of these companies.

The number of connected components is very high. There are 61 different groups which are not connected to each other (Figure 4.5). Moreover, these groups are formed by only 254 companies in the network. High amount of isolated dyads and triads is the main reason behind this situation since all of them are counted as components. Therefore, the disconnectedness between these groups is a source of the network's low density value.

Modularity value represents the quality of network's partitioning. According to Bastian et al. (2009), the networks whose modularity values higher than 0.4 decompose better. When the general network's high modularity value is combined with number of weakly connected components, it is seen that the network is highly separated. As mentioned earlier, the nodes in the network are divided into 61 different groups. However, the main structure can also be divided into different cliques. According to the results obtained from the software there are 68 different modularity classes in the network. Since 61 of these classes are formed by the connected components and displayed in Figure 4.5, the modularity classes in the main structure are shown separately by various colored groups in Figure 4.6.

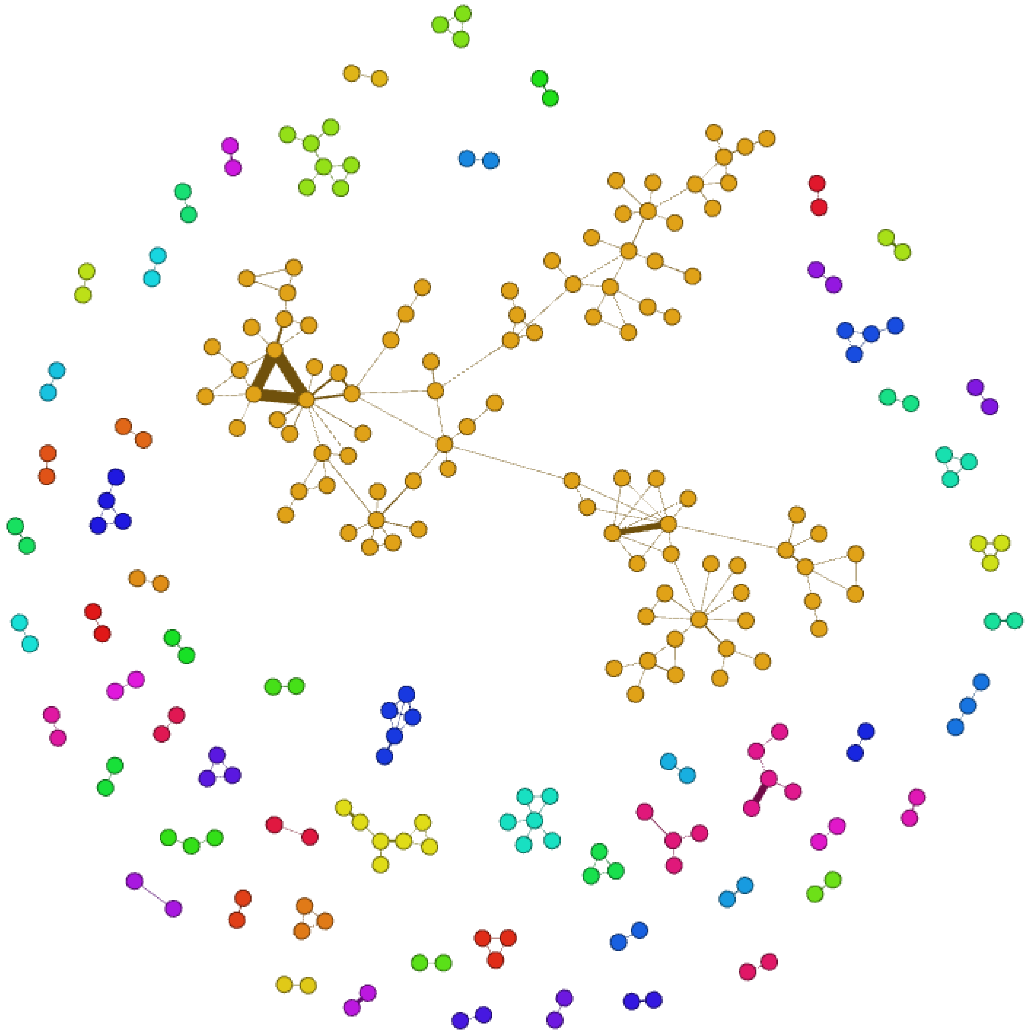

Figure 4.5: The Connected Components in the General Network

According to these network measures, various interpretations can be made about the general network of Turkish Contractors in collaborative international projects. Firstly, as it can be seen from Figure 4.3, the network is very wide. The main reason behind this situation is the encouragement in the Turkish construction sector for the contractors to conduct business internationally. With high competition in the domestic market and high risk taking ability in the international market, the companies do not hesitate to enter the international market. Since collaborated projects are considered in formation of the network, the increase in the number of companies results in the decrease of network density. The companies are not forced to collaborate with the same companies because of the advanced situation in the Turkish construction industry. There are many options for them to find suitable partners from both international and domestic market. Therefore, the contractors are not obliged to select partners from a small group and this condition results in the enlargement of the collaboration network.

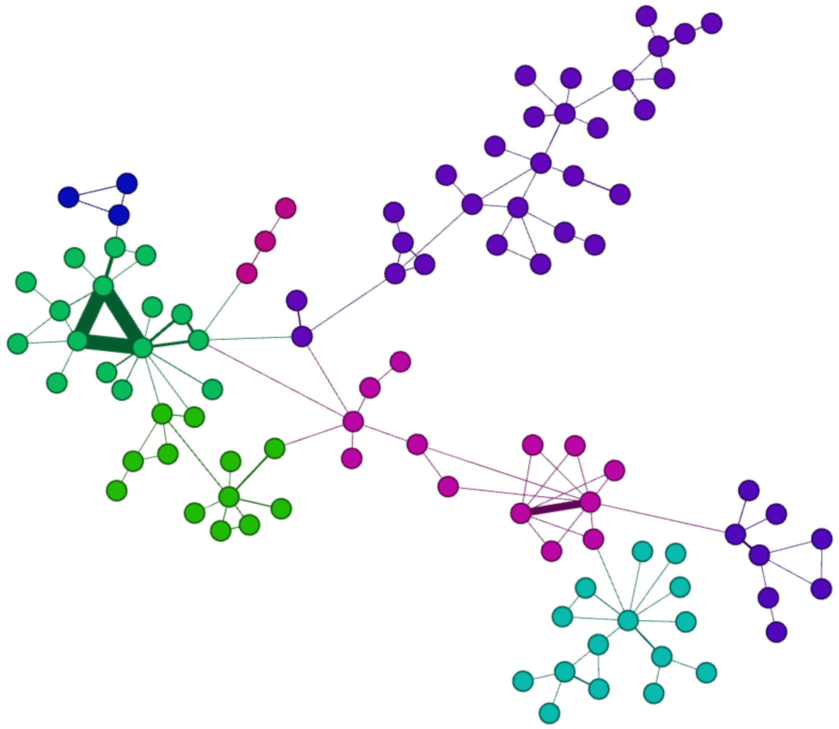

Figure 4.6: The Modularity Classes in the Main Structure

Most of the connected components in the network are isolated dyads. Moreover, there is a considerable amount of isolated triads. As previously stated, one of the reasons behind this situation is the contractors' willingness to enter international projects. They participate in the collaborations because of the need for reducing the risks and increasing their ability for completion of the project. In this way, even very small companies can find themselves a chance to open up international market with a single project and form an isolated dyad or triad in the network by not involving any other collaboration activity in the international market. On the other hand, there are some companies in the network which become partners for the international projects and have not collaborated in any other companies. In this way, these companies also form an isolated dyad or triad by performing various international projects.

Despite the fact that the general network seems to be separated and there are a lot of options for the contractors, a major component is existent in the network which shows the network topology. This major component is constituted by 99 companies which is approximately 40 % of the companies in the network. Therefore, it can be interpreted that social network approach is useful for the Turkish Contractors for the international market. In other words, even though there is a tendency between the smaller firms to collaborate with only one firm, there is a network among the internationally working Turkish Contractors. The companies in the major structure collaborated in various projects to increase their earnings. A company could enhance its opportunities in the international market by the help of the other companies in the same group. As in the case of the general network, the chances of the companies in the major component are higher in the international market. The reason for this situation is that although the construction industry is large, it can be seen as a small world since all companies follow each other and are aware of what is happening in the market. By being part of the major component, companies become more reachable and more able to develop relationships with other ones in the sector. In this way, these companies gain competitive advantages in the international market and have ability to retain stronger positions in the industry. On the other hand, there are a few sub-groups which are formed by more than 4 companies. These cliques can also be considered as significant components in the network since the companies in these cliques are connected to each other and they could also behave dependently in the market. Although their reachability and recognition by the other companies are relatively less than the ones in the major component, these companies still have stronger condition in the network than the isolated dyads.

In conclusion, Turkish Contractors show a network topology based on the collaborative projects in the international market when these projects are taken as relationships between the companies. There is a major structure in the network where 99 companies from the sector are connected and show network features. In this way, these companies are able to use the benefits of the network characteristics for the international projects. On the other side, there are many isolated components in the networks which are mostly isolated dyads. These companies do not have connections to the rest of the companies and stay in the background of the sector. It can be expected that they may have difficulties in maintaining their competitiveness in the international market since they may face with problems while finding partners which are reliable for entering the complex and profitable projects.

Node Level Measures:

While calculating the measures of the network, the software also calculates the metrics for each node. In other words, the network measures are calculated based on the measures and features of all the nodes in the network.

The average degree of the nodes in the network is calculated as 1.835, when the individual nodes in the network are investigated, the nodes with highest degree are shown in Table 4.3. Higher degree is the clearest indication of power in the network. The highest degree node in the general network is Company-77 which have collaborated with 10 different companies for performing the international projects. The company is on the 124$^{th}$ rank in the ENR's Top 250 International Contractors List in the year 2013. In the same manner, Company-145 and Company-262 have also collaborated with 9 different companies. These companies are also appeared in the same list with 188$^{th}$ and 240$^{th}$ ranks respectively. Although being in the ENR list does not highly related to our network since only the collaborative projects are considered in the study, most of the high degree companies are on this list. These companies have great strength in the international market since their recognition by other ones and their experience in collaborative projects are higher.

Table 4.3: The Nodes with Highest Degree in the General Network

| **Company ID** | **Degree** |
|---|---|
| 77 | 10 |
| 145 | 9 |
| 262 | 9 |
| 117 | 7 |
| 130 | 6 |
| 135 | 6 |
| 161 | 6 |
| 268 | 6 |

The software provides opportunity to classify the nodes based on their degree. As it can be seen from the Figure 4.7, more than half of the companies have collaborated with only one company in the international market. Moreover, less than 20 % of the companies have relationships with more than 2 companies for the international projects. Therefore, the high degree companies become stronger in the market since they are very rare and most of the other companies are far from their experience.

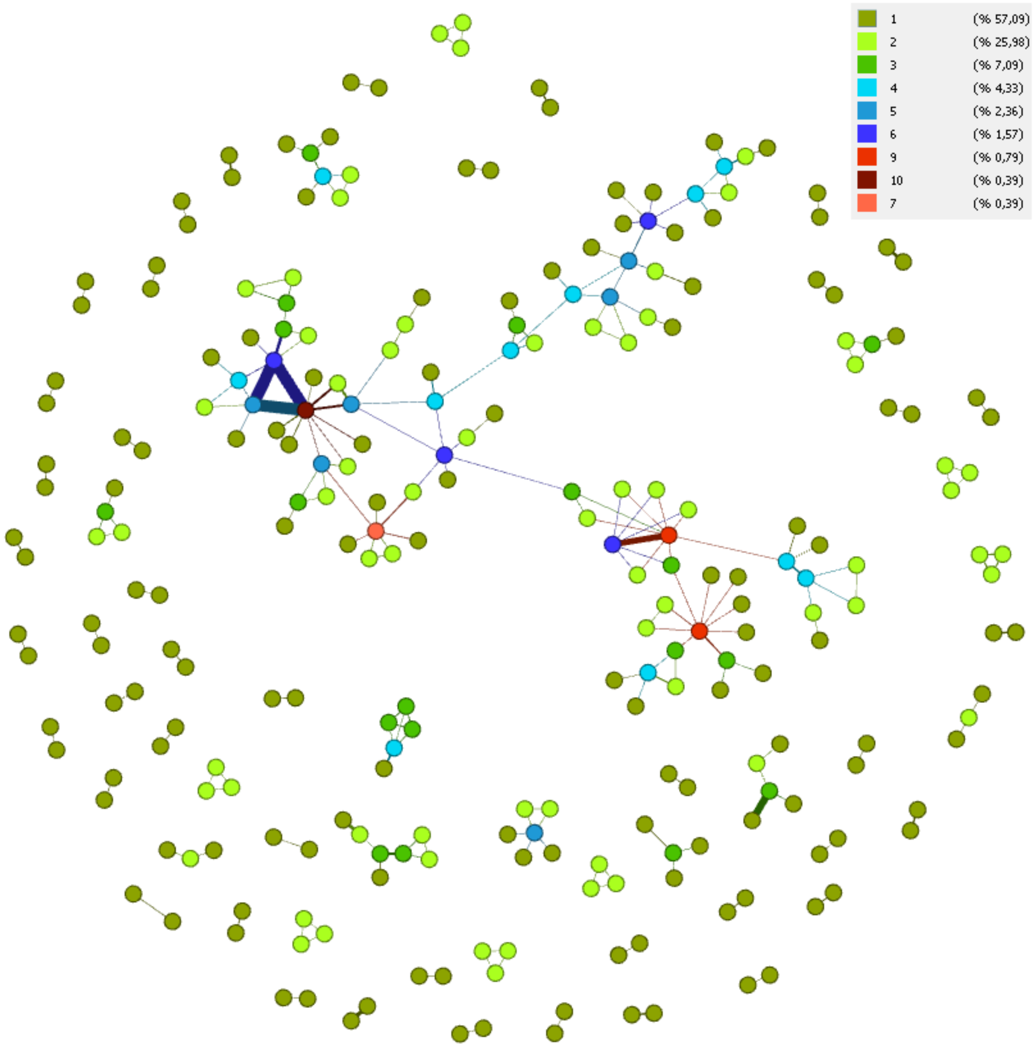


Figure 4.7: Degree Based Colored Nodes of the General Network

On the other hand, the experience of a company is not only measured by the number of its partners but also by the number of projects that the company is involved in. In the case study, the network is formed by the weighted ties. Therefore, the weighted degree values for the nodes are also computed (Table 4.4). In this way, both the number of involved projects and the number of partners in these projects are considered. In other words, the total number of relationships for the nodes in the network is counted. This measure can be seen as an indicator for the experience of the companies in the international market and can be regarded in the evaluation of the companies' strengths.

Table 4.4: The Nodes with Highest Weighted Degree in the General Network

| Company ID | Weighted Degree |
|---|---|
| 77 | 137 |
| 161 | 124 |
| 177 | 111 |
| 192 | 36 |
| 145 | 35 |
| 193 | 33 |
| 268 | 32 |
| 131 | 21 |

When the results of Table 4.3 and Table 4.4 are compared, it is seen that Company-77 is top of both lists. Therefore, it can be interpreted that the Company-77 is the most experienced company in international collaborative projects. According to the obtained data, this company participated in many different projects with 10 different companies. These numbers make Company-77 as the most powerful and important member of the social network which is formed based on the international collaborative projects of Turkish Contractors. Besides, the experience of the Company-161, Company-177, Company-192, Company-193 and Company-131 become prominent when the total number of relationships is considered. Although these companies selected to work together with familiar companies, it can be interpreted that they are involved in many projects. Among these nodes, Company-192 and Company-193 are relatively smaller companies. Company-131 is a relatively newer company in the international sector while the others have a long-standing background. On the other hand, the companies such as Company-262, Company-117, Company-130 and Company-135 involved in relatively less projects, however, they have cooperated with relatively high number of companies. Therefore; it can be asserted that while some powerful companies formulate their strategy in the international market for enhancing their network and collaborating with various companies, the other ones prefer to maintain their partnerships and take part in high number of projects with the advantage of acquaintance. Other than Company-117, Company-131, Company-193 and Compay-268, the remaining companies are in the Top 250 Contractors list of ENR for the year 2013.

As previously stated, degree of a node is not the only indicator of power and importance in the network. Betweenness centrality shows a node's ability to connect others. Table 4.5 shows the companies which have highest normalized betweenness centrality values in the network.

Table 4.5: The Nodes with Highest Betweenness Centrality in General Network

| **Company ID** | **Betweenness Centrality** |
|---|---|
| 130 | 0.079412 |
| 145 | 0.069139 |
| 144 | 0.065155 |
| 66 | 0.062331 |
| 227 | 0.060888 |
| 131 | 0.053877 |
| 273 | 0.053109 |
| 77 | 0.052136 |
| 96 | 0.040247 |
| 262 | 0.039306 |
| 267 | 0.039055 |

The betweenness centrality values are normalized to obtain values between 0 and 1 which will be useful in comparing. As in the case of density, the betweenness centrality values are also low. The reason behind is that as there are not much connections in the network, the nodes cannot be in a position that is between many other ones. Nonetheless, these values provide relative information about the nodes in the network. Company-130 appeared on top of this list while Company-145 becomes in the second place. These firms were the ones which had relatively higher ranks in the degree table but lost their position in the weighted degree table. On the other hand, there are some companies such as Company-144, Company-66, Company-273, Company-96 and Company-267, which were not available in the previous tables. These are generally middle-sized companies that have not involved in many projects. However, they are located in positions that give them chances to connect the other companies. In construction sector, the relationships between companies are important while finding and selecting partners for collaborative projects. Moreover, when the international market is considered, partner finding becomes more critical. High betweenness companies are capable of reaching other ones relatively easier. If these companies are seen as people, they have ability to introduce unacquainted companies to each other.

The eccentricity and closeness centrality values for the nodes are also calculated by the software. Former one gives the distance from the farthest node in the network while latter one shows the average distance to all the nodes in the network. Therefore, eccentricity values are small for the nodes of the isolated smaller components since the nodes in smaller components have less distance to the other members in the same component. However, if a company is in the major structure, it has higher eccentricity since it is located with higher distance with the other companies in other part of the major structure.

Table 4.6: The Nodes with Highest Eccentricity in General Network

| Company ID | Eccentricity |
|---|---|
| 149 | 16 |
| 302 | 16 |
| 244 | 16 |
| 102 | 15 |
| 101 | 15 |
| 89 | 15 |
| 300 | 15 |
| 299 | 15 |

Table 4.6 shows the nodes with highest eccentricity values. The network diameter value comes from the maximum eccentricity value. The companies in this list are in the major structure and far from an eccentricity value to reach the farthest node in the major structure. On the other hand, the nodes in the isolated dyads have eccentricity values of 1. This measure does not provide much valuable information when used in this kind of collaboration network for construction companies. Although higher eccentricity seems to be an unfavorable feature, they are still parts of the major component. On the other side, the nodes in the isolated dyads and triads get smaller values which shows smaller distance. Therefore, these results do not help to identify the ones with higher importance or strength. Only the farthest ones in the major structure can be determined with this measure.

Another previously mentioned measure is the clustering coefficient. However, the values in the general network also fall short for giving dependable information to make deductions. The reason behind is that there are many isolated dyads and triads in the network. These dyads are not capable of producing clustering coefficient since they do not have neighbors. On the other hand, the isolated triads are mainly formed by the projects where three different companies have collaborated. Therefore, these triads have clustering coefficient of 1. In this way, the clustering coefficients of the nodes are not reliable measures because of the network's structure.

Eigenvector centrality values are also calculated by the software. As it was stated, this measure considers the connections of the nodes in a broader view. The ability to influence the other nodes is represented by assigning each node a value between 0 and 1. The number of iterations for this measure is used as standard value which is 100. Unfortunately, this measure does not take into account the weights of the ties in the network. Therefore, the degree of the nodes play important role in calculation of this measure. Nevertheless, it still provides the ability to comment the effectuality of the nodes in the network based on the existence of the ties. The nodes with highest eigenvector centrality are shown in Table 4.7. When compared to the table 4.3, Company-77 and Company-145 retained their positions. However, it can be seen that there are some changes in these rankings. This situation means that although some companies do not have high degree or betweenness, they have connections that are more significant and powerful in the network. Therefore, these companies become more influential in the network.

Table 4.7: The Nodes with Highest Eigenvector Centrality in General Network

| **Company ID** | **Eigenvector Centrality** |
|---|---|
| 77 | 1 |
| 145 | 0.9196 |
| 268 | 0.7094 |
| 161 | 0.6468 |
| 131 | 0.5939 |
| 177 | 0.5936 |
| 121 | 0.5397 |
| 267 | 0.5220 |
| 262 | 0.4963 |

If there were more small structures in the network, then the effect of eigenvector would be seen more clearly. The reason behind is that, in that case the effect of the degree and the centrality values for these companies would be decreased by the effect of the features of their connections. Since there is a major component in the general network and the isolated ones are mainly dyads and triads, the efficiency of the eigenvector centrality is lower. Nonetheless, the effects of the connections in the general network can still be noticed.

Comments about the General Network:

The network of the Turkish contractors based on the collaborative international projects is constructed. According to the previously stated measures the summary of the comments about the general network and the behavior of the companies are given below:

- Turkish Contractors adopt self-confident strategies in international market. Their high risk taking ability could be the reason for their eagerness for involving international projects. Therefore, Turkish Contractors are known in many different countries.
- Collaboration is less frequently preferred for receiving projects by Turkish Contractors. Most of the taken projects were performed individually.
- Most of the companies in the network have involved in only one international project by collaborating one or two firms. The reason for this could be in two ways. First, the companies could see the risks of these projects and turn their attention to domestic projects or the projects which they are able to complete on their own. Secondly, these companies are new players in the international market and they are aiming to increase their share in the collaborative projects.
- Although, there are many companies, there is a major network structure constituted by the Turkish Contracts with foreign counterparts. This

situation shows that in a sort of way the Turkish Contractors behave dependently in the international market. Their position in the network provide advantages to some of the companies while affecting some others in the opposite way.

- Company-77 is a well-known company in the Turkish construction industry. When the various SNA measures are considered this company is the most powerful company in the international collaborative projects. According to the results, it is the most experienced one based on the amount of collaborated parties and the number of relationships. Moreover, Company-77 also has the best eigenvector centrality which shows that not only the power of this company is high but also its connected companies are significant ones in the whole network.
- Company-145 is also another important company which achieved very good results in various SNA measures at the same time. As in the case of Company-77, this company is also a recognized one in the sector. Although its total number of projects is relatively less, Company-145 have collaborated with many other companies which are also stronger ones in the network. Additionally, Company-145 has a position in the network which provides the ability to connect various companies. If the companies in the network are considered as references to each other, Company-145 is among the top ones which have the ability to introduce different companies.
- Some companies in the network follow the strategy to collaborate various partners which make them more attractive in the market since they are proved as adaptable partners in the market. These companies have participated in relatively less projects but have various partners. Best examples for this strategy are: Company-262, Company-117, Company-51, Company-83, Company-96 and Company-135. Among these companies the ones with the ID numbers 51, 83 and 117 can be considered as relatively

small companies. On the other hand, the remaining companies are veteran companies of Turkish construction industry.

- On the other hand, some companies implemented a contrary strategy. These companies carried out relatively high number of collaborated projects while keeping their partner amount minimum. In this way, it can be interpreted that these companies aimed to cooperate only with the familiar companies and they are reluctant to take risks by establishing partnerships with various companies. Best examples for this strategy are: Company-161, Company-177, Company-192 and Company-193. All of these companies have more than 40 years of experience in the construction industry and can be regarded as significant players.
- In the social network theory, betweenness centrality is an indicator of critical positions in the network. As mentioned earlier, although in this case study that measure does not acquire much significance, it can still be benefited. When the companies are being represented by individual staff members, the relationships between the firms become more humanlike. Therefore, betweenness centrality can be used to understand the ability of the companies to introduce each other. For example, while connecting an unknown company representative, the ones from the companies with high betweenness centrality could play a crucial role. The examples from the case study are: Company-130, Company-144, Company-66 and Company-227. These companies are able to play mediator role when the interaction is needed in personal level. The common feature of these companies is that they are relatively smaller companies which are not as significant as others.
- The companies who are not striking in the network but have respectable positions are detected by their eigenvector centrality values. According to this measure, the companies whose connections provide them much credibility in the sector are conceived. Although the weights of the ties are not considered in this measure, it provides ability to evaluate the

connections of the nodes. Other than the previously mentioned companies the most significant ones for the international collaborative projects are: Company-268, Company-131, Company-121 and Company-267. Among these companies Company-267 is a famous foreign company that have collaborated with powerful Turkish counterparts. The other companies are the ones that become active in the international market in recent years.

- Some of the measures do not provide dependable information to make deductions because of the network's structure. Since the network has many isolated components, these values become ineffective. The isolated dyads mostly have not been included in these measures or become outliers. In the same way isolated triads also negatively affect the reliability of these measures. These are the eccentricity, the clustering coefficient and the closeness centrality of the nodes.

### 4.5 Budget-Based Collaboration Networks of Turkish Contractors in International Projects

The size of the construction projects is a very important criteria for contractors to make a tender. Since these projects could have a wide variety of scopes, budgets of them can be defined in various scales. The behavior of the companies may change according to the project size. For example, a company may prefer to make collaboration only in large size projects, if it has enough capacity to complete smaller ones by itself. On the other hand, if a company does not have capacity to involve in large projects, it can only take part in collaborations of relatively small projects. Therefore, analyzing the social networks of the Turkish Contractors based on various project sizes can help to make comparison of the companies' roles in the industry. In other words, the difference between being a fish in the ocean and a fish in the small pond can be displayed by considering the project sizes.

As can be seen in Table 4.8, given projects are classified into 3 categories with different project budgets.

Table 4.8: Information about the Budget-Based Networks

| Network Name | Project Budget | Number of Projects |
|---|---|---|
| Small | Smaller than US $10 Million | 158 |
| Medium | US $10 Million-US $ 50 Million | 148 |
| Large | Larger than US $50 Million | 143 |

According to this classification, the projects whose budget is under than US $ 10 million are defined as small projects. The projects which are contracted in between US $ 10 million and US $ 50 million are classified as medium projects. Finally, the ones whose budgets are more than US $ 50 million are considered as large projects throughout this case study. Moreover, as can be seen from Table 4.8, the numbers of projects in these networks are closer. Therefore, fairer comparisons on network measures can be done based on these networks.

### 4.5.1 Collaboration Network of Small Scale Projects

The summary of the data of for the collaborations of the Small Scale Project Network (SSPN) are summarized in Table 4.9.

Table 4.9: Summary of the Data for the SSPN

| | |
|---|---|
| Total Number of Collaborated Projects | 158 |
| Total Number of Companies | 116 |
| Total Number of Edges | 77 |

The sociogram of the network for small scale projects are shown in Figure 4.8.

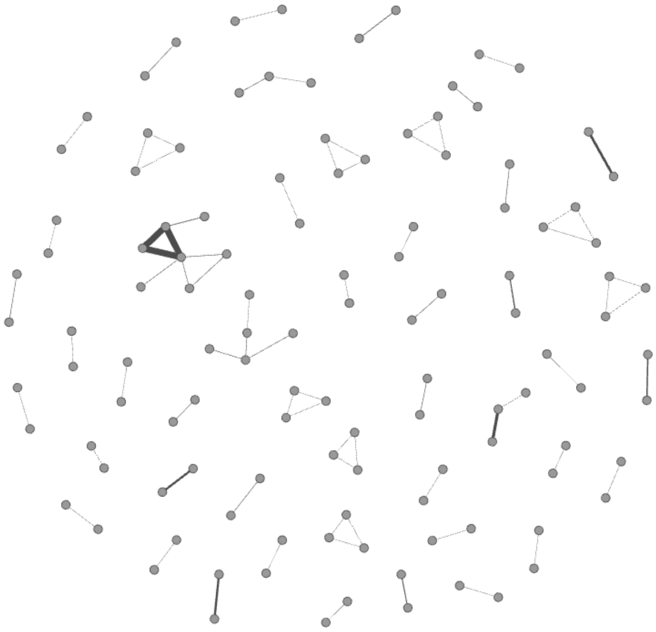

Figure 4.8: Sociogram of Small Scale Project Collaborations

#### 4.5.1.1 Discussion of the Results for the Small Scale Project Network

Network Measures:

The network level measures for the collaborations of small scale projects are shown in the table below:

Table 4.10: Network Measures of SSPN

| | |
|---|---|
| Density | 0.012 |
| Average Degree | 1.328 |
| Average Weighted Degree | 4.138 |
| Network Diameter | 3 |
| Modularity | 0.798 |
| Weakly Connected Components | 49 |
| Average Clustering Coefficient | 0.834 |
| Average Path Length | 1.265 |

The network measures indicate that for the small scale projects, the network is wide. The degree measures show that the number of collaborations with various partners is low. Most of the contractors form a partnership with one company. Another measure shows this situation is the connected components. There are 116 companies in the network which form 49 isolated components. Since there is only one significant structure which also do not have a complex shape, the network diameter and average path length of the network seems very small.

Node measures:

After this point of the research the dependable node level measures are shown in each sub network. The reason is that some of the measures are not suitable for making interpretations due to the structure of the networks. Therefore only the degree, the weighted degree, the betweenness centrality and the eigenvector centrality results of the nodes will be shown for the budget-based and market-based networks.

The highest degree nodes in SSPN are shown in Table 4.11 and colored sociogram based on the degree of the nodes are shown in Figure 4.9.

Table 4.11: The Nodes with Highest Degree in SSPN

| **Company ID** | **Degree** |
|---|---|
| 77 | 5 |
| 117 | 3 |
| 161 | 3 |
| 51 | 2 |
| 177 | 2 |

Since the average degree of the network is very low and the network is highly dispersed, it is expected that the nodes in the network do not have high degree values. As in the case of general network, Company-77 has the highest number of partners in this network. However, since making collaboration with many other partners is not the only identifier, the effect of the number of projects and the number of partners in these projects are also considered as in all networks in the research.

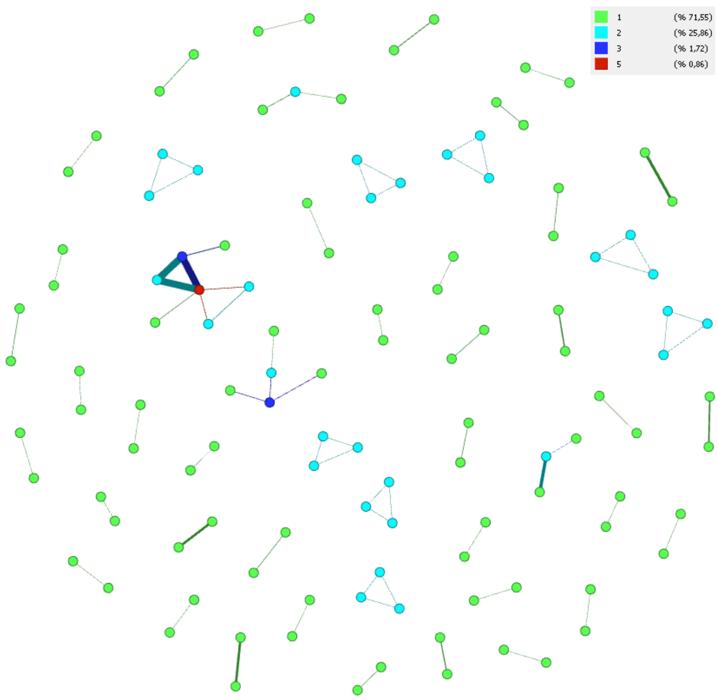


Figure 4.9: Colored Nodes of SSPN Regarding Their Degree

Table 4.12 displays the weighted degree of the companies in this network

Table 4.12: The Nodes with Highest Weighted Degree in SSPN

| Company ID | Weighted Degree |
|---|---|
| 77 | 68 |
| 161 | 65 |
| 177 | 62 |
| 192 | 15 |
| 193 | 14 |

According to the results of the weighted degree measure, Company-161 and Company-177 can be defined as experienced as Company-77 in small scale projects. Moreover, Company-192 also becomes prominent in the network.

When the betweenness centralities are considered, the results are not much dependable. The reason behind this situation is the structure of the small project network. Even the biggest sub group in the network does not have high number of members which results that the members cannot have ability to connect others. Therefore, in this network very few companies has betweenness centrality scores (Table 4.13).

Table 4.13: The Nodes with Highest Betweenness Centrality Scores in SSPN

| **Company ID** | **Betweenness Centrality** |
|---|---|
| 77 | 0.001678 |
| 161 | 0.000763 |
| 117 | 0.000763 |
| 121 | 0.000458 |
| 192 | 0.000153 |

Only these three companies have ability to introduce two unfamiliar companies in the network. However, this ability is only for connecting the firms in the same sub groups. As mentioned earlier, since the network is very highly fragmented, the companies are isolated from each other. Eigenvector centralities of the nodes are also calculated by the software to consider all the connections of the nodes in SSPN (Table 4.14).

Table 4.14: The Nodes with Highest Eigenvector Centrality in SSPN

| **Company ID** | **Eigenvector Centrality** |
|---|---|
| 77 | 1 |
| 161 | 0.6705 |
| 177 | 0.6049 |
| 131 | 0.5644 |
| 298 | 0.5644 |

According to Table 4.14, the most important member of the small project network is Company-77. As it can be expected, since the network is not well structured, the highly experienced companies are located in the most critical positions in the network.

Comments about the SSPN:

- The small projects are done by many different companies. 158 projects are performed by 116 companies.
- Approximately 96 % of the nodes have collaborated with less than 3 companies. When the sociogram of this network is examined, it is seen that most of the projects are done by isolated dyads or triads. This situation can be explained by the fact that it is relatively easier to take smaller projects. Therefore, many small scale companies can take part in these projects.
- According to the network structure, it can be interpreted that there are not any significant figures in this network other than the highly experienced companies.
- When the data of the small projects investigated in detail, the most of the collaborated projects that link Company-77, Company-177 and Company-161 had been performed in 1990s. In the same manner relationship between Company-192 and Company-193 is crucial for these companies, whose weighted degree is mainly resulted from this relationship. The thickness of the ties between these companies indicates this situation.

- The relatively newer projects were generally performed by small scale companies as their first step to international market. The formed relationships in this network may be maintained to take advanced projects. For this reason, there is a very high probability to encounter the companies in the isolated dyads and triads in the other budget-based networks.
- When the scale of the projects is smaller, the risks of these projects are lower. Therefore, small scale companies can take these risks by forming partnership between them. This circumstance is the main reason behind the diversity in this network.
- Moreover, in these small scale projects, the need for the specialized companies are not significant since the complexity of these projects is low. In the same manner, experience also is not seen as indispensable feature for these projects. Therefore, the amount of popular companies in this network is less.

### 4.5.2 Collaboration Network of Medium Scale Projects

The summary of the data of for the collaborations of the Medium Scale Project Network (MSPN) are summarized in Table 4.15.

Table 4.15: Summary of the Data for the MSPN

| | |
|---|---|
| Total Number of Collaborated Projects | 148 |
| Total Number of Companies | 132 |
| Total Number of Edges | 105 |

The sociogram of the network for medium scale projects are shown in Figure 4.10.

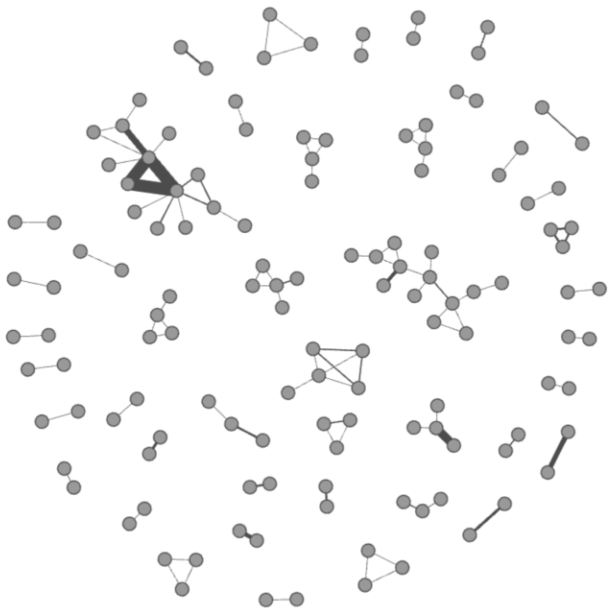

Figure 4.10: Sociogram of MSPN

### 4.5.2.1 Discussion of the Results for the Medium Scale Project Network

Network Measures:

The network level measures for the collaborations of medium scale projects are shown in the table below:

Table 4.16: Network Measures of MSPN

| | |
|---|---|
| Density | 0.012 |
| Average Degree | 1.591 |
| Average Weighted Degree | 3.348 |
| Network Diameter | 6 |
| Modularity | 0.860 |
| Weakly Connected Components | 44 |
| Average Clustering Coefficient | 0.719 |
| Average Path Length | 2.076 |

The density of the medium scale project network is also low and high number of companies in this network is the main reason behind this situation. The average degree of the network is slightly higher when compared to small scale project network. However, the average weighted degree is lower. Therefore, it can be interpreted that in this network the variety of the companies higher for collaboration while the amount of relationship is less. Although this network is formed by higher number of companies, the fragmentation of the network is less than small scale project network. When all the network measures related to segmentation are considered, the medium scale network gives better values in terms of network structure. When Figure 4.10 is examined, there are some major and medium size structures other than the isolated dyad and triads.

Node Measures:

In this section, the measures are considered individually for the companies in the medium scale projects. The Table 4.17 shows the companies which have highest degree while Figure 4.11 shows the colored nodes based on their degree.

Table 4.17: The Nodes with Highest Degree in MSPN

| **Company ID** | **Degree** |
|---|---|
| 77 | 7 |
| 161 | 6 |
| 137 | 4 |
| 81 | 4 |
| 117 | 4 |

As in the case of small scale projects, Company-77 has the widest experience in making collaborations with various partners. Company-161 also retains its position in this measure for medium scale projects.

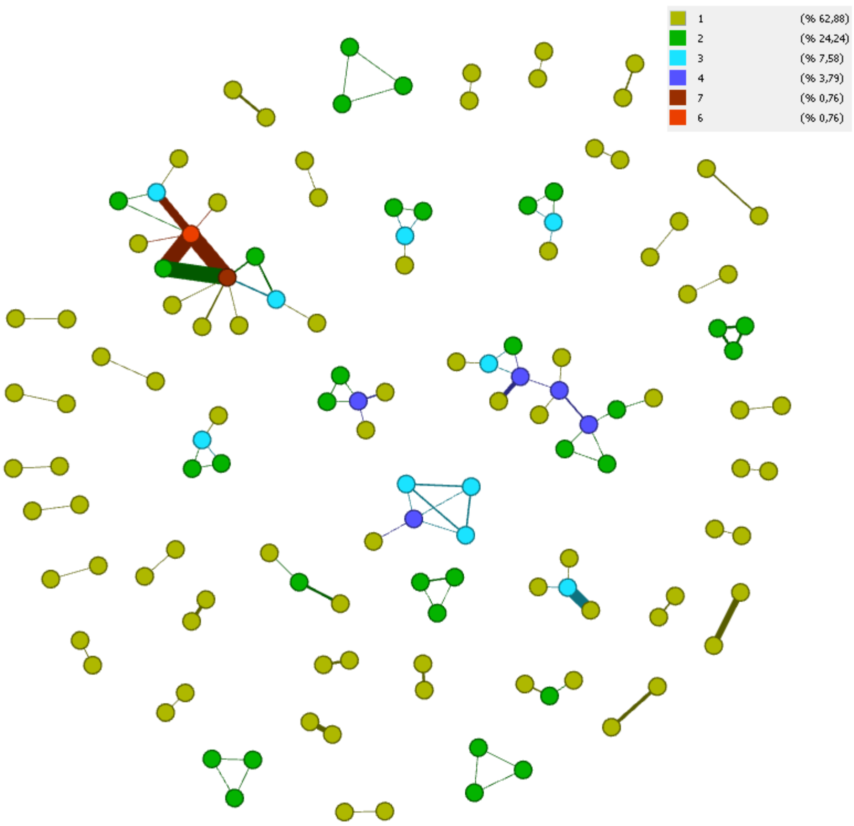


Figure 4.11: Colored Nodes of MSPN Regarding Their Degree

Table 4.18 shows the weighted degree of the nodes where all the relationships and their weights are also considered

Table 4.18: The Nodes with Highest Weighted Degree in MSPN

| Company ID | Weighted Degree |
|---|---|
| 161 | 46 |
| 77 | 42 |
| 177 | 34 |
| 192 | 14 |
| 193 | 12 |

When the weighted degrees are considered, Company-161 become the leading company in the MSPN. Company-77 and Company-177 also ranked among top players in the network. As in the previous network, the relationships between these three companies constitute the significant percentage of the total projects. In the same manner, the international collaboration experience of Company-192 and Company-193 mainly comes from their relationship as in SSPN. Company-137 lost its position in the degree list when the total relationship numbers are considered.

There are more than one isolated components which have relatively high number of members in the MSPN. Therefore, some companies in the network are able to produce betweenness centrality scores. These scores are displayed below:

Table 4.19: The Nodes with Highest Betweenness Centrality Scores in MSPN

| **Company ID** | **Betweenness Centrality** |
|---|---|
| 77 | 0.006342 |
| 161 | 0.005520 |
| 137 | 0.005402 |
| 232 | 0.004228 |
| 145 | 0.004110 |

Familiar companies from previous measures of MSPN are also in the top of the list for the betweenness centrality. As in the degree centrality, Company-137 demonstrates its strength with this measure. Moreover, Company-232 and Company-145 also become critical players in MSPN even though they have a limited ability to connect some other companies.

Eigenvector centrality values for MSPN are shown in Table 4.20.

Table 4.20: The Nodes with Highest Eigenvector Centrality in MSPN

| **Company ID** | **Eigenvector Centrality** |
|---|---|
| 77 | 1 |
| 161 | 0.8991 |
| 177 | 0.5728 |
| 131 | 0.4851 |
| 81 | 0.4629 |

When all the connections are considered, Company-77 comes out as the most important company in MSPN. Since Company-161 and Company-177 made most of their collaborations with each other and Company-77, they are placed on top of this list. Company-81 and Company-131 also appeared as the other significant members of this network.

Comments about the MSPN:

- The network of medium scale projects is formed by more companies relative to the small scale projects. However, the structure is more ordered since it contains several advanced minor structures. Therefore, it can be interpreted that when the projects start to get larger, the companies have more intention to search for various partners.
- Since the MSPN is more developed and have several significant components, there are some critical companies in these components. Unlike the previous network, local leaders emerge in MSPN. When different measures are considered, the importance of these leaders from various components is demonstrated. For example, Company-77 and Company-137 are members of different components; both have powerful roles for their group.
- As in the case of small scale projects, Company-77, Company-177 and Company-161 have collaborated in various medium scale projects. The involvement of this triad in many projects is the main reason behind their

significance in both SSPN and MSPN. For example, although Company-177 has not collaborated with any other companies in medium scale projects, it still has significance due to the strength of these relationships. On the other hand, Company-77 and Company-161 also collaborated with other companies in various projects which increase their power and significance in the network. Moreover, when all the connections are considered with eigenvector centrality, Company-177 also utilizes this feature of its partners.

- Company-137 is another company which can also be regarded as a local leader in the network due to its position in the other larger component. Its strength in this network resulted from its experience in making collaboration with high number of companies and ability to connect various counterparts in its neighborhood. Therefore, Company-137 has also an important role in MSPN and leader of its community.
- Some companies become salient due to their positions in their component. From these companies, Company-145 and Company-232 are members of the second larger component. Since the weights of ties are more balanced and the structure is wider in this component, these companies have connective features due to their positions. On the other hand, although Company-131 is not much effective in the first component, its importance originated from its connection to Company-77.
- Besides, some companies seemed powerful due to their efficiency in smaller components. Company-81 and Company-117 can be given as examples to these companies. Although these companies are members of small components, their potential in the medium scale market should be recognized.
- Even though the network the structure of MSPN is more advanced, the isolated dyads and triads still constitute most of the isolated components. However, this situation could be originated from the fact that these isolated

components are familiar companies due to previous collaboration in small scale projects.

- Although a relatively small range is considered in MSPN, the number of projects is very high and the collaboration structure is highly developed relative to the SSPN. Therefore, it can be interpreted that the collaboration practice is more needed in this scale of projects. As mentioned earlier, some communities are formed in these projects. This situation can be explained with the necessity of specializations in various scopes. Strong or specialized companies are more popular in medium scale projects. Therefore, the nodes that represent these companies are surrounded by other ones very easily.

### 4.5.3 Collaboration Network of Large Scale Projects

The summary of the data of for the collaborations of the Large Scale Project Network (LSPN) are summarized in Table 4.21.

Table 4.21: Summary of the Data for the LSPN

| | |
|---|---|
| Total number of collaborated projects | 143 |
| Total number of companies | 124 |
| Total number of edges | 118 |

The sociogram of the network for medium scale projects are shown in Figure 4.12.

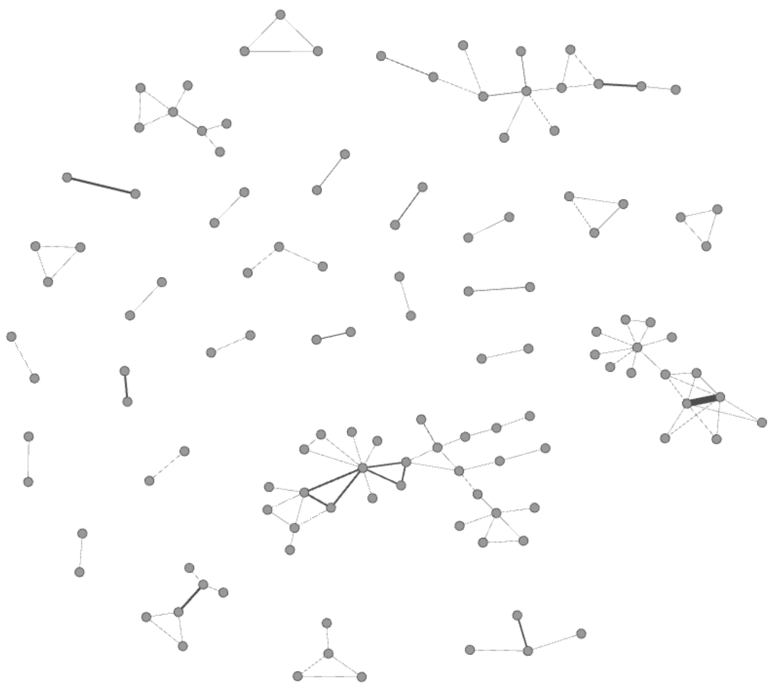

Figure 4.12: Sociogram of LSPN

#### 4.5.3.1 Discussion of the Results for the Large Scale Project Network

Network Measures:

The network level measures for the collaborations of large scale projects are shown in the table below:

Table 4.22: Network Measures of LSPN

| | |
|---|---|
| Density | 0.015 |
| Average Degree | 1.903 |
| Average Weighted Degree | 3.258 |
| Network Diameter | 8 |
| Modularity | 0.878 |
| Weakly connected components | 28 |
| Average clustering coefficient | 0.600 |
| Average Path Length | 3.228 |

When the LSPN is considered based on these network measures, the density of the network is slightly higher than the previous budget-based networks. This increase is an indicator of higher interaction among the companies. This claim can be supported by the average degree of the network. According to this measure, the average number of partners for each company is increased. On the other hand, the average number of interactions for all companies in the network is slightly decreased when compared to MSPN. This condition shows that when the scale of the projects gets higher, the weights of the relationships decrease. Although the companies and projects in this network are close to the ones in other budget-based network, the number of connected components is very small in LSPN. The ratio of isolated dyads and triads in these components are relatively smaller. Therefore, the variety of components in LSPN is less and they are in a more advanced shape. Finally, when all the remaining network measures are considered, a more successful network structure is indicated where fragmentation is relatively less and connections are relatively high.

Node Measures:

In this section, the nodal measures for large scale project network will be provided. The companies with highest degree results are shown in Table 4.23 while Figure 4.13 displays the nodes which are colored based on their degree.

Table 4.23: The Nodes with Highest Degree in LSPN

| **Company ID** | **Degree** |
|---|---|
| 77 | 9 |
| 262 | 8 |
| 145 | 6 |
| 268 | 6 |
| 117 | 5 |

When the highest degree nodes are examined, Company-77 resides the top position as in the other budget-based networks. Its tendency of making collaborations with many other partners is maintained in this network. On the other hand, there are some companies in Table 4.23 which had not developed various relationships in the previous budget-based networks. Company-262, Company-145 and Company-268 are the ones which become prominent in the network of large scale projects in terms of their degree. Company-117 succeeded to be on the high-degree nodes list as in the case of previous networks. Figure 4.13 shows the network with colored node regarding their degree.

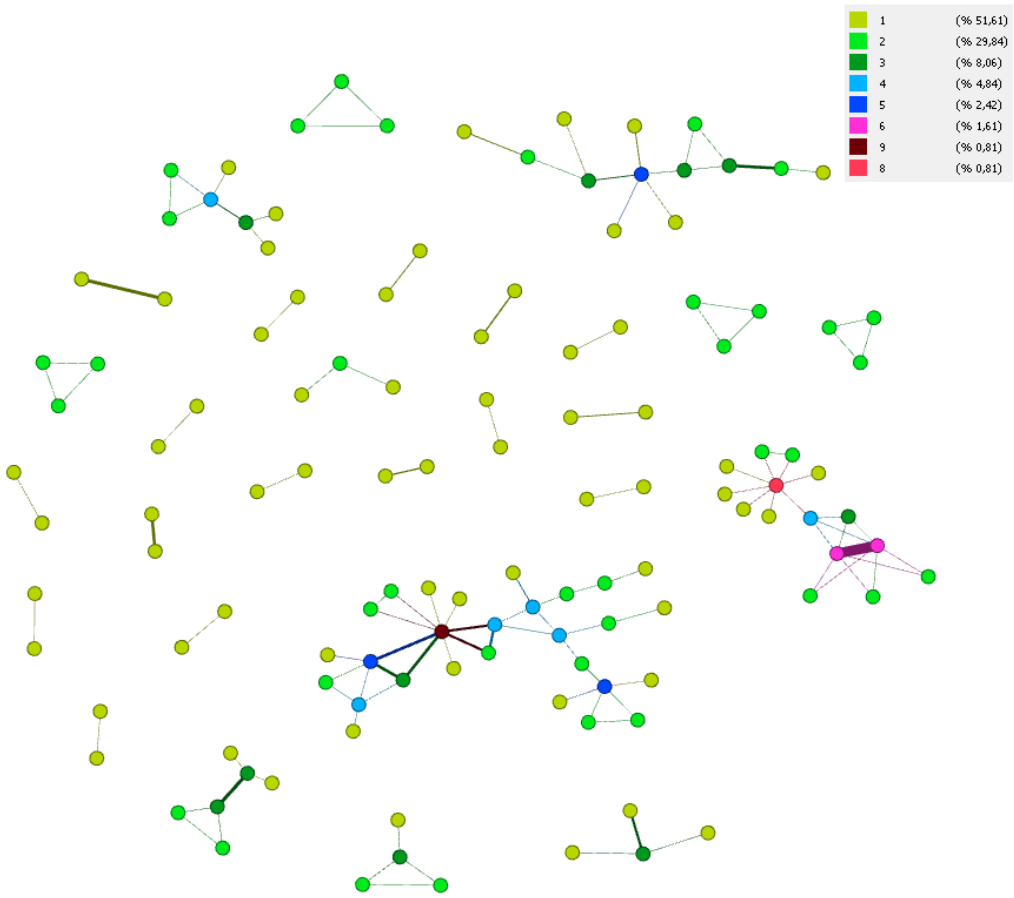


Figure 4.13: Colored Nodes of LSPN Regarding Their Degree

All the relationships of LSPN are considered in the table below:

Table 4.24: The Weighted Degree of the Nodes in LSPN

| **Company ID** | **Weighted Degree** |
|---|---|
| 77 | 27 |
| 145 | 26 |
| 268 | 26 |
| 177 | 15 |
| 161 | 13 |

Due to its general collaborative behavior and high amount of partners, Company-77 involved in the highest number of relationships in LSPN. In the same manner, Company-177 and Company-161, which are main partners of Company-77, are also located in the weighted degree list. Moreover, Company-145 and Company-268 also strengthened their importance by involving high number of relationships. On the other hand, Company-262 is the only company which lost its position when all the relationships are considered.

Since there are remarkable structures in LSPN, many companies have the ability to introduce other ones which are not familiar to each other. In Table 4.25, these companies with highest betweenness centrality scores are shown.

Table 4.25: The Highest Betweenness Centralities in LSPN

| **Company ID** | **Betweenness Centrality** |
|---|---|
| 77 | 0.028655 |
| 131 | 0.024257 |
| 130 | 0.021858 |
| 120 | 0.014661 |
| 117 | 0.012928 |

Company-77 also has the highest betweenness centrality score in LSPN. The effects of high amount of degree and weighted degree are the main reason behind these scores. Besides, there are other companies in this list which become important due to their position in the network. Company-131, Company-130, Company-120 and Company-117 can be given as examples of these companies which have the highest ability to connect a number of other companies.

The eigenvector centrality which is the last measure for LSPN are shown in the Table 4.26.

Table 4.26: Companies with Highest Eigenvector Centrality in LSPN

| **Company ID** | **Eigenvector Centrality** |
|---|---|
| 77 | 1 |
| 145 | 0.9836 |
| 268 | 0.9836 |
| 267 | 0.8269 |
| 269 | 0.6947 |

When all the connections are considered, the results show that the Company-77 is the most powerful company in the LSPN. Being leader of the largest component is the main reason behind these high values for this company. However, the other companies in this list are members of another large component in the network. The success of these companies is directly related to their interrelationships in the network. Among these companies, Company-267 and Company-269 are the foreign ones, whose importance are directly related to their relationships with Company-145 and Company-268.

<u>Comments about the LSPN:</u>

- There is a substantial drop in the isolated dyads and triads. Therefore, they constitute lower percentage of the connected components in the network.

- According to the results of the network, when the scale of the projects gets larger, the general tendency of the companies is to increase their number of partners. When we combine this result with the average weighted degree, it can be interpreted that the companies collaborate with relatively high number of companies in relatively less number of projects. Therefore, the need for making connection is higher while the opportunity to involve in various projects is lower in large scale projects.
- Although the total number of projects in LSPN is close to the previous budget-based networks, structure of LSPN is much better. The reason behind this situation is that, when the total project budget increases, generally the complexity of the project also increases. This situation results in higher need for specialization and risk sharing. Reasonably, in this network the collaborations are realized between precious companies.
- Company-77 obtained the best results from all the SNA measures which indicate that this company is the most powerful and important company in the LSPN. Its high collaborative experience with various companies and central position in the largest component are the factors which provide this unquestionable strength in the collaboration of large projects.
- As previously stated, there are several minor significant components in this network which give rise to the emergence of local leaders. Company-183, Company-164 and Company-135 can be given as examples of the companies which are prominent for various components. All of these companies are on the list of ENR Top 250 Contractors for the year 2013. Company-135 and Company-164 are significant Turkish companies while Company-183 is a foreign one.
- There are also other significant companies from the other major component where the relationship intensity is noteworthy. These companies are: Company-262, Company-145 and Company-268.

- When the relationships are scrutinized, it is seen that the triad which is comprised of Company-177, Company-161 and Company-77 loses its importance when large projects are investigated. This triad has involved more projects in the previous budget-based networks.
- The relationship between Company-145 and Company-268 become prominent due to its numerousness. When the sociogram of LSPN is examined, the widest tie is existent between these two companies.
- Although Company-262 was not an outstanding member of previous budget-based networks, this company has an important role in the LSPN due to its predisposition to make collaboration with various companies. As stated earlier, this company is a longstanding company that is also ranked in ENR list.
- The multi-membered components in the LSPN lead several companies to become prominent in the network. Company-131, Company-130 and Company-120 can be given as examples of these companies which become significant based on their bounding feature. These companies provide attainability in these components.

### 4.5.4 General Comments about the Budget-Based Networks

In this chapter of the study, the collaborative projects of Turkish Contractors in the international market were examined to construct networks by classifying these projects according to their budgets. When these networks are considered in detail, various collaborative approaches of construction companies in different networks can be deduced.

Unsurprisingly, the collaborative actions in small scale projects do not display a proper network shape. Since the difficulty of these projects are not very severe, there cannot be mentioned about a high demand in specializations. Therefore, the companies prefer to make collaboration with only one recognized partner and maintain their relationship in various projects. However, when the project sizes increase, the attitude of the companies adapted to change. As the size of the projects gets larger, companies become more predisposed to make collaborations with other companies. This situation results in more advanced network structures.

The main reason behind this evolution of the networks is that there is a limited number of companies that remain eligible to take part in these highly complex projects. Therefore, the companies select their partners among these capable ones. Moreover, partnership between more than two companies become a need in some very large projects. Hence, the companies start to form various neighborhoods when the project size increases.

Several important deductions can be made when the behavior of the companies in these networks are investigated individually. Some companies are highly active in all budget-based networks while some other companies direct their attention to specific networks. These companies are exemplified based on their collaborative behavior:

- Some companies aim to be active in all scale of projects. The most prominent ones in all networks are Company-77, Company-177 and Company-161. The main reason behind this situation is the continuation of the partnerships in all scale of projects. In the same manner, Company-192 and Company-193 also reveal their presence in all networks by maintaining the collaboration between them.
- Some companies become more active as the project scale gets larger. The most striking ones are Company-145 and Company-268. The activity of these two companies are resulted from the constant relationship between them. On the other hand, similar actions are also shown by Company-164, Company-168, Company-298, Company-131 and Company-262. Most of the activities of these companies are originated from their particular

collaborations. However, only the activity of Company-262 cannot be explained by a certain relationship.

- Some companies are effective in small scale projects, while they are inert in larger ones. This behavior is mainly adopted by Company-68, Company-69, Company-56, Company-57, Company-272 and Company-277. These are relatively smaller companies and most of them are in the telecommunication field.

Consequently, the results of this study shows that Turkish Contractors adopt various strategies for their collaborative actions in the international market when the project budgets are taken as decisive factor.

### 4.6 Market-Based Collaboration Networks of Turkish Contractors in International Projects

The host countries of the collaborative projects were included in the data for the case study. Therefore, the networks of various markets were also aimed to be constructed. As previously mentioned, all the existing host countries were incorporated in 4 different markets except the USA. These markets and countries will be explained in the following sections.

#### 4.6.1 Collaboration Network of Turkish Contractors in CIS Market

As mentioned in Chapter 3, most of the projects of Turkish Contractors were performed in CIS countries. As it can be expected, the same situation is valid for the collaborative projects. According to the given data, approximately 43.3 % of the collaborative projects were performed in the CIS market which almost the same with the total international projects. Since this market is a very attractive one for the Turkish contractors, a highly connected structure with many companies is expected from its network.

The countries in this market are:

- ✓ Azerbaijan
- ✓ Belarus
- ✓ Georgia
- ✓ Kazakhstan
- ✓ Kyrgyzstan
- ✓ Moldova
- ✓ Russia
- ✓ Tajikistan
- ✓ Turkmenistan
- ✓ Ukraine
- ✓ Uzbekistan

The summary of the CIS data is given in Table 4.27.

Table 4.27: Data of CIS Market

| | |
|---|---|
| Total Number of Collaborated Projects | 198 |
| Total Number of Companies | 76 |
| Total Number of Host Countries | 11 |
| Total Number of Edges | 54 |

#### 4.6.1.1 Discussion of the Results for the CIS Market Network

Network Measures:

The network level measures for the network of CIS market are given in Table 4.28.

Table 4.28: Network Measures of CIS Market

| | |
|---|---|
| Density | 0.019 |
| Average Degree | 1.421 |
| Average Weighted Degree | 8.421 |
| Network Diameter | 7 |
| Modularity | 0.689 |
| Weakly connected components | 28 |
| Average clustering coefficient | 0.525 |
| Average Path Length | 2.688 |

Since the network is smaller when it is compared with general network, the network produced results which show a more dense structure. The measures show that the market is constituted by 28 isolated components but the distances are closer. The effect of being involved in various projects is higher in this network since the average weighted degree is approximately 6 times of the average degree. If the effect of projects with more than two companies is neglected, it can be said that in the CIS market, the companies' tendency to collaborate with familiar partners is relatively higher than the behavior in the general market. The 44.10 % of the projects in the given data were undertaken in this market. On the other hand, the number of companies in this market is relatively low. Only the 29.80 % of the companies in the international market participated in collaborative projects in CIS market. Therefore, it can be said that partnering in more than one project is a common practice in this market. The sociogram for the CIS market where the companies are classified based on the degree can be seen in Figure 4.14.

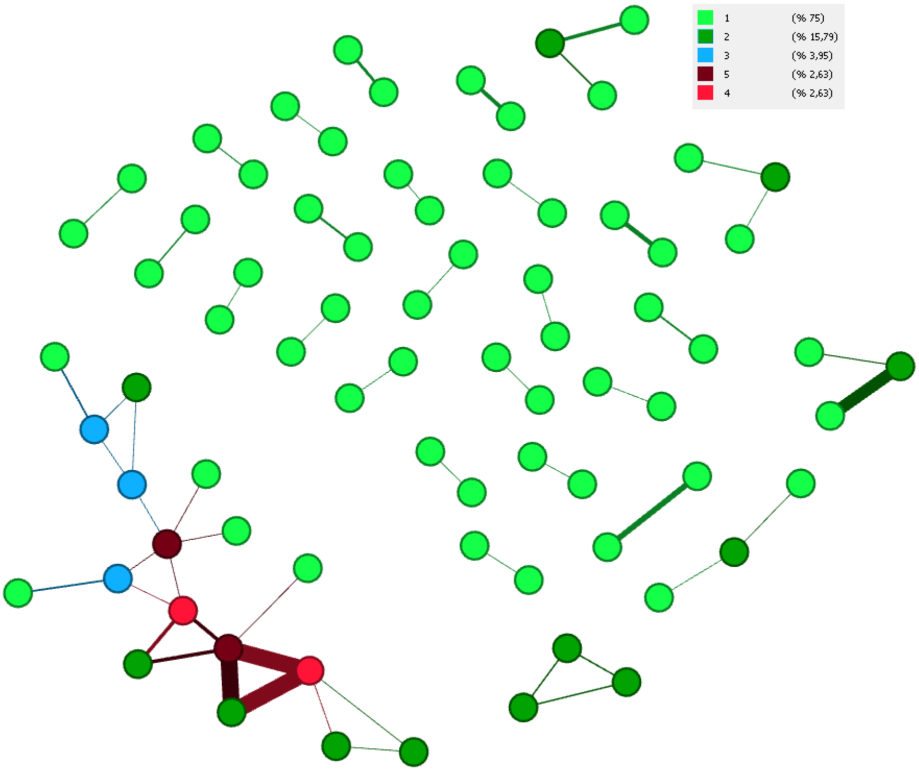


Figure 4.14: The Network of CIS Market

As it can be seen from the Figure 4.14, the network of CIS market can be described as a small-scale model of the general network. Although there are many isolated dyads in this network, a major structure is existent in the left part of the Figure 4.14.

<u>Node Measures:</u>

In the same manner with the budget-based networks, the interpretable node level measures are shown in this section. As mentioned earlier, degree is the simplest measure that gives indication about the abilities of the nodes. Table 4.29 shows the nodes with highest degree in the CIS market.

Table 4.29: The Nodes with Highest Degree in the CIS Market

| **Company ID** | **Degree** |
|---|---|
| 77 | 5 |
| 130 | 5 |
| 131 | 4 |
| 161 | 4 |

According to Table 4.29, Company-77 and Company-130 become the leading firms in the market when the amount of partners are considered. On the other hand, Table 4.30 shows the list of the companies based on the highest weighted degree which indicates the total number of connections.

Table 4.30: The Nodes with Highest Weighted Degree in the CIS Market

| **Company ID** | **Weighted Degree** |
|---|---|
| 77 | 111 |
| 161 | 94 |
| 177 | 92 |
| 192 | 35 |

Company-177 and Company-192 become prominent when the weighted degree is considered. These companies have involved in high number of relationships relative to the other companies. Another measure which is considered for the nodes is the betweenness centrality. In the CIS market network there are very few companies who have score in this measure and these values are very low. The highest ones are also shown in Table 4.31.

Table 4.31: The Nodes with Highest Betweenness Centralities in the CIS Market

| Company ID | Betweenness Centrality |
|---|---|
| 130 | 0.024865 |
| 131 | 0.022703 |
| 77 | 0.021261 |
| 144 | 0.014054 |

As mentioned before, these companies in Table 4.31 have the ability to introduce various partners in the network. Company-144 is the only company that has not appeared in the high degree list. Moreover, the importance of the companies is displayed with the help of eigenvector centrality (Table 4.32).

Table 4.32: The Nodes with Highest Eigenvector Centrality Scores in the CIS Market

| Company ID | Eigenvector Centrality |
|---|---|
| 77 | 1 |
| 131 | 0.9889 |
| 130 | 0.8632 |
| 161 | 0.7136 |

Unsurprisingly, the companies, which are the best ones according to degree based lists, have the highest importance in the CIS market. However, there are some interesting results in this network when all the relationships are considered. Although they are not ranked in any of the other measures, Company-66 and Company-298 obtain high eigenvector centrality results that follow the mentioned ones in Table 4.32. This situation demonstrates how some relationships can play a characteristic role for the companies.

As mentioned earlier, CIS market can be seen as a small model of the general network. Company-77 has the strongest position in this market. In addition to that

Company-131, Company-161 and Company-130 also have crucial roles in the network. Company-177, Company-192 and Company-193 are other experienced companies in this market who have collaborated relatively less partners but involved in large number of projects. Company-145 and Company-268 lost their position on the general market. This shows that these companies are not powerful in CIS Market and the significance of them is resulted from their performance in the other markets.

### 4.6.2 Collaboration Network of Turkish Contractors in Middle East Market

Middle East is also an important market for the Turkish contractors which comes in the second place when the host countries are classified based on their region. With the earnings from their petroleum resources, these countries have been making huge investments on construction projects. The regional and cultural closeness to these countries provide advantages to the Turkish contractors for taking place in these projects. However, the risky structure of these countries could force them to make collaborations. Therefore, it is aimed to elucidate the situation in this market with the result of the network.

In this network, some countries were taken under Middle East market even though they are not geographically in that region. The countries classified in this market are:

- ✓ Afghanistan
- ✓ Bahrain
- ✓ Iran
- ✓ Iraq
- ✓ Jordan
- ✓ Kuwait
- ✓ Oman
- ✓ Pakistan

- ✓ Qatar
- ✓ Saudi Arabia
- ✓ Syria
- ✓ UAE
- ✓ Turkish Republic of Northern Cyprus
- ✓ Yemen

The summary of the Middle East data is given in Table 4.33.

Table 4.33: Data of Middle East Market

| | |
|---|---|
| Total Number of Collaborated Projects | 151 |
| Total Number of Companies | 122 |
| Total Number of Host Countries | 14 |
| Total Number of Edges | 112 |

#### 4.6.2.1 Discussion of the Results for the Middle East Market Network

Network Measures:

Network level measures for the Middle East market are given in Table 4.34.

Table 4.34: Network Measures of Middle East Market

| | |
|---|---|
| Density | 0.015 |
| Average Degree | 1.836 |
| Average Weighted Degree | 3.590 |
| Network Diameter | 8 |
| Modularity | 0.920 |
| Weakly Connected Components | 33 |
| Average Clustering Coefficient | 0.716 |
| Average Path Length | 3.031 |

The Middle East market network is bigger than the CIS network. 48.03 % of the companies and 48.28 % of the ties are found in this market. Therefore, the diameter of the network is higher and the density is smaller relative to the CIS market. When the average degree values are considered, it can be seen that in the Middle East market the companies have higher connections with other companies. However, the average weighted degree is fewer in this network. Therefore, the companies in this network generally preferred to make partnerships with various companies rather than going on with the same partner. The measures which indicate the fragmentariness of the network imply that the Middle East network is relatively partial. However, the structure of the networks does not seem to be separated since the total number of projects and companies are very high (Figure 4.15).

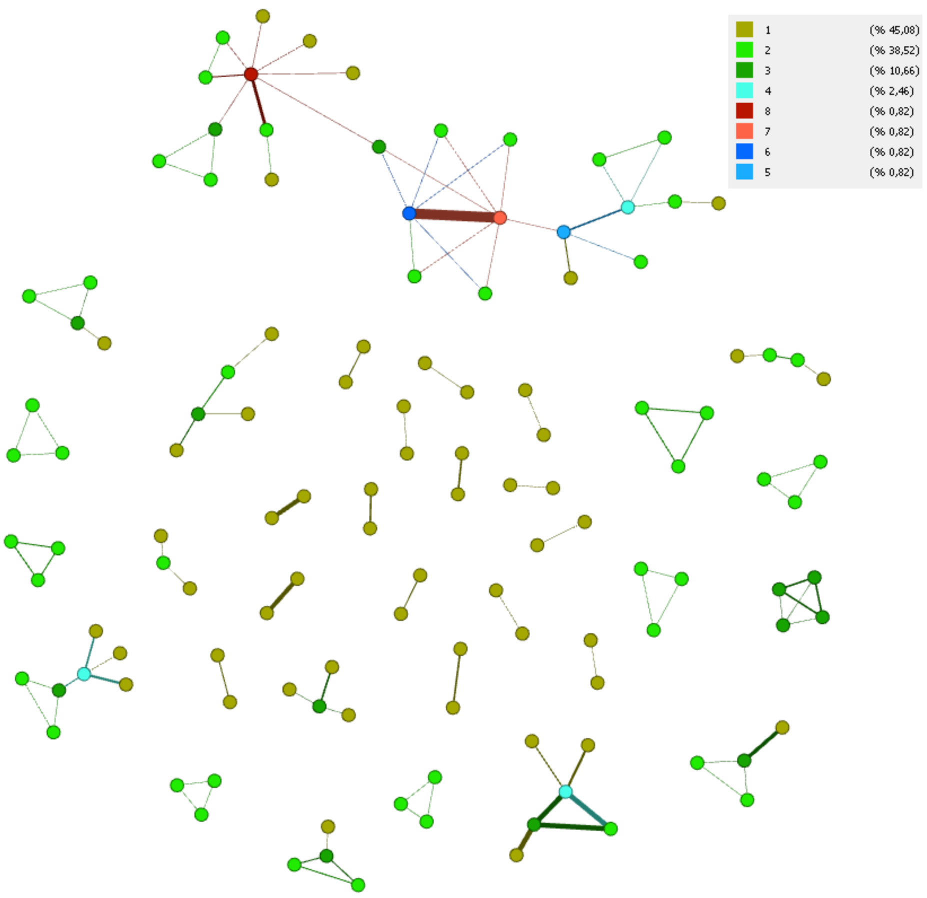


Figure 4.15: The Network of Middle East Market

The network of Middle East market contains a major structure which can be seen on the top of the Figure 4.15. Moreover, there are smaller groups in the network which are located at the bottom of the Figure 4.15. High number of companies and interactions can be explained as the reason of this situation.

Node Measures:

The nodes with highest degree are listed in Table 4.35.

Table 4.35: The Nodes with Highest Degree in the Middle East Market

| Company ID | Degree |
|---|---|
| 262 | 8 |
| 145 | 7 |
| 268 | 6 |
| 137 | 4 |

These companies have collaborated in this market with various other companies. The values are relatively higher and this can be explained with the size of the network. The companies which are not much active in the CIS market become prominent in the Middle East market by involving various partnerships. The Table 4.36 shows the weighted degree ranking in the Middle East market.

Table 4.36: The Nodes with Highest Weighted Degree in the Middle East Market

| Company ID | Weighted Degree |
|---|---|
| 161 | 24 |
| 145 | 22 |
| 77 | 22 |
| 268 | 21 |

As expected from the network measures the highest values for the weighted degree of the companies are relatively smaller. The most intriguing result comes from Company-161 that have 24 connections in this market with only 3 different partners. Moreover, Company-77 which is the biggest player of CIS network also becomes prominent in the Middle East market when total connections are considered. On the other hand, Company-262 lost its position in the list since the relationship amount of the company is lower. Betweenness centrality scores are shown in Table 4.37.

Table 4.37: The Nodes with Highest Betweenness Centralities in the Middle East Market

| **Company ID** | **Betweenness Centrality** |
|---|---|
| 262 | 0.026171 |
| 145 | 0.022452 |
| 267 | 0.021212 |
| 137 | 0.018871 |

When the betweenness centralities are considered, another company comes into the picture: Company-267. Although this company has involved in only 3 projects, it plays an important role in the network. The main reason behind this situation is that the company made collaboration with various critical partners in each project. On the other hand, the eigenvector centralities of the Middle East market are shown in Table 4.38.

Table 4.38: Eigenvector Centralities of the Nodes in the Middle East Market

| **Company ID** | **Eigenvector Centrality** |
|---|---|
| 145 | 1 |
| 268 | 0.9134 |
| 267 | 0.6595 |
| 262 | 0.6077 |

As can be seen from Table 4.38, when all the connections are considered, Company-145 becomes the most significant member of this network and Company-268 comes in the second place. The significant companies with high betweenness centrality and degree values are also noted in the eigenvector centrality list. On the other hand, in spite of the fact that Company-161 has the most experience in the total number of relationships, this company loses its significance when all the connections are considered.

### 4.6.3 Collaboration Network of Turkish Contractors in Africa Market

Africa was the starting point of the Turkish Contractors for the international market. However, Turkish contractors turn their attention newly-opened markets with passing years. In addition to the new opportunities in other markets, political crises in these countries restrain the Turkish contractors to enter this market in recent years. Nevertheless, when all the international history of Turkish contracting is considered, this market still has a considerable share. The role of collaboration practice in this share can be understood by the results of this network. In this network, the countries in this market are:

- ✓ Algeria
- ✓ Egypt
- ✓ Equatorial Guinea
- ✓ Gabon
- ✓ Ghana
- ✓ Libya
- ✓ Mali
- ✓ Nigeria
- ✓ Sudan
- ✓ Tunisia

The summary of the Africa data is given in Table 4.39.

Table 4.39: Data of Africa Market

| | |
|---|---|
| Total Number of Collaborated Projects | 64 |
| Total Number of Companies | 70 |
| Total Number of Host Countries | 10 |
| Total Number of Edges | 48 |

### 4.6.3.1 Discussion of the Results for the Africa Market Network

Network Measures:

Network level measures for the network of Africa market are given in Table 4.40.

Table 4.40: Network Measures of Africa Market

| | |
|---|---|
| Density | 0.020 |
| Average Degree | 1.371 |
| Average Weighted Degree | 2.229 |
| Network Diameter | 3 |
| Modularity | 0.941 |
| Weakly Connected Components | 28 |
| Average Clustering Coefficient | 0.740 |
| Average Path Length | 1.328 |

The Africa market is smaller than the previously mentioned markets. The density of the network is relatively higher since the number of possible ties is very low. However, the average degree and weighted degree is considered it can be interpreted that the relationships in the network are not plentiful. Moreover, the number of isolated components in the network is very high when compared to the number of projects in this market. Therefore, the collaboration network does not have a developed structure.

As it can be seen from Figure 4.16, most of the companies have involved in dyadic relationships. There are only 3 small groups in the network. As the network measures indicated the network is highly dispersed and separated.

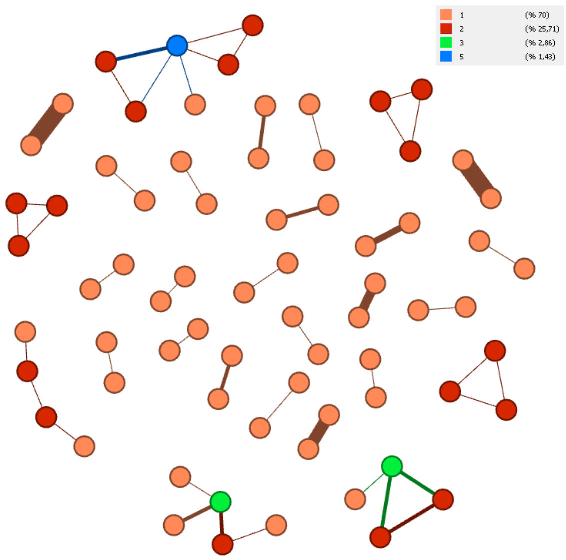


Figure 4.16: The Network of Africa Market

<u>Node Measures:</u>

The nodes with highest degree are listed in Table 4.41.

Table 4.41: The Nodes with Highest Degree in the Africa Market

| Company ID | Degree |
|---|---|
| 83 | 5 |
| 117 | 3 |
| 161 | 3 |
| 172 | 2 |

As it can be expected, the degree values for the nodes are smaller for the Africa market. Company-83 becomes prominent in this network with having five different partners. Moreover, Company-117 and Company-161 also differentiate from the rest of the network since they have collaborated with three different partners. The Table 4.42 shows the weighted degree ranking in the Africa Market.

Table 4.42: The Nodes with Highest Weighted Degree in the Africa Market

| Company ID | Weighted Degree |
|---|---|
| 173 | 7 |
| 174 | 7 |
| 81 | 7 |
| 82 | 7 |

When the weighted degrees of the companies are considered the ones on top of the list are changed. The reason behind is that, the high degree companies have involved in less projects with various companies while the high weighted degree companies cooperate only with each other. Company-173 and Company-174 collaborate only with each other and performed seven projects in this market. The same situation is also valid for Company-81 and Company-82.

Betweenness centrality scores are shown in Table 4.43.

Table 4.43: The Nodes with Highest Betweenness Centralities in the Africa Market

| Company ID | Betweenness Centrality |
|---|---|
| 83 | 0.003410 |
| 161 | 0.002131 |
| 229 | 0.001279 |
| 117 | 0.000853 |

The betweenness centrality scores of the companies are very low in this market since there is not a remarkable structure in the network. Most of the companies do not have a betweenness centrality score. Therefore, this measure can be seen as impracticable for this network. The eigenvector centralities of the Middle East market show in Table 4.44.

Table 4.44: The Nodes with Highest Eigenvector Centrality Scores in the Africa Market

| **Company ID** | **Eigenvector Centrality** |
|---|---|
| 83 | 1 |
| 172 | 0.5849 |
| 179 | 0.5849 |
| 180 | 0.5849 |

When the all connections are considered for the Africa market, unsurprisingly Company-83 comes out as the most important company. Company-172, Company-179 and Company-180 also becomes prominent based on their connections. The reason behind this situation is that all of these companies are connected to Company-83. Moreover, these members have some connections between each other. Since the network is separated, the connected component which has the maximum amount of members becomes the hearth of the network according to the SNA measures.

### 4.6.4 Collaboration Network of Turkish Contractors in Europe Market

Europe is the last market that will be studied in this case study. As mentioned earlier, this market is a relatively fresh one for the Turkish Contractors. Moreover, due to some other problems such as competitiveness, quality expectations, difficulty in adaptation to the local conditions, etc. the Europe market remained unattractive for the contractors. Therefore, the number of projects in this market is very low. However, in recent years there are some actions in this market with projects in Eastern Europe. According to the given data, the countries in this market where collaborated projects were performed are:

- ✓ Albania
- ✓ Bosnia Herzegovina
- ✓ Bulgaria
- ✓ Kosovo
- ✓ Lithuania
- ✓ Macedonia
- ✓ Montenegro
- ✓ Poland
- ✓ Romania
- ✓ Serbia

The summary of the Europe data is given in Table 4.45.

Table 4.45: Data of Europe Market

| | |
|---|---|
| Total Number of Collaborated Projects | 35 |
| Total Number of Companies | 48 |
| Total Number of Host Countries | 10 |
| Total Number of Edges | 32 |

#### 4.6.4.1 Discussion of the Results for the Europe Network

<u>Network Measures:</u>

Network level measures for the network of Europe market are given in Table 4.46.

Table 4.46: Network Measures of Europe Market

| | |
|---|---|
| Density | 0.028 |
| Average Degree | 1.333 |
| Average Weighted Degree | 1.667 |
| Network Diameter | 3 |
| Modularity | 0.931 |
| Weakly Connected Components | 20 |
| Average Clustering Coefficient | 0.756 |
| Average Path Length | 1.231 |

As mentioned earlier Europe market has the smallest share among these 4 markets. The density of the network is higher since the number of the nodes in the network is very low. 20 isolated components were formed by only 48 companies in this network. Therefore, when the network measures were considered, it can be clearly seen that Turkish Contractors could not be able to form a dependable network structure in the Europe market (Figure 4.17).

As can be seen from Figure 4.17, most of the nodes in the network have participated projects with only one partner and these partnerships are generally made for only one project. Moreover, there are a few triads in the network which are formed by the projects with three participants. Thus, the network is highly dispersed and formed by many components which are not favorable for social network approach

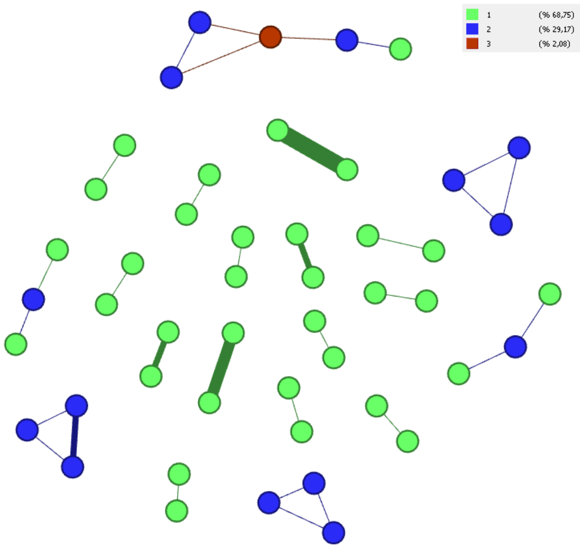


Figure 4.17: The Network of Europe Market

Node Measures:

As it is expected the degree values of the nodes are very low due to the network structure. The nodes with highest degree are listed in Table 4.47.

Table 4.47: The Nodes with Highest Degree in the Europe Market

| Company ID | Degree |
|---|---|
| 51 | 3 |
| 52 | 2 |
| 77 | 2 |
| 97 | 2 |

The company which has involved in highest number of partnership with various companies is Company-51. The weighted degree values are shown in Table 4.48

Table 4.48: The Nodes with Highest Weighted Degree in the Europe Market

| **Company ID** | **Weighted Degree** |
|---|---|
| 272 | 4 |
| 277 | 4 |
| 51 | 3 |
| 101 | 3 |

Company-272 and Company-277 have collaborated with each other in 4 different projects in this market. Therefore, these companies take place on top of Table 4.48 together. Since both the amount of the projects and the partners in these projects are low, the weighted degree values are also low in this network. In the same manner, betweenness centrality is not applicable in this network since there is not a notable structure (Table 4.49).

Table 4.49: The Nodes with Highest Betweenness Centralities in the Europe Market

| **Company ID** | **Betweenness Centrality** |
|---|---|
| 51 | 0.003700 |
| 52 | 0.002775 |
| 135 | 0.000925 |
| 151 | 0.000925 |

Only these four companies have the ability to connect some other ones in the network since they have collaborations with other companies which are not directly connected. The eigenvector centralities of the Middle East market show in Table 4.50.

Table 4.50: The Nodes with Highest Eigenvector Centrality Scores in the Europe Market

| Company ID | Eigenvector Centrality |
|---|---|
| 51 | 1 |
| 97 | 0.8161 |
| 98 | 0.8161 |
| 52 | 0.5816 |

Unsurprisingly, the companies which form the connected component with the highest member size have the highest eigenvector centrality values. Therefore, the companies of the connected component on the top of Figure 4.17 are expressed as the important companies in the Europe market network.

### 4.6.5 General Comments about the Market-Based Networks

Each of the market-based networks in the case study showed different structures which are indicative of different strategic approaches and behaviors of Turkish Contractors in these markets. The deductions from these networks are summarized below:

- When all the markets are compared, it is easily seen that the CIS market has the highest number of projects while Middle East market has the highest number of companies and ties. Therefore, it can be interpreted that less amount of companies eager to enter the CIS market. However, the market is advantageous for the active contractors since there is a reasonable possibility to receive projects in this market.
- Since the number of projects is high and the number of companies is relatively small, the collaboration ratio is smaller than expected in CIS market. Therefore, it can be interpreted that Turkish Contractors generally adopted the approach of collaborating with the familiar companies. In

another viewpoint, the weighted relationships become prominent in the CIS network. In this way, the collaborated projects of Turkish Contractors are mostly done by a group of companies. As in the case of the general international network, Company-77 can be described as the most powerful company in the CIS market. In other words, the important position of this company in the general market is originated from its high performance in CIS market. Although the CIS market seems like a small system, the new contractors could enhance their chance of being successful by finding right partners.

- Although the number of collaborated projects is slightly lower in the Middle East market, the collaborations among the companies constitute a wider and more connected network. The companies in this market adopt the behavior of cooperating with various partners to benefit from their resources, experiences and risk taking capabilities. There are many companies in this market which showed different indicators of power. Company-262 becomes prominent when its collaboration experience with many other companies is considered. On the other hand, Company-145 is the most powerful and influential company in this market under favors of its experience and connections. Besides, there are also locally effective companies since there are some small structures in the network. If a company is willing to get into Middle East market with a partner, there are many options in this network which have various strengths in the market.
- The network structure of the Africa market failed to satisfy the expectations. Although Africa was an important market for the Turkish Contractors, the collaboration network of this market is small and dispersed. The number of companies in Africa market is close to the ones in CIS network. However, there is not a connected structure in Africa network due to the limited number of projects. Most of the companies form isolated pairs. Therefore, it is very difficult to determine the important companies in this market since the companies do not show interpretable correlations. The main reason

behind this situation is that the companies in this network do not prefer to share their profit with others. Since the projects in this market are relatively easier, the need for sharing abilities and resources is not sufficient to force the companies to make collaboration. In other words, taking projects individually in this market is a common practice between the Turkish Contractors. Moreover, the tendering phases and quality requirements can also play an encouraging role for the individual projects. In this way, less number of projects are done collaboratively and various companies showed up in the network. The results indicate that collaborative approach is not suitable for the projects in the Africa market and there cannot be mentioned about a strong Turkish company in this network. The best option for the new companies is to work with experienced sub-contractors or local companies in case of neediness.

- The Europe market is a relatively newer market for Turkish Contractors. Although nearly all of the remaining projects in the data were performed in the European countries, the ratio of these projects is very low. The network of this market also shows a dispersed structure where there are very few companies which have participated more than one project. Therefore, it should be avoided to make individual interpretations for the companies. The most concrete interpretation from this network is that the Turkish Contractors are not effective in this market. High competitiveness and high quality expectancy can be seen as the deterrents for the Turkish Contractors. Moreover, high restrictions of European countries in various topics such as working hours, labor rights, etc. neutralized their advantages. According to the results of the network, there is not any significant company in this market based on the experience and strength in collaborative projects. Therefore, the companies that have intention to enter the Europe market should search for local companies for collaborative actions.

As can be seen from these deductions, the strategies and behaviors of the companies vary from market to market. Each company should be aware of the general approach in these markets to implement the right actions. Therefore, recognizing the position of other companies in these markets provides a great advantage for the companies to determine their actions.

# CHAPTER 5

# VALIDATION OF THE STUDY

In order to check the validity for the results of the case study, interviews were carried out with specialists from the Turkish construction industry in a face-to-face format. During these interviews, the results of the case were presented to the respondents and their reflection and comments about these results were obtained. The respondent profiles were summarized in Table 5.1.

Table 5.1 Respondent Profiles

| Respondent | Position in the sector |
|---|---|
| 1 | Assistant General Manager in a Large Construction Company |
| 2 | Country Manager of Turkey for a Foreign Company |
| 3 | Senior Official of TCA |

Respondent 1 has more than 30 years of experience in construction sector and he is currently working as the Assistant General Manager in one of the leading companies of the Turkish construction sector. The company has nearly 50 years of experience in the construction sector and 35 years of which is also in the international field. In the interview, Respondent 1 stated that the results of the case study can be regarded as realistic when compared to the real conditions. Then the justification for the results were made by Respondent 1. During the interview, it was stated that the highly risky conditions and requirements to collaborate with local partners could be the major factors for the higher connectedness in the Middle East market. For the CIS countries, he asserted that the requirements can be considered as challenging and all the partners should satisfy them. Therefore, generally the created partnerships are maintained in this market. The Arabic Spring, embargo in Libya and not having French-speaking employees were expressed as the reasoning behind the results by the Respondent 1. On the other hand, the tender models and legislations are the factors that prevent the Turkish contractors from being strong in the Europe market. For budget-based markets, the reasoning behind the existence of large scale companies in relatively smaller projects is becoming able to obtain certificate of competency. Consequently, Respondent 1, who is in an administrator position in one of the significant companies from the network, gave a positive feedback for the results of the case study.

Respondent 2 has more than 30 years of experience in construction sector in various companies. He had experiences in the operational positions of the projects which were performed in miscellaneous countries. He is currently working in a foreign company as the country manager of Turkey. During the interview, Respondent 2 commented the conditions of the study and the results. According to his interpretations, the results show the situation of the sector in a way that reflect his general opinions. Moreover, he asserted that the most of the results provide general indications for the behavior of the companies. However, he put forward that the continuation of these collaborations, missing projects, and the existing conditions of the companies should be investigated elaborately for the individual company level, if the results will be used in real life as a decision support element for future collaborative projects. In conclusion, Respondent 2 also defined the results of the case study as realistic and meaningful for the determination of general situation of Turkish contractors in collaborative projects.

Respondent 3 has an administrative position in the TCA. During the interview, Respondent 3 stated that the results of the study seemed coherent. He asserted that the Turkish contractors' main activity is in the high risky and developing countries and the results of the study are expressing some of the facts that are related to their behaviors. Nevertheless, he opposed that the situation of Africa market should be considered in a different way. According to his perspective, Libya should be isolated from the rest of the Africa due to its special situation for Turkish contractors. Moreover, Respondent 3 also insisted that these kind of studies should be done periodically. He expressed that, in this way they could be very helpful for developing strategies for the contractors. Ultimately, the findings of the study display the general opinions of the experts.

# CHAPTER 6

# CONCLUSION

The nature of the construction industry is very complex and abstruse which make the construction projects and companies difficult to manage. Therefore, various applications on management of these companies and projects should be welcomed in this industry. SNA can be regarded as an emergent technique to enhance the managing abilities of the members in the construction sector. It can be used to investigate the companies and staff members in many different ways. As explained in Chapter 3, a number of researchers have applied SNA to construction industry in various concepts. The interactions among the staff members is the most popular topic in this sector. Since understanding the reasons of the problems in these relationships can be found easily, the solutions for these problems can be determined rapidly and management duty can be improved. Throughout the literature survey, it is presented that in addition to human level investigation for the staff members, there is an opportunity to work on construction companies by using SNA. Although these researches are limited at the time being, there can be expected an increase with rising interest on this topic. In this way, the strategies of the companies in construction markets could be identified by the interactions among them. Furthermore, the construction companies become more able to find new opportunities by understanding perfectly the competition in their field.

In this study, it is aimed to analyze the interactions between the Turkish contractors when their collaborations are considered as their relationships. Since the Turkish contractors are being considered among the powerful companies in the world, it could be asserted that the behavior of the Turkish contractors is in a determiner role in this sector. In this manner, this study could play an instructive role both for the domestic and international companies that want to have information about the collaborative strategies of the Turkish contractors. Therefore, the main goal is to take the picture of the sector in the collaborative projects which were performed in abroad.

On the other hand, the SNA is not a recognized concept in the Turkish construction industry. In this study, it is also intended to demonstrate the implementation of SNA in this industry. The analysis of the construction projects and companies with social network approach could provide a different point of view for the administrative staff. Therefore, a new path could be opened for improving the management of the construction with the light of this study which investigates the international collaborations of Turkish contractors by the SNA.

In the context of this study, the data of the projects that Turkish contractors performed in the international market were obtained from the Turkish Contracting and Engineering Services unit of Turkish Republic Ministry of Economy. At this point, there was a need to make classifications on these data to find out the suitable projects where the collaborations were indicated clearly.

Based on this obtained data, the network structure was formed for the Turkish contractors and their foreign partners. In this network, 449 collaborative projects which are carried out in 46 different countries were used to show the relationships between 255 companies. The weights were assigned to the relationships between the firms if they were collaborated in more than one projects. When the network is constructed it is seen that although there are many isolated components, there is a major component which is comprised of approximately 40% of the companies. The main findings of the study for the general network are:

- Since Turkish contractors are very self-confident, the individual performance of the projects is much more preferred relative to collaborations.
- Turkish contractors are willing to expand abroad. Even very small companies do not hesitate to be involved in the international projects.
- When the structure of the network is considered, it can be interpreted that the companies form a groups where the significant amount of the companies are somehow connected to each other.
- There are different strategies followed by these companies. Some companies prefer to collaborate with many other companies, while some others prefer to be involved in many projects with less number of partners. On the other hand, many companies have performed in a project with only one company which also isolated from the rest of the network. These are mostly the smaller ones. These strategies determine the positions and the roles of the companies in the network.
- Various companies become prominent in the network according to their position and individual features.

On the other hand, the project budgets should be considered as a distinctive factor since the ranges for construction projects are highly variable. This situation could be an important factor which effects the actions of the companies. Therefore, three different networks were created for each project scale, based on the provided classification of the project budgets in the data. In this way, it is aimed to observe whether any change occurs in the attitude of the construction companies in accordance with the project scale. Due to the fact that the amount of projects are analogous in all defined intervals, the general collaborative behavior in these networks can be compared. When these networks are examined by SNA, the following deductions can be made:

- The networks have shown different structures according to the project scale. Therefore, there can be mentioned about change in the strategies with respect to the project scale. As the project scale gets larger, the companies in these network structures become more connected. The reason behind this situation can be explained with the increasing complexity of the projects. Since the complex projects requires more capability, they force the companies to make cooperation with limited number of companies. Therefore, when the scale of the projects get larger the companies started to form various groups in the network.
- The companies follow different strategies in these collaborative networks. While relatively small companies only appeared in small scale projects, some bigger ones only appear in the larger projects by collaborating with big counterparts. On the other side, several companies maintain their strategy in all networks.

In the final part of the case study, the location of the projects were investigated to learn the market-based strategies of the Turkish contractors in the collaborative projects. With the exception of one project, all of the remaining ones were classified under four different markets: CIS countries, Middle East, Africa and Europe. In this way, it is targeted to form an opinion about the general situations and the leading companies of various markets. According to the results of these networks, the dispositions of the Turkish contractors are also searched for the collaborative projects based on their location. The obtained conclusions from these networks are:

- The networks of CIS countries and Middle East have shown more developed structures relative to the Africa and Europe markets.
- The attitude in the successful markets are also different. The number of companies that enter collaborative projects in CIS market is not very high. However, in this market the existent companies complete many projects with the familiar ones. On the other side, more companies appeared in the

Middle East market. Nevertheless, in this market these companies are more prone to collaborate with various companies. There can be mentioned about high knowledge and power of Turkish companies in these markets.

- When Africa market is considered, it is seen that collaboration is not a common practice in this market. The ratio of the collaborated projects is less than expected due to the importance of this market for the Turkish contractors. There cannot be mentioned about a consistent collaborative behavior for the companies. It can be suggested to enter this market either individually or cooperating with a local partner.
- Although only the collaborative projects were examined in this case study, the interpretation can be made that Europe is not an attractive market for the Turkish contractors. Therefore, there is gap in the knowledge of the Turkish companies for this market. It can be recommended to find partners from the local or the other European companies that have considerable knowledge in the host country.
- According to the results of these networks, each market has its own rules. It is seen that various companies become prominent in each market. Therefore, it can be interpreted that the companies select their target and turn their attention to this selected market. Besides, they can adapt their strategy according to the location of the project.

Although the case study was mainly aimed to take the picture of the collaborative behaviors, the contractors could be benefited from this study for selecting best collaborative behavior according to the related conditions of the projects. Moreover, this study may help them to find suitable partners when the conditions of the project are combined with these results.

Consequently, the companies increase their success when they select suitable strategies for the projects. The social network theory could be used in explaining the collaborative actions of the companies. With the light of the information provided by SNA, correct partners and strategies for the related project size and market can be identified easily. In this study, this situation is exemplified by the case for the actions of Turkish contractors in the international projects.

In this study there are several limitations. The major limitation is the vulnerability of the data. Since the obtained data are based on the declarations of the companies, there should be mentioned about the possibility of the missing projects. If there were projects that were underspecified or not informed to the Turkish Contracting and Engineering Services, it would harm the accuracy of the data. In order to improve this limitation, more accurate records for these projects should be kept. Turkish Contracting and Engineering Services unit has started to make some improvements in their data collection methods. In the future, the probability of finding more accurate data for the following years could increase.

Another shortcoming is the classification of the project budgets. Some of the projects are vulnerable to the effect of inflation since a very long time interval is considered during the case study. The budgets that were striking two decades earlier, could become ordinary when compared to the values in recent years. Moreover, the values are valid for the worth of Turkish side in the projects. Therefore, if the exact values of the project budgets were known for the whole projects, then the preciseness of the classification could be much better.

Final shortcoming is the recent conditions of the companies and partnerships. Since the projects from the start of opening Turkish companies to the international were considered, some companies that faced bankruptcy in the following years are included in the network. Therefore, paying attention to the actual conditions of the companies and partnerships might have increased the consistency of the study.

Since SNA is a recent approach for construction management, future researches on this field are recommended to improve the administration of the construction companies and projects. Both the relationships and the social players of construction industry are very diverse. Therefore, SNA could be implemented to understand the dynamics behind these interactions among various players. If convenient data could be obtained, the best future work related to this study is to investigate the behaviors of the Turkish contractors by classifying the projects various time intervals. In this manner, the comparison between the strategies could be clearly understood. Moreover, the same logic could also be applied to domestic projects which provides the ability to make comparisons between the collaborative strategies in the domestic and international markets. On the other hand, the interactions between the members of management staff is the most frequently used scenario for the application of SNA in construction industry. Accordingly, this type of research could be performed for the Turkish construction companies to promote the efficiency of the interactions. Moreover, SNA may be used in various new researches. For example, relationships between main contracting and subcontracting companies could be investigated with SNA. In this manner, the actions and positions of these companies can be comprehended.

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# APPENDIX A

## A.Node Results for the General Network

### Table A.1

| Id | Degree | Weighted Degree | Eccentricity | Closeness Centrality | Betweenness Centrality | Component ID | Clustering Coefficient | Eigenvector Centrality |
|---|---|---|---|---|---|---|---|---|
| 77 | 10 | 137 | 10 | 0.2103 | 0.052136 | 0 | 0.0667 | 1 |
| 145 | 9 | 35 | 11 | 0.2037 | 0.069139 | 0 | 0.1667 | 0.9196 |
| 268 | 6 | 32 | 12 | 0.1756 | 0.001098 | 0 | 0.3333 | 0.7094 |
| 161 | 6 | 124 | 11 | 0.1801 | 0.020202 | 0 | 0.2000 | 0.6468 |
| 131 | 5 | 21 | 9 | 0.2311 | 0.053877 | 0 | 0.2000 | 0.5939 |
| 177 | 5 | 111 | 11 | 0.1788 | 0.008611 | 0 | 0.3000 | 0.5936 |
| 121 | 5 | 7 | 11 | 0.1808 | 0.013191 | 0 | 0.2000 | 0.5397 |
| 267 | 3 | 3 | 12 | 0.1792 | 0.039055 | 0 | 0.3333 | 0.5220 |
| 262 | 9 | 14 | 13 | 0.1591 | 0.039306 | 0 | 0.0278 | 0.4963 |
| 130 | 6 | 6 | 9 | 0.2402 | 0.079412 | 0 | 0.0667 | 0.4737 |
| 144 | 3 | 3 | 10 | 0.2212 | 0.065155 | 0 | 0.3333 | 0.4177 |
| 229 | 4 | 5 | 12 | 0.1543 | 0.003153 | 0 | 0.3333 | 0.3900 |
| 298 | 2 | 18 | 10 | 0.1988 | 0 | 0 | 1 | 0.3869 |
| 221 | 2 | 2 | 12 | 0.1698 | 0 | 0 | 1 | 0.3861 |
| 269 | 2 | 2 | 12 | 0.1698 | 0 | 0 | 1 | 0.3861 |
| 270 | 2 | 2 | 12 | 0.1698 | 0 | 0 | 1 | 0.3861 |
| 308 | 2 | 2 | 12 | 0.1698 | 0 | 0 | 1 | 0.3861 |
| 148 | 2 | 3 | 11 | 0.1775 | 0 | 0 | 1 | 0.3763 |
| 117 | 7 | 16 | 11 | 0.1863 | 0.017551 | 0 | 0.0476 | 0.3712 |
| 66 | 4 | 7 | 8 | 0.2322 | 0.062331 | 0 | 0.1667 | 0.3640 |
| 146 | 2 | 2 | 11 | 0.1922 | 0 | 0 | 1 | 0.3207 |
| 137 | 4 | 11 | 12 | 0.1738 | 0.020327 | 0 | 0 | 0.3186 |
| 96 | 5 | 6 | 11 | 0.1684 | 0.040247 | 0 | 0.1000 | 0.2879 |
| 51 | 5 | 5 | 11 | 0.1653 | 0.011920 | 0 | 0.2000 | 0.2622 |
| 273 | 4 | 4 | 10 | 0.1885 | 0.053109 | 0 | 0.1667 | 0.2578 |
| 151 | 3 | 14 | 12 | 0.1546 | 0.008940 | 0 | 0.3333 | 0.2530 |
| 227 | 4 | 6 | 9 | 0.2099 | 0.060888 | 0 | 0.1667 | 0.2423 |
| 230 | 2 | 2 | 12 | 0.1524 | 0 | 0 | 1 | 0.2417 |
| 135 | 6 | 8 | 12 | 0.1492 | 0.031087 | 0 | 0 | 0.2416 |
| 76 | 1 | 4 | 11 | 0.1741 | 0 | 0 | 0 | 0.2408 |
| 243 | 1 | 2 | 11 | 0.1741 | 0 | 0 | 0 | 0.2408 |
| 297 | 1 | 2 | 11 | 0.1741 | 0 | 0 | 0 | 0.2408 |
| 296 | 1 | 1 | 11 | 0.1741 | 0 | 0 | 0 | 0.2408 |
| 303 | 2 | 2 | 12 | 0.1538 | 0 | 0 | 1 | 0.2255 |

## Table A.1 Node Results for the General Network (continued)

| Id | Degree | Weighted Degree | Eccentricity | Closeness Centrality | Betweenness Centrality | Component ID | Clustering Coefficient | Eigenvector Centrality |
|---|---|---|---|---|---|---|---|---|
| 120 | 2 | 6 | 10 | 0.2025 | 0.014869 | 0 | 0 | 0.2247 |
| 103 | 3 | 3 | 14 | 0.1390 | 0.011795 | 0 | 0.3333 | 0.2128 |
| 191 | 3 | 3 | 12 | 0.1541 | 0.003043 | 0 | 0.3333 | 0.2032 |
| 190 | 2 | 2 | 12 | 0.1538 | 0 | 0 | 1 | 0.1904 |
| 266 | 2 | 3 | 14 | 0.1376 | 0 | 0 | 1 | 0.1882 |
| 307 | 2 | 2 | 14 | 0.1376 | 0 | 0 | 1 | 0.1882 |
| 60 | 4 | 5 | 13 | 0.1321 | 0.017473 | 0 | 0.1667 | 0.1751 |
| 88 | 3 | 7 | 14 | 0.1382 | 0.006054 | 0 | 0 | 0.1702 |
| 147 | 2 | 3 | 10 | 0.1896 | 0.006023 | 0 | 0 | 0.1656 |
| 232 | 4 | 10 | 13 | 0.1501 | 0.011920 | 0 | 0.1667 | 0.1616 |
| 234 | 1 | 1 | 12 | 0.1529 | 0 | 0 | 0 | 0.1588 |
| 81 | 4 | 10 | 1 | 1 | 0.000094 | 11 | 0.5000 | 0.1585 |
| 283 | 2 | 4 | 12 | 0.1576 | 0 | 0 | 1 | 0.1455 |
| 284 | 2 | 4 | 12 | 0.1576 | 0 | 0 | 1 | 0.1455 |
| 138 | 3 | 7 | 2 | 0.8000 | 0 | 11 | 1 | 0.1451 |
| 139 | 3 | 7 | 2 | 0.8000 | 0 | 11 | 1 | 0.1451 |
| 140 | 3 | 7 | 2 | 0.8000 | 0 | 11 | 1 | 0.1451 |
| 178 | 1 | 1 | 12 | 0.1519 | 0 | 0 | 0 | 0.1445 |
| 263 | 1 | 1 | 14 | 0.1374 | 0 | 0 | 0 | 0.1359 |
| 264 | 1 | 1 | 14 | 0.1374 | 0 | 0 | 0 | 0.1359 |
| 265 | 1 | 1 | 14 | 0.1374 | 0 | 0 | 0 | 0.1359 |
| 309 | 1 | 1 | 14 | 0.1374 | 0 | 0 | 0 | 0.1359 |
| 133 | 2 | 2 | 10 | 0.1948 | 0.003043 | 0 | 0 | 0.1352 |
| 156 | 4 | 9 | 14 | 0.1178 | 0.009003 | 0 | 0.1667 | 0.1304 |
| 102 | 4 | 8 | 15 | 0.1230 | 0.006054 | 0 | 0.1667 | 0.1289 |
| 132 | 1 | 1 | 10 | 0.1941 | 0 | 0 | 0 | 0.1216 |
| 226 | 3 | 5 | 10 | 0.1747 | 0.003043 | 0 | 0.3333 | 0.1184 |
| 97 | 2 | 2 | 12 | 0.1422 | 0 | 0 | 1 | 0.1142 |
| 98 | 2 | 2 | 12 | 0.1422 | 0 | 0 | 1 | 0.1142 |
| 150 | 3 | 5 | 13 | 0.1348 | 0.006023 | 0 | 0.3333 | 0.1118 |
| 228 | 2 | 4 | 10 | 0.1744 | 0 | 0 | 1 | 0.1082 |
| 101 | 2 | 6 | 15 | 0.1227 | 0 | 0 | 1 | 0.1056 |
| 119 | 1 | 3 | 12 | 0.1573 | 0 | 0 | 0 | 0.1031 |
| 118 | 1 | 1 | 12 | 0.1573 | 0 | 0 | 0 | 0.1031 |
| 167 | 1 | 1 | 12 | 0.1573 | 0 | 0 | 0 | 0.1031 |
| 242 | 2 | 2 | 14 | 0.1174 | 0 | 0 | 1 | 0.1024 |
| 83 | 5 | 6 | 1 | 1 | 0.000282 | 12 | 0.1000 | 0.1021 |
| 225 | 2 | 4 | 12 | 0.1448 | 0.003043 | 0 | 0 | 0.0984 |
| 231 | 1 | 1 | 13 | 0.1339 | 0 | 0 | 0 | 0.0972 |
| 67 | 1 | 4 | 9 | 0.1888 | 0 | 0 | 0 | 0.0947 |
| 52 | 2 | 2 | 12 | 0.1424 | 0.003043 | 0 | 0 | 0.0908 |
| 183 | 4 | 5 | 2 | 0.7500 | 0.000345 | 24 | 0.1667 | 0.0894 |
| 95 | 1 | 1 | 12 | 0.1443 | 0 | 0 | 0 | 0.0859 |
| 136 | 1 | 2 | 13 | 0.1483 | 0 | 0 | 0 | 0.0837 |
| 216 | 1 | 1 | 13 | 0.1483 | 0 | 0 | 0 | 0.0837 |

## Table A.1 Node Results for the General Network (continued)

| Id | Degree | Weighted Degree | Eccentricity | Closeness Centrality | Betweenness Centrality | Component ID | Clustering Coefficient | Eigenvector Centrality |
|---|---|---|---|---|---|---|---|---|
| 292 | 2 | 2 | 14 | 0.1308 | 0 | 0 | 1 | 0.0787 |
| 293 | 2 | 2 | 14 | 0.1308 | 0 | 0 | 1 | 0.0787 |
| 220 | 1 | 2 | 13 | 0.1300 | 0 | 0 | 0 | 0.0758 |
| 134 | 1 | 1 | 13 | 0.1300 | 0 | 0 | 0 | 0.0758 |
| 218 | 1 | 1 | 13 | 0.1300 | 0 | 0 | 0 | 0.0758 |
| 219 | 1 | 1 | 13 | 0.1300 | 0 | 0 | 0 | 0.0758 |
| 274 | 1 | 1 | 11 | 0.1588 | 0 | 0 | 0 | 0.0754 |
| 164 | 3 | 12 | 3 | 0.6000 | 0.000251 | 30 | 0.3333 | 0.0676 |
| 172 | 2 | 3 | 2 | 0.6250 | 0 | 12 | 1 | 0.0666 |
| 304 | 2 | 2 | 2 | 0.6250 | 0 | 12 | 1 | 0.0666 |
| 291 | 2 | 2 | 14 | 0.1310 | 0.003043 | 0 | 0 | 0.0620 |
| 129 | 3 | 4 | 2 | 0.6667 | 0.000282 | 24 | 0 | 0.0607 |
| 182 | 2 | 2 | 3 | 0.5000 | 0 | 24 | 1 | 0.0601 |
| 184 | 2 | 2 | 3 | 0.5000 | 0 | 24 | 1 | 0.0601 |
| 210 | 2 | 4 | 14 | 0.1191 | 0 | 0 | 1 | 0.0591 |
| 211 | 2 | 4 | 14 | 0.1191 | 0 | 0 | 1 | 0.0591 |
| 168 | 3 | 14 | 2 | 0.6667 | 0.000345 | 30 | 0 | 0.0577 |
| 61 | 1 | 2 | 14 | 0.1168 | 0 | 0 | 0 | 0.0571 |
| 157 | 2 | 9 | 15 | 0.1057 | 0.003043 | 0 | 0 | 0.0559 |
| 205 | 1 | 1 | 13 | 0.1337 | 0 | 0 | 0 | 0.0549 |
| 113 | 2 | 3 | 11 | 0.1601 | 0.003043 | 0 | 0 | 0.0541 |
| 82 | 1 | 7 | 2 | 0.5714 | 0 | 11 | 0 | 0.0517 |
| 108 | 3 | 3 | 1 | 1 | 0.000063 | 18 | 0.3333 | 0.0507 |
| 202 | 3 | 3 | 1 | 1 | 0.000063 | 40 | 0.3333 | 0.0507 |
| 89 | 1 | 1 | 15 | 0.1216 | 0 | 0 | 0 | 0.0505 |
| 300 | 1 | 1 | 15 | 0.1216 | 0 | 0 | 0 | 0.0505 |
| 165 | 2 | 2 | 4 | 0.4286 | 0 | 30 | 1 | 0.0495 |
| 166 | 2 | 2 | 4 | 0.4286 | 0 | 30 | 1 | 0.0495 |
| 158 | 1 | 1 | 15 | 0.1055 | 0 | 0 | 0 | 0.0453 |
| 149 | 1 | 1 | 16 | 0.1096 | 0 | 0 | 0 | 0.0431 |
| 302 | 1 | 1 | 16 | 0.1096 | 0 | 0 | 0 | 0.0431 |
| 185 | 2 | 2 | 2 | 0.7500 | 0 | 18 | 1 | 0.0429 |
| 203 | 2 | 2 | 2 | 0.7500 | 0 | 40 | 1 | 0.0429 |
| 204 | 2 | 2 | 2 | 0.7500 | 0 | 40 | 1 | 0.0429 |
| 305 | 2 | 2 | 2 | 0.7500 | 0 | 18 | 1 | 0.0429 |
| 84 | 1 | 1 | 2 | 0.5556 | 0 | 12 | 0 | 0.0406 |
| 179 | 1 | 1 | 2 | 0.5556 | 0 | 12 | 0 | 0.0406 |
| 180 | 1 | 1 | 2 | 0.5556 | 0 | 12 | 0 | 0.0406 |
| 249 | 1 | 1 | 11 | 0.1489 | 0 | 0 | 0 | 0.0382 |
| 141 | 1 | 1 | 11 | 0.1633 | 0 | 0 | 0 | 0.0382 |
| 192 | 3 | 36 | 2 | 0.8000 | 0.000157 | 36 | 0 | 0.0373 |
| 250 | 1 | 1 | 3 | 0.4615 | 0 | 24 | 0 | 0.0361 |
| 272 | 2 | 15 | 3 | 0.5000 | 0.000157 | 30 | 0 | 0.0351 |
| 85 | 2 | 10 | 1 | 1 | 0 | 13 | 1 | 0.0334 |
| 86 | 2 | 10 | 1 | 1 | 0 | 13 | 1 | 0.0334 |

## Table A.1 Node Results for the General Network (continued)

| Id | Degree | Weighted Degree | Eccentricity | Closeness Centrality | Betweenness Centrality | Component ID | Clustering Coefficient | Eigenvector Centrality |
|---|---|---|---|---|---|---|---|---|
| 87 | 2 | 10 | 1 | 1 | 0 | 13 | 1 | 0.0334 |
| 78 | 2 | 2 | 1 | 1 | 0 | 10 | 1 | 0.0334 |
| 79 | 2 | 2 | 1 | 1 | 0 | 10 | 1 | 0.0334 |
| 80 | 2 | 2 | 1 | 1 | 0 | 10 | 1 | 0.0334 |
| 90 | 2 | 2 | 1 | 1 | 0 | 14 | 1 | 0.0334 |
| 91 | 2 | 2 | 1 | 1 | 0 | 14 | 1 | 0.0334 |
| 92 | 2 | 2 | 1 | 1 | 0 | 14 | 1 | 0.0334 |
| 104 | 2 | 2 | 1 | 1 | 0 | 17 | 1 | 0.0334 |
| 105 | 2 | 2 | 1 | 1 | 0 | 17 | 1 | 0.0334 |
| 106 | 2 | 2 | 1 | 1 | 0 | 17 | 1 | 0.0334 |
| 212 | 2 | 2 | 1 | 1 | 0 | 42 | 1 | 0.0334 |
| 213 | 2 | 2 | 1 | 1 | 0 | 42 | 1 | 0.0334 |
| 214 | 2 | 2 | 1 | 1 | 0 | 42 | 1 | 0.0334 |
| 278 | 2 | 2 | 1 | 1 | 0 | 56 | 1 | 0.0334 |
| 279 | 2 | 2 | 1 | 1 | 0 | 56 | 1 | 0.0334 |
| 280 | 2 | 2 | 1 | 1 | 0 | 56 | 1 | 0.0334 |
| 286 | 2 | 2 | 1 | 1 | 0 | 58 | 1 | 0.0334 |
| 287 | 2 | 2 | 1 | 1 | 0 | 58 | 1 | 0.0334 |
| 288 | 2 | 2 | 1 | 1 | 0 | 58 | 1 | 0.0334 |
| 224 | 1 | 3 | 13 | 0.1266 | 0 | 0 | 0 | 0.0316 |
| 53 | 3 | 5 | 1 | 1 | 0.000094 | 1 | 0 | 0.0309 |
| 169 | 1 | 1 | 13 | 0.1248 | 0 | 0 | 0 | 0.0298 |
| 206 | 2 | 2 | 2 | 0.6667 | 0.000094 | 36 | 0 | 0.0290 |
| 128 | 1 | 1 | 3 | 0.4286 | 0 | 24 | 0 | 0.0261 |
| 197 | 1 | 1 | 3 | 0.4286 | 0 | 24 | 0 | 0.0261 |
| 271 | 1 | 3 | 3 | 0.4286 | 0 | 30 | 0 | 0.0255 |
| 107 | 1 | 1 | 2 | 0.6000 | 0 | 18 | 0 | 0.0234 |
| 215 | 1 | 1 | 2 | 0.6000 | 0 | 40 | 0 | 0.0234 |
| 299 | 1 | 1 | 15 | 0.1160 | 0 | 0 | 0 | 0.0231 |
| 244 | 1 | 3 | 16 | 0.0957 | 0 | 0 | 0 | 0.0220 |
| 193 | 1 | 33 | 3 | 0.5000 | 0 | 36 | 0 | 0.0196 |
| 194 | 1 | 2 | 3 | 0.5000 | 0 | 36 | 0 | 0.0196 |
| 112 | 1 | 1 | 12 | 0.1382 | 0 | 0 | 0 | 0.0194 |
| 111 | 1 | 3 | 2 | 0.6000 | 0 | 1 | 0 | 0.0176 |
| 54 | 1 | 1 | 2 | 0.6000 | 0 | 1 | 0 | 0.0176 |
| 55 | 1 | 1 | 2 | 0.6000 | 0 | 1 | 0 | 0.0176 |
| 277 | 1 | 14 | 4 | 0.3529 | 0 | 30 | 0 | 0.0170 |
| 65 | 2 | 2 | 1 | 1 | 0.000031 | 5 | 0 | 0.0165 |
| 301 | 2 | 2 | 1 | 1 | 0.000031 | 16 | 0 | 0.0165 |
| 207 | 1 | 1 | 3 | 0.4444 | 0 | 36 | 0 | 0.0156 |
| 64 | 1 | 1 | 2 | 0.6667 | 0 | 5 | 0 | 0.0114 |
| 100 | 1 | 1 | 2 | 0.6667 | 0 | 16 | 0 | 0.0114 |
| 116 | 1 | 1 | 2 | 0.6667 | 0 | 5 | 0 | 0.0114 |
| 285 | 1 | 1 | 2 | 0.6667 | 0 | 16 | 0 | 0.0114 |
| 56 | 1 | 18 | 1 | 1 | 0 | 2 | 0 | 0.0064 |

## Table A.1 Node Results for the General Network (continued)

| Id | Degree | Weighted Degree | Eccentricity | Closeness Centrality | Betweenness Centrality | Component ID | Clustering Coefficient | Eigenvector Centrality |
|---|---|---|---|---|---|---|---|---|
| 57 | 1 | 18 | 1 | 1 | 0 | 2 | 0 | 0.0064 |
| 68 | 1 | 12 | 1 | 1 | 0 | 6 | 0 | 0.0064 |
| 69 | 1 | 12 | 1 | 1 | 0 | 6 | 0 | 0.0064 |
| 58 | 1 | 7 | 1 | 1 | 0 | 3 | 0 | 0.0064 |
| 59 | 1 | 7 | 1 | 1 | 0 | 3 | 0 | 0.0064 |
| 122 | 1 | 7 | 1 | 1 | 0 | 21 | 0 | 0.0064 |
| 123 | 1 | 7 | 1 | 1 | 0 | 21 | 0 | 0.0064 |
| 154 | 1 | 7 | 1 | 1 | 0 | 27 | 0 | 0.0064 |
| 155 | 1 | 7 | 1 | 1 | 0 | 27 | 0 | 0.0064 |
| 173 | 1 | 7 | 1 | 1 | 0 | 32 | 0 | 0.0064 |
| 174 | 1 | 7 | 1 | 1 | 0 | 32 | 0 | 0.0064 |
| 114 | 1 | 5 | 1 | 1 | 0 | 20 | 0 | 0.0064 |
| 115 | 1 | 5 | 1 | 1 | 0 | 20 | 0 | 0.0064 |
| 175 | 1 | 4 | 1 | 1 | 0 | 33 | 0 | 0.0064 |
| 176 | 1 | 4 | 1 | 1 | 0 | 33 | 0 | 0.0064 |
| 72 | 1 | 3 | 1 | 1 | 0 | 8 | 0 | 0.0064 |
| 73 | 1 | 3 | 1 | 1 | 0 | 8 | 0 | 0.0064 |
| 142 | 1 | 3 | 1 | 1 | 0 | 25 | 0 | 0.0064 |
| 143 | 1 | 3 | 1 | 1 | 0 | 25 | 0 | 0.0064 |
| 245 | 1 | 3 | 1 | 1 | 0 | 47 | 0 | 0.0064 |
| 246 | 1 | 3 | 1 | 1 | 0 | 47 | 0 | 0.0064 |
| 124 | 1 | 2 | 1 | 1 | 0 | 22 | 0 | 0.0064 |
| 125 | 1 | 2 | 1 | 1 | 0 | 22 | 0 | 0.0064 |
| 159 | 1 | 2 | 1 | 1 | 0 | 28 | 0 | 0.0064 |
| 160 | 1 | 2 | 1 | 1 | 0 | 28 | 0 | 0.0064 |
| 162 | 1 | 2 | 1 | 1 | 0 | 29 | 0 | 0.0064 |
| 163 | 1 | 2 | 1 | 1 | 0 | 29 | 0 | 0.0064 |
| 188 | 1 | 2 | 1 | 1 | 0 | 35 | 0 | 0.0064 |
| 189 | 1 | 2 | 1 | 1 | 0 | 35 | 0 | 0.0064 |
| 200 | 1 | 2 | 1 | 1 | 0 | 39 | 0 | 0.0064 |
| 201 | 1 | 2 | 1 | 1 | 0 | 39 | 0 | 0.0064 |
| 240 | 1 | 2 | 1 | 1 | 0 | 46 | 0 | 0.0064 |
| 241 | 1 | 2 | 1 | 1 | 0 | 46 | 0 | 0.0064 |
| 62 | 1 | 1 | 1 | 1 | 0 | 4 | 0 | 0.0064 |
| 63 | 1 | 1 | 1 | 1 | 0 | 4 | 0 | 0.0064 |
| 70 | 1 | 1 | 1 | 1 | 0 | 7 | 0 | 0.0064 |
| 71 | 1 | 1 | 1 | 1 | 0 | 7 | 0 | 0.0064 |
| 74 | 1 | 1 | 1 | 1 | 0 | 9 | 0 | 0.0064 |
| 75 | 1 | 1 | 1 | 1 | 0 | 9 | 0 | 0.0064 |
| 93 | 1 | 1 | 1 | 1 | 0 | 15 | 0 | 0.0064 |
| 94 | 1 | 1 | 1 | 1 | 0 | 15 | 0 | 0.0064 |
| 109 | 1 | 1 | 1 | 1 | 0 | 19 | 0 | 0.0064 |
| 110 | 1 | 1 | 1 | 1 | 0 | 19 | 0 | 0.0064 |
| 126 | 1 | 1 | 1 | 1 | 0 | 23 | 0 | 0.0064 |
| 127 | 1 | 1 | 1 | 1 | 0 | 23 | 0 | 0.0064 |

## Table A.1 Node Results for the General Network (continued)

| Id | Degree | Weighted Degree | Eccentricity | Closeness Centrality | Betweenness Centrality | Component ID | Clustering Coefficient | Eigenvector Centrality |
|---|---|---|---|---|---|---|---|---|
| 152 | 1 | 1 | 1 | 1 | 0 | 26 | 0 | 0.0064 |
| 153 | 1 | 1 | 1 | 1 | 0 | 26 | 0 | 0.0064 |
| 170 | 1 | 1 | 1 | 1 | 0 | 31 | 0 | 0.0064 |
| 171 | 1 | 1 | 1 | 1 | 0 | 31 | 0 | 0.0064 |
| 186 | 1 | 1 | 1 | 1 | 0 | 34 | 0 | 0.0064 |
| 187 | 1 | 1 | 1 | 1 | 0 | 34 | 0 | 0.0064 |
| 195 | 1 | 1 | 1 | 1 | 0 | 37 | 0 | 0.0064 |
| 196 | 1 | 1 | 1 | 1 | 0 | 37 | 0 | 0.0064 |
| 198 | 1 | 1 | 1 | 1 | 0 | 38 | 0 | 0.0064 |
| 199 | 1 | 1 | 1 | 1 | 0 | 38 | 0 | 0.0064 |
| 208 | 1 | 1 | 1 | 1 | 0 | 41 | 0 | 0.0064 |
| 209 | 1 | 1 | 1 | 1 | 0 | 41 | 0 | 0.0064 |
| 222 | 1 | 1 | 1 | 1 | 0 | 43 | 0 | 0.0064 |
| 223 | 1 | 1 | 1 | 1 | 0 | 43 | 0 | 0.0064 |
| 235 | 1 | 1 | 1 | 1 | 0 | 44 | 0 | 0.0064 |
| 236 | 1 | 1 | 1 | 1 | 0 | 44 | 0 | 0.0064 |
| 237 | 1 | 1 | 1 | 1 | 0 | 45 | 0 | 0.0064 |
| 238 | 1 | 1 | 1 | 1 | 0 | 45 | 0 | 0.0064 |
| 247 | 1 | 1 | 1 | 1 | 0 | 48 | 0 | 0.0064 |
| 248 | 1 | 1 | 1 | 1 | 0 | 48 | 0 | 0.0064 |
| 251 | 1 | 1 | 1 | 1 | 0 | 49 | 0 | 0.0064 |
| 252 | 1 | 1 | 1 | 1 | 0 | 49 | 0 | 0.0064 |
| 253 | 1 | 1 | 1 | 1 | 0 | 50 | 0 | 0.0064 |
| 254 | 1 | 1 | 1 | 1 | 0 | 50 | 0 | 0.0064 |
| 255 | 1 | 1 | 1 | 1 | 0 | 51 | 0 | 0.0064 |
| 256 | 1 | 1 | 1 | 1 | 0 | 52 | 0 | 0.0064 |
| 257 | 1 | 1 | 1 | 1 | 0 | 52 | 0 | 0.0064 |
| 258 | 1 | 1 | 1 | 1 | 0 | 53 | 0 | 0.0064 |
| 259 | 1 | 1 | 1 | 1 | 0 | 53 | 0 | 0.0064 |
| 260 | 1 | 1 | 1 | 1 | 0 | 54 | 0 | 0.0064 |
| 261 | 1 | 1 | 1 | 1 | 0 | 54 | 0 | 0.0064 |
| 275 | 1 | 1 | 1 | 1 | 0 | 55 | 0 | 0.0064 |
| 276 | 1 | 1 | 1 | 1 | 0 | 55 | 0 | 0.0064 |
| 281 | 1 | 1 | 1 | 1 | 0 | 57 | 0 | 0.0064 |
| 282 | 1 | 1 | 1 | 1 | 0 | 57 | 0 | 0.0064 |
| 289 | 1 | 1 | 1 | 1 | 0 | 59 | 0 | 0.0064 |
| 290 | 1 | 1 | 1 | 1 | 0 | 59 | 0 | 0.0064 |
| 294 | 1 | 1 | 1 | 1 | 0 | 60 | 0 | 0.0064 |
| 295 | 1 | 1 | 1 | 1 | 0 | 60 | 0 | 0.0064 |
| 306 | 1 | 1 | 1 | 1 | 0 | 51 | 0 | 0.0064 |

# APPENDIX B

## B.Node Results for the Small Scale Project Network

**Table B.1**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 77 | 5 | 68 | 0.001678 | 1 |
| 161 | 3 | 65 | 0.000763 | 0.6705 |
| 177 | 2 | 62 | 0 | 0.6049 |
| 131 | 2 | 4 | 0 | 0.5644 |
| 298 | 2 | 4 | 0 | 0.5644 |
| 76 | 1 | 2 | 0 | 0.3611 |
| 151 | 1 | 3 | 0 | 0.2439 |
| 117 | 3 | 6 | 0.000763 | 0.1625 |
| 51 | 2 | 2 | 0 | 0.1584 |
| 78 | 2 | 2 | 0 | 0.1584 |
| 79 | 2 | 2 | 0 | 0.1584 |
| 80 | 2 | 2 | 0 | 0.1584 |
| 83 | 2 | 2 | 0 | 0.1584 |
| 85 | 2 | 2 | 0 | 0.1584 |
| 86 | 2 | 2 | 0 | 0.1584 |
| 87 | 2 | 2 | 0 | 0.1584 |
| 97 | 2 | 2 | 0 | 0.1584 |
| 98 | 2 | 2 | 0 | 0.1584 |
| 138 | 2 | 2 | 0 | 0.1584 |
| 139 | 2 | 2 | 0 | 0.1584 |
| 140 | 2 | 2 | 0 | 0.1584 |
| 150 | 2 | 2 | 0 | 0.1584 |
| 179 | 2 | 2 | 0 | 0.1584 |
| 180 | 2 | 2 | 0 | 0.1584 |
| 210 | 2 | 2 | 0 | 0.1584 |
| 211 | 2 | 2 | 0 | 0.1584 |
| 226 | 2 | 2 | 0 | 0.1584 |

**Table B.1 Node Results for the Small Scale Project Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 227 | 2 | 2 | 0 | 0.1584 |
| 228 | 2 | 2 | 0 | 0.1584 |
| 278 | 2 | 2 | 0 | 0.1584 |
| 279 | 2 | 2 | 0 | 0.1584 |
| 280 | 2 | 2 | 0 | 0.1584 |
| 121 | 2 | 3 | 0.000458 | 0.1256 |
| 119 | 1 | 2 | 0 | 0.0873 |
| 120 | 1 | 2 | 0 | 0.0873 |
| 148 | 1 | 1 | 0 | 0.0682 |
| 113 | 2 | 3 | 0.000153 | 0.0567 |
| 192 | 2 | 15 | 0.000153 | 0.0567 |
| 112 | 1 | 1 | 0 | 0.0399 |
| 147 | 1 | 2 | 0 | 0.0399 |
| 193 | 1 | 14 | 0 | 0.0399 |
| 194 | 1 | 1 | 0 | 0.0399 |
| 53 | 1 | 1 | 0 | 0.0176 |
| 55 | 1 | 1 | 0 | 0.0176 |
| 56 | 1 | 10 | 0 | 0.0176 |
| 57 | 1 | 10 | 0 | 0.0176 |
| 58 | 1 | 4 | 0 | 0.0176 |
| 59 | 1 | 4 | 0 | 0.0176 |
| 60 | 1 | 2 | 0 | 0.0176 |
| 61 | 1 | 2 | 0 | 0.0176 |
| 64 | 1 | 1 | 0 | 0.0176 |
| 65 | 1 | 1 | 0 | 0.0176 |
| 66 | 1 | 1 | 0 | 0.0176 |
| 67 | 1 | 1 | 0 | 0.0176 |
| 68 | 1 | 12 | 0 | 0.0176 |
| 69 | 1 | 12 | 0 | 0.0176 |
| 70 | 1 | 1 | 0 | 0.0176 |
| 71 | 1 | 1 | 0 | 0.0176 |
| 88 | 1 | 2 | 0 | 0.0176 |
| 109 | 1 | 1 | 0 | 0.0176 |
| 110 | 1 | 1 | 0 | 0.0176 |
| 114 | 1 | 3 | 0 | 0.0176 |
| 115 | 1 | 3 | 0 | 0.0176 |

**Table B.1 Node Results for the Small Scale Project Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 122 | 1 | 2 | 0 | 0.0176 |
| 123 | 1 | 2 | 0 | 0.0176 |
| 124 | 1 | 2 | 0 | 0.0176 |
| 125 | 1 | 2 | 0 | 0.0176 |
| 126 | 1 | 1 | 0 | 0.0176 |
| 127 | 1 | 1 | 0 | 0.0176 |
| 130 | 1 | 1 | 0 | 0.0176 |
| 132 | 1 | 1 | 0 | 0.0176 |
| 137 | 1 | 5 | 0 | 0.0176 |
| 142 | 1 | 1 | 0 | 0.0176 |
| 143 | 1 | 1 | 0 | 0.0176 |
| 145 | 1 | 1 | 0 | 0.0176 |
| 152 | 1 | 1 | 0 | 0.0176 |
| 153 | 1 | 1 | 0 | 0.0176 |
| 154 | 1 | 6 | 0 | 0.0176 |
| 155 | 1 | 6 | 0 | 0.0176 |
| 159 | 1 | 2 | 0 | 0.0176 |
| 160 | 1 | 2 | 0 | 0.0176 |
| 162 | 1 | 1 | 0 | 0.0176 |
| 163 | 1 | 1 | 0 | 0.0176 |
| 168 | 1 | 2 | 0 | 0.0176 |
| 170 | 1 | 1 | 0 | 0.0176 |
| 171 | 1 | 1 | 0 | 0.0176 |
| 188 | 1 | 1 | 0 | 0.0176 |
| 189 | 1 | 1 | 0 | 0.0176 |
| 195 | 1 | 1 | 0 | 0.0176 |
| 196 | 1 | 1 | 0 | 0.0176 |
| 200 | 1 | 2 | 0 | 0.0176 |
| 201 | 1 | 2 | 0 | 0.0176 |
| 232 | 1 | 5 | 0 | 0.0176 |
| 235 | 1 | 1 | 0 | 0.0176 |
| 236 | 1 | 1 | 0 | 0.0176 |
| 237 | 1 | 1 | 0 | 0.0176 |
| 238 | 1 | 1 | 0 | 0.0176 |
| 240 | 1 | 1 | 0 | 0.0176 |
| 241 | 1 | 1 | 0 | 0.0176 |

**Table B.1 Node Results for the Small Scale Project Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 255 | 1 | 1 | 0 | 0.0176 |
| 256 | 1 | 1 | 0 | 0.0176 |
| 257 | 1 | 1 | 0 | 0.0176 |
| 258 | 1 | 1 | 0 | 0.0176 |
| 259 | 1 | 1 | 0 | 0.0176 |
| 262 | 1 | 2 | 0 | 0.0176 |
| 268 | 1 | 1 | 0 | 0.0176 |
| 271 | 1 | 2 | 0 | 0.0176 |
| 272 | 1 | 10 | 0 | 0.0176 |
| 275 | 1 | 1 | 0 | 0.0176 |
| 276 | 1 | 1 | 0 | 0.0176 |
| 277 | 1 | 10 | 0 | 0.0176 |
| 281 | 1 | 1 | 0 | 0.0176 |
| 282 | 1 | 1 | 0 | 0.0176 |
| 294 | 1 | 1 | 0 | 0.0176 |
| 295 | 1 | 1 | 0 | 0.0176 |
| 306 | 1 | 1 | 0 | 0.0176 |

## APPENDIX C

## C.Node Results for the Medium Scale Project Network

### Table C.1

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 77 | 7 | 42 | 0.006342 | 1.0000 |
| 161 | 6 | 46 | 0.005520 | 0.8991 |
| 177 | 2 | 34 | 0 | 0.5728 |
| 131 | 3 | 5 | 0.001409 | 0.4851 |
| 81 | 4 | 4 | 0.000352 | 0.4629 |
| 298 | 2 | 4 | 0 | 0.4495 |
| 151 | 3 | 11 | 0.001409 | 0.4418 |
| 138 | 3 | 5 | 0 | 0.4253 |
| 139 | 3 | 5 | 0 | 0.4253 |
| 140 | 3 | 5 | 0 | 0.4253 |
| 303 | 2 | 2 | 0 | 0.4085 |
| 145 | 4 | 8 | 0.004110 | 0.3248 |
| 137 | 4 | 5 | 0.005402 | 0.3245 |
| 232 | 4 | 5 | 0.004228 | 0.3123 |
| 76 | 1 | 2 | 0 | 0.3011 |
| 243 | 1 | 1 | 0 | 0.3011 |
| 297 | 1 | 1 | 0 | 0.3011 |
| 229 | 1 | 1 | 0 | 0.2717 |
| 234 | 1 | 1 | 0 | 0.2717 |
| 144 | 3 | 3 | 0.001292 | 0.2286 |
| 146 | 2 | 2 | 0 | 0.2048 |
| 292 | 2 | 2 | 0 | 0.1849 |
| 293 | 2 | 2 | 0 | 0.1849 |
| 117 | 4 | 5 | 0.000587 | 0.1772 |
| 82 | 1 | 1 | 0 | 0.1507 |
| 147 | 1 | 1 | 0 | 0.1484 |
| 291 | 2 | 2 | 0.001292 | 0.1405 |
| 150 | 1 | 1 | 0 | 0.1368 |
| 283 | 2 | 2 | 0 | 0.1311 |
| 284 | 2 | 2 | 0 | 0.1311 |
| 268 | 1 | 5 | 0 | 0.1193 |
| 136 | 1 | 1 | 0 | 0.1192 |
| 216 | 1 | 1 | 0 | 0.1192 |
| 51 | 3 | 3 | 0.000235 | 0.1171 |

**Table C.1 Node Results for the Medium Scale Project Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 284 | 2 | 2 | 0 | 0.1311 |
| 268 | 1 | 5 | 0 | 0.1193 |
| 136 | 1 | 1 | 0 | 0.1192 |
| 216 | 1 | 1 | 0 | 0.1192 |
| 51 | 3 | 3 | 0.000235 | 0.1171 |
| 191 | 3 | 3 | 0.000235 | 0.1171 |
| 226 | 3 | 3 | 0.000235 | 0.1171 |
| 96 | 2 | 2 | 0 | 0.0996 |
| 227 | 2 | 2 | 0 | 0.0996 |
| 228 | 2 | 2 | 0 | 0.0996 |
| 273 | 2 | 2 | 0 | 0.0996 |
| 121 | 2 | 2 | 0 | 0.0996 |
| 190 | 2 | 2 | 0 | 0.0996 |
| 130 | 1 | 1 | 0 | 0.0855 |
| 119 | 1 | 1 | 0 | 0.0758 |
| 120 | 1 | 2 | 0 | 0.0758 |
| 83 | 2 | 3 | 0 | 0.0740 |
| 85 | 2 | 6 | 0 | 0.0740 |
| 86 | 2 | 6 | 0 | 0.0740 |
| 87 | 2 | 6 | 0 | 0.0740 |
| 104 | 2 | 2 | 0 | 0.0740 |
| 105 | 2 | 2 | 0 | 0.0740 |
| 106 | 2 | 2 | 0 | 0.0740 |
| 172 | 2 | 3 | 0 | 0.0740 |
| 212 | 2 | 2 | 0 | 0.0740 |
| 213 | 2 | 2 | 0 | 0.0740 |
| 214 | 2 | 2 | 0 | 0.0740 |
| 286 | 2 | 2 | 0 | 0.0740 |
| 287 | 2 | 2 | 0 | 0.0740 |
| 288 | 2 | 2 | 0 | 0.0740 |
| 304 | 2 | 2 | 0 | 0.0740 |
| 192 | 3 | 14 | 0.000352 | 0.0635 |
| 299 | 1 | 1 | 0 | 0.0553 |
| 52 | 1 | 1 | 0 | 0.0541 |
| 205 | 1 | 1 | 0 | 0.0541 |
| 249 | 1 | 1 | 0 | 0.0541 |
| 193 | 1 | 12 | 0 | 0.0364 |
| 194 | 1 | 1 | 0 | 0.0364 |
| 206 | 1 | 1 | 0 | 0.0364 |
| 53 | 2 | 3 | 0.000117 | 0.0311 |
| 262 | 2 | 4 | 0.000117 | 0.0311 |
| 54 | 1 | 1 | 0 | 0.0218 |
| 88 | 1 | 3 | 0 | 0.0218 |
| 111 | 1 | 2 | 0 | 0.0218 |
| 266 | 1 | 1 | 0 | 0.0218 |

**Table C.1 Node Results for the Medium Scale Project Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 56 | 1 | 6 | 0 | 0.0108 |
| 57 | 1 | 6 | 0 | 0.0108 |
| 58 | 1 | 3 | 0 | 0.0108 |
| 59 | 1 | 3 | 0 | 0.0108 |
| 62 | 1 | 1 | 0 | 0.0108 |
| 63 | 1 | 1 | 0 | 0.0108 |
| 65 | 1 | 1 | 0 | 0.0108 |
| 66 | 1 | 1 | 0 | 0.0108 |
| 67 | 1 | 1 | 0 | 0.0108 |
| 74 | 1 | 1 | 0 | 0.0108 |
| 75 | 1 | 1 | 0 | 0.0108 |
| 93 | 1 | 1 | 0 | 0.0108 |
| 94 | 1 | 1 | 0 | 0.0108 |
| 107 | 1 | 1 | 0 | 0.0108 |
| 108 | 1 | 1 | 0 | 0.0108 |
| 114 | 1 | 2 | 0 | 0.0108 |
| 115 | 1 | 2 | 0 | 0.0108 |
| 116 | 1 | 1 | 0 | 0.0108 |
| 122 | 1 | 3 | 0 | 0.0108 |
| 123 | 1 | 3 | 0 | 0.0108 |
| 134 | 1 | 1 | 0 | 0.0108 |
| 135 | 1 | 1 | 0 | 0.0108 |
| 142 | 1 | 2 | 0 | 0.0108 |
| 143 | 1 | 2 | 0 | 0.0108 |
| 154 | 1 | 1 | 0 | 0.0108 |
| 155 | 1 | 1 | 0 | 0.0108 |
| 156 | 1 | 1 | 0 | 0.0108 |
| 157 | 1 | 2 | 0 | 0.0108 |
| 158 | 1 | 1 | 0 | 0.0108 |
| 162 | 1 | 1 | 0 | 0.0108 |
| 163 | 1 | 1 | 0 | 0.0108 |
| 164 | 1 | 3 | 0 | 0.0108 |
| 168 | 1 | 3 | 0 | 0.0108 |
| 173 | 1 | 7 | 0 | 0.0108 |
| 174 | 1 | 7 | 0 | 0.0108 |
| 175 | 1 | 4 | 0 | 0.0108 |
| 176 | 1 | 4 | 0 | 0.0108 |
| 186 | 1 | 1 | 0 | 0.0108 |
| 187 | 1 | 1 | 0 | 0.0108 |
| 208 | 1 | 1 | 0 | 0.0108 |
| 209 | 1 | 1 | 0 | 0.0108 |
| 222 | 1 | 1 | 0 | 0.0108 |
| 223 | 1 | 1 | 0 | 0.0108 |
| 224 | 1 | 1 | 0 | 0.0108 |
| 225 | 1 | 1 | 0 | 0.0108 |

**Table C.1 Node Results for the Medium Scale Project Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 240 | 1 | 1 | 0 | 0.0108 |
| 241 | 1 | 1 | 0 | 0.0108 |
| 244 | 1 | 2 | 0 | 0.0108 |
| 247 | 1 | 1 | 0 | 0.0108 |
| 248 | 1 | 1 | 0 | 0.0108 |
| 253 | 1 | 1 | 0 | 0.0108 |
| 254 | 1 | 1 | 0 | 0.0108 |
| 260 | 1 | 1 | 0 | 0.0108 |
| 261 | 1 | 1 | 0 | 0.0108 |
| 272 | 1 | 4 | 0 | 0.0108 |
| 277 | 1 | 4 | 0 | 0.0108 |
| 285 | 1 | 1 | 0 | 0.0108 |
| 301 | 1 | 1 | 0 | 0.0108 |

# APPENDIX D

## D.Node Results for the Large Scale Project Network

**Table D.1**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 77 | 9 | 27 | 0.028655 | 1 |
| 145 | 6 | 26 | 0.002199 | 0.9836 |
| 268 | 6 | 26 | 0.002199 | 0.9836 |
| 267 | 4 | 4 | 0.006397 | 0.8269 |
| 269 | 3 | 3 | 0 | 0.6947 |
| 177 | 5 | 15 | 0.009396 | 0.6641 |
| 262 | 8 | 8 | 0.009196 | 0.5980 |
| 131 | 4 | 12 | 0.024257 | 0.5801 |
| 161 | 3 | 13 | 0.002932 | 0.5628 |
| 221 | 2 | 2 | 0 | 0.4860 |
| 270 | 2 | 2 | 0 | 0.4860 |
| 308 | 2 | 2 | 0 | 0.4860 |
| 229 | 4 | 4 | 0.003532 | 0.4425 |
| 298 | 2 | 10 | 0 | 0.4232 |
| 121 | 2 | 2 | 0 | 0.3610 |
| 148 | 2 | 2 | 0 | 0.3610 |
| 130 | 4 | 4 | 0.021858 | 0.3529 |
| 66 | 4 | 5 | 0.012662 | 0.3346 |
| 230 | 2 | 2 | 0 | 0.2977 |
| 243 | 1 | 1 | 0 | 0.2651 |
| 296 | 1 | 1 | 0 | 0.2651 |
| 297 | 1 | 1 | 0 | 0.2651 |
| 266 | 2 | 2 | 0 | 0.2398 |
| 307 | 2 | 2 | 0 | 0.2398 |
| 117 | 5 | 5 | 0.012928 | 0.1905 |
| 135 | 5 | 7 | 0.006664 | 0.1832 |
| 178 | 1 | 1 | 0 | 0.1774 |
| 120 | 2 | 2 | 0.014661 | 0.1734 |
| 103 | 1 | 1 | 0 | 0.1695 |
| 263 | 1 | 1 | 0 | 0.1695 |
| 264 | 1 | 1 | 0 | 0.1695 |
| 265 | 1 | 1 | 0 | 0.1695 |
| 309 | 1 | 1 | 0 | 0.1695 |

**Table D.1 Node Results for the Large Scale Project Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 60 | 3 | 3 | 0.004265 | 0.1554 |
| 183 | 4 | 5 | 0.001466 | 0.1295 |
| 156 | 3 | 8 | 0.002666 | 0.1228 |
| 227 | 2 | 2 | 0.006664 | 0.1220 |
| 133 | 2 | 2 | 0.003465 | 0.1203 |
| 231 | 1 | 1 | 0 | 0.1203 |
| 96 | 3 | 4 | 0.003865 | 0.1147 |
| 283 | 2 | 2 | 0 | 0.1101 |
| 284 | 2 | 2 | 0 | 0.1101 |
| 242 | 2 | 2 | 0 | 0.1045 |
| 67 | 1 | 2 | 0 | 0.0988 |
| 164 | 3 | 9 | 0.000800 | 0.0930 |
| 182 | 2 | 2 | 0 | 0.0876 |
| 184 | 2 | 2 | 0 | 0.0876 |
| 129 | 3 | 4 | 0.001200 | 0.0871 |
| 168 | 3 | 9 | 0.000933 | 0.0724 |
| 202 | 3 | 3 | 0.000267 | 0.0713 |
| 165 | 2 | 2 | 0 | 0.0700 |
| 166 | 2 | 2 | 0 | 0.0700 |
| 118 | 1 | 1 | 0 | 0.0693 |
| 167 | 1 | 1 | 0 | 0.0693 |
| 218 | 1 | 1 | 0 | 0.0693 |
| 219 | 1 | 1 | 0 | 0.0693 |
| 220 | 1 | 2 | 0 | 0.0693 |
| 203 | 2 | 2 | 0 | 0.0605 |
| 204 | 2 | 2 | 0 | 0.0605 |
| 157 | 2 | 7 | 0.001466 | 0.0605 |
| 225 | 2 | 3 | 0.001466 | 0.0591 |
| 273 | 2 | 2 | 0.003465 | 0.0537 |
| 250 | 1 | 1 | 0 | 0.0525 |
| 85 | 2 | 2 | 0 | 0.0462 |
| 86 | 2 | 2 | 0 | 0.0462 |
| 87 | 2 | 2 | 0 | 0.0462 |
| 90 | 2 | 2 | 0 | 0.0462 |
| 91 | 2 | 2 | 0 | 0.0462 |
| 92 | 2 | 2 | 0 | 0.0462 |
| 108 | 2 | 2 | 0 | 0.0462 |
| 150 | 2 | 2 | 0 | 0.0462 |
| 185 | 2 | 2 | 0 | 0.0462 |
| 210 | 2 | 2 | 0 | 0.0462 |
| 211 | 2 | 2 | 0 | 0.0462 |
| 305 | 2 | 2 | 0 | 0.0462 |
| 95 | 1 | 1 | 0 | 0.0457 |
| 102 | 3 | 7 | 0.000400 | 0.0415 |
| 141 | 1 | 1 | 0 | 0.0398 |

## Table D.1 Node Results for the Large Scale Project Network (continued)

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 128 | 1 | 1 | 0 | 0.0374 |
| 197 | 1 | 1 | 0 | 0.0374 |
| 271 | 1 | 1 | 0 | 0.0331 |
| 272 | 1 | 1 | 0 | 0.0331 |
| 215 | 1 | 1 | 0 | 0.0329 |
| 244 | 1 | 1 | 0 | 0.0262 |
| 224 | 1 | 2 | 0 | 0.0261 |
| 101 | 1 | 5 | 0 | 0.0237 |
| 149 | 1 | 1 | 0 | 0.0237 |
| 302 | 1 | 1 | 0 | 0.0237 |
| 274 | 1 | 1 | 0 | 0.0232 |
| 88 | 2 | 2 | 0.000133 | 0.0214 |
| 89 | 1 | 1 | 0 | 0.0149 |
| 300 | 1 | 1 | 0 | 0.0149 |
| 52 | 1 | 1 | 0 | 0.0080 |
| 53 | 1 | 1 | 0 | 0.0080 |
| 56 | 1 | 2 | 0 | 0.0080 |
| 57 | 1 | 2 | 0 | 0.0080 |
| 72 | 1 | 3 | 0 | 0.0080 |
| 73 | 1 | 3 | 0 | 0.0080 |
| 81 | 1 | 6 | 0 | 0.0080 |
| 82 | 1 | 6 | 0 | 0.0080 |
| 83 | 1 | 1 | 0 | 0.0080 |
| 84 | 1 | 1 | 0 | 0.0080 |
| 100 | 1 | 1 | 0 | 0.0080 |
| 111 | 1 | 1 | 0 | 0.0080 |
| 122 | 1 | 2 | 0 | 0.0080 |
| 123 | 1 | 2 | 0 | 0.0080 |
| 136 | 1 | 1 | 0 | 0.0080 |
| 137 | 1 | 1 | 0 | 0.0080 |
| 169 | 1 | 1 | 0 | 0.0080 |
| 188 | 1 | 1 | 0 | 0.0080 |
| 189 | 1 | 1 | 0 | 0.0080 |
| 192 | 1 | 7 | 0 | 0.0080 |
| 193 | 1 | 7 | 0 | 0.0080 |
| 198 | 1 | 1 | 0 | 0.0080 |
| 199 | 1 | 1 | 0 | 0.0080 |
| 206 | 1 | 1 | 0 | 0.0080 |
| 207 | 1 | 1 | 0 | 0.0080 |
| 245 | 1 | 3 | 0 | 0.0080 |
| 246 | 1 | 3 | 0 | 0.0080 |
| 251 | 1 | 1 | 0 | 0.0080 |
| 252 | 1 | 1 | 0 | 0.0080 |
| 289 | 1 | 1 | 0 | 0.0080 |

**Table D.1 Node Results for the Large Scale Project Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 290 | 1 | 1 | 0 | 0.0080 |
| 301 | 1 | 1 | 0 | 0.0080 |

# APPENDIX E

## E.Node Results for the CIS Market Network

### Table E.1

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 77 | 5 | 111 | 0.021261 | 1 |
| 131 | 4 | 20 | 0.022703 | 0.9889 |
| 130 | 5 | 5 | 0.024865 | 0.8632 |
| 161 | 4 | 94 | 0.010090 | 0.7136 |
| 66 | 3 | 6 | 0.005405 | 0.6534 |
| 298 | 2 | 18 | 0 | 0.6213 |
| 177 | 2 | 92 | 0 | 0.5424 |
| 144 | 3 | 3 | 0.014054 | 0.4909 |
| 151 | 2 | 2 | 0 | 0.3443 |
| 303 | 2 | 2 | 0 | 0.3443 |
| 296 | 1 | 1 | 0 | 0.3128 |
| 145 | 3 | 6 | 0.005405 | 0.3119 |
| 146 | 2 | 2 | 0 | 0.2807 |
| 120 | 1 | 1 | 0 | 0.2772 |
| 132 | 1 | 1 | 0 | 0.2772 |
| 67 | 1 | 4 | 0 | 0.2071 |
| 268 | 1 | 4 | 0 | 0.1134 |
| 85 | 2 | 6 | 0 | 0.0972 |
| 86 | 2 | 6 | 0 | 0.0972 |
| 87 | 2 | 6 | 0 | 0.0972 |
| 102 | 2 | 2 | 0.000360 | 0.0383 |
| 129 | 2 | 3 | 0.000360 | 0.0383 |
| 168 | 2 | 12 | 0.000360 | 0.0383 |
| 192 | 2 | 35 | 0.000360 | 0.0383 |
| 101 | 1 | 1 | 0 | 0.0270 |
| 128 | 1 | 1 | 0 | 0.0270 |
| 149 | 1 | 1 | 0 | 0.0270 |
| 164 | 1 | 9 | 0 | 0.0270 |
| 183 | 1 | 2 | 0 | 0.0270 |
| 193 | 1 | 33 | 0 | 0.0270 |
| 194 | 1 | 2 | 0 | 0.0270 |
| 271 | 1 | 3 | 0 | 0.0270 |
| 56 | 1 | 15 | 0 | 0.0128 |

**Table E.1 Node Results for the CIS Market Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 57 | 1 | 15 | 0 | 0.0128 |
| 60 | 1 | 2 | 0 | 0.0128 |
| 61 | 1 | 2 | 0 | 0.0128 |
| 68 | 1 | 12 | 0 | 0.0128 |
| 69 | 1 | 12 | 0 | 0.0128 |
| 74 | 1 | 1 | 0 | 0.0128 |
| 75 | 1 | 1 | 0 | 0.0128 |
| 88 | 1 | 1 | 0 | 0.0128 |
| 93 | 1 | 1 | 0 | 0.0128 |
| 94 | 1 | 1 | 0 | 0.0128 |
| 109 | 1 | 1 | 0 | 0.0128 |
| 110 | 1 | 1 | 0 | 0.0128 |
| 114 | 1 | 5 | 0 | 0.0128 |
| 115 | 1 | 5 | 0 | 0.0128 |
| 122 | 1 | 7 | 0 | 0.0128 |
| 123 | 1 | 7 | 0 | 0.0128 |
| 133 | 1 | 1 | 0 | 0.0128 |
| 137 | 1 | 4 | 0 | 0.0128 |
| 141 | 1 | 1 | 0 | 0.0128 |
| 152 | 1 | 1 | 0 | 0.0128 |
| 153 | 1 | 1 | 0 | 0.0128 |
| 157 | 1 | 2 | 0 | 0.0128 |
| 191 | 1 | 1 | 0 | 0.0128 |
| 195 | 1 | 1 | 0 | 0.0128 |
| 196 | 1 | 1 | 0 | 0.0128 |
| 202 | 1 | 1 | 0 | 0.0128 |
| 205 | 1 | 1 | 0 | 0.0128 |
| 215 | 1 | 1 | 0 | 0.0128 |
| 232 | 1 | 4 | 0 | 0.0128 |
| 237 | 1 | 1 | 0 | 0.0128 |
| 238 | 1 | 1 | 0 | 0.0128 |
| 244 | 1 | 2 | 0 | 0.0128 |
| 245 | 1 | 3 | 0 | 0.0128 |
| 246 | 1 | 3 | 0 | 0.0128 |
| 247 | 1 | 1 | 0 | 0.0128 |
| 248 | 1 | 1 | 0 | 0.0128 |
| 251 | 1 | 1 | 0 | 0.0128 |
| 252 | 1 | 1 | 0 | 0.0128 |
| 255 | 1 | 1 | 0 | 0.0128 |
| 272 | 1 | 10 | 0 | 0.0128 |
| 277 | 1 | 10 | 0 | 0.0128 |
| 300 | 1 | 1 | 0 | 0.0128 |
| 306 | 1 | 1 | 0 | 0.0128 |

## APPENDIX F

## F.Node Results for the Middle East Market Network

**Table F.1**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 145 | 7 | 22 | 0.022452 | 1 |
| 268 | 6 | 21 | 0.003719 | 0.9134 |
| 267 | 3 | 3 | 0.021212 | 0.6595 |
| 262 | 8 | 13 | 0.026171 | 0.6077 |
| 221 | 2 | 2 | 0 | 0.4845 |
| 269 | 2 | 2 | 0 | 0.4845 |
| 270 | 2 | 2 | 0 | 0.4845 |
| 308 | 2 | 2 | 0 | 0.4845 |
| 137 | 4 | 7 | 0.018871 | 0.3955 |
| 103 | 3 | 3 | 0.006336 | 0.2550 |
| 266 | 2 | 3 | 0 | 0.2473 |
| 307 | 2 | 2 | 0 | 0.2473 |
| 232 | 4 | 6 | 0.012121 | 0.2247 |
| 88 | 2 | 6 | 0.003306 | 0.1957 |
| 81 | 3 | 3 | 0 | 0.1933 |
| 138 | 3 | 7 | 0 | 0.1933 |
| 139 | 3 | 7 | 0 | 0.1933 |
| 140 | 3 | 7 | 0 | 0.1933 |
| 263 | 1 | 1 | 0 | 0.1750 |
| 264 | 1 | 1 | 0 | 0.1750 |
| 309 | 1 | 1 | 0 | 0.1750 |
| 77 | 4 | 22 | 0.000964 | 0.1215 |
| 101 | 2 | 2 | 0 | 0.1187 |
| 102 | 2 | 2 | 0 | 0.1187 |
| 292 | 2 | 2 | 0 | 0.1141 |
| 293 | 2 | 2 | 0 | 0.1141 |
| 216 | 1 | 1 | 0 | 0.1111 |
| 136 | 1 | 2 | 0 | 0.1111 |
| 121 | 3 | 4 | 0.001102 | 0.1061 |
| 161 | 3 | 24 | 0.000551 | 0.1049 |
| 117 | 4 | 10 | 0.001653 | 0.1028 |
| 177 | 2 | 16 | 0 | 0.0922 |
| 291 | 2 | 2 | 0.003306 | 0.0888 |
| 190 | 2 | 2 | 0 | 0.0748 |

**Table F.1 Node Results for the Middle East Market Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 191 | 2 | 2 | 0 | 0.0748 |
| 108 | 3 | 3 | 0.000275 | 0.0705 |
| 156 | 3 | 8 | 0.000275 | 0.0705 |
| 226 | 3 | 5 | 0.000275 | 0.0705 |
| 227 | 2 | 4 | 0 | 0.0598 |
| 242 | 2 | 2 | 0 | 0.0598 |
| 60 | 2 | 2 | 0 | 0.0598 |
| 185 | 2 | 2 | 0 | 0.0598 |
| 228 | 2 | 4 | 0 | 0.0598 |
| 305 | 2 | 2 | 0 | 0.0598 |
| 89 | 1 | 1 | 0 | 0.0594 |
| 135 | 3 | 5 | 0.000689 | 0.0499 |
| 76 | 1 | 4 | 0 | 0.0495 |
| 297 | 1 | 2 | 0 | 0.0495 |
| 78 | 2 | 2 | 0 | 0.0456 |
| 79 | 2 | 2 | 0 | 0.0456 |
| 80 | 2 | 2 | 0 | 0.0456 |
| 85 | 2 | 4 | 0 | 0.0456 |
| 86 | 2 | 4 | 0 | 0.0456 |
| 87 | 2 | 4 | 0 | 0.0456 |
| 90 | 2 | 2 | 0 | 0.0456 |
| 91 | 2 | 2 | 0 | 0.0456 |
| 92 | 2 | 2 | 0 | 0.0456 |
| 104 | 2 | 2 | 0 | 0.0456 |
| 105 | 2 | 2 | 0 | 0.0456 |
| 106 | 2 | 2 | 0 | 0.0456 |
| 150 | 2 | 4 | 0 | 0.0456 |
| 164 | 2 | 2 | 0 | 0.0456 |
| 165 | 2 | 2 | 0 | 0.0456 |
| 166 | 2 | 2 | 0 | 0.0456 |
| 210 | 2 | 4 | 0 | 0.0456 |
| 211 | 2 | 4 | 0 | 0.0456 |
| 212 | 2 | 2 | 0 | 0.0456 |
| 213 | 2 | 2 | 0 | 0.0456 |
| 214 | 2 | 2 | 0 | 0.0456 |
| 119 | 1 | 3 | 0 | 0.0441 |
| 120 | 1 | 4 | 0 | 0.0441 |
| 167 | 1 | 1 | 0 | 0.0441 |
| 151 | 1 | 8 | 0 | 0.0426 |
| 53 | 3 | 5 | 0.000413 | 0.0408 |
| 96 | 2 | 3 | 0.000413 | 0.0388 |
| 299 | 1 | 1 | 0 | 0.0331 |
| 107 | 1 | 1 | 0 | 0.0325 |
| 157 | 1 | 6 | 0 | 0.0325 |
| 249 | 1 | 1 | 0 | 0.0325 |

## Table F.1 Node Results for the Middle East Market Network (continued)

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 113 | 2 | 3 | 0.000275 | 0.0289 |
| 147 | 2 | 3 | 0.000275 | 0.0289 |
| 134 | 1 | 1 | 0 | 0.0265 |
| 220 | 1 | 2 | 0 | 0.0265 |
| 54 | 1 | 1 | 0 | 0.0233 |
| 55 | 1 | 1 | 0 | 0.0233 |
| 111 | 1 | 3 | 0 | 0.0233 |
| 301 | 2 | 2 | 0.000138 | 0.0210 |
| 95 | 1 | 1 | 0 | 0.0209 |
| 112 | 1 | 1 | 0 | 0.0176 |
| 131 | 1 | 1 | 0 | 0.0176 |
| 100 | 1 | 1 | 0 | 0.0146 |
| 285 | 1 | 1 | 0 | 0.0146 |
| 56 | 1 | 3 | 0 | 0.0078 |
| 57 | 1 | 3 | 0 | 0.0078 |
| 58 | 1 | 7 | 0 | 0.0078 |
| 59 | 1 | 7 | 0 | 0.0078 |
| 62 | 1 | 1 | 0 | 0.0078 |
| 63 | 1 | 1 | 0 | 0.0078 |
| 65 | 1 | 1 | 0 | 0.0078 |
| 116 | 1 | 1 | 0 | 0.0078 |
| 124 | 1 | 2 | 0 | 0.0078 |
| 125 | 1 | 2 | 0 | 0.0078 |
| 142 | 1 | 3 | 0 | 0.0078 |
| 143 | 1 | 3 | 0 | 0.0078 |
| 154 | 1 | 7 | 0 | 0.0078 |
| 155 | 1 | 7 | 0 | 0.0078 |
| 159 | 1 | 2 | 0 | 0.0078 |
| 160 | 1 | 2 | 0 | 0.0078 |
| 183 | 1 | 1 | 0 | 0.0078 |
| 198 | 1 | 1 | 0 | 0.0078 |
| 199 | 1 | 1 | 0 | 0.0078 |
| 224 | 1 | 3 | 0 | 0.0078 |
| 225 | 1 | 3 | 0 | 0.0078 |
| 240 | 1 | 2 | 0 | 0.0078 |
| 241 | 1 | 2 | 0 | 0.0078 |
| 250 | 1 | 1 | 0 | 0.0078 |
| 256 | 1 | 1 | 0 | 0.0078 |
| 257 | 1 | 1 | 0 | 0.0078 |
| 258 | 1 | 1 | 0 | 0.0078 |
| 259 | 1 | 1 | 0 | 0.0078 |
| 281 | 1 | 1 | 0 | 0.0078 |
| 282 | 1 | 1 | 0 | 0.0078 |

## APPENDIX G

## G.Node Results for the Africa Market Network

### Table G.1

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 83 | 5 | 6 | 0.003410 | 1 |
| 172 | 2 | 3 | 0 | 0.5849 |
| 179 | 2 | 2 | 0 | 0.5849 |
| 180 | 2 | 2 | 0 | 0.5849 |
| 304 | 2 | 2 | 0 | 0.5849 |
| 84 | 1 | 1 | 0 | 0.3692 |
| 117 | 3 | 5 | 0.000853 | 0.2904 |
| 283 | 2 | 4 | 0 | 0.2477 |
| 284 | 2 | 4 | 0 | 0.2477 |
| 161 | 3 | 5 | 0.002131 | 0.1785 |
| 202 | 2 | 2 | 0 | 0.1748 |
| 203 | 2 | 2 | 0 | 0.1748 |
| 204 | 2 | 2 | 0 | 0.1748 |
| 278 | 2 | 2 | 0 | 0.1748 |
| 279 | 2 | 2 | 0 | 0.1748 |
| 280 | 2 | 2 | 0 | 0.1748 |
| 286 | 2 | 2 | 0 | 0.1748 |
| 287 | 2 | 2 | 0 | 0.1748 |
| 288 | 2 | 2 | 0 | 0.1748 |
| 229 | 2 | 3 | 0.001279 | 0.1379 |
| 118 | 1 | 1 | 0 | 0.1341 |
| 151 | 1 | 2 | 0 | 0.0960 |
| 234 | 1 | 1 | 0 | 0.0960 |
| 227 | 2 | 2 | 0.000853 | 0.0930 |
| 273 | 2 | 2 | 0.000853 | 0.0930 |
| 231 | 1 | 1 | 0 | 0.0749 |
| 66 | 1 | 1 | 0 | 0.0572 |
| 274 | 1 | 1 | 0 | 0.0572 |
| 64 | 1 | 1 | 0 | 0.0188 |
| 65 | 1 | 1 | 0 | 0.0188 |
| 72 | 1 | 3 | 0 | 0.0188 |
| 73 | 1 | 3 | 0 | 0.0188 |
| 77 | 1 | 2 | 0 | 0.0188 |
| 81 | 1 | 7 | 0 | 0.0188 |

**Table G.1 Node Results for the Africa Market Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 82 | 1 | 7 | 0 | 0.0188 |
| 102 | 1 | 1 | 0 | 0.0188 |
| 126 | 1 | 1 | 0 | 0.0188 |
| 127 | 1 | 1 | 0 | 0.0188 |
| 135 | 1 | 1 | 0 | 0.0188 |
| 145 | 1 | 5 | 0 | 0.0188 |
| 157 | 1 | 1 | 0 | 0.0188 |
| 162 | 1 | 2 | 0 | 0.0188 |
| 163 | 1 | 2 | 0 | 0.0188 |
| 168 | 1 | 1 | 0 | 0.0188 |
| 170 | 1 | 1 | 0 | 0.0188 |
| 171 | 1 | 1 | 0 | 0.0188 |
| 173 | 1 | 7 | 0 | 0.0188 |
| 174 | 1 | 7 | 0 | 0.0188 |
| 175 | 1 | 4 | 0 | 0.0188 |
| 176 | 1 | 4 | 0 | 0.0188 |
| 177 | 1 | 1 | 0 | 0.0188 |
| 178 | 1 | 1 | 0 | 0.0188 |
| 188 | 1 | 2 | 0 | 0.0188 |
| 189 | 1 | 2 | 0 | 0.0188 |
| 208 | 1 | 1 | 0 | 0.0188 |
| 209 | 1 | 1 | 0 | 0.0188 |
| 219 | 1 | 1 | 0 | 0.0188 |
| 235 | 1 | 1 | 0 | 0.0188 |
| 236 | 1 | 1 | 0 | 0.0188 |
| 243 | 1 | 2 | 0 | 0.0188 |
| 244 | 1 | 1 | 0 | 0.0188 |
| 253 | 1 | 1 | 0 | 0.0188 |
| 254 | 1 | 1 | 0 | 0.0188 |
| 262 | 1 | 1 | 0 | 0.0188 |
| 265 | 1 | 1 | 0 | 0.0188 |
| 268 | 1 | 5 | 0 | 0.0188 |
| 272 | 1 | 1 | 0 | 0.0188 |
| 289 | 1 | 1 | 0 | 0.0188 |
| 290 | 1 | 1 | 0 | 0.0188 |
| 302 | 1 | 1 | 0 | 0.0188 |

# APPENDIX H

## H.Node Results for the Europe Market Network

**Table H.1**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 51 | 3 | 3 | 0.003700 | 1 |
| 97 | 2 | 2 | 0 | 0.8161 |
| 98 | 2 | 2 | 0 | 0.8161 |
| 52 | 2 | 2 | 0.002775 | 0.5816 |
| 77 | 2 | 2 | 0 | 0.4817 |
| 121 | 2 | 3 | 0 | 0.4817 |
| 148 | 2 | 3 | 0 | 0.4817 |
| 182 | 2 | 2 | 0 | 0.4817 |
| 183 | 2 | 2 | 0 | 0.4817 |
| 184 | 2 | 2 | 0 | 0.4817 |
| 229 | 2 | 2 | 0 | 0.4817 |
| 230 | 2 | 2 | 0 | 0.4817 |
| 231 | 2 | 2 | 0 | 0.4817 |
| 169 | 1 | 1 | 0 | 0.2702 |
| 135 | 2 | 2 | 0.000925 | 0.1364 |
| 151 | 2 | 2 | 0.000925 | 0.1364 |
| 60 | 1 | 1 | 0 | 0.0964 |
| 150 | 1 | 1 | 0 | 0.0964 |
| 161 | 1 | 1 | 0 | 0.0964 |
| 218 | 1 | 1 | 0 | 0.0964 |
| 70 | 1 | 1 | 0 | 0.0356 |
| 71 | 1 | 1 | 0 | 0.0356 |
| 96 | 1 | 1 | 0 | 0.0356 |
| 101 | 1 | 3 | 0 | 0.0356 |
| 102 | 1 | 3 | 0 | 0.0356 |
| 129 | 1 | 1 | 0 | 0.0356 |
| 130 | 1 | 1 | 0 | 0.0356 |
| 133 | 1 | 1 | 0 | 0.0356 |
| 145 | 1 | 2 | 0 | 0.0356 |
| 156 | 1 | 1 | 0 | 0.0356 |
| 158 | 1 | 1 | 0 | 0.0356 |
| 164 | 1 | 1 | 0 | 0.0356 |
| 168 | 1 | 1 | 0 | 0.0356 |
| 186 | 1 | 1 | 0 | 0.0356 |

**Table H.1 Node Results for the Europe Market Network (continued)**

| Id | Degree | Weighted Degree | Betweenness Centrality | Eigenvector Centrality |
|---|---|---|---|---|
| 187 | 1 | 1 | 0 | 0.0356 |
| 192 | 1 | 1 | 0 | 0.0356 |
| 197 | 1 | 1 | 0 | 0.0356 |
| 200 | 1 | 2 | 0 | 0.0356 |
| 201 | 1 | 2 | 0 | 0.0356 |
| 206 | 1 | 1 | 0 | 0.0356 |
| 225 | 1 | 1 | 0 | 0.0356 |
| 260 | 1 | 1 | 0 | 0.0356 |
| 261 | 1 | 1 | 0 | 0.0356 |
| 268 | 1 | 2 | 0 | 0.0356 |
| 272 | 1 | 4 | 0 | 0.0356 |
| 277 | 1 | 4 | 0 | 0.0356 |
| 294 | 1 | 1 | 0 | 0.0356 |
| 295 | 1 | 1 | 0 | 0.0356 |

# APPENDIX I

## I. Companies in the ENR 250 list for the year 2013

### Table I.1

| ID | Company Name | 2013 ENR Rank |
|---|---|---|
| 101 | Bechtel, San Francisco, Calif., U.S.A. | 3 |
| 115 | STRABAG SE, Vienna, Austria | 6 |
| 183 | Astaldi SpA, Rome, Italy | 62 |
| 231 | BESIX SA, Brussels, Belgium | 63 |
| 253 | Renaissance Construction, Ankara, Turkey | 64 |
| 308 | Taisei Corp., Tokyo, Japan | 76 |
| 102 | Enka Construction & Industry Co. Inc., Istanbul, Turkey | 79 |
| 168 | Tekfen Construction and Installation Co. Inc., Istanbul, Turkey | 85 |
| 74 | ANT YAPI Industry & Trade JSC, Istanbul, Turkey | 94 |
| * | TAV Construction, Istanbul, Turkey | 103 |
| 164 | GAMA, Ankara, Turkey | 118 |
| 128 | Dia Holding FZCO, Dubai, U.A.E. | 120 |
| 77 | Yuksel Insaat Co. Inc., Ankara, Turkey | 124 |
| 225 | Cengiz Construction Industry & Trade Co. Inc., Istanbul, Turkey | 127 |
| 129 | IC Ictas Insaat Sanayi Ve Ticaret AS, Ankara, Turkey | 129 |
| 157 | Onur Taahhut Ticaret Ltd. Stl., Ankara, Turkey | 135 |
| 216 | Lakeshore TolTest Corp., Detroit, Mich., U.S.A. | 144 |
| ** | MAPA Insaat ve Ticaret AS, Ankara, Turkey | 146 |
| 290 | Yapi Merkezi Insaat ve Sanayi AS, Istanbul, Turkey | 159 |
| 245 | Kayi Insaat San. ve Tic. AS, Istanbul, Turkey | 171 |
| 202 | Kontek Construction, Istanbul, Turkey | 174 |
| 66 | Alarko Contracting Group, Gebze/Kocaeli, Turkey | 176 |
| 135 | Limak Insaat Sanayi ve Ticaret AS, Ankara, Turkey | 180 |
| 156 | Eser Contracting and Industry Co.Inc., Ankara, Turkey | 182 |
| 145 | Tepe Insaat Sanayi A.S., Ankara, Turkey | 188 |
| 137 | Metag Insaat Ticaret AS, Ankara, Turkey | 190 |

**Table I.1 Companies in the ENR 250 list for the year 2013 (continued)**

| ID | Company Name | 2013 ENR Rank |
|---|---|---|
| 267 | Habtoor Leighton Group, Dubai, U.A.E. | 193 |
| 244 | Summa Turizm Yatirimciligi AS, Ankara, Turkey | 198 |
| 192 | Hazinedaroglu Construction Group, Istanbul, Turkey | 200 |
| 130 | Dogus Insaat ve Ticaret AS, Istanbul, Turkey | 203 |
| 177 | Nurol Construction and Trading Co., Ankara, Turkey | 208 |
| 232 | Yenigun Construction Inc., Ankara, Turkey | 213 |
| 224 | MAKYOL Constr. Indus. Tourism & Trading Inc., Istanbul, Turkey | 218 |
| 262 | STFA Construction Group, Istanbul, Turkey | 240 |
| 150 | Kolin Insaat Turizm Sanayi ve Ticaret AS, Ankara, Turkey | 242 |

- TAV Construction is a continued collaboration between Tepe (ID-145) and Akfen (ID-268). All their projects were taken as a tie in between these companies.
- MAPA Insaat ve Tic AS is a group company of MNG Holding (ID-96).