ABSTRACT

Title of Thesis:	EMERGENCE OF PRIVATE SECTOR IN PUBLIC-PRIVATE PARTNERSHIP PROJECTS AND ANALYSIS OF RELATIONSHIP BETWEEN STAKEHOLDER NETWORK CENTRALITY AND PROJECT PERFORMANCE
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Infrastructure and construction projects are large, complex, and arduous ventures involving various actors or stakeholders. However, taking decisions based on the individual attributes of stakeholders is insufficient. The emergence of the private sector in Public-Private Partnership (PPP) projects reveal the need to consider how multiple stakeholders in an inter-reliant network can impact the project's performance. This research uses stakeholder and social network theories, and analyzes the centrality measures – total-degree, betweenness, closeness – of the key public and private entities against two project performance criteria: cost and schedule. Findings reveal that private sector becomes significantly more central in PPP projects, and there is a statistically significant correlation between private sector centrality measures and project schedule performance. In addition, the research reveals that the number of public agencies or sponsors involved in the project also plays a significant role in determining project performance.

EMERGENCE OF PRIVATE SECTOR IN PUBLIC-PRIVATE PARTNERSHIP PROJECTS AND ANALYSIS OF RELATIONSHIP BETWEEN STAKEHOLDER NETWORK CENTRALITY AND PROJECT PERFORMANCE

by

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List of Abbreviations

CMAR	Construction-Management-At-Risk
DB	Design-Build
DBB	Design-Bid-Build
DBF	Design-Build Finance
DBFM	Design-Build-Finance-Maintain
FHWA	Federal Highway Administration
GC	General Contractor
PMI	Project Management Institute
PPP	Public-Private Partnership
SPV	Special Purpose Vehicle
TIFIA	Transportation Infrastructure Finance and Innovation Act
USDOT	United States Department of Transportation

Chapter 1 Introduction

Introduction

Infrastructure and construction projects are large, complex, and arduous ventures where various components of a project are undertaken or carried out by different companies in different phases (Clough, Sears, & Sears, 2000). Each phase of construction involves various actors or participants. These stakeholders can either benefit or negatively impact projects (Chinyio & Olomolaiye, 2010). Hence, it is necessary to understand the needs and expectations of these actors or stakeholders, and develop strategies that can help to satisfy them, and to prevent "their negative influences" that might harm the firm or a project's goals and objectives (Chinyio & Olomolaiye, 2010).

By knowing and understanding one's stakeholders, their needs, expectations, as well as their roles in a project, a project manager will have the artillery to be better able to manage the project stakeholders. As proposed by Rowley (1997), in his article on "Network Theory of Stakeholder Influences", relationships between stakeholders in a project or an organization have evolved from a "dyadic relationship". Knowing how one stakeholder can influence the project is not enough. It has become critical to understand how multiple stakeholders in an inter-reliant network can impact the project, and eventually a project's performance. Therefore, in addition to the individual stakeholders and their behavior in a project, it is important to understand the behavior of the entire network and how they correlate with each other. It is interesting to find how the influence changes when networks are introduced into the equation.

Problem Statement

Stakeholder analysis is an extremely important tool for project managers or organization leaders to identify the parties, consider their opinions, and take into account their expectations in the decision-making process. However, as stated by (Chung & Crawford, 2016) in their article on "The Role of Social Networks Theory and Methodology for Project Stakeholder Management", there are certain limitations of stakeholder analysis. Social networks and their roles in the organization or project are not considered, which is the core of links between different parties. Analysis tools such as Salience Model has been disparaged for not considering stakeholders from "lower-ranked" groups.

This is the gap which could possibly filled by social network analysis. Instead of focusing on the individual stakeholders and the attributes that they carry through their position, power, authority, or salience, social network analysis considers the network formed between these stakeholders; characteristics of the ties between them are taken into account. Thus, providing a different perspective on stakeholders (Chung & Crawford, 2016). Moreover, a research by Wang & Huang (2006) on "The relationships between key stakeholders' project performance and project success" in the Chinese construction industry shows the most critical factor for project success is the "relation" between the key stakeholders based on the triple constraint criteria.

Therefore, instead of just linking stakeholder analysis and management with project performance (Atkin & Skitmore, 2008), project performance should also be linked with social network analysis or analyzing the relationships between stakeholders. More specifically, project performance needs to be linked with the measures of social network analysis. One of the measures that is taken into account is centrality of stakeholders. This is a "micro" level measure allowing us to assess a given stakeholder relative to the entire stakeholder network.

Research Objectives

This thesis aims to determine whether private sector parties become more central or influential in public-private partnership projects over the design and construction phase, and to find relationships between three centrality measures – total-degree, betweenness, and closeness – and project performance. In addition, this thesis also aims to identify contribution, if any, number of public agencies to project performance. Data for this thesis will be collected through "Information Source for Major Highway Transportation Projects" database, a project sponsored by Federal Highway Administration and undertaken by University of Maryland, College Park with Battelle as the lead contractor.

Based on this data, the author will be able to determine the trend in project performance based on three types of project procurement methods, and determine if project performance, including cost and schedule performance, will be impacted by the centrality of two key stakeholders. The results from this thesis will provide evidence of the emergence of private partners in large public-private partnership projects, their impact on project performance, and the importance of considering stakeholder networks rather than focusing only on individuals separately.

Hypothesis

The stakeholder theory and social network theory suggests that understanding one's key stakeholders can lead to better communication, engagement, and overall management process, eventually leading to a better project performance from increasing positive impacts and decreasing negative ones from the project stakeholders (Sutterfield, Friday-Stroud, & Shivers-Blackwell, 2006).

Due to the limitations of stakeholder management in understanding the stakeholder network, social network theory and its tools and methods can be used to identify key players in the network and to understand their level of influence over other stakeholders (Chung & Crawford, 2016). Therefore, this thesis aims to identify the relationship between network centrality measures and project performance based on cost and schedule. To do this, this thesis compares empirical project performance data on three general types of procurement methods design-build/construction-management-at-risk, design-bid-build, and public-private partnership projects to find out which method provides the best project performance given the centrality of two main stakeholders – client and contractor/concessionaire.

Given that public-private partnership projects outperform traditionally procured projects (Ramsey & El Asmar, 2015), and using the centrality measures, this thesis also aims to identify if there is an emergence of the general contractor or special purpose vehicle in public-private partnership projects or alternative project delivery methods, and whether the general contractor or special purpose vehicle being more central than the client has any impact on project performance.

Additionally, this thesis aims to find out if the data collected supports or disagrees with the "Triple Constraint" theory which states that the project cost is directly affected by the project schedule, and that there is a predictable trend to this relationship. In addition, project sponsors and their activities also impact the project performance or success based on the type activities, interaction with client and project manager, and project management as a whole (Bryde, 2008). While the paper by (Bryde, 2008) discusses ‘how’ project sponsors behave in the projects and its impact on project performance, this thesis, based on this theory, aims to determine whether the number of public agencies or sponsors has an impact on cost and schedule performance.

Hypothesis 1*: If projects are procured as public-private partnership projects or using alternative project delivery methods, the general contractors or special purpose vehicles becomes more central than the clients.*

Hypothesis 2*: Based on Triple Constraint theory, if project schedule is delayed, project cost will increase.*

Hypothesis 3*: If the centrality measures – total-degree, betweenness, and closeness – of general contractor/special purpose vehicle increases, cost and schedule performance improve.*

Hypothesis 4*: If the number of public agencies/sponsors is greater, cost and schedule performance will decrease.*

Thesis Format

Following the first chapter, the remaining chapters are categorized into four parts. The ‘Literature Review’ chapter will discuss on the existing literature on stakeholders, stakeholder analysis and its importance. This chapter will also discuss different types of stakeholders and provide brief descriptions on how to manage them. Furthermore, social network analysis and centrality will also be discussed. Finally, an overall stakeholder management framework will be provided.

'Research Methodology' chapter will provide a brief description of the database project and discuss on what type of data was used in the analysis, and the data sources. The centrality measures are explained in detail along with the equations used in formulating the results obtained. In addition, two tools that are used in stakeholder analysis are also explained.

'Empirical Analysis' chapter will provide the results obtained through various analysis. Descriptive statistics as well as regression analysis of the three centrality measures considered in the analysis along with the project performance data are explained and discussed.

'Discussion' will be the last chapter that will provide the discussion on the results obtained against the hypotheses proposed, and conclusion of the study based on the data collected and analyzed. Research limitations are also presented and described, along with the limitations on data availability. Suggestions for potential future research are provided, followed by recommendations on how this research can contribute to the state of practice in the construction industry and the importance of considering network behaviors in addition to individual stakeholder behaviors.

Finally, the 'Appendices' section will provide the data sets used in the analysis in 'Results and Findings' chapter along with network diagrams and centrality measures for all projects studied in this research.

Chapter 2 Literature Review

Stakeholders and their Importance

Who are Project Stakeholders? According to Project Management Institute (PMI 2013), "Project Stakeholders are individuals, groups, or organizations who may affect, be affected by, or perceive themselves to be affected by a decision, activity, or outcome of a project. They are comprised of persons and organizations such as customers, sponsors, the performing organization, and the public who are actively involved in the project, or whose interests may be positively or negatively affected by the execution or completion of the project," and/or vice versa. In other words, anyone who is in any way connected to the project would be considered as a stakeholder of that project. As (Freeman, Harrison, & Zyglidopoulos, 2018) has put forward, the stakeholder view provides a different perspective on how the "companies and people" can "create value and trade with each other". Due to this, it will be beneficial to identify who the stakeholders of a project are and know each stakeholder's influence on the project.

As a Project Manager, there are four Project Stakeholder Management processes that one needs to follow, as given in the PMI (2013). The four processes are: "Identify Stakeholders, Plan Stakeholder Management, Manage Stakeholder Management, and Control Stakeholder Management." Among these, one that will be discussed in this thesis will be Stakeholder Analysis, which is one of the important tools and techniques in identifying stakeholders and their expectations, and planning strategies to manage them. Stakeholders can range from the clients, contractors, and consultants who are directly involved in the project to local agencies, communities, and media, who can affect or can be affected by the project. Therefore, it is critical for a project manager to be able to identify, understand and possibly segregate the stakeholders into different categories to develop corresponding strategies for each category.

This is important because is stakeholder management is an important and necessary “skill” required in construction projects (Atkin & Skitmore, 2008). Not only this, a project’s successful completion is based on the fulfilment of requirements or expectations set by the stakeholders (Atkin & Skitmore, 2008); they also add that failing “to address the concerns” or stakeholders has led to many project failures.

Types of Stakeholders

Stakeholders play a big role in determining the output of the project. Hence, the project manager has the duty to identify and allocate the stakeholders in their rightful place. Clients and contractors would have a larger stake in, or high influence on and by, the project than a subcontractor. This difference comes from the difference in power, interest, or commitment that the project manager has which is obviously much higher than that of the welder. A deeper look into this distinction will show that the stakeholders who have more to lose are the ones who have bigger influence, stronger power, and more interest in the project. Stakeholders such as the client, sponsors, lead contractors, architects, lead engineering firms, equity investors will be the ones most concerned about the outcome of a project. Even in this category, there is a difference in interests of different stakeholders such as the sponsors or investors, and the contractor; the sponsors or investors will be concerned about the economical aspect of the project or simply, their return of investment, whereas the contractor will be more worried about the planning, execution, and completion of the project within a given deadline, budget, and the project's requirements.

While identifying stakeholders, it is important to keep an open mind. As the definition says "individuals, groups, or organizations who may affect, be affected by, or perceive themselves to be affected by a decision, activity, or outcome of a project.", it includes people who are working on the project as well as who have no ties with any of the companies, like people or organizations who have ties with the project such that their livelihood or business is affected by this project either in a negative or a positive way. As Watt (2014) has mentioned in the article on stakeholder management, a project to add lanes to a highway will benefit the motorists, but negatively affect the residents around the project site due to noises during construction, and far-reaching implications such as traffic noise and pollution after construction. Due to this wide range of possibilities of stakeholders of a project, it would be a good idea to create a stakeholder register containing key information about them including contact information, requirements and/or expectations, their interest in the project and its different stages, their power over the project, and so on (Meredith, Shafer and Mantel, 2017). Besides this register, a separate stakeholder issue log should also be maintained to catalog issues that arose and how they were resolved. This system allows the project manager to properly analyze which stakeholder is to be prioritized based on the stage of the project or any circumstantial condition. In general, there are two types of stakeholders: internal and external.

Internal Stakeholders

As mentioned earlier, stakeholders can cover a vast range of people that have to be considered when planning, designing, constructing, or executing a task in a project. Internal stakeholders are the ones who work in the project as the clients or sponsors, the project team and their manager, lenders, contractors and subcontractors, consultants, engineering firms, labors, vendors, and so forth ((Khan, Skibniewski, & Cable, 2017). These categories of in-project stakeholders are directly influencing or affecting the outcome of the project. However, the outcome of the project is not conceived to be equally significant by all parties involved. Therefore, even within a project, stakeholders will have different priorities. Contractors and sub-contractors are worried about the quality of their work because it directly affects their paycheck from the owners, and the owners are concerned about the quality of the work because it will reflect the economic or basically any potential of the project, like attracting investors. Even though both these parties are apprehensive about the same aspect of the project, their reasons are different, which is due to differences in their interest, power, and commitment towards the project.

External Stakeholders

Stakeholders with its broad array containing different types of people and parties also include those who are not directly involved with the project. In a construction site around in downtown, it is virtually impossible to find an isolated piece of land. Any project site will have houses, buildings, offices, malls around its vicinity. This means that the residents of the surrounding buildings are indirectly impacted by the project, making them stakeholders. Usually in public projects, the government entity conducts public hearing. This is one of the ways to involve out-of-project stakeholders to get their input of their personal contact information, the ways they are affected, to what extent, and what remedies do they suggest for those problems. This type of local community stakeholder is as equally important as the ones who work in the project. Other out-of-project stakeholders would include the government and banks. Governments can introduce new laws such as raising the minimum wage of workers that can affect the project operation, and banks can charge different interest rates or decide whether to permit or deny a loan (BBC, 2014). Moreover, even the press or the media can be considered as a stakeholder (MindTools.com). The Media in today's world has vast influence on the public, which can greatly affect the project, either leaning towards success or failure. Another important stakeholder who does not, technically, work on site is the supplier for the project. The suppliers also play a major role in determining the project schedule, budget, as well as the quality. In summary, external stakeholders include local residents affected by the project's activities, environmentalists, media, local public and political agencies, and even researchers (Khan et al., 2017).

Stakeholder Analysis

After identifying all the stakeholders of the project, who are on and off site, the project manager and his/her team will have to analyze each stakeholder's importance, influence, interest, and commitment towards the project. This step, also called Stakeholder Analysis, is crucial in keeping the project progress stable in the future because it will show which stakeholders are to be contacted or informed about specific parts of the project in a particular time when necessary. Stakeholder

Analysis, according to PMI (2013), "is a technique of systematically gathering and analyzing quantitative and qualitative information to determine whose interests should be taken into account throughout the project. It identifies the interests, expectations, and influence of the stakeholders and relates them to the purpose of the project. It also helps to identify stakeholder relationships (with the project and with other stakeholders) that can be leveraged to build coalitions and potential partnerships to enhance the project's chance of success, along with stakeholder relationships that need to be influenced differently at different stages of the project or phase." In other words, stakeholder analysis is the process of knowing which stakeholder should be given more importance and which should be given less. PMI (2013) also presents a few steps that stakeholder analysis process follows:

- Firstly, identify all possible stakeholders and their information such as their roles and interest in the project, knowledge and expectations of the project, their department and influence levels. Key stakeholders are the decision makers or part of the management who are affected by the outcome of the project and are usually easy to identify. They include sponsors, the project manager, and the client. Interviewing already known stakeholders can help to identify other stakeholders, so that the list contains all potential stakeholders.
- Secondly, the support or the potential impact the stakeholders can generate should be analyzed. Based on this information, the stakeholders should be classified to define and assign specific strategies for approach. This classification helps to prioritize different stakeholders, especially in a large

community, which makes stakeholder communication and their expectation management efficient.

- Finally, evaluate the possible reaction or response of key stakeholders in various situations to plan on how to stimulate them to increase their support and decrease possible negative impacts.

This can be done by using tools like Power-Interest Grid, or Commitment Assessment Matrix (Meredith, Shafer and Mantel, 2017). Similarly, PMI (2013) provides more models that can be used for stakeholder analysis such as, Power/Interest grid, Power/Influence grid, Influence/Impact grid, and Salience model.

Now, why is stakeholder analysis important or necessary? Besides the fact that it lists out all the stakeholders of a project along with their information as well as their connection to the project with additional information on various ways to deal with different stakeholders, stakeholder analysis can also provide the necessary medium of communication when contacting or informing any of the stakeholders. For example, the board of directors should be contacted using a formal letter or an official email, but a team member could be notified of something via text message or a casual talk during lunch hours. Using the same concept in an organizational level, general contractors would have to conduct weekly or monthly meetings with clients and sponsors to provide them construction progress updates, in addition to the daily communication on site. On the other hand, this type of formal communication would not be necessary when dealing with subcontractors.

The stakeholder register, which can be drafted using expert judgment such as the help of "senior management, other units in the organization, identified key stakeholders, project managers with similar experiences, subject matter experts (SMEs) in the business or project area, industry group and consultants, and professional and technical associations, regulatory bodies, and nongovernmental organizations (NGOs)" (PMI, 2013), provides necessary information of stakeholders, their interest levels, expectations, importance and influence in the planning phases of the project to avoid unexpected mishaps midway through the project. It is the project manager's duty to gather as much information possible through meetings, interviews, consultations, surveys, focus groups, and so on. Using this information, project managers can distinguish key stakeholders from non-key ones and plan accordingly with their expectations and requirements taken into consideration. In addition to this, the information gathered can be incorporated with the required medium of communication as well as the urgency in which it should be communicated.

According to Project-Management.com (2017), "stakeholder analysis can help to identify:

- Interests of all stakeholders
- Potential issues that could disrupt the project
- Key people for information distributing during project execution
- Groups that should be encouraged to participate in different stages of the project
- Communication planning and stakeholder management strategy during project planning phase
- Ways to reduce potential negative impacts and manage negative stakeholders"

Knowing who the stakeholders are can help to determine possible shortcomings that may be caused by any of the stakeholder which can help avoid unexpected disasters. Moreover, the project manager will know who to engage with and involve more in the project depending on the project timeline. In addition to this, Project-Management.com (2017) has also given a list of importance of managing stakeholders' expectations and ensuring their active involvement using stakeholder analysis:

- Important for continuity of the project and its successful completion
- Provides a platform for people to ask questions, give suggestions, or show their concern about the project
- Gives a sense of responsibility and accountability
- Allows effectively identifying risk and planning a response for it
- Creates excellent learning opportunities for the project team and stakeholders

Stakeholder Network

Stakeholder network as defined by Svendsen & Laberge (2005), is an interconnection of "groups, organizations and/or individuals" working with each other to tackle issues or explore opportunities that are "complex and shared cross-boundary". Based on the conference paper "presented at PMI® Global Congress 2014" by Deguire (2014), the concept of stakeholder network can be generally divided into three categories: centralized, decentralized, and distributed. As Deguire (2014) explains, centralized network is customary such that there is an entity which sits in the center of the network, collecting information and engaging with stakeholders. Moreover, due to discrepancies in stakeholder salience, such as power or interest, there forms a hierarchy following each stakeholder's priority level, based on which stakeholder engagement is defined. Hence, if any entity chose to communicate with another, they would need to go through the central one as there is no connection established between them. Decentralized network, based on Deguire's paper, seems to be a hybrid of centralized and distributed networks, where a few entities act as the interconnections for a number of other parties, and these few entities are connected with one another maintaining the connections between all the parties involved. In this type of network, the communication is similar to that of centralized such that it would need to be done through the interconnecting entities. However, due to the lack of a single principal entity, the communication channel is elongated. Lastly, distributed network is a "more resilient" network model due to its high number of interconnectivities between various entities which allows communication of information through multiple ways or routes rather than following a preset path depicted in centralized and decentralized models. In addition, no single entity is giving the orders. Rather, each entity brings its own perspectives and value to the network given their diversity.

Relating the three network models to project delivery methods, the traditional DBB would be similar to centralized network where the client/owner controls majority of the aspects of the project such as design, planning, contracts, funding, and so forth. Therefore, any other stakeholder or organization such as a contractor or an architect would have to communicate with each through the client as they are not connected with each other. A DB or a PPP would be more relatable to decentralized or distributed depending on the parties involved in a project as well as their functions. DB, for instance, requires direct communication between the design and construction team along with the client providing their requirements, making a distributed network among the three entities, and centralized over the client when financiers, advisors, and other public sponsors are dealt by the client. Likewise, a PPP project will reflect a decentralized network as the client or sponsor and the private concessionaire, while have a contract between themselves, will both have their own set of advisors and consultants. Clients will be dealing with lenders, advisors, environmental and public agencies, while concessionaires will be managing contractors, designers, equity investors, and lenders.

Stakeholder Relationships

Relationships between stakeholders can be established and developed in many ways. Some relationships are based on good faith such as an architect or a design engineer with the responsibility of coming up with a structure that is beneficial to the local residents while fulfilling the requirements of their clients; some can be based on oral agreements or a shake of hands between two parties such as a contractor and a supplier; and lastly, some relationships are based on contractual agreements which comprises of a written agreement between the involved parties along with specific conditions and requirements. These relationships or networks, for the purpose of social network analysis can be categorized into "networks of contractual relationships", "performance incentives", and "information exchange" (Pryke, 2004). The relationships exhibited in this thesis between the stakeholders in the project database are based on formal written agreements or contracts. Using contractual relationships to represent connections between stakeholders not only shows that there is a relation or a link between specific parties, but also gives an idea of what terms and conditions the parties involved adhered to, creating an obligation to one another to fulfill the contract requirements (UpCounsel, 2019). As stated by UpCounsel (2019), reciprocity is necessary for a contractual relationship to exist. In other words, one party provides goods or services in exchange for monetary compensation from the other party to which the goods or services are provided to. Based on this, the relationships shown in this thesis are all two-way connections between each stakeholder pair. In addition, contractual relationships also plays a part in determining the centrality of stakeholders based on ‘power’, which is derived from the research conducted by Loosemore in 1999 (Pryke, 2004).

Every legally bound contract has three attributes among others that are considered significant in determining whether a contract should exist. Harvard University’s Financial Administration (The President and Fellows of Harvard College, 2019) lists these attributes as important factors to be considered before getting into negotiations. First, is to determine the “business objectives” of the contract or the opportunities for both parties. In addition, scope of work and responsibilities of each party should also be outlined. Second, is the “business risks” that come about due to the contract. Risk and risk allocation are different for each party based on the type of contract and their position in the contract. Clients’ risk would be delays in work or unexpected financial burdens, whereas contractor’s risks would be facing penalties or fines in case of being unable to achieve the contract objectives. And third, is to see if the compensation expected or proposed is reasonable based on the work to be performed considering the risks allocated. This claim is supported by a research article by Cox and Thompson (1997). They state the “contractual terms” as “the relationship, the risk apportionment, the division of responsibilities and the reimbursement mechanism.” For example, a client hires a contractor to construct a bridge. The objective of the contract is to build a safe and reliable bridge within a certain amount of time and cost. Risk is allocated based on the scope of work. If the same contractor was to construct the bridge from design to final completion, then usually risks involving design, construction, equipment, materials, supplies and so forth would be carried by the contractor, whereas risks involving permits, environmental processes, right-of-way, and so forth would be the client’s responsibility, unless stated otherwise in the contract. In addition, risks would also encompass penalties or fees that either of the party will have to pay for depending on the fulfilment of the requirements as stated in the contract. Then, based on the scope of work and risks involved, the contractor can state a reasonable remuneration amount for their services or the client can use an in-house or a third-party engineer to provide a reasonable cost estimation of the work and the risks involved to use as a base for negotiation or even as a threshold for contractors to try and match. Once the compensation amount is agreed upon, the contract can be revised, if needed, and can be awarded to the contractor, which marks the beginning of the stakeholder relationship.

Social Network Analysis

A social network is defined by a set of individuals or organizations connected to each other by single or multiple connections. These members of a network are also referred to as nodes or units connected to each other by some type of relations (Scott & Carrington, 2011). Social network analysis is an “application of graph theory” which represents the interconnections and relationships between nodes of a network as points connected by lines (Scott & Carrington, 2011). In other words, it is a "study of relations" (Scott, 2000). The graphical representation of nodes and lines can be further modified to show more precise or accurate information on the relationships that each point has with another by appointing a direction depicting the contrast or similarity of flow of resources or information between two nodes; a relation's strength could be taken into account based on a line's value or weight; and, a connection between two nodes could also have multiple relationships shown by multiple lines.

In general, there are two types of network analysis, "ego-centered and whole networks" (Mead, 2001). Ego-centered revolves around one entity, individual or an organization and analyzes the links that this particular entity has with others in a network. This type of analysis helps to identify or measures the number of contacts of that entity in a project, communication of information with its contacts, and each connection's strength. Its benefits are better gained in situations where there are many project participants with unclear boundary lines separating them. Whole network analysis, on the other hand, is beneficial in situations where network boundaries are well established, since the "whole communication network" is analyzed. In other words, all the relationships in a network, among each entity is measured. However, for this method of analysis to be effective, data needs to be collected from each entity in the network, preferably automatically. Examples for networks with well-established boundaries can be an organization's department, a small independent company or organizations in a project (Mead, 2001). This thesis will analyze the networks and stakeholder relationships in projects considering both ego-centered and whole network analysis. In other words, the individual organization's connections to other participants, number of connections and type of connections will be analyzed along with an overall look at the entire stakeholder network and its different types.

Furthermore, Scott & Carrington (2011) mentions that analysis of a network measures various characteristics such as the network's "overall density", the points' "relative centrality" in a network, and formation of cliques within a network. Jackson (2008) provides other aspects such as a node's degree which is the number of lines connected to that node, network's cohesiveness or scale of how well interweaved a network is, and a micro level analysis, named centrality, which is similar to Scott & Carrington's relative centrality (Jackson, 2008). These measures can help improve flow of information, influence of a stakeholder over the network, power of bargain, and other attributes related to the stakeholder's behavior in the network. Since this thesis will focus more on the aspect of a node's centrality in a network and its impacts on project's performance, the following chapters will discuss in more detail on the different measurements of centrality of nodes within a network. The three centrality measurements undertaken are degree or total-degree, closeness, and betweenness. Degree centrality defines "how connected a node is" in a network. Closeness implies the number of links or connections from one given node to all other nodes. And, betweenness determines the how well a node is connected, the number of paths between two other nodes that it lies on or a node's importance in connecting other nodes in a network. Graphical representations of these stakeholder networks, with nodes size based on degree centrality for seven random projects of each procurement type are provided in Project Stakeholder Network Diagrams. Social network analysis was made possible by ORA 3, a social network analysis software under the copyright of Kathleen M. Carley, from Center for Computational Analysis of Social and Organization Systems (CASOS). All network diagrams produced in this research as well as those shown in this thesis were completed with the help of this software. In addition, this software was also used to compute centrality measures of all project stakeholders.

Among the studies that have been conducted correlating social network with construction (Pryke, 2004) mentions of "Hagedoorn on strategic alliances" which focused on the links connecting "large corporate bodies". Another study conducted described by (Pryke, 2004) is by Soda and Usai on construction firms in Italy which focused on "networks of contractors" competing to win public sector work and found that there was collaboration between contractors to be able to win large contracts that would have normally been impossible to win individually. This concept of contractors working together is similar to what's called as 'joint-ventures'.

Stakeholder Management

Different stakeholders should be dealt in different ways, depending on their professional position, their position in the project, their influence and power over the project, and their investment into the project. The following text borrowed from Watt (2014) discusses the techniques for various important stakeholders that can be used by a project manager to manage them.

Top Management

Top Management can include the president or vice-presidents of the company, board of directors, senior or division managers, corporate operating committee, and so on. They are responsible for implanting strategy and development of the organization. Their main expectation from the project is its success, and consequently, profit. They will not be involved as much as the project manager or the project team, however, they will require the project manager to provide timely updates about the project so that they will have information to consider when they plan to take new steps for the project. The benefit of having top management considered is that the project manager might get their support, making it easier to recruit the best team members into the project, obtain necessary resources; also, this will improve the project manager’s image and professional standing in the company. On the other hand, failure to do the same can be significantly devastating, and if projects are large and expensive, which is usually the case, the consequences of project failure will be far greater than that of smaller projects. Therefore, to deal with top management, Watt (2014) has suggested the following:

- “Develop in-depth plans and major milestones that must be approved by top management during the planning and design phases of the project.
- Ask top management associated with your project for their information reporting needs and frequency.
- Develop a status reporting methodology to be distributed on a scheduled basis.
- Keep them informed of project risks and potential impacts at all times.”

Project Team

A project team is made up of those people dedicated or committed to the project on a part-time or full-time basis. The objective of the team members is to successfully complete the project for their own agendas, such as promotion, salary raise, recognition, respect, as well as the company's strategic goals. If the members are assigned to only one project, they will be able to engage full-time, whereas part-time assignments will segregate their attention depending on the priority of the project. A project manager should provide leadership, direction, and more importantly, support to the team members during the project. This will help the project manager earn the team members' respect and support and will also lead to cooperation. To achieve this, working closely with the team to solve problems is required, which can help a project manager learn from the team and build rapport. Some issues, as stated by Watt (2014) that might be encountered when dealing with team members are as follows:

- Lack of priority shown by team members as they are borrowed for a temporary duration
- Members might be working on other projects as well as their full-time job simultaneously which might affect the productivity and deadlines
- Members can be from different backgrounds or bad history which may lead to personal conflicts
- Members might hesitate to inform project manager about missed deadline

Some of the problems can be solved by good interpersonal skills such as the following:

- Involving team members in project planning and encouraging them to participate
- Maintaining relationship by meeting privately and informally, like lunch or coffee
- Be available any time to hear team members' concerns and inspire them to do the same
- Complete a project performance review for team

Senior Manager

The manager who is in charge of the project manager decides the project and the members who can work with the project manager on that project. Senior managers are more involved in the project than Top Management as they are responsible for the success of the project, and the team's productivity. Senior managers will not accept failure and are to be kept up-to-date about the project as they can play key roles in helping out the project manager. A project manager's duty is to keep his senior informed at all times about everything. This will help the project manager get the necessary resources needed for the project and also will make the boss more understanding and supportive. Some simple steps that can be taken are:

- Knowing how performance will be measured
- Asking for clarifications when unclear about directions
- Developing a reporting schedule acceptable to the boss
- Frequent communication

Peers

People of the same level in an organization are called peers. Even though they may or may not be on the project team, they will have some interest in the project and can provide valuable suggestions based on their experience and knowledge. The outcome of the project might not be of significance to them as they are not investing anything in to the project. However, they won't be held accountable for neither the success or the failure of the project. Therefore, it is rather difficult to maintain a good relationship with the peers for their support and also focus on the project. Some ways to overcome obstacles are as follows:

- Making it clear who's the boss and having adequate control over peers
- Resolving personal and technical conflicts, such as envy or jealousy, level of expertise, with peers by confronting them
- Being explicit in asking for full support for peers and arranging frequent review meetings

Resource Managers

A project cannot be executed or completed without resources. Resource managers, thus, play a key role in the success or failure of the project. A successful project means that the resource manager is efficient and punctual, which can provide an incentive to contribute positively to the project. And therefore, it is important to maintain a good and healthy relationship with the ones who control the resources. Resources include materials, equipment, people, and even funding. Hence, if the project manager has a good professional working relationship with resource managers, he/she will be able to get the best quality of resources. A healthy relationship could be maintained by:

- Confronting the resource manager about defective equipment or any other problem instead of finding a new supplier
- Making agreements that can benefit both the parties on the long run or binding contracts
- Constant communication and updates can help gain their confidence

Internal Customers

Customers, from within the organization, for projects that meet the needs of internal demands are internal customers. They hold the power to accept or reject a project manager's work. Hence, in the beginning of the project, the project manager should negotiate, clarify, and present the project specifications and deliverables. During the project, the manager should stay connected with the customers as to hear out their issues and concerns and keep them informed. Because they are internal customers, communication will be easier compared to customers from outside, from which it can be presumed that meeting the demands of internal customers can be successfully done with more certainty. As any other stakeholder, internal customers should also be dealt with in their own unique ways:

- Avoiding ambiguity by clarifying project requirements, specifications, and scope in a written agreement.
- Specifying a change procedure to manage for changes in project scope
- Negotiating for practical deadlines and budgets
- Knowing the customer's organization and operating characteristics
- Establishing the project manager as the focal point of communications in the project

External Customer

External customers are those when projects are marketed to outside customers. This type of customer can be rather unpredictable as communication is minimum and the requirements can be misunderstood. In the case of Ford Motor Company, for instance, the external customers would be the buyers of the vehicles. Also, if project is being managed at one company for another company, the other company will be an external customer. Customers or clients should be treated like owners, and the ways to deal with them are quite similar to dealing with Internal customers. The difference would be that consulting or planning with these types of customers is rarely done due to lack of strong communication and conflict in technical understanding.

Government

Government will play a role, small or large, in any construction project; this might include laws and regulations required to follow for a specific location, a particular type of building, or the purpose of the project. Public projects are, by default, highly regulated and controlled in accordance with the law; but even private projects have to deal with some part of the law, maybe acquiring land, obtaining permissions, and so on. The government can be involved in all the levels starting from municipal, provincial, state, federal, to international or global. It all depends on the type of project, the parties involved in the project, and the location. As a general rule, it is best to follow the regulations as per required and make sure the project does not deviate from its scope.

Contractors, Subcontractors, and Suppliers

Contractors and subcontractors are another vital part on the list of stakeholders. Although they are hired by the owner, they play a major role in determining the output of the project because they are the ones who will be executing the project. A project manager should be skilled at negotiating, resolving conflict, and maintaining interpersonal relations to be able to manage these parties by keeping a healthy professional relationship with them. Similarly, suppliers are also important. Suppliers can be related to resource managers with the only difference being that suppliers are not part of the organization. This makes it even more difficult for a project manager to be able to control the outcome. Thus, it would be wise for the project manager to have a few loyal and dedicated suppliers, so that the deliveries of the required quality are made on time and at affordable rates.

Project Stakeholder Management Overview

Stakeholder analysis is one part of the overall project stakeholder management process. With a holistic view of this process, it can be said that there are four major components:" 1) Identify Stakeholders 2) Plan Stakeholder Management 3) Manage Stakeholder Engagement 4) Control Stakeholder Engagement. Identifying Stakeholders include finding people, groups, or organizations that could affect or be affected by a decision, activity, or outcome of the project, analyzing and documenting relevant information regarding their interest, involvement, interdependencies, influence, and potential impact on project success" (PMI 2013). This process helps in knowing the required amount of attention for each stakeholder/s. With the help of documents such as Project charter, Procurement documents, Enterprise environmental factors (EEF) and Organizational process assets (OPA), stakeholder analysis can be used to classify different stakeholders based on appropriate criteria as well as using expert judgments or simply conducting meetings. The output of this process is a Stakeholder register.

Plan Stakeholder Management is the process of developing suitable management strategies to involve stakeholders during the entire project life cycle, depending on the information gathered in the stakeholder register. This process provides an explicit, practical plan to get the stakeholders to support and contribute to project success. With the input of the stakeholder register, project management plan, EEF, and OPA, analytical techniques such as Stakeholder Engagement Assessment matrix, along with expert judgments and meetings, can be used to identify the management strategies required to effectively engage stakeholders and produce a stakeholder management plan which provides the current and desired levels of involvement from key stakeholders, “scope and impact of change to stakeholders”, communication requirements, “methods for updating and refining the stakeholder management plan as project progresses”, and so on (PMI 2013).

Manage Stakeholder Engagement is the process of communicating, discussing, and working with stakeholders to fulfill their expectations, address their issues, and implement the required amount of involvement from stakeholders in the project. This allows the project manager to increase support and minimize resistance from stakeholders, making probability of the success of the project higher. The stakeholder management plan, communications management plan, a change log, and OPA, are used as an input for tools and techniques such as appropriate communication methods, interpersonal skills, and management skills, which leads to an issue log, possible change requests, and various documents' updates (PMI 2013).

Control Stakeholder Engagement is the process of monitoring overall project stakeholder relationships and fine-tuning plans and strategies for involved stakeholders. This process maintains or increases the efficiency and effectiveness of stakeholder engagement activities as project develops and its environment changes. Project documents such as project management plan, issue log, and work performance data are incorporated with information management systems to yield work performance information, possible change requests and updates for different project documents (PMI 2013).

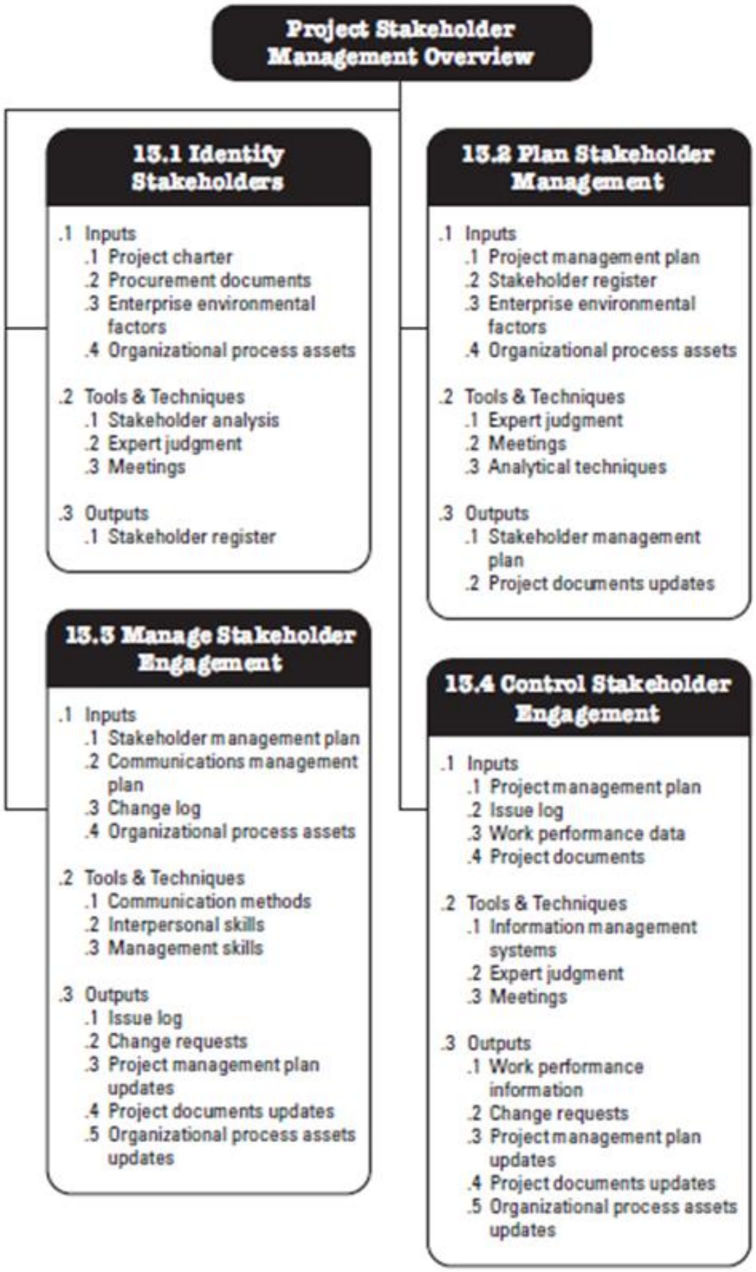

Figure 2-1 Project Stakeholder Management Overview

**http://resources.intenseschool.com/pmp-prep-project-stakeholder-management/*

Chapter 3 Research Methodologies

The research for this thesis has been carried out in four steps:

1. Collect stakeholder and project performance data from FHWA research project database
2. Compute centrality measures for each project's stakeholder network and relationships in a network
3. Correlate project performance metrics with stakeholder centrality
4. Observe patterns or trends in the network centrality measurement reports combining project performance and centrality measures.

Project Database

The data used for this research paper is a part of a FHWA sponsored project, "Online Information Source for Major Surface Transportation Projects", which aims to provide a publicly accessible information platform to help set benchmarks and compare projects in various phases, delivered either conventionally (Design-Bid-Build or DBB) or using a Public-Private Partnerships (P3s) that can be utilized by state DOTs and private companies to make better decisions during the project planning and procurement stages. This database project is an initiation of Fixing America's Surface Transportation (FAST) Act of 2015. The FAST Act of 2015 required the formation of a National Surface Transportation and Innovative Finance Bureau. To follow up on this requirement, United States Department of Transportation (USDOT) established the Build America Bureau (BAB) in 2016. One of the functions that BAB will serve, mandated by the FAST Act is to promote best practices in project delivery for major projects receiving federal assistance. To be able to accomplish this task, BAB was to set procurement benchmarks to keep track of the federal financial assistance provided to the projects over their life-cycle.

There are 137 projects, some of which are further divided into multiple phases or segments depending on various circumstances, located all over the country. There are two tiers of data being collected: Tier 1 data, which is collected from existing databases and information sources, focuses on descriptive information that shows how the project performed or is performing based on different delivery methods. This set of data are those which are publicly accessible or provided on different FHWA databases, project and state DOT websites, and the Federal Register database. Tier 2 data, on the other hand, is a more detailed level of information on projects which are to be collected through interviews, surveys, and questionnaires.

For the purposes of this thesis, 72 projects were considered which included 20 Design-Build (DB) and Design-Bid-Build (DBB) projects each, 2 Construction Management at Risk (CMAR) and 30 Public-Private Partnership (PPP) projects. The project's cost ranges from half a billion dollars to almost 15 billion dollars, while the project duration has a range of around 450 days to more than 6000 days. Figure 3-1 and Figure 3-2 represents the number of projects in the cost range of every $500 million and duration range of every 750 days. The data sample encompasses various types of projects such as interchange reconstruction, bridge reconstruction, highway widening, tolled or express lanes, tunnels, parkways, and transit centers. A tabulated list of the projects and their corresponding types are provided in Appendix D: Project Data Profile.

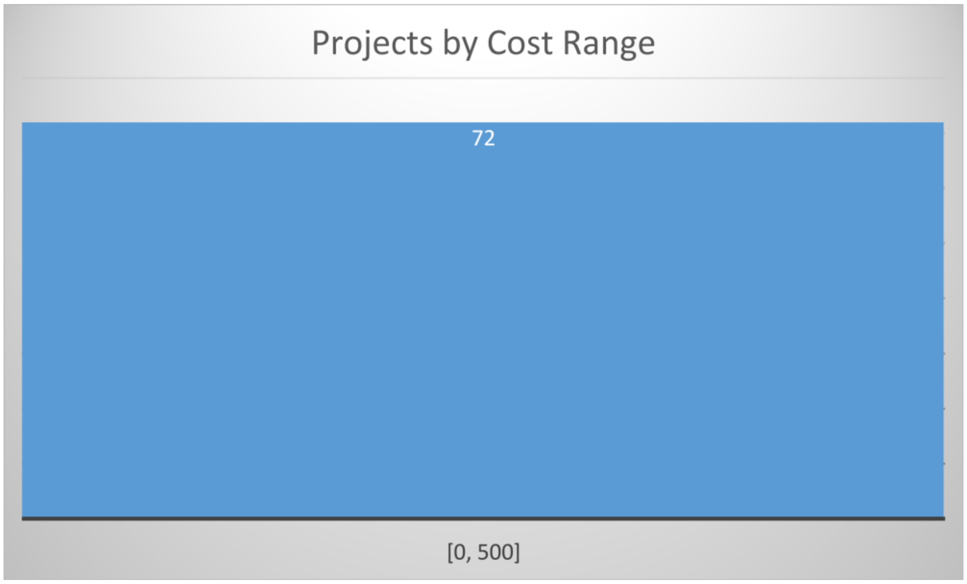

Figure 3-1 Project Distribution by Cost

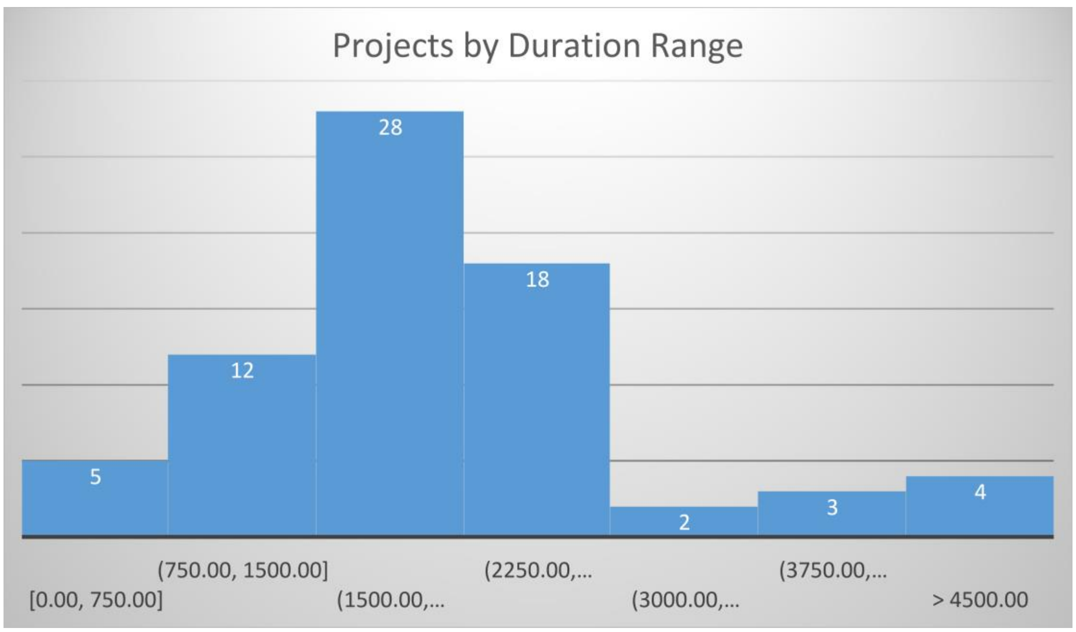

Figure 3-2 Project Distribution by Duration

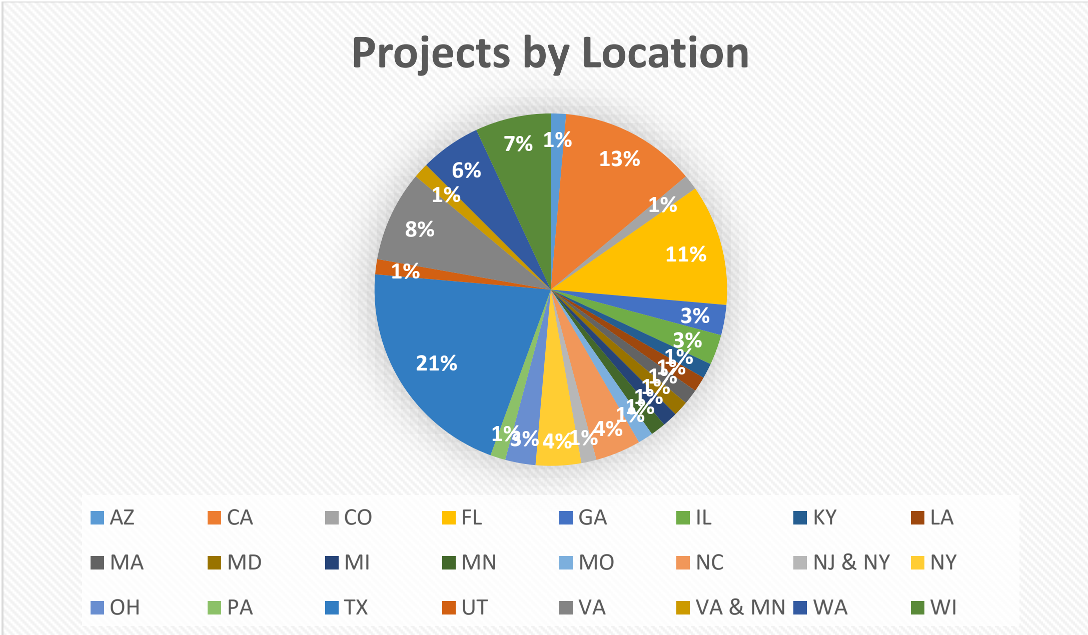

Figure 3-3 Project Distribution by States

Projects were chosen on the basis of their data availability. They represent many different states in the US such as Florida, Texas, Illinois, California, North Carolina, New York, Maryland, Colorado, Ohio, Minnesota, Utah, Virginia, Massachusetts, and so on as shown in Figure 3-3. There are two performance measurements from the database that are being used in this thesis, namely time and cost performance. Although it is arguable that these parameters along with quality, as coined by Atkinson (1999) as the 'iron triangle', are no longer the only factors that are important to be considered as project success factors and that there are other factors such as "product success" (Low & Chuan, 2006), "customer satisfaction" (Pinto & Slevin, 1988), and "overall satisfaction of stakeholders" (Bryde & Brown , 2005) which have gained more importance or significance over the recent decade, the two parameters cost and time as well as quality are still critical and have been synonymous with successful projects for many years (Naoum and Egbu, 2015) .

Moreover, these parameters can be easily quantified based on estimated or required specifications and can provide numerical benchmarks on a project's performance, providing a level-field for projects to be compared with one another.

$$Schedule\ performance = \frac{Final\ Project\ Time - Original\ Project\ Time}{Original\ Original\ Time}$$

$$Cost\ performance = \frac{Final\ Project\ Cost - Original\ Project\ Cost}{Original\ Project\ Cost}$$

In the above equations, final project time and cost denotes the actual duration until project completion, and total costs incurred at project's completion, while original project time and cost denotes the winning bidder's estimated completion date and cost.

Tools and Techniques

Social Network Analysis – Centrality

First is the centrality analysis and its different measures. Thanks to ORA Network Analysis software, assessing and analyzing social networks among project stakeholders has been made easier and understandable. The reports provide a ranking system of organizations in a network based on the three different measures of centrality along with the normalized or scaled values as well as their raw or unscaled values. In addition, the application also calculates the number of standard deviations from the mean of a random network of the same size and density, which helps the user contextualize the given network compared to other similar networks. Furthermore, other general information such as the minimum, maximum, mean, and standard deviation of the network in study as well as the mean and standard deviation of random similar network are also provided.

Centrality is a concept of point of an individual or an organization who "stands at the centre of attention" (Scott, 2000). It typically indicates a node's prestige, popularity, influence, and power. The relative centrality among various members or points also known as "point centrality" is differentiated into local and global centrality (Scott, 2000). The points also called as nodes can help us determine their centrality in a network (Jackson, 2008). There are four ways that the centrality of a node can be measured: degree, closeness, betweenness, neighbor's characteristics (Jackson, 2008). Among these, three will be used in this thesis: degree, closeness, and betweenness due to the type and quality of data accessible from the FHWA research project.

Total Degree

The simplest measure among the three, degree defines the number of connections to and from other nodes in the network (Jackson, 2008). The higher the degree of a node, the higher the number of direct connections that node has with other nodes, meaning high degree centrality. As provided by Jackson (2008), a given node's "degree centrality" equates to "$d_i(g) / (n - 1)$", producing a number ranging from 0 to 1, where $(n - 1)$ is the highest degree a node can have in a single network, and $d_i(g)$ represents the number of degrees of a particular node.

The measure of degree centrality simply represents the "first neighbors" (Cadini, Zio, & Petrescu, 2008) of a node in the network. Higher the number of relationships, higher the centrality measure. Acknowledging the fact that, in construction projects, traditional procurement will point out that the clients will have the highest degree centrality given that majority of the relationships are directly with the client. However, alternative procurement methods deviate from this notion. Due to the private partner or the concessionaire doing the hiring of other contractors and advisors, degree centrality of clients will be much lower compared to the private entity simply because of the direct contractual relationships.

As simple as it is, degree centrality does not, however, provide other information such as how well a node is located in a network, or its distance or number of connections between one given node and other nodes, which is also known as "Closeness centrality". The measure of degree centrality, used in this research paper based on ORA 3 2018, is calculated using the following equation:

$$Total\ Degree\ Centrality\ for\ node\ i = \frac{\sum\{A(i,:)\} + \sum\{A(:,i)\} - A(i,i)}{2 * V * (N-1)}$$

where, A is the input network with N number of nodes and a maximum link value of V. '$A(i,:)$ shows the number of links from node i in the network A while $A(:,i)$ shows the number of links to node i in the same network. $A(i,j)$ denotes self-loops which is '0' for all measures as self-loops are not considered in this research.

Note:

- If the network A is symmetric, then the measure is normalized by $V * (N-1)$

Closeness

While degree measures the number of direct connections a node has in a given network, closeness measures the number of connections of a node has with every other node (Jackson, 2008). Hence, the higher the number of connections between two nodes i.e., nodes on a path from one node to another, the lower the closeness of that node. Or, to put it in a simpler way, it is the inverse of the total distances in a given network from one node to other nodes in that network. However, there are instances where the number of connections of several nodes can be the same. In these cases, the number of direct connections plays a part in determining the ranks of nodes. So, the node with higher number of direct connections, which is also the shortest distance between two nodes, has a higher value of closeness centrality as that node is more closely connected to other nodes in a network compared to those nodes having a lower number of direct connections.

Closeness reveals how long it takes information to spread from one node to others in the network (Cadini, Zio, & Petrescu, 2008). Nodes with a high closeness centrality value will have the shortest paths to every other node in the network, allowing these nodes to monitor the flow of information in a project better than other nodes. In other words, these nodes will generally have a better idea of the things happening throughout the network. For example, a general assumption is that the clients will have the best picture of what is happening in the project and among the stakeholders, and that clients are able to influence the network as a whole due to their connections to other stakeholders. As true as this may be for traditional networks where projects are funded by the clients themselves, designed by architects, delivered by contractors who are all directly hired by the client, the case is not same in alternative delivery methods where the client establishes a contractual relationship with an entity such as a design-builder, construction manager or a special purpose vehicle. In these cases, because the client has contract with only one stakeholder, the measure of closeness is lower compared to the other party in the contract who hires other contractors and consultants for the project.

The formulaic representation is "$(n - 1) / \sum_{j \neq I} l(i, j)$", where $l(i, j)$ is the lowest number of connections between *i* and *j* (Jackson, 2008). As described by Jackson (2008), "a richer way" to measure closeness is by considering a "decay parameter" δ with value ranging between 0 and 1 and considering the "proximity" between the node considered and other nodes "weighted by the decay". This helps in measuring the benefit that a node can get in a network based on its distance with each other.

ORA 3 equation, which has been adopted in this thesis to calculate the closeness centrality, follows the same logic of closeness being inverse of the distances from one node to all other nodes in a given network '*A*' with '*N*' number of nodes, and is represented as follows.

Assuming '*D*' as the distance network defined as:

D(i,j) = shortest path from '*i*' to '*j*', IF path exists from '*i*' to '*j*'

D(i,j) = N*V, IF no path exists from '*i*' to '*j*'

D(i,i) = 0

Now, to compute the sum of shortest paths from node '*i*' to every other node,

Let $d = \sum D_{i,j}$: for all nodes '*j*'

Finally, based on the distances computed, the closeness centrality can be determined using the following equation.

$$Closeness\ Centrality\ value\ for\ node\ i = \frac{V * (N - 1)}{d}$$

Where, V is the maximum link value, which in this case, means the distances rather than binary

Betweenness

Betweenness, considered as “one of the key measures used by those interested in networks” (Freeman, 1979), considers the location of a given node in a network (Jackson, 2008) or its position “in terms of the paths that it lies on”. Freeman (1979) defines betweenness as the fraction of nodes that passes through a given node among all node pairs that have the shortest path containing that node. Nodes with high betweenness can be considered as a popular “broker of indirect connections” or “a gatekeeper of information flow”, amongst the nodes in a network. This means that there are many links or lines between two other nodes that passes through the given node, making that one node more ‘popular’ compared to other nodes.

In construction projects, connections are made through contracts where one entity hires another for a product or service, holding them responsible and accountable, which will be compensated through some form of financial remuneration. These contracts are the connections between two stakeholders or two nodes. A stakeholder with multiple contracts with numerous stakeholders in a network means that this particular stakeholder lies in between other stakeholders, which directly impacts that stakeholder’s betweenness centrality measure. The more contracts a stakeholder holds in a network with other stakeholders who has contractual relationships with another set of stakeholders, the higher the betweenness value. For example, in the case of traditional delivery methods, clients hold contracts with every other major stakeholder. This brings their betweenness to a maximum value because they are the central node relative to other nodes. However, in alternative delivery methods, the high betweenness centrality is shown by the general contractor or special purpose vehicles who act as the central node due to their contractual relationships with multiple contractors and consultants, in addition to the one with the client. So, if the client wants to change something in the design, the communication goes through the special purpose vehicle to the engineering firm based on the contractual relationships.

Jackson (2008) formulated the measurement of betweenness centrality by assuming '$P_i(kj)$' as the number of shortest links between '*k*' and '*j*' that '*i*' lies on, and '$P(kj)$' as the total number of shortest links between '*k*' and '*j*'. By the ratio of '$P_i(kj)$' over '$P(kj)$', the importance of '*i*' in connecting '*k*' and '*j*' can be determined. This value, ranging from 0 to 1, reflects that '*i*' is important when the value is closer to 1, whereas '*i*' is unimportant if value inclines towards 0.

However, for the purposes of this research paper, this measurement has been calculated using ORA software's equation for betweenness centrality which is shown in the following.

Assume that '*D*' is the distance network for the input network, and D(i,j) is the shortest path distance between i to j, with the condition that D(i,j) is 0 if no path exists. Let '*C*' be the network of number of shortest paths for the given network, and

C(i,j) is the number of shortest paths from i to j, and 0 if no path exists. The equation that calculates the total fraction of shortest paths that node i lies on is:

$$Betweenness\ Centrality\ value\ for\ node\ i = \frac{\sum(\mathrm{C\ u,i} * \mathrm{C\ i,v})}{C\ u,v}$$

for (u,v), where $D_{u,v} = D_{u,i} + D_{i,v}$

The computed value is then normalized by the maximum number of shortest paths possible.

Stakeholder Analysis

The second type of analysis carried out in this thesis is the individual stakeholder analysis. Two tools have been utilized to accomplish this task: Power-Interest grid and Salience model. Power-Interest grid classifies stakeholders based on their power and interest in a project while Salience model classifies stakeholders based on power, urgency, and legitimacy of individual stakeholders.

Power-Interest Grid

Power-Interest Grid is one of the most common tools used in analyzing stakeholders. The reason for that might be because of the two variables considered in this tool – power and interest – can be easily measured. Power is defined by a person’s position in the organization or the project, which is pretty straightforward. Interest can be determined by their expectations or requirements of the project. The grid is divided into four quadrants with power and interest on each axis. As different stakeholders have varying interest and power in the organization and the project, the stakeholders will be distributed among the four quadrants such that the most important stakeholders – who have the highest power and interest in the project and the organization – are put into the top-right quadrant, stakeholders with not too much importance will be put into the top-left or bottom-right quadrant depending on their level of power and interest. And lastly, the stakeholders with minimal importance with least interest and lowest level of power in the project falls in the bottom-left quadrant.

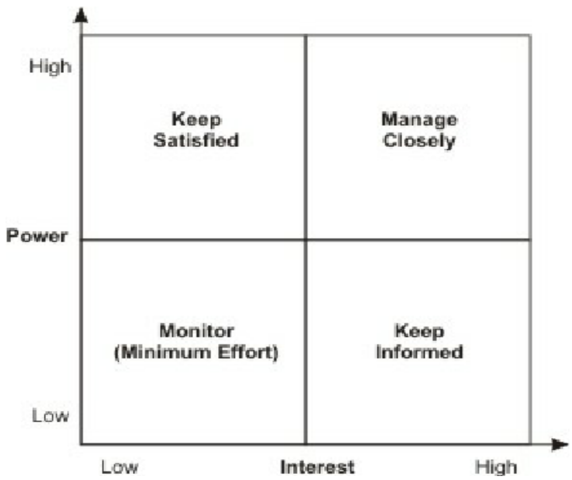

Figure 3-4 Power-Interest Grid[1]

As shown in the figure, there are different ways to deal with stakeholders in different categories. Mindtools.com (2018) has provided the following information regarding dealing with stakeholders:

- High-Interest, High-Power: Manage Closely, must fully engage with these people, and make the greatest efforts to satisfy them. Example: Program Manager, Project Head

[1] *https://www.researchgate.net/figure/Power-Interest-grid-for-stakeholder-prioritization-Thompson-2006_fig1_255573909

- Low-Interest, High-Power: Keep Satisfied, do just enough work to keep them satisfied, and avoid too much communication. Example: Board of Directors, Chairman
- High-Interest, Low-Power: Keep Informed, inform these people about every detail of the project, and discuss to make sure there are no major issues. This category often contains helpful people who can assist in the detail of the project. Example: Family
- Low-Interest, Low-Power: Monitor, only monitor these people, and avoid excessive communication. Example: Labor

However, because stakeholders are people or group of people, and their position in the company or the project can possibly change, the allocation of the stakeholders might differ in the case of changes in their position as it causes changes in their authoritative power as well as interest in the project. In a construction project, for instance, a project team member might be asked to switch projects due to manpower reasons. In this case, the team member will lose their power over the current project and most probably their interest as well, since he/she will have to focus their attention on the new project. It would be a good idea to consider the possibility of these type of situations.

Likewise, Power-Influence and Influence-Impact models also have similar characteristics that of Power-Interest, with the only difference being the variables Influence and Impact. The behavioral pattern required in both Power-Influence and Influence-Impact are little to no different than Power-Interest grid.

Salience Model

Salience model, developed by Mitchell, Agle, and Wood, is different compared to other tools and techniques, such that the variables considered in this model are Power, Legitimacy, and Urgency. According to Sharma (2010), “Power is the ability of the stakeholders to influence the outcome of a project or an organization. Legitimacy is the authority; level of involvement stakeholders has on a project. And, Urgency is the time expected by project stakeholders for responses to their expectations.” The model uses Venn diagram concept for showing different needs for various stakeholders. Salience model can be compared to Power-Interest Grid as well. According to (Singh, 2017), Definitive ones should be Managed Closely, Dominant and Dangerous stakeholders should be Kept Satisfied, Dependent ones should be Informed, and Dormant, Discretionary, and the Demanding ones should be Monitored. Salience model helps to identify who or what really counts as it emphasizes the need to pay attention to stakeholders in a timely manner. Compared to other techniques, Salience model considers attributes such as legitimacy and urgency which can help make the segregation of stakeholders more precise.

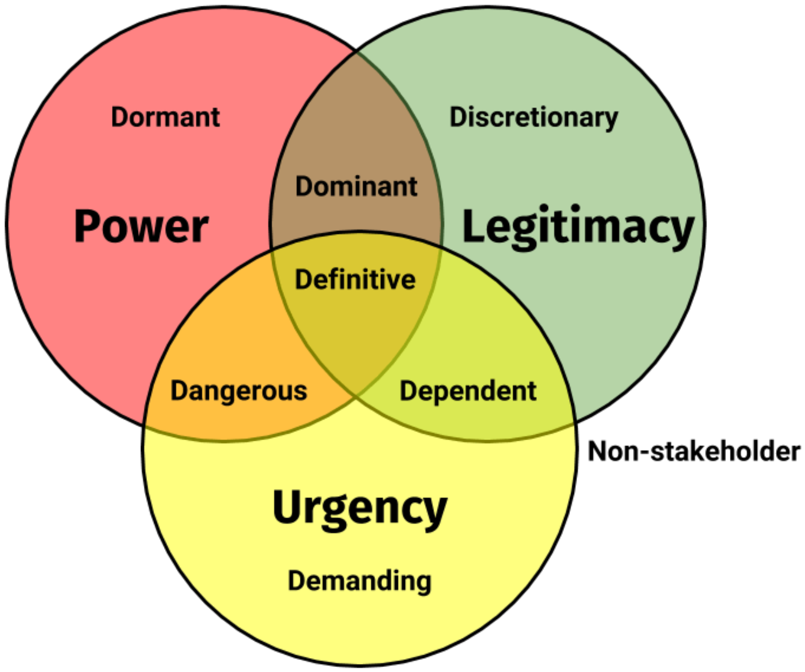

Figure 3-5 Salience Model[2]

According to Sharma (2010) and Singh (2017), there are eight different categories of stakeholders based on this model, and each are shown on the diagram above. The different types of stakeholders are briefly described below:

1) Definitive/Core: Critical project Stakeholders who need to be provided utmost attention and need to be constantly engaged with. Example: Project Manager's Boss, powerful and legitimate Stockholders of the organization
2) Dominant: Stakeholders with legitimate stakes and who possess power to act on those stakes. A project manager needs to actively engage them with a focus on their expectations but not with urgency. Example: A local government body

[2] https://www.deepfriedbrainproject.com/2017/09/salience-model-for-stakeholder-classification.html

3) Dangerous: Stakeholders with power over and urgency towards the project, but no legitimate authority in the project itself. They are a potential threat to the project and must be dealt with accordingly. Example: Local mafia or terrorist organization
4) Dependent: Stakeholders with no power but urgency and legitimacy in the project. They can be severely affected by the project and don't have any control over the outcome. Example: Farmers being displaced by a project
5) Dormant: Stakeholders who possess power but no legitimacy or urgency. Example: Former employees with information about the project
6) Discretionary: Stakeholders with legitimacy but no power or their interest in the project is not considered urgent. Example: Charity organizations who receive funding from the company
7) Demanding: Stakeholders with urgent demands, but no power or authority. Can be more of a nuisance or irritation, but do not affect the project in any significant way. Example: An employee asking for salary raise frequently
8) Non-Stakeholders: People or entity with none of the three parameters

In the Salience model there are certain confines (Singh, 2017). Firstly, stakeholders can be perceived differently by different project managers depending on their experience, culture and values. Secondly, the levels of power, legitimacy, and urgency can vary as well. The attributes used in this model are fixed or definitive, whereas in real life the attributes can change based on the circumstances. Lastly, there are only three attributes compared in this model. However, there might be other attributes as well that can influence stakeholder relationships. Regardless, the

Salience model is able to provide a much more accurate classification of stakeholders due to its higher number of variables considered.

Chapter 4 Empirical Analysis

As PPP projects are being more considered for large construction projects, it is important to understand the stakeholder network characteristics of such projects. Due to high involvement of numerous project participants, the need to pay attention to particular key stakeholders can prove to be challenging. This thesis aims to determine whether general contractors (GCs) or special purpose vehicles (SPVs) become more influential or central than the clients themselves in projects based on the 3 measures of centrality, and whether there is significant impact of the stakeholder's centrality on the two project performance criteria, cost and schedule performance. The results also aim to show if there is any significant relationship between project schedule delay and increase in cost, as well as the impact of the number of public agencies involved in a project on cost and schedule performance.

Data for this research includes 20 DB and 2 CMAR projects, grouped into the same category due to high similarity in the way the project is executed i.e., a general contractor or a design-builder is completely responsible for the project delivery as well as for the risks relating to design, construction, supplies, equipment, and so forth. 20 traditionally procured projects or DBB were considered along with 30 PPP projects, among which three projects did not have performance data. I-75 Modernization Segment 3 and Transform 66 – Outside the Beltway started their construction only recently, while Brent Spence Bridge Corridor is still in the procurement phase; more specifically, in the NEPA phase. In addition, one DB project, SH 99 Grand Parkway Segment H & I-1, also had started construction in July 2018, thus, no data was available. For these projects, a neutral value for both cost and schedule performance are assumed for calculation purposes. For the projects which are still under construction, the cost and schedule performance were calculated based on the project's most recent cost and schedule estimate provided in their financial plan updates, while the actual cost and duration were taken into account for completed projects. The three PPP projects and one DB project without performance data is included in the list for the purpose of centrality analysis among the three different categories of procurement. A tabulated representation of the project data as well as the three centrality measures of GC/SPV and DOT are provided in Research Data.

PPP method is a growing trend (Ramsey & El Asmar, 2015). Due to the increase in scope of responsibility as well as "decision rights" in the project, the participation from the private parties is higher in PPP than in traditional projects (Ramsey & El Asmar, 2015). Consequently, this shift in risk and responsibility from public sector to private leads to private parties being responsible for the entirety of the project, from design, construction, financing, operation and maintenance. Based on this phenomenon, this research paper aims to determine whether there is a shift in the centrality from public to private sector in projects. To better explain and help understand the concept of emergence of private entities in stakeholder networks, figures are provided below which shows the centrality measure of stakeholders in projects of different procurement types by the size of their node in the network. Total-degree centrality measure was used when creating these networks since the size of the node is determined by the number of direct connections of that node to other nodes in its immediate proximity. So, a stakeholder having the maximum number of direct connections in a network has the highest degree centrality. Other centrality measures including betweenness and closeness are also considered in the analysis. However, for explanatory purposes, degree centrality has been utilized for the network diagrams.

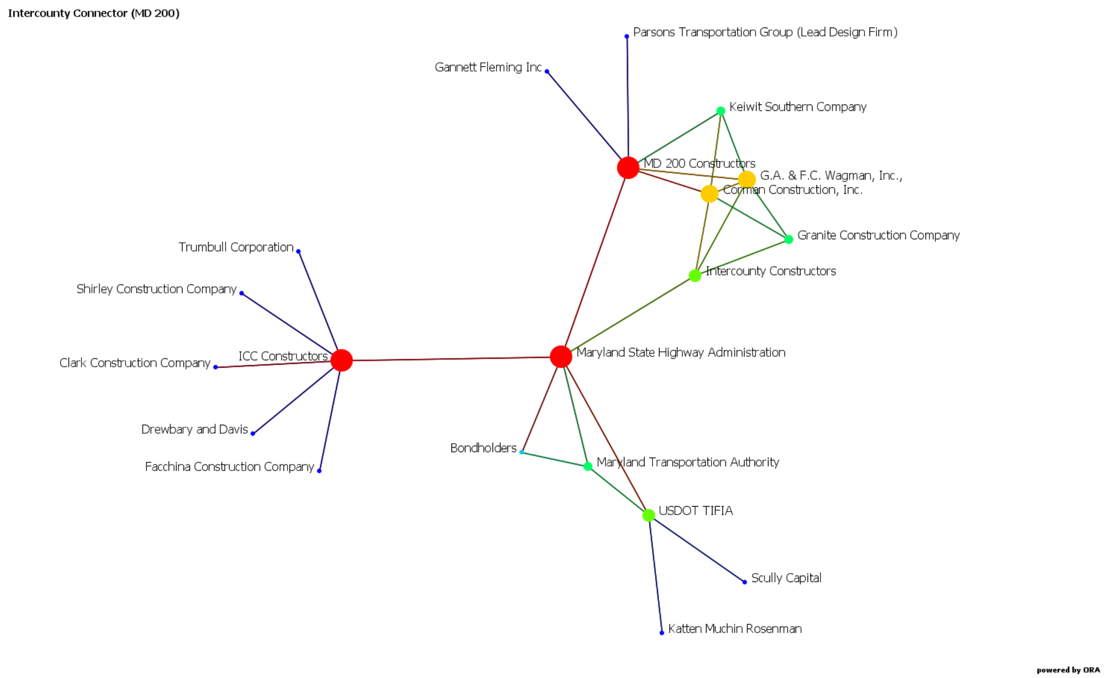

Figure 4-1 Intercounty Connector – DB

Figure 4-1 and Figure 4-2 show stakeholder networks of two DB projects – Intercounty Connector and Thimble Shoal Parallel Tunnel Project. The red dots indicate nodes with same total-degree centrality. In the case of Intercounty Connector, the joint-venture contractors have the same degree centrality as the public sponsor or client. Moreover, the three red nodes interconnecting multiple groups of stakeholders shows that this network is a decentralized stakeholder network. On contrary, in the project Thimble Shoal Parallel Tunnel, the client has a larger node size than the joint-venture contractor, meaning the centrality level of the client is higher than that of the joint-venture contractor, inclining towards a more centralized stakeholder network due to high centrality shown by one particular node. In DB methods, the emergence is inconsistent among different projects but there is the possibility that contractors may show higher centrality measures than clients themselves.

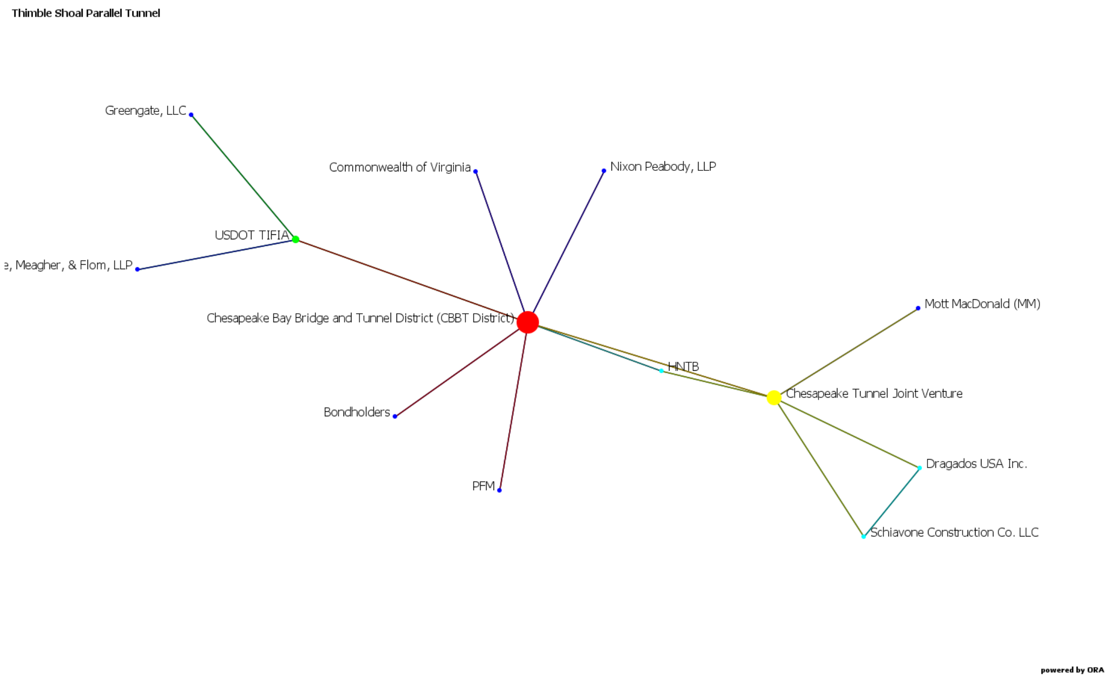

Figure 4-2 Thimble Shoal Parallel Tunnel – DB

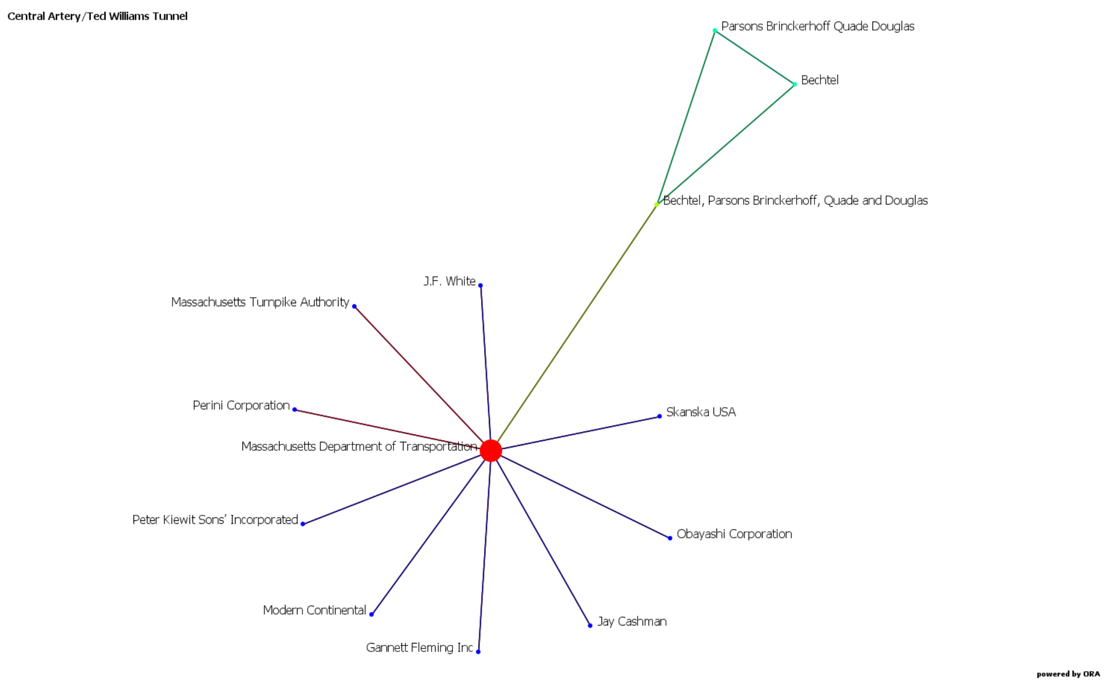

Figure 4-3 Central Artery/Ted Williams Tunnel – DBB

Figure 4-3 and Figure 4-4 show stakeholder network diagrams for DBB projects – Central Artery/Ted Williams Tunnel and I-95/Woodrow Wilson Bridge. While both these projects have the client or public entity as the most central stakeholder in the network, Central Artery/Ted Williams Tunnel project has a fairly centralized network with almost all stakeholders directly connected with the client, whereas Woodrow Wilson Bridge network has a more decentralized network with multiple junctions of connections at joint-venture contractors. Regardless of it being a decentralized network, Woodrow Wilson Bridge still has the client as the most central entity by a large margin compared to other stakeholders. In other words, despite so many contractors and joint-ventures being involved in the project, the most central stakeholder came out to be the client due to direct involvement and contractual relationships with contractors and other project participants.

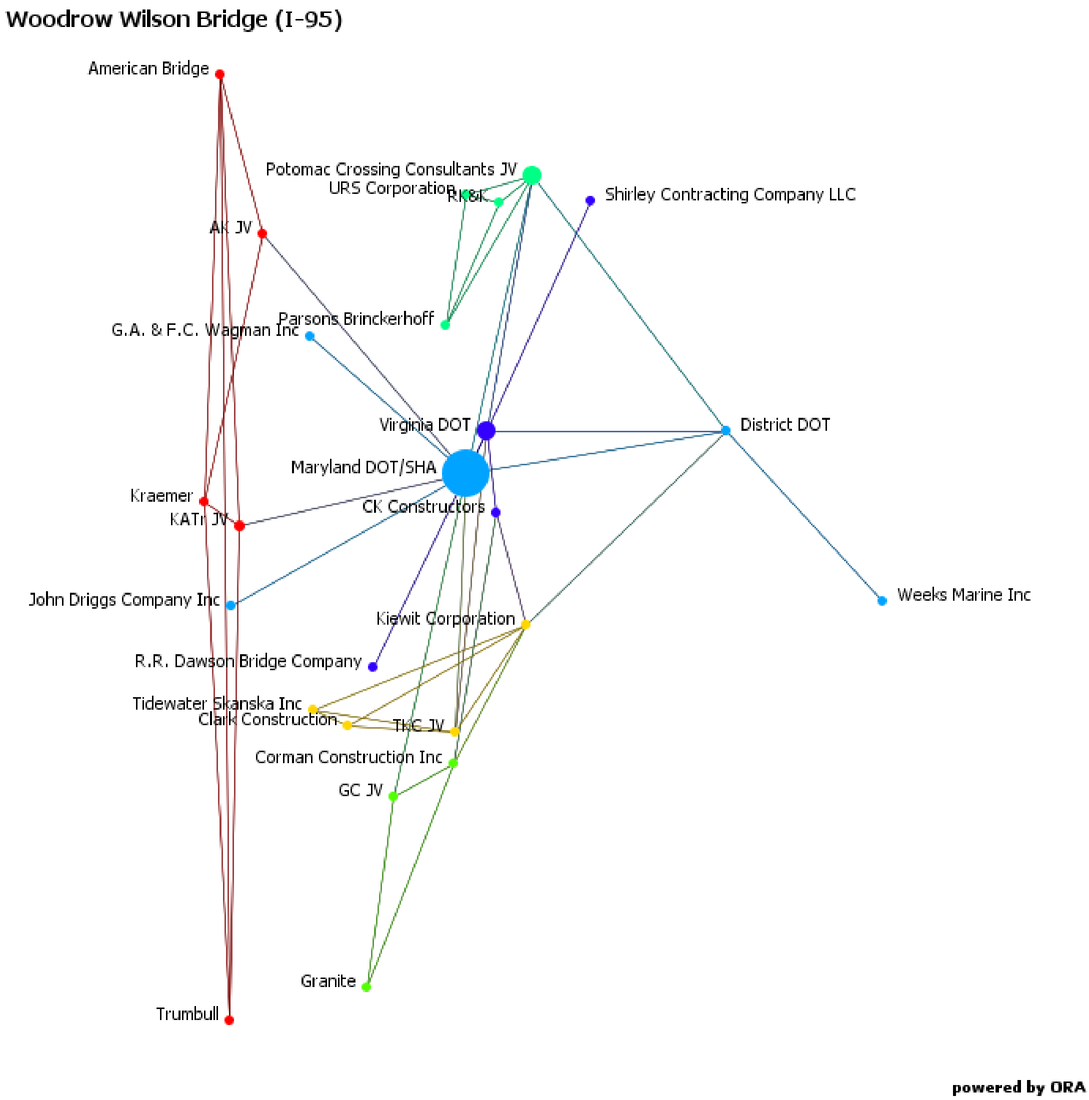

Figure 4-4 I-95/Woodrow Wilson Bridge – DBB

In contrast, PPP projects show the opposite trend regarding the most central stakeholders in a network. Figure 4-5 shows the network for Midtown/Downtown/MLK Tunnel project which was procured using a Design-Build-Finance-Operate-Maintain (DBFOM) contract between the client and concessionaire. Due to this contract, concessionaire is responsible for the entirety of the project from its design to maintenance over a certain number of years as stated in the contract. Consequently, the concessionaire goes into contract with general contractors, joint-ventures, consultants, designers, O&M contractors, and so forth leading to a much higher number of connections in the network compared to the client, who usually holds a contract with the concessionaire and a handful of advisors. This phenomenon of shift in centrality from clients or sponsors of a project to the private concessionaire or special purpose vehicle shows the emergence of these private entities in PPP projects. This emergence can also be related to the positive numbers shown by the PPP projects based on cost and schedule performance. It can be seen from the following figure the large-sized node of the concessionaire who holds contracts with other contractors, financiers, O&M contractors, bondholders, and so on. Furthermore, this network also shows characteristics of a decentralized network with two large nodes interconnecting many others. Although the client does remain the primary priority for the concessionaire, the change in centrality affects the influence a stakeholder has over the network.

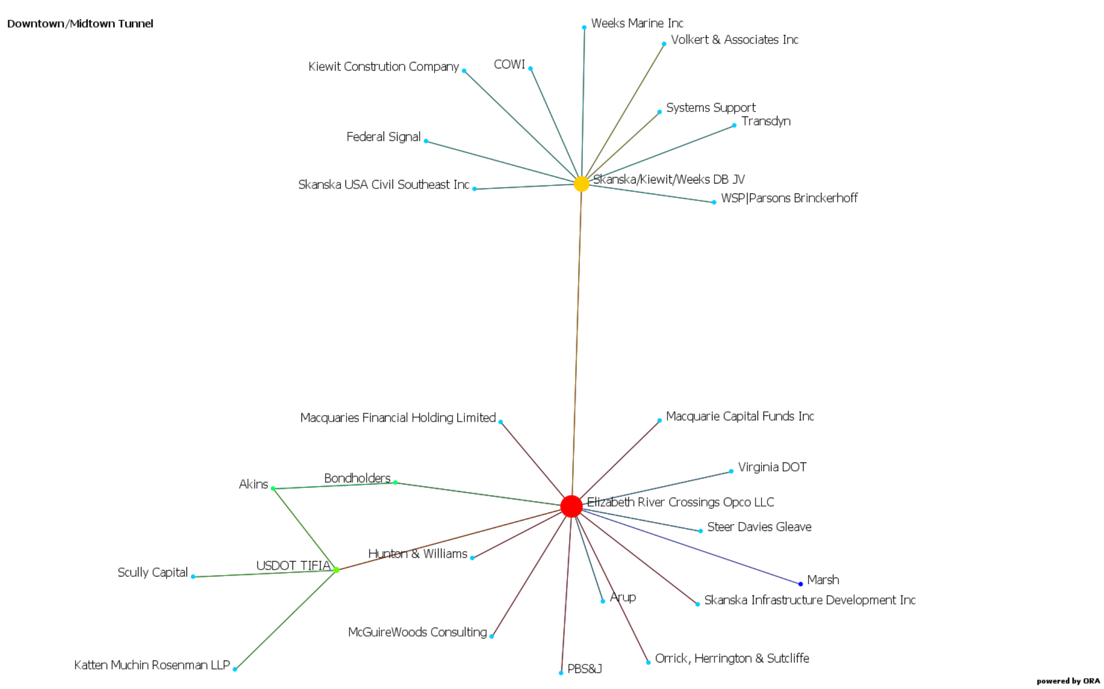

Figure 4-5 Midtown/Downtown/MLK Tunnel – PPP – DBFOM

Likewise, SR 8026/SR 836 Interchange Reconstruction Project, shown in Figure 4-6, shows the same trend where the private design-build joint-venture has a higher centrality measure than that of the client, despite the project being procured as Design-Build-Finance (DBF). It can be noticed that the relativity of the level of centrality has changed. The DBFOM project's concessionaire had a much bigger size node than that of DBF project. This should be largely due to the decrease in work scope, operate and maintain, which leads to a smaller number of contracts that the private contractor would be required to have. Nonetheless, due to involvement of multiple stakeholders holding contracts with both the client and contractors, this network shows attributes of decentralized network as well as a distributed network.

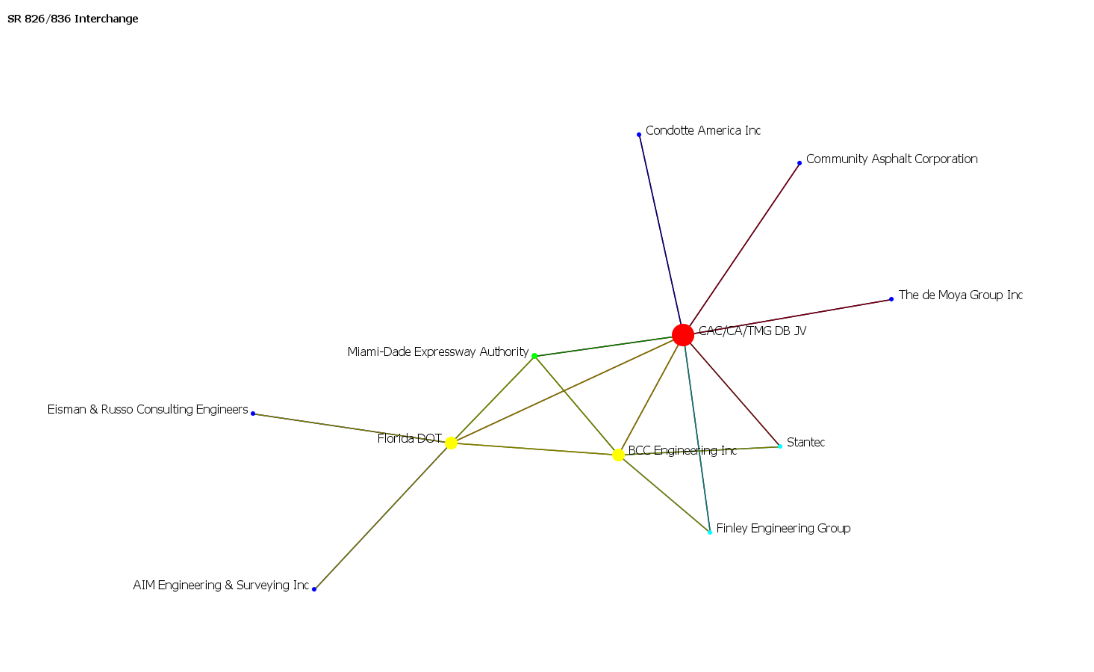

Figure 4-6 SR 826/SR 836 Interchange Reconstruction – PPP – DBF

Other projects, SR 202L South Mountain Freeway and Goethals Bridge Replacement, are shown in Figure 4-8 and Figure 4-9 to show different PPP procurement methods – Design-Build-Maintain (DBM) and Design-Build-Finance-

Maintain (DBFM). Even in different types of PPP methods, the most central entities are private contractors or partners connected with other contractors and consultants. These projects and their network diagrams show the shift in centrality from clients to contractors as the procurement method goes from traditional DBB methods to a more alternate DB method and to PPP method. A tabular representation of the centrality measures of the given projects is provided in Figure 4-7. The ‘0’ and ‘1’ indicates the centrality measure significance ($\alpha \leq 0.05$) relative to other stakeholders in that project’s network. A trend can be observed where the centrality significance of private entities is consistently ‘1’ in PPP projects while for clients is significantly central, or value is ‘1’ in DBB and DB projects.

Project Name	**Proc. Typ**	**GC / SF**	**Signific**	**DOT Be**	**Signific**	**GC / SF**	**Signific**	**DOT Cl**	**Signific**	**GC / SF**	**Signific**	**DOT To**	**Signific**	**No. of**
Intercounty Connector	DB	0.345	0	0.705	1	0.487	0	0.594	1	0.316	0	0.316	0	2
Thimble Shoal Tunnel	DB	0.439	0	0.803	1	0.571	0	0.706	1	0.417	0	0.583	1	2
Central Artery/Ted Williams Tunnel	DBB	0.303	0	0.955	1	0.571	0	0.857	1	0.25	0	0.833	1	2
I-95/Woodrow Wilson Bridge	DBB	0.228	0	0.614	1	0.49	0	0.632	1	0.25	0	0.417	1	3
Midtown Tunnel/Downtown Tunnel/Martin Lu	DBFOM	0.797	1	0	0	0.406	1	0.295	0	0.519	1	0.038	0	1
SR 826/SR 836 Interchange Reconstruction	DBF	0.633	1	0.378	0	0.833	1	0.667	0	0.8	1	0.5	0	2
Loop 202 South Mountain Freeway	DBM	0.924	1	0.133	0	0.937	1	0.556	0	0.933	1	0.2	0	1
Goethals Bridge Replacement	DBFM	0.667	1	0.429	0	0.636	1	0.568	1	0.429	1	0.333	1	1

Figure 4-7 Centrality measures of GC/SPV and DOT in different procurement methods

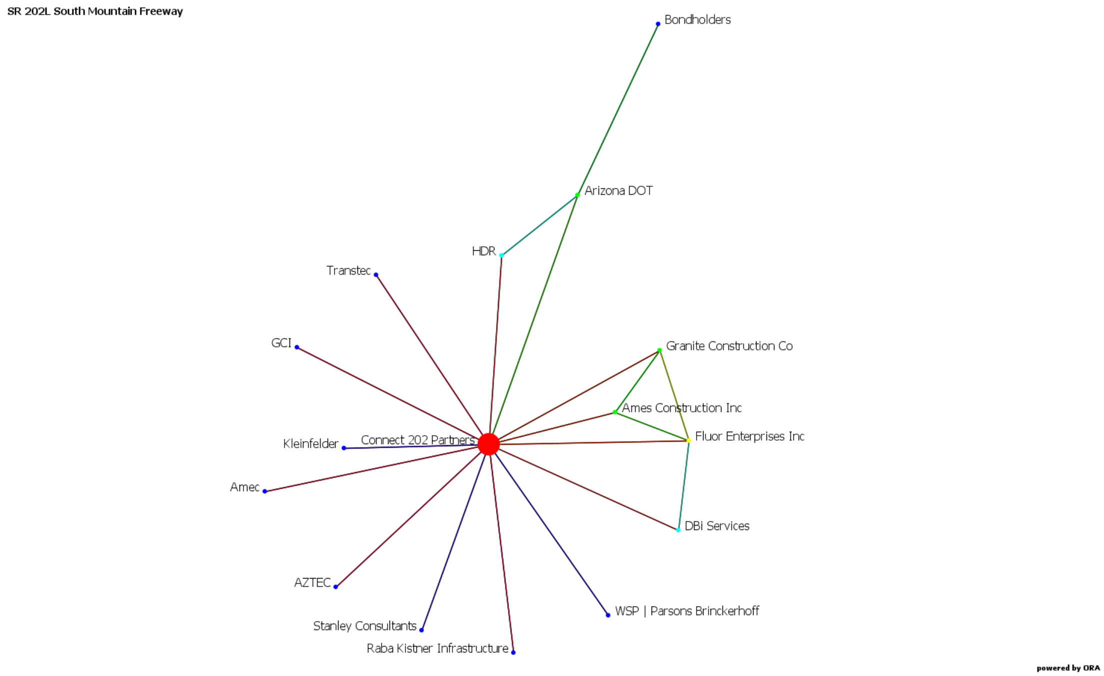

Figure 4-8 SR 202L South Mountain Freeway – PPP – DBM

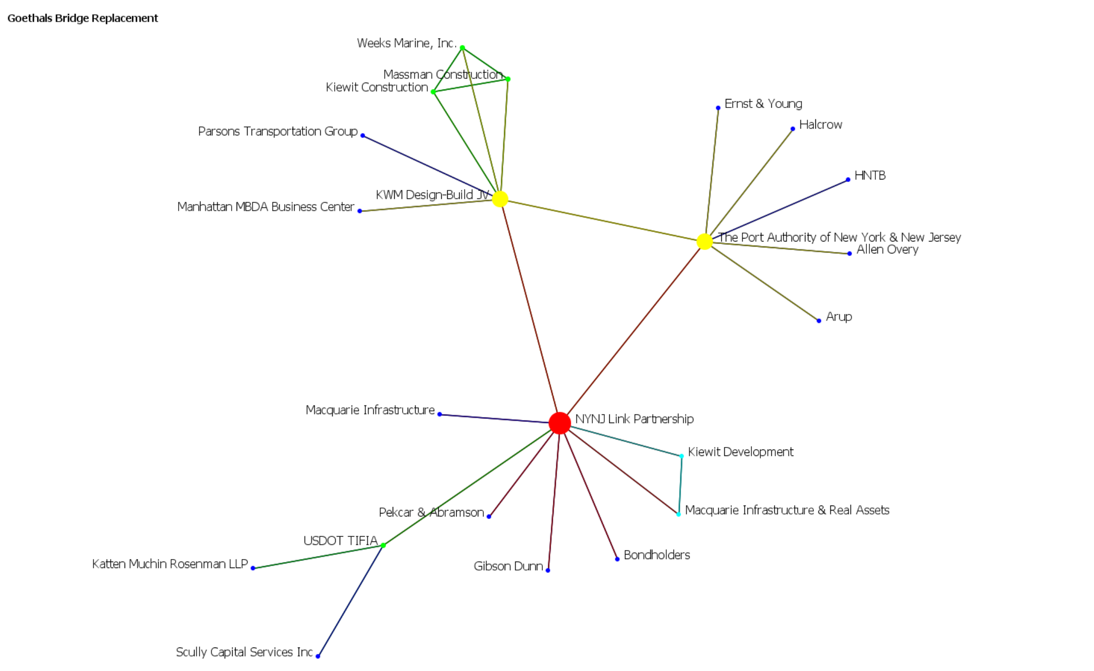

Figure 4-9 Goethals Bridge Replacement – PPP – DBFM

The results obtained through this study supports the first hypothesis that PPP projects have GC/SPVs as more central stakeholders than DOTs. In addition to this, the results also show that DB projects tend to show a mix of central entities, although clients are generally more central than their private counterparts in the stakeholder network.

Descriptive statistic of the projects included in this research is provided below. Projects that are on budget or under budget will have a value less than or equal to ‘1’, and those that are over budget will be more than 1. The neutral value was set to ‘1’, unlike the usual method of setting to ‘0’, to avoid having negative numbers in the analysis as an attempt to get the most accurate result possible.

Table 4-1 Overall Project Data

Overall Project Data	Cost Performance	Schedule Performance
Number of Projects	72	72
Minimum	0.620	0.800
Maximum	2.500	2.420
Mean	1.037	1.184
Standard Deviation	0.235	0.299
Variance	0.055	0.089

Table 4-1 provides the general description of the overall project data based on the two project performance criteria. In the total sample of 72 projects, the minimum or the best performing project, I-405 Sepulveda Pass Widening and HOV, in terms of cost growth has a value of 0.62, whereas the maximum or the worst performing project in terms of cost growth is I-80/San Francisco-Oakland Bay Bridge with a value of 2.50. The average cost performance of the sample data is 1.037 with a standard deviation of 0.235 and variance of 0.055. Similarly, the best performing project based on schedule is SR 99: Alaskan Way Viaduct Replacement with a value of 0.80 and the worst performing project is Miami Intermodal Center with a performance recorded at 2.42. The average schedule performance measure is slightly higher than cost performance with a value of 1.184, with standard deviation and variance larger than that of cost performance with values of 0.299 and 0.089, respectively.

In addition to the overall project data sample, the following lists the statistical numbers of the data based on the three different procurement methods. It is interesting to observe that the cost performance was much more consistent over the three different procurement methods compared to the schedule performance.

Table 4-2 Project Performance Data based on Procurement Methods

	DB/CMAR		DBB		PPP	
	CP	SP	CP	SP	CP	SP
Number of Projects	22	22	20	20	30	30
Minimum	0.930	0.800	0.62	0.93	0.83	0.81
Maximum	1.530	2.420	2.50	1.96	1.11	1.77
Mean	1.071	1.221	1.059	1.325	0.996	1.063
Standard Deviation	0.161	0.346	0.412	0.315	0.055	0.193
Variance	0.026	0.120	0.169	0.099	0.003	0.037

In Table 4-2, it can be seen that DBB projects are responsible for the best and worst cost performance, while DB/CMAR projects show the same traits for schedule performance. The minimum values of cost performance and schedule performance for DB/CMAR projects are 0.930 and 0.800, respectively, while the maximum values are 1.530 and 2.420, respectively. The average performance measure differs by 0.15 with cost performance having a relatively better performance value with 1.071 and schedule performance with 1.221. Like the mean value, there is higher deviation and variance among the data in schedule performance compared to cost performance with 0.346 compared to 0.161 regarding standard deviation, and 0.120 compared to 0.026 in variance. Likewise, the minimum values of cost and schedule performance for

DBB projects are 0.62 and 0.93, respectively, while the maximum values are 2.50 and 1.96, respectively. There is a higher gap between the average of the two performance criteria compared to DB/CMAR with schedule performance at 1.325 compared 1.059 in cost performance. However, deviation from the mean and variance shows an opposite trend such that cost performance for DBB projects have higher values of 0.412 (standard deviation) and 0.169 (variance), compared to 0.315 and 0.099 of schedule performance, respectively. PPP projects have values that lie within maximum and minimum values of DB/CMAR and DBB projects. The minimum values for cost and schedule performances are 0.83 and 0.81, respectively. Likewise, the maximum values are 1.11 and 1.77, respectively. Both the maximum values for PPP are lower than either of the other two procurement methods which shows that PPP projects have both better performing cost and schedule performances. In addition, mean values of 0.996 for cost performance and 1.063 for schedule performance indicate that PPP projects, on average, performed better than DB/CMAR and DBB projects.

The results obtained in this thesis also matches with that of the research carried out by (Shrestha, Migliaccio, O'Connor, & Gibson, 2007) on comparing DB projects with DBB projects in the US highway sector. The mean "cost growth" for DB projects in their research paper was -5.47%, while DBB projects had 4.12%. "Schedule growth", on the other hand, came out to be 7.59% for DB projects and 12.88% for DBB projects which shows a similar pattern to that of this thesis. The schedule performance has larger growth than cost performance on average over the entire data sample.

Schedule performance, the independent variable, was also measured against cost performance as the dependent variable. Regression analysis of these two variables showed a statistically significant result as depicted in the following.

Table 4-3 Overall Cost Performance Vs Schedule Performance

Schedule Performance		Cost Performance
Constant	p value	0.000***
Schedule Performance	p value	0.002**
F test value		10.280
p value		0.002**
R^2		0.128
Unstandardized Coefficients	Constant	0.703
	Schedule Performance	0.282
Standardized Coefficients	Constant	
	Schedule Performance	0.358
t value	Constant	6.550
	Schedule Performance	3.206

The results of the analysis are displayed in Table 4-3. As you can see, there is a significant difference in cost and schedule performance in the entire project sample including all three different procurement methods. The significance value of 0.2% indicates a statistically significant result among the two project performance criteria. R^2 is determined as 12.8% while F is determined as 10.280. Coefficients are positive, showing a positive relationship between cost and schedule performance. As explained in the concept of “Triple Constraint” by Baratta (2006), this finding coincides with what this theory claims about increase in cost due to impact of schedule. Although this theory states that to shorten the duration than what it was planned, clients would have to increase their cost, in this result, it can be assumed that to decrease the amount of delay already occurred, the clients had to pay more to either bring the project back on track or to keep the schedule growth at minimum. Therefore, this result supports second hypothesis, and the theory of "Triple Constraint" that cost is affected by a project's schedule such that when projects are behind schedule or delayed, clients and contractors have to increase their cost to reduce the delay.

A real-world example for this observation could be the I-80/San Francisco Oakland Bay Bridge project which got delayed. Due to this delay, and other causes, the project budget had to be increased almost every year based on the financial plan updates. The cost and schedule performance for this project is 2.50 and 1.90, respectively. This means, the project was 150% over budget and 90% behind schedule.

However, after dissecting the projects based on procurement type and conducting the same analysis, the individual results of DB/CMAR, DBB, and PPP projects were found to be not consistent.

Table 4-4 DB/CMAR Cost Performance Vs Schedule Performance

Schedule Performance – DB/CMAR		Cost Performance
Constant	p $value$	0.000***
Schedule Performance	p $value$	0.001**
F $test$ $value$		13.987
p $value$		0.001**
R^2		0.412
Unstandardized Coefficients	Constant	0.706
	Schedule Performance	0.298
Standardized Coefficients	Constant	
	Schedule Performance	0.642
t $value$	Constant	6.984
	Schedule Performance	3.740

Table 4-4 shows the cost performance against schedule performance data for DB/CMAR projects. Here, the significance with a value of 0.1% is slightly higher than the significance value of all three procurement types, meaning, the data shows a statistically significant relationship between the two variables. The R^2 is calculated to be 41.2% and F is calculated to be 13.987. In other words, there is a statistically significant relationship between schedule and cost performances within DB/CMAR projects.

A similar test was carried out for DBB and PPP projects as shown below, and the results of the analysis are shown in Table 4-5 and Table 4-6.

Table 4-5 DBB Cost Performance Vs Schedule Performance

Schedule Performance – DBB		Cost Performance
Constant	p $value$	0.000***
Schedule Performance	p $value$	0.175
F $test$ $value$		1.998
p $value$		0.175
R^2		0.100
Unstandardized Coefficients	Constant	0.512
	Schedule Performance	0.413
Standardized Coefficients	Constant	
	Schedule Performance	0.316
t $value$	Constant	1.287
	Schedule Performance	1.413

It can be seen that DBB projects do not show a statistically significant result between cost and schedule performance, based on the data collected. The significance value of 17.5%, R^2 of 10.0%, and F of 1.998 means that the data collected does not show significance between cost and schedule performance in traditionally procured and delivered projects.

Table 4-6 PPP Cost Performance Vs Schedule Performance

Schedule Performance – PPP		Cost Performance
Constant	$value$	0.000***
Schedule Performance	p $value$	0.735
F $test$ $value$		0.117

$p\ value$		0.735
R^2		0.004
Unstandardized Coefficients	Constant	0.977
	Schedule Performance	0.018
Standardized Coefficients	Constant	
	Schedule Performance	0.065
$t\ value$	Constant	16.916
	Schedule Performance	0.342

Likewise, PPP projects also do not show a statistically significant result with a $p\ value$ of 73.5%, R^2 of 0.4% and F of 0.117. This means that the statistical significance shown in the overall project data is largely due to the DB/CMAR projects based on the data collected and the results of the analysis.

Based on the above results, while DB projects' schedule performance does have a statistically significant impact on their cost performance, DBB and PPP projects do not. This means that the theory of "Triple Constraint" is supported only by DB projects, and not by DBB and PPP projects based on the data collected and results of the analysis. Therefore, the second hypothesis is supported by DB/CMAR projects only based on the data collected for this thesis. A graphical representation of the regression plot on the analysis discussed above is shown in the following Figure 4-10, Figure 4-11, and Figure 4-12 for DB/CMAR, DBB, and PPP, respectively.

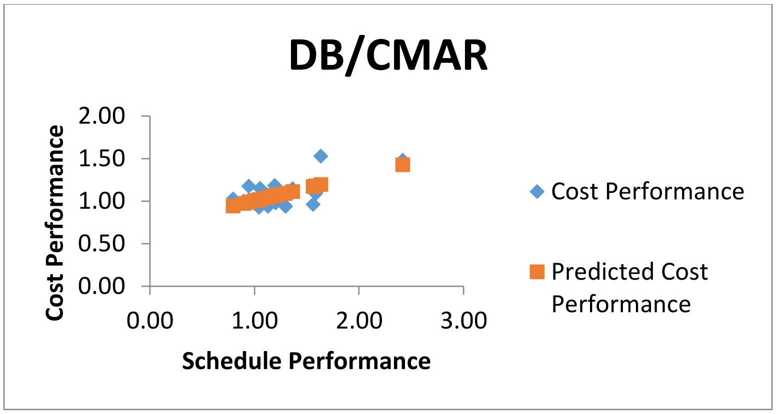

Figure 4-10 DB/CMAR Cost Performance Vs Schedule Performance

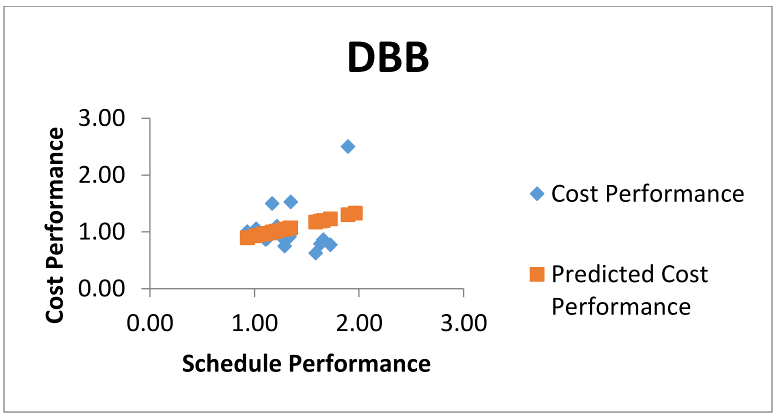

Figure 4-11 DBB Cost Performance Vs Schedule Performance

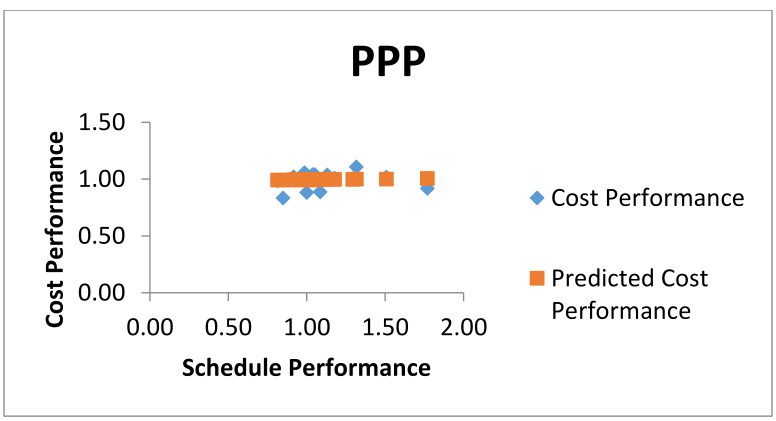

Figure 4-12 PPP Cost Performance Vs Schedule Performance

Analysis was also carried out between the performance criteria, as the dependent variables, and the procurement type as the independent variable. This analysis differs from the above analysis such that this analysis measures whether the variable procurement type has a statistically significant impact on the either of the two performance criteria.

Table 4-7 Cost Performance Vs Procurement Type

Procurement Type		Cost Performance
Constant	$p\ value$	0.000***
Procurement Type	$p\ value$	0.246
$F\ test\ value$		1.368
$p\ value$		0.246
R^2		0.019
Unstandardized Coefficients	Constant	1.079
	Procurement Type	-0.038
Standardized Coefficients	Constant	
	Procurement Type	-0.138
$t\ value$	Constant	23.566
	Procurement Type	-1.169

Based on Table 4-7, there is no statistically significant linear impact of procurement type on cost performance observed based on the data. The $p\ value$ is 24.6% with R^2 as 1.19% and F value of 1.368. The coefficients are less than 0, showing a negative relationship between cost performance and procurement type.

Table 4-8 Schedule Performance Vs Procurement Type

Procurement Type		Schedule Performance
Constant	$p\ value$	0.000***
Procurement Type	$p\ value$	0.036*
$F\ test\ value$		4.581
$p\ value$		0.036*
R^2		0.061
Unstandardized Coefficients	Constant	1.281
	Procurement Type	-0.87
Standardized Coefficients	Constant	
	Procurement Type	-0.248
$t\ value$	Constant	22.523
	Procurement Type	-2.140

Schedule performance, on the other hand, is statistically significantly linearly affected by the procurement type with a $p\ value$ of 3.6%, R^2 of 6.1% and F value of

4.581, based on a linear regression of the data as shown in Table 4-8. However, like cost performance, there is a negative correlation between procurement type and schedule performance, like that of cost performance. This result is, however, opposite of what (Shrestha et al., 2007) obtained in their research. The $p\ value$ for "cost growth" and "schedule growth" were 3% and 51%, respectively, in the results of their analysis. Their reasoning for the result obtained points towards the lack of experience with DB projects as well as the small sample size being largely affected by a one project data with extreme anomalies. Due to the larger data sample in this thesis, as well as almost equal number of projects (22 DB/CMAR Vs 20 DBB) projects being compared to one another, this thesis's result seems to stand on stronger grounds. Nonetheless, the difference might be due to the cost data being much more consistent over the different procurement types. This may be caused by the fixed-price contracts in PPP projects which are completely missing in the mentioned research paper by (Shrestha et al., 2007). Figure 4-13 shows a boxplot figure of schedule performance of the projects based on the three procurement types considered in this research. As it can be seen, '2' or PPP projects have the best overall schedule performance with the least amount of variation, whereas '1' or DBB projects have the worst overall schedule performance with the highest variation in the data collected.

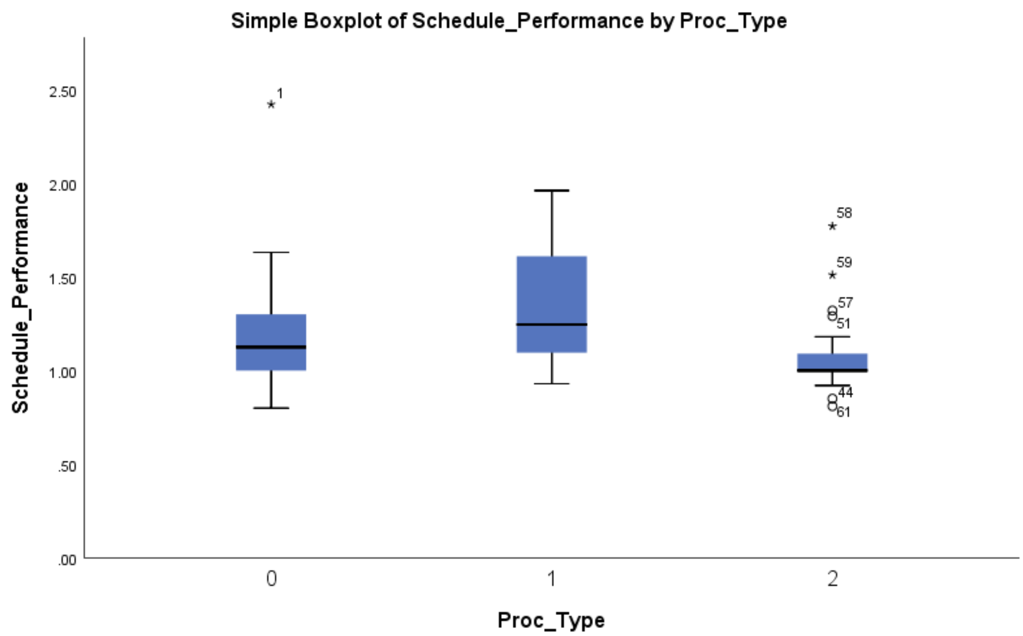

Figure 4-13 Boxplot of Schedule Performance Vs Procurement Type. (0=DB/CMAR, 1=DBB, 2=PPP)

Figure 4-14 provides a graphical representation of cost performance based on the three procurement types. In contrast to schedule performance, cost performance is more consistent with less variance over the three procurement types. All three procurement types have performance near the '1.00' mark which is the neutral point or 'point-zero' regarding project performance. Although each procurement type has less variance than their counter-parts in schedule performance, the trend in variance is similar in both cost and schedule performance diagrams.

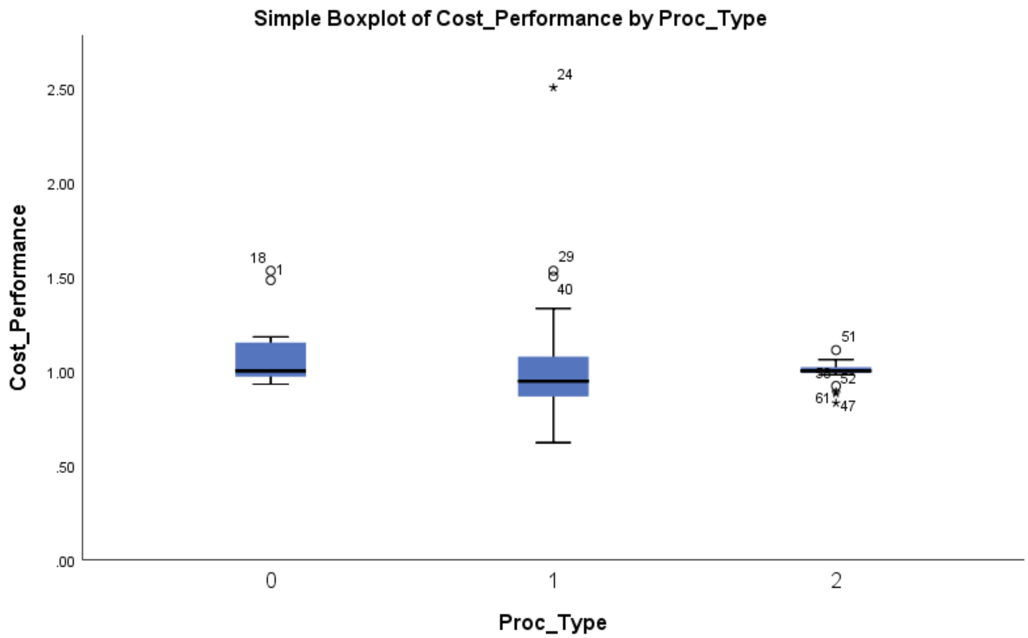

Figure 4-14 Boxplot of Cost Performance Vs Procurement Type. (0=DB/CMAR, 1=DBB, 2=PPP)

After analyzing the data based on the performance criteria against procurement type, regression analysis was also carried out between the two performance criteria against different centrality measures to check whether the two main entities of a project – clients or DOTs and contractors or GC/SPVs – and their centrality measures have any statistically significant impact on the two project performance criteria. First, multiple variable analysis was carried out that included all six different centrality measures for each project. Based on multicollinear diagnostics, those measures that had Tolerance lower than 0.2 or VIF higher than 10, and Variance Proportions values larger than 0.8 were removed and analysis for these variables were carried out separately.

Analysis was first started by including all variables. The regression analysis was repeated until the values of Variance Proportions, Tolerance and VIF all matched the required criteria as stated above. After numerous iterative steps, the multivariables analysis with no multicollinearity problem were brought down to three variables: GC/SPV Betweenness and Closeness, and DOT Betweenness. An example of the analysis and results of collinearity diagnostics is provided below.

Table 4-9 Multicollinearity Diagnostics with Variance Proportions

Dimension		1	2	3	4	5	6	7	8
	(Constant)	0	0	0	0	0	0.09	0.9	0.01
Variance Proportions	GC/SPV Closeness	0	0	0	0	0.01	0.05	0.05	0.88
	GC/SPV Betweenness	0	0.02	0	0.18	0.44	0.08	0.27	0
	DOT Betweenness	0	0.02	0	0.19	0.59	0.11	0.06	0.03
	DOT Closeness	0	0	0	0	0.01	0.09	0.13	0.77
	GC/SPV Total degree	0	0.01	0	0.03	0.16	0.29	0.02	0.49
	DOT Total degree measure	0	0.01	0.01	0.02	0.32	0.34	0.02	0.28
	No of Public agencies	0	0.02	0.53	0.07	0.01	0.02	0.3	0.05

The first result checked was the value of Variance proportions of each variable considered in the analysis. If their value was higher than 0.8, then these were eliminated first, and the process was repeated with the remaining variables. From Table 4-9, it can be said that No. of Public agencies does not go well with this group as its value is 0.88 with GC/SPV Closeness, hence this variable was eliminated, and a separate regression analysis was conducted.

Table 4-10 Multicollinearity Diagnostics with Tolerance and VIF

			Collinearity Statistics	
Model	t	Sig.	Tolerance	VIF
(Constant)	3.971	.000		
GC/SPV Closeness	.041	.968	.114	8.750
GC/SPV Betweenness	-1.094	.278	.256	3.902
DOT Betweenness	.864	.391	.251	3.978
DOT Closeness	.061	.952	.121	8.250

GC/SPV Total degree	-.075	.941	.130	7.668
DOT Total degree measure	-.194	.847	.134	7.458
No of Public agencies	2.457	.017	.650	1.539

Table 4-10 shows the collinearity diagnostics based on Tolerance and VIF. If there were no variables with variance proportions higher than 0.8, then these two statistical variables were considered. If the value for Tolerance is less than 0.2 or VIF is higher than 10, then those variables are removed from the analysis, and the process is repeated for the variables remaining in the set. Here, GC/SPV and DOT Closeness, GC/SPV and DOT Total Degree all have values less than 0.2. Now, after eliminating No of Public agencies from the data list, another multicollinear diagnostics is carried out. After a few iterations, the variables that were remaining in the end went through a regression analysis.

The results show that there is a statistically significant linear relationship between these three variables and schedule performance based on the data, but the data do not show a statistically significant linear relationship between cost performance and these variables.

Table 4-11 Multi-Variable Analysis

Multi-Variable analysis		Cost Performance	Schedule Performance
Constant	$p\ value$	0.000***	0.000***
GC Closeness	$p\ value$	0.922	0.173
GC Betweenness	$p\ value$	0.558	0.086
DOT Betweenness	$p\ value$	0.349	0.442
$F\ test\ value$		0.323	6.279
$p\ value$		0.809	0.001**
R^2		0.014	0.217
Unstandardized Coefficients	Constant	0.914	1.447
	GC Closeness	0.019	-0.295
	GC Betweenness	0.080	-0.266
	DOT Betweenness	0.131	0.122

Standardized Coefficients	Constant		
	GC Closeness	0.014	-0.175
	GC Betweenness	0.098	-0.259
	DOT Betweenness	0.168	0.123
$t\ value$	Constant	4.721	6.606
	GC Closeness	0.099	-1.378
	GC Betweenness	0.589	-1.740
	DOT Betweenness	0.943	0.773

As seen in Table 4-11, there is a statistically significant relationship between schedule performance and variables including GC/SPV Closeness, GC Betweenness, and DOT Betweenness. The $p\ value$ of the analysis is 0.1%, with F value of 6.279, and R^2 of 0.217. While there is a positive relationship between DOT Betweenness and Schedule Performance, both centrality measures of GC/SPV carry a negative valued coefficient. This means that if closeness and betweenness centrality of GC/SPV increases, then the schedule performance becomes better, and vice versa. However, if betweenness centrality of DOT decreases, then this will lead to better schedule performance. Comparing this to $p\ value$ of 0.809, F value of 0.323, and R^2 of 0.014, with all three coefficients depicting a positive relationship between the independent variables and dependent variables, the cost performance data collected does not show a statistically significant linear relationship with the three variables. This result partly supports and partly disagrees with the third hypothesis. The hypothesis states that projects perform better if GC/SPV centrality increases. While this hypothesis is supported by the results for schedule performance, it is not supported by cost performance. The reason for this occurrence might be due to the schedule of the project being delayed by the clients themselves which cannot be considered in the total project cost as project costs are based on the engineer's estimate of the project cost regarding preliminary engineering, design, construction, finance, operation, and maintenance, among others rather than the total costs incurred by the clients in the project.

Separate analyses were then carried out to check whether the project performance criteria have a statistically significant relationship with the two specific stakeholders' – GC/SPV and DOT – centrality measures. Like done previously, first a multi-variable analysis was carried out and the variables that did not fall under the acceptable category based on multicollinear diagnostics were removed and analysis was carried out for the remaining variables and the removed variables separately as presented in the following.

Table 4-12 shows the result of the analysis between DOT centrality measures – closeness and betweenness– against cost and schedule performance. As expected, based on previous results, the data shows a statistically significant linear relationship between schedule performance and the two DOT centrality measures – closeness and betweenness. The $p\ value$ of this analysis is 0.3% with F value of 6.339 and R^2 of 0.155. Digging deeper into the result, separate $p\ values$ for both centrality measures are also provided. The $p\ value$ for closeness is 87%, which is statistically not significant, and betweenness is 0.4%, which is statistically significant based on the collected data. In addition, there is contrast between the two variables regarding their coefficients as well. While closeness carries a negative coefficient value, betweenness has a positive coefficient value, showing the type of relationship schedule performance has with the two independent variables. This keeps consistent with the results shown in Table 4-11. Therefore, if the DOT betweenness increases, schedule performance decreases i.e., performs badly, and if DOT closeness increases, schedule performance increases i.e., performs better. Cost performance, on the other hand, does not show a statistically significant linear relationship with the two centrality measures of DOT. The $p\ value$ is 73.5%, with R^2 of 0.9% and F value of 0.310.

Table 4-12 Project Performance Vs DOT Closeness & Betweenness

DOT Closeness & Betweenness		Cost Performance	Schedule Performance
Constant	$p\ value$	0.000***	0.000***
Closeness	$p\ value$	0.904	0.870
Betweenness	$p\ value$	0.583	0.004**
$F\ test\ value$		0.310	6.339
$p\ value$		0.735	0.003**
R^2		0.009	0.155
Unstandardized Coefficients	Constant	0.987	0.994
	Closeness	0.024	-0.037
	Betweenness	0.064	0.402
Standardized Coefficients	Constant		
	Closeness	0.018	-0.023
	Betweenness	0.082	0.407
$t\ value$	Constant	9.415	8.087
	Closeness	0.121	2.952
	Betweenness	0.551	-0.164

Comparing this result with the ones in Table 4-11, the $p\ value$ is larger for DOT closeness and betweenness with the value of 0.3%. The result in Table 4-11 is from a mix of variables that have been filtered through iterative process of multicollinear diagnostics. The variables GC/SPV closeness and betweenness and DOT betweenness are cohesive of each other which leads to a better statistically significant result than that was obtained when DOT betweenness and closeness were analyzed against the project performance criteria due to a relatively lower multicollinear attribute. However, although statistically insignificant, the $p\ value$ for cost performance is smaller for DOT closeness and betweenness than in the multi-variable analysis result unlike schedule performance.

Table 4-13 Project Performance Vs DOT Total Degree

DOT Total Degree		Cost Performance	Schedule Performance
Constant	p $value$	0.000***	0.000***
Total Degree	p $value$	0.803	0.002**
F $test$ $value$		0.063	10.157
p $value$		0.803	0.002**
R^2		0.001	0.127
Unstandardized Coefficients	Constant	1.024	0.987
	Total Degree	0.027	0.403
Standardized Coefficients	Constant		
	Total Degree	0.030	0.356
t $value$	Constant	17.287	14.039
	Total Degree	0.251	3.187

Table 4-13 shows the results for DOT total degree. As mentioned previously, this variable was analyzed separately due to multicollinear diagnostics requirements not being satisfied. Regardless, this variable shows statistically significant linear relationship with schedule performance but not with cost performance, similar to trait shown by previous variables. The p $value$ for schedule performance is 0.2%, R^2 of 12.7%, and F value of 10.157 with positive coefficient of 0.403. This result along with the result in Table 4-12, adds to the third hypothesis that project performance, schedule performance in this case, is impacted by not only GC/SPV's centrality but also DOT's centrality. The nature of this relationship however, is different compared to that of GC/SPV. Only when DOT closeness centrality increases, does projects perform better based on duration. If DOT betweenness and total-degree increases, there will be delay in schedule. This implies that DOTs having close connection to all other stakeholders in the network will be able to deliver projects faster. And, DOTs having higher number of direct connections and falling in between other pairs of stakeholders leads to project delays. On the other hand, cost performance has a $p\ value$ of 80.3%, R^2 of 0.1% and F value of 0.063 with positive coefficient of 0.027. As is the pattern, again, the data did not show statistical significance based on linear relationship between cost performance and DOT total degree, whereas there is a statistically significant relationship between schedule performance and DOT total degree.

In addition to DOTs centrality measures analysis against project performance criteria, separate analysis was carried out using only GC/SPV centrality measures. Multicollinearity diagnostic was conducted for this analysis as well which lead to the grouping of closeness and betweenness, and total degree being analyzed separately.

Table 4-14 shows results of the regression analysis between GC/SPV closeness and betweenness against cost and schedule performance. As it is consistent with results shown above, it is found from the data collected that there exists a statistically significant linear relationship between schedule performance and the centrality measure variables of GC/SPV, whereas no statistically significant linear relationship was found between cost performance and the independent variables. The $p\ value$ is 0.0%, R^2 is 21%, and F value of 9.173. The significance value of 0.0% indicates extremely high level of significance in the result. This means that schedule performance is affected by the centrality measures, closeness and betweenness, of GC/SPV by a large margin. The coefficients are negative for both types of centrality measures, which is consistent with the results presented in Table 4-11. In contrary, cost performance $p\ value$ is 96.1%, which is the opposite extreme of schedule performance, with R^2 of -0.1% and F value of 0.040. The coefficients in this result are found not consistent with the ones in Table 4-11 such that in Table 4-11 both closeness and betweenness have positive relationships with dependent variables, or the performance criteria, but results shown in Table 4-14 provides a negative relationship between cost performance and GC/SPV closeness.

Table 4-14 Project Performance Vs GC/SPV Closeness & Betweenness

GC/SPV Closeness & Betweenness		Cost Performance	Schedule Performance
Constant	$p\ value$	0.000***	0.000***
Closeness	$p\ value$	0.983	0.078
Betweenness	$p\ value$	0.792	0.007**
$F\ test\ value$		0.040	9.173
$p\ value$		0.961	0.000***
R^2		0.001	0.210
Unstandardized Coefficients	Constant	1.066	1.588
	Closeness	-0.047	-0.355
	Betweenness	0.002	-0.338
Standardized Coefficients	Constant		
	Closeness	-0.035	-0.211
	Betweenness	0.003	-0.328
$t\ value$	Constant	9.901	13.066
	Closeness	-0.265	-1.789
	Betweenness	0.021	-2.787

Similar analysis was carried out separately for GC/SPV total degree centrality since this variable did not meet the required collinearity index with the other two variables. Nonetheless, the results in Table 4-15 show a statistically significant linear relationship between schedule performance and GC/SPV total degree. The $p\ value$ of 0.1% indicates high statistical significance between the two variables, with R^2 of 14.8% and F value of 12.155. Coefficients show a negative relationship for both schedule and cost performance with GC/SPV total degree. In contrary, the data does not show a statistically significant linear relationship between cost performance and

GC/SPV total degree. The $p\ value$ of 84.4%, R^2 of 0.1% and F value of 0.039, all contribute to this insignificance. The results from Table 4-14 and Table 4-15 adds more solid evidence to one part of the third hypothesis claiming increased in GC/SPV centrality leads to better project performance. All three centrality measures of GC/SPV show statistical significance in addition to the same type of relationship regarding schedule performance.

Table 4-15 Project Performance Vs GC/SPV Total Degree

GC/SPV Total Degree		Cost Performance	Schedule Performance
Constant	$p\ value$	0.000***	0.000***
Total Degree	$p\ value$	0.844	0.001**
$F\ test\ value$		0.039	12.155
$p\ value$		0.844	0.001**
R^2		0.001	0.148
Unstandardized Coefficients	Constant	1.048	1.427
	Total Degree	-0.023	-0.473
Standardized Coefficients	Constant		
	Total Degree	-0.024	-0.385
$t\ value$	Constant	15.977	18.548
	Total Degree	-0.198	-3.486

Finally, regression analysis was carried out for the last variable in the data set, No. of Public agencies. This variable, although does not measure the centrality of stakeholders, contributes to the value of centrality measures of DOTs, which affects the centrality values of all other stakeholders. Moreover, based on the theory that project sponsors can contribute to project performance, this analysis aims to determine if the number of public agencies or sponsors involved in a project plays any part in affecting the project performance.

Table 4-16 Project Performance Vs No. of Public agencies

No. of Public agencies		Cost Performance	Schedule Performance
Constant	$p\ value$	0.000***	0.000***
No. of agencies	$p\ value$	0.093	0.000***
$F\ test\ value$		2.896	14.495
$p\ value$		0.093	0.000***
R^2		0.040	0.172
Unstandardized Coefficients	Constant	0.971	1.011
	No. of agencies	0.034	0.089
Standardized Coefficients	Constant		
	No. of agencies	0.199	0.414
$t\ value$	Constant	20.512	18.108
	No. of agencies	1.702	3.807

Based on the data shown in Table 4-16, it is evident that there is a statistically significant linear relationship between schedule performance and no. of public agencies with a $p\ value$ of 0.0%, R^2 of 0.172, and F value of 14.495. The 0.0% significance value indicates that the number of public agencies involved in a project does play a crucial role in determining the project's duration and schedule performance, whereas the same cannot be said about cost performance based on the data. The positive coefficient and the significance in schedule performance partly support the fourth hypothesis that a greater number of public agencies involved in a project leads to reduced performance. Cost performance has a $p\ value$ of 9.3%, which is statistically insignificant based on the linear relationship that was utilized in the analysis, although relatively, the value of 9.3% is much better than the level of statistical significance that other independent variables show with the two project performance criteria. R^2 was calculated to be 4% and F value equal to 2.896.

Chapter 5 Discussion

Discussion

There were four hypotheses proposed in this thesis. The first one, based on stakeholder and social network theories, proposed that if PPP method or alternative delivery method is used to procure projects, the private entity represented by general contractors or special purpose vehicles will show higher centrality in the network than the public sector parties like the project sponsors due to the increase in work scope, responsibilities, risks allocated, and overall responsibility of project delivery. Second proposed that project cost will increase if project schedule is delayed based on the "Triple Constraint" theory which implies that clients have to spend more in order to complete the project faster. The third one claimed that the increase in centrality measures – total-degree, betweenness, and closeness – of the private key stakeholders including general contractors or special purpose vehicles improves both cost and schedule performance. And, the final claim states that an increase in the number of public agencies or project sponsors in the project will lead to projects performing worse, on both cost and schedule basis. Out of the four hypotheses, first was fully supported by the data while the remaining three were partly supported and partly rejected based on the data.

The social network analysis of stakeholders in this research paper shows that private sector companies like general contractors or special purpose vehicles tend to become the most central node in the network in public-private partnership projects. This might be due to the transfer of work responsibilities from public to private sector. The article by (Pryke, 2004) on "application of social network analysis" in construction project coalitions supports this hypothesis as they also deduce that influence pattern changes in a network as the "actors" are mapped out based on degree centrality. In design-bid-build projects, the average betweenness centrality of GC/SPVs is 0.256 compared to 0.754 of DOTs. Similarly, closeness centrality of GC/SPV falls short compared to 0.810 of DOTs as well as total-degree centrality of 0.357 of GC/SPVs against 0.762 of DOTs. DB/CMAR projects show a relatively closer comparison with 0.422 against 0.639, 0.590 against 0.658, and 0.443 against 0.512 of GC/SPV and DOT, respectively. In contrary, GC/SPVs out score DOTs in PPP projects with 0.751, 0.720, and 0.658 compared to 0.305, 0.474, and 0.229 for betweenness, closeness, and total-degree, respectively. Figure 5-1 provides a graphical representation. The grey line, representing PPP, is near the outer circle for GC/SPV centrality measures, while the orange line, representing PPP, is further from the center for points at DOT centrality measures. DB/CMAR projects, shown as the blue line, hovers between PPP and DBB rings. DB has higher GC/SPV betweenness and total-degree than PPP due to the contracts that are held between the design-builders, architects, and contractors.

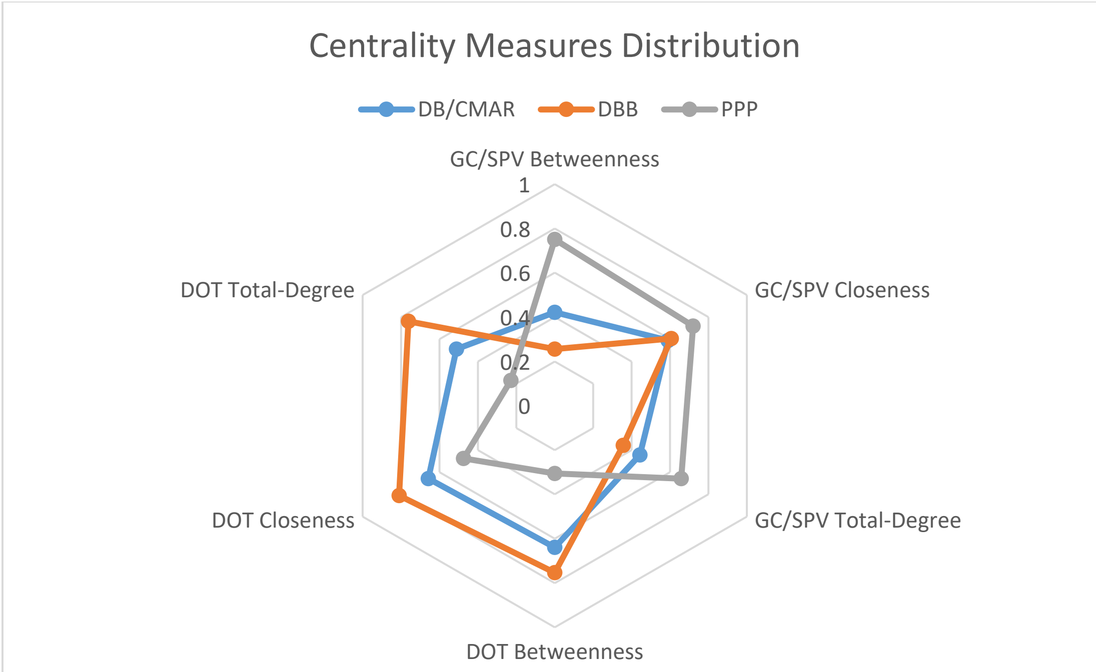

Figure 5-1 Centrality Measures Distribution between GC/SPVs and DOTs

The second hypothesis that the results partly support is that project cost will increase if the project schedule is delayed. The theory of triple constraint implies that cost increases when schedule is to be shortened. Applying the logic behind this theory, the results of the analysis shows that project cost is significantly affected by the project schedule such that when the schedule needs to be reduced, the cost will increase. This nature of relationship is supported by the positive coefficient obtained in the result. In addition, (Ahsan & Gunawan, 2010) states that "projects taking more time cost more money." However, this was not the case when the analysis was carried out based on three different procurement methods – DB/CMAR, DBB, and PPP. There was a significant relationship only in the case of DB/CMAR projects, whereas DBB and PPP projects results did not show significance. The reason for this might be different contracting methods used in the projects. PPP projects are financed through various sources such as private bonds, bank loans, equity investment, and so forth.

Therefore, delays regarding construction and design are bore upon by the private entity unless the clients are the reason behind the delay. DBB projects usually have fixed-price lump sum contracts where the contractor is obliged to complete their contract requirements, generally construction, within a certain budget and time frame. The scope is technically fixed since the design is completed beforehand. In the case of DB projects, design and construction are done simultaneously, which might lead to scope and design changes, affecting the project schedule as well as the cost since the changes are usually based on mutual agreement between client and contractor.

Third hypothesis, regarding impact of centrality measures on project performance is also only partly supported by the data. Due to the insignificance in the results between cost performance and every other variable, this hypothesis was not fully supported for any of the centrality measures. The reason for this insignificance might be due to the fact that highway project costs, although paid by the DOTs, are money from the public earned through taxes and other funds which might provide an incentive to control the cost. However, for schedule performance, the claim that increase in GC/SPV centrality in the stakeholder network leads to better performance has been fully backed up by the results. The level of significance ($p \leq 0.000$) indicates the level of impact that GC/SPV centrality measures have on project schedule performance. For instance, SR826/SR836 Interchange Reconstruction project has the best performing schedule among PPP projects with a value of 0.81 or 19% ahead of schedule. In this project, the GC/SPVs centrality measures are consistently higher than DOT with all three measures having the significant value of '1'. Louisville-Southern Indiana Ohio River Bridge East End Crossing project had a schedule performance value of 0.85, meaning 15% ahead of schedule. This project also has GC/SPV centrality measures significantly higher than DOTs for all three measures. Moreover, high involvement of DOTs as the information broker or just having high number of direct connections negatively impacts schedule performance. Projects like I-80/San Francisco-Oakland Bay Bridge (East Span), and Circle Interchange were delayed by more than 90%, with values 1.90 and 1.96, respectively. In both these projects, the DOT betweenness and total-degree are significantly high. Instead, DOTs maintaining close connections with all other stakeholders in the network instead of being directly involved between other stakeholders will lead to better schedule performance. This is illustrated in projects namely, New Mississippi River Bridge, I-95/I-395/I-395 Springfield Interchange, and I-41 Reconstruction where these projects have performance values of 1.02, 0.93, and 1.08, respectively. All these projects have significantly higher DOT closeness centrality. In addition, the conclusion from the research by Wang & Huang (2006) supports the point that GC/SPVs or "supervision companies" being responsible for the project leads to better performance. On the other hand, the conclusion stating "project owners play the most important role in determining project success" contradicts with the results of this study in the case for PPP projects which shows the project contractors play the bigger role.

The last hypothesis claiming that higher number of public agencies involvement will lead to reduced project performance is also only partly supported due to lack of significant result with cost performance, although the nature of relationship between these two variables is the same. Regardless, the data does prove that higher the number of public agencies involved, mainly comprising of project sponsors, reduce the schedule performance. This trend, as shown in Table 5-1, can be observed in projects such as Miami Intermodal Center, Gerald Desmond Bridge Replacement, I-80/San Francisco-Oakland Bay Bridge East End Crossing, PGBT – Eastern Extension, and I-10/Katy Freeway Project, where the number of public agencies involved in the project were 4, 3, 6, 4, and 3, respectively. Therefore, the theory of how project sponsors can influence project's success (Hall, Holt, & Purchase, 2003) could also include the notion of 'how many', based on the implications of the results obtained in this research paper. The assumption behind this claim is that higher number of sponsors from the public sector will increase the diversity of expectations and requirements among the sponsors, which need to be considered. The case of Presidio Parkway exemplifies this claim. Presidio Trust, the owner of the land on which the project was being built required showed "erratic behavior" due to their lack of "experience with big construction" as stated in a Public Works Financing article on September 2016 by William G. Reinhardt.

Project Name	Cost Perf.	Schd. Perf.	NPA
Miami Intermodal Center	1.48	2.42	4
Gerald Desmond Bridge Replacement	1.53	1.63	3
I-80/San Francisco-Oakland Bay Bridge EEC	2.50	1.90	6
PGBT – Eastern Extension	0.77	1.73	4
I-10/Katy Freeway Project	1.53	1.35	3

Table 5-1 Project Performance based on No. of Public Agencies (NPA)

Conclusion

The findings from this research provides empirical evidence to support the theory laid out by (Pryke, 2004) that conducting a social network analysis on a stakeholder network in construction firms can lead to change in the influence patterns observed in the network. The shift in centrality from DOT as the client to GC/SPV as the contractor in PPP projects and some DB/CMAR projects is evidence to this claim. In addition, this finding can also be useful to the PPP practitioners of construction industry such that GC/SPVs realize their importance and influence over the network and the project is higher than DOTs as they have a greater number of contractual relationships with multiple parties. Moreover, DOTs can use this knowledge in their decision-making process in the project by involving the concessionaire or SPVs in all phases of the project from planning to completion.

In addition, the results also reveal that PPP projects outperform DB/CMAR and DBB projects on average with lower variance in the data. In other words, PPP projects are more consistent and reliable. It is not a coincidence that in these projects, GC/SPVs are more central. This result provides one empirical reason of how and why PPP projects perform better based on stakeholders and stakeholder network. Based on this logic, it can be concluded that GC/SPVs high involvement in projects provides a very high and positive contribution to the project success, regarding schedule.

Based on additional analysis between schedule and cost performance, using the Triple Constraint theory, it is argued that cost will increase not only to deliver projects earlier, but also when projects are delayed, even though cost performance was statistically insignificant with all other variables considered in the data.

The number of public agencies or sponsors involved in a project also plays a significant role in project schedule performance. This observed data can add the notion of ‘how many’ to the theory of ‘how’ project sponsors can contribute to project success.

Research Limitations

Although every effort was made to make this study as comprehensive and accurate as possible, there are a few limitations to the scope of this study that need to be taken into account when assessing the results. External stakeholders such as local residents, non-profit organizations, charity foundations, media, and so forth were not considered in the analysis due to the lack of proper and consistent source of data for these variables. Including these stakeholders could most likely change the individual entities of the results, although, the pattern should be the same overall. Moreover, due to the size of the data sample, it was deemed that including external stakeholders might make this thesis ambiguous. The data collected for this thesis are completely based on 'major' transportation projects in the US. The cutoff for projects to be considered as 'major' is projects with cost higher than $500 million. Therefore, the results might not be as useful when dealing with smaller scaled projects.

Moreover, the data sample includes transportation and highway projects only in the United States. In addition, stakeholder data for all projects were not available or accessible due to number of reasons. Projects that were completed did not have working project websites, which meant that contractors were searched on DOT website's contract logs or award logs. To find out which contract was awarded to which contractor, the contract price given on the website was compared to the contract prices listed in other sources and name of the contractors and their links to the project were established.

In addition, projects which had recently started construction were assumed to have a neutral performance value. Since there were only a handful of projects without performance data, it was anticipated that the results would not have changed significantly. Subcontractors and subconsultants were not considered in the analysis due to the extremely large numbers and high time consumption. They were also excluded from the research to maintain consistency of data quality over all the projects. While some projects had provided subcontractor information, not all of them had this data. Moreover, some projects have more than 30-40 subcontractors while some have less than 10 that are readily accessible. Projects that did not have complete data or quality data were ignored to improve the accuracy and preciseness of the result as much as possible. This was the main reason the data sample was not as big as it was planned.

Recommendations

Due to the large number of stakeholders involved in a project, it is a challenge to be able to fully understand each stakeholder's interest and expectations. The concept of analyzing stakeholders based on their individual attributes is not wrong. However, this analysis is limited in a way that it does not consider the stakeholders behavior relative to the network. A conceivably low-level stakeholder might be more influential than high-level stakeholders. This is exemplified by the emergence of private sector stakeholders such as GCs or SPVs and even financiers, such as USDOT TIFIA, Banks, and Bondholders, who have higher centrality measures than many other stakeholders, such as contractors or consultants, who are more directly involved in the project. The higher centrality is because of the connections (contractual relationships) that they have in the network, and their roles with relation to the network as a whole rather than just their roles in the project. Therefore, using both stakeholder and social network analysis to appropriately classify and stakeholders could one of the first steps in properly understanding the key project stakeholders and their behavior (Prell, Hubacek, & Reed, 2009).

Greater involvement by contractors or the private sector in the design and construction phase will be “most efficient” as stated by (Quiggin, 1996) in his article on “Private Sector Involvement in Infrastructure Projects”. This claim is supported by the data and results obtained in this research paper which shows higher centrality of the private entity in projects have a direct and positive impact on project’s schedule performance, although cost performance, statistically, was not affected significantly. While private companies’ betweenness centrality brings about negative impact on cost performance, total-degree and closeness centrality leads to positive impacts. Thus, public and governmental agencies should encourage more participation from the private parties during the design and construction phase. Moreover, governmental agencies holding contracts with many stakeholders negatively affects project’s schedule performance in statistically significant way; cost performance is also negatively affected but insignificantly. The data and results from this thesis provide evidence that governmental agencies should, while maintaining a close relationship with stakeholders, avoid having too many contractual relationships with other stakeholders. In other words, the number of connections between them and every other stakeholder should be high while the number of direct connections between them and other stakeholder should be lower.

Finally, the number of public agencies or sponsors involved in a project should not be more than what’s absolutely required to avoid the conflict of ideas and expectations among sponsors which will significantly hamper a project’s progress.

Additional research is necessary to determine whether the variables considered in this thesis can affect other project performance criteria. It would be interesting, and even deserving, to find out the specific reasons behind the performance values for specific projects such as the Miami Intermodal Center or I-80/San Francisco-Oakland Bay Bridge by conducting a detailed case study or interviews. In addition, expanding stakeholder analysis to include intangible attributes such as "motivation", "concern", "expectations", "perception", "attitude", and "behavior" of the stakeholders in addition to their salience can significantly improve the accuracy of the results of analysis ((Khan et al., 2017), which can also help to understand their network behavior. Adding to this, it is also important to determine if there are variables other than the ones included in this thesis and listed above that are related to stakeholder and network centrality that affect project performance. Overall, a framework for the construction industry that combines stakeholder analysis and social network analysis theories similar to what Lienert, Schnetzer, & Ingold (2013) conducted for "water infrastructure planning" would be another potentially very beneficial field to explore in the near future.

Appendices

Appendix A: Research Data

Project_Name	PT	CP	SP	IC	ID	AC	AD	GSB	SGSB	DB	SDB	GSC	SGSC	DC	SDC	GST	SGST	DT	SDT	NPA	UTC	BBC
Miami Intermodal Center (MIC)	0	1.48	2.42	1350.00	2192.00	1999.50	5297.00	0.000	0	0.811	1	0.500	0	0.833	1	0.200	0	0.800	1	4	0.588	0.476
O'Hare Con-RAC	0	0.96	1.56	817.00	1207.00	786.00	1884.00	0.325	0	0.925	1	0.533	0	0.762	1	0.250	0	0.688	1	2	0.500	0.444
Intercounty Connector	0	0.98	1.20	2445.90	2379.00	2399.10	2864.00	0.345	0	0.705	1	0.487	0	0.594	1	0.316	0	0.316	0	2	0.422	0.388
Triangle Expressway, Western Wake Freewa	0	0.94	1.30	1031.40	813.00	971.10	1055.00	0.399	0	0.608	1	0.563	0	0.720	1	0.333	0	0.611	1	2	0.500	0.450
Central Texas Turnpike	0	0.93	1.04	2942.00	2048.00	2733.00	2140.00	0.239	0	0.771	1	0.511	0	0.727	1	0.271	0	0.625	1	2	0.480	0.429
I-64, from Spoede Rd. to Sarah Street	0	0.99	1.00	535.00	1583.00	529.10	1583.00	0.286	1	0.000	0	1.000	0	0.538	0	1.000	0	0.143	0	1	NA	NA
Kosciuszko Bridge Replacement	0	0.97	1.00	970.70	2849.00	945.50	2849.00	0.639	1	0.583	0	0.750	1	0.692	0	0.667	1	0.556	0	2	NA	NA
SR-91 Corridor Improvement/HOT lanes initial project	0	1.08	1.12	1311.70	1560.00	1421.30	1740.00	0.350	0	0.882	1	0.563	0	0.750	1	0.333	0	0.667	1	1	0.486	NA
IH 35E Managed Lanes (Dallas & Denton)	0	1.18	1.19	1222.20	1402.00	1445.60	1672.00	0.409	0	0.848	1	0.545	0	0.706	1	0.333	0	0.583	1	1	0.500	NA
SR 99: Alaskan Way Viaduct Replacement P	0	1.03	0.80	2184.30	2698.00	2240.00	2149.00	0.600	0	0.400	0	0.833	0	0.714	0	0.800	0	0.600	0	1	NA	NA
SR 520, Medina to SR202: Eastside Trans	0	0.95	1.28	534.40	1180.00	510.10	1516.00	0.484	0	0.824	1	0.563	0	0.692	1	0.389	1	0.556	1	1	0.486	NA
SR 520, I-5 to Medina: Bridge Replaceme	0	1.15	1.05	1128.50	1771.00	1299.80	1863.00	0.404	0	0.846	1	0.548	0	0.708	1	0.353	0	0.588	1	1	0.500	NA
SR 520 - Pontoon Construction Project	0	0.94	1.13	608.60	1391.00	571.40	1572.00	0.419	0	0.846	1	0.548	0	0.708	1	0.353	0	0.588	1	1	0.500	NA
Thimble Shoal Tunnel	0	1.00	1.12	919.00	2069.00	921.00	2311.00	0.439	0	0.803	1	0.571	0	0.706	1	0.417	0	0.583	1	2	0.500	0.429
I-405 Improvement Project (SR-73 to I-605)	0	1.00	1.01	1900.00	2397.00	1900.00	2409.00	0.600	1	0.676	1	0.536	1	0.556	1	0.333	0	0.400	1	2	0.429	0.366
Bergstrom Expressway - US 183 from US 290 to SH 71	0	1.00	0.90	743.00	1827.00	743.00	1643.00	0.327	0	0.836	1	0.524	0	0.733	1	0.273	0	0.636	1	5	0.524	0.440
Monroe Expressway	0	1.09	1.58	671.00	1736.00	731.00	2751.00	0.506	1	0.577	1	0.232	0	0.228	0	0.462	1	0.423	0	2	0.464	0.197
Gerald Desmond Bridge Replacement	0	1.53	1.63	960.00	2069.00	1467.00	3381.00	0.506	1	0.564	1	0.591	0	0.650	0	0.462	1	0.423	0	3	0.192	NA
Tappan Zee Hudson River Crossing/New NY Bridge	0	1.03	1.23	4023.00	2007.00	4128.00	2464.00	0.471	0	0.738	1	0.593	0	0.696	1	0.438	0	0.531	1	1	0.471	0.059
SH 99 Grand Parkway Segment H & i-1	0	1.00	1.00	-	-	-	-	0.281	0	0.164	0	0.388	0	0.500	0	0.263	0	0.158	0	2	0.463	0.404
SH 99 Grand Parkway Segment F-G	0	1.15	1.36	1527.00	1036.00	1749.00	1414.00	0.648	1	0.665	1	0.609	0	0.636	0	0.500	1	0.393	0	1	0.452	0.067
I-15 Corridor Salt Lake County	0	1.18	0.95	1360.00	1675.00	1600.00	1583.00	0.600	1	0.000	0	1.000	1	0.625	0	1.000	0	0.400	0	1	NA	NA
I-405 Sepulveda Pass Widen and HOV	1	0.62	1.59	950.00	1440.00	593.60	2283.00	0.000	0	0.773	1	0.474	0	0.818	1	0.111	0	0.778	1	4	NA	0.529
I-80/San Francisco-Oakland Bay Bridge (E	1	2.50	1.90	2587.00	2953.00	6465.30	5599.00	0.363	0	0.799	1	0.519	0	0.700	1	0.286	0	0.571	1	6	NA	NA
I-10 Twin Span Structures	1	0.91	1.33	803.00	1826.00	732.60	2436.00	0.600	0	0.600	0	0.750	0	0.667	0	0.667	0	0.500	0	1	NA	NA
I-95/Woodrow Wilson Bridge	1	0.97	1.20	2443.00	3589.00	2374.60	4320.00	0.228	0	0.614	1	0.490	0	0.632	1	0.250	0	0.417	1	3	NA	NA
New Mississippi River Bridge	1	1.05	1.02	660.00	1596.00	694.40	1624.00	0.343	0	0.440	1	0.600	0	0.833	1	0.333	0	0.800	1	2	NA	NA
PGBT - Eastern Extension	1	0.77	1.73	1037.20	1422.00	801.10	2455.00	0.000	0	0.872	1	0.481	0	0.867	1	0.077	0	0.846	1	4	NA	NA
I-10/Katy Freeway Project	1	1.53	1.35	1761.00	2098.00	2690.50	2828.00	0.310	0	0.643	1	0.700	0	0.875	1	0.571	0	0.857	1	3	NA	NA
Southwest Parkway (SH 121)	1	0.79	1.63	1480.90	1012.00	1168.90	1650.00	0.225	0	0.297	1	0.933	0	1.000	1	0.929	0	1.000	1	2	NA	NA
I-95/I-395/I-495 Springfield Interchange	1	1.00	0.93	676.00	1779.00	676.00	1657.00	0.286	0	0.952	1	0.583	0	0.875	1	0.286	0	0.857	1	1	NA	NA
Central Artery/Ted Williams Tunnel	1	1.10	1.21	13500.00	5040.00	14798.00	6120.00	0.303	0	0.955	1	0.571	0	0.857	1	0.250	0	0.833	1	2	NA	NA
I-43/I-94/I-794 Marquette Interchange	1	0.97	0.93	810.00	1763.00	784.00	1645.00	0.643	0	0.571	0	0.700	0	0.700	0	0.571	0	0.500	0	1	NA	NA
Zoo Interchange	1	1.00	1.01	1717.78	2220.00	1718.00	2251.00	0.583	0	0.714	0	0.700	0	0.700	0	0.571	0	0.571	0	1	**NA**	**NA**
I-94 North-South	1	0.86	1.66	1912.00	2822.00	1650.00	4678.00	0.366	0	0.856	1	0.486	0	0.643	1	0.278	0	0.444	1	2	NA	NA
SR-52 Extension	1	0.87	1.11	599.50	855.00	520.50	945.00	0.000	0	1.000	0	0.571	0	1.000	0	0.250	0	1.000	0	2	NA	NA

Figure A-1 Project Performance and Centrality Measures Data Part 1

Project_Name	PT	CP	SP	IC	ID	AC	AD	GSB	SGSB	DB	SDB	GSC	SGSC	DC	SDC	GST	SGST	DT	SDT	NPA	UTC	BBC
Tri-County Freeway, USH 10/441	1	0.75	1.29	545.00	2010.00	410.00	2588.00	0.000	0	0.750	0	0.571	0	0.500	0	0.125	0	0.875	0	1	NA	NA
I-41 Reconstruction	1	0.92	1.08	1515.00	3820.00	1390.10	4124.00	0.000	0	1.000	1	0.529	0	1.000	1	0.111	0	1.000	1	1	NA	NA
I-215 San Bernardino North Corridor Proj	1	0.88	1.12	675.60	2039.00	593.60	2283.00	0.000	0	0.700	1	0.625	0	1.000	1	0.400	0	1.000	1	3	NA	NA
Willis Avenue Bridge	1	1.50	1.17	495.00	2173.00	742.50	2540.00	0.600	0	0.700	0	0.714	0	0.714	0	0.600	0	0.600	0	1	NA	NA
SR-4 (East) Widening Project	1	0.87	1.28	600.10	1771.00	524.80	2259.00	0.264	0	0.868	1	0.538	0	0.824	1	0.214	0	0.786	1	5	NA	NA
Circle Interchange	1	1.33	1.96	535.00	1673.00	713.00	3287.00	0.000	0	0.967	1	0.600	0	1.000	1	0.250	0	1.000	1	1	NA	NA
Connector - I-4 to Lee Roy Selmon Expres	2	1.01	1.18	654.00	1378.00	659.30	1622.00	0.385	0	0.912	1	0.778	1	0.560	0	0.714	1	0.286	0	2	NA	0.483
SR 826/SR 836 Interchange Reconstruction	2	0.98	0.81	838.00	2631.00	824.00	2143.00	0.633	1	0.378	0	0.833	1	0.667	0	0.800	1	0.500	0	2	NA	NA
(iROX) I-75 from GG Parkway to SR-80, D/	2	1.04	1.04	473.00	1348.00	492.00	1401.00	0.068	0	0.741	1	0.667	0	0.889	1	0.500	0	0.938	1	2	NA	NA
Northwest Corridor Project (I-75/I-575)	2	1.02	1.00	834.90	1857.00	854.10	1857.00	0.419	1	0.501	1	0.682	0	0.750	1	0.667	1	0.667	1	2	0.500	0.441
I-285/SR 400 Interchange Project	2	0.88	1.00	864.60	1290.00	763.60	1290.00	0.687	1	0.610	1	0.737	1	0.700	1	0.643	1	0.571	1	3	NA	0.437
I-395 Reconstruction	2	1.04	1.05	846.00	1770.00	879.62	1860.00	0.972	1	0.000	0	1.000	1	0.563	0	1.000	1	0.222	0	2	NA	NA
Goethals Bridge Replacement	2	1.04	1.13	1292.90	1580.00	1341.90	1785.00	0.667	1	0.429	0	0.636	1	0.568	1	0.429	1	0.333	1	1	0.429	0.396
I-75 Modernization Segment 3	2	1.00	1.00	-	-	-	-	0.857	1	0.275	0	0.875	1	0.560	0	0.857	1	0.214	0	1	NA	0.483
Commonwealth of PA Rapid Bridge Replacement	2	1.11	1.32	1095.60	1156.00	1212.80	1521.00	0.879	1	0.447	0	0.800	1	0.606	0	0.750	1	0.350	0	2	NA	0.455
I-4 Ultimate W/Managed (Tolled) Lanes	2	0.89	1.09	6942.30	2407.00	6163.30	2615.00	0.828	1	0.300	0	0.688	1	0.489	0	0.523	1	0.273	0	1	0.449	0.415
I-70 East	2	1.03	1.00	1200.00	1883.00	1235.00	1883.00	0.897	1	0.000	0	0.867	1	0.520	0	0.846	1	0.231	0	1	0.565	0.481
I-77 Express lanes from Exit 11 to Exit 36	2	1.02	0.92	692.90	1747.00	707.70	1600.00	0.889	1	0.386	0	0.704	1	0.514	0	0.579	1	0.263	0	1	0.463	0.422
SH 288 Toll Lanes	2	1.00	1.00	897.00	1351.00	898.00	1351.00	0.690	1	0.276	0	0.714	1	0.488	0	0.600	1	0.200	0	1	0.465	0.426
Transform 66 Outside the Beltway	2	1.00	1.00	-	-	-	-	0.866	1	0.239	0	0.667	1	0.453	0	0.500	1	0.167	0	1	0.471	0.407
Midtown Express (SH 183 Managed Lanes Project)	2	1.00	1.29	1415.00	1290.00	1415.00	1668.00	0.919	1	0.052	0	0.882	1	0.536	0	0.867	1	0.133	0	1	NA	NA
Doyle Drive / Presidio Parkway Project	2	0.92	1.77	928.80	1508.00	853.30	2667.00	0.672	1	0.538	1	0.184	0	0.177	0	0.448	1	0.397	1	8	0.185	0.159
I-595 Corridor Improvements	2	1.02	1.51	1410.00	1495.00	1433.70	2254.00	0.915	1	0.298	0	0.760	1	0.514	0	0.684	1	0.211	0	1	0.514	0.463
Port of Miami Tunnel & Access Improvemen	2	1.00	1.09	915.00	1277.00	914.06	1390.00	0.848	1	0.476	0	0.652	1	0.517	0	0.467	1	0.333	0	3	0.455	0.405
Louisville-Southern Indiana Ohio River Bridge- EEC	2	0.83	0.85	1276.30	1603.00	1064.00	1360.00	0.929	1	0.207	0	0.750	1	0.492	0	0.733	1	0.100	0	2	0.476	0.448
Portsmouth Bypass	2	1.00	0.92	580.00	4850.00	580.00	4485.00	0.915	1	0.405	0	0.750	1	0.545	0	0.667	1	0.278	0	1	0.486	0.439
LBJ Freeway	2	0.99	0.94	2231.40	1668.00	2214.20	1576.00	0.664	1	0.342	1	0.136	1	0.127	0	0.444	1	0.259	0	6	0.215	0.125
North Tarrant Express (Segment 1&2A)	2	1.00	1.00	1874.40	1203.00	1872.10	1203.00	0.925	1	0.170	0	0.793	1	0.489	0	0.739	1	0.130	0	1	0.535	0.469
North Tarrant Express (Segment 3A&3B)	2	0.99	1.00	1443.80	2114.00	1434.80	2114.00	0.845	1	0.271	0	0.724	1	0.525	0	0.619	1	0.238	0	1	0.488	0.447
SH 130 Segments 5 & 6	2	0.99	0.92	1116.80	478.00	1106.70	441.00	0.745	1	0.005	0	0.737	1	0.467	0	0.643	1	0.214	0	1	0.636	0.500
Capital Beltway high occupancy toll (HOT	2	1.06	0.99	1632.20	1350.00	1725.40	1331.00	0.485	1	0.117	0	0.655	1	0.487	0	0.474	1	0.316	0	2	0.452	0.413
I-95 HOT/HOV Lanes, Northern Segment	2	1.00	1.00	862.70	984.00	862.70	984.00	0.841	1	0.396	0	0.700	1	0.519	0	0.571	1	0.286	0	1	0.483	0.424
Midtown Tunnel/Downtown Tunnel/Martin Lu	2	1.04	1.00	1576.90	2023.00	1635.40	2023.00	0.797	1	0.000	0	0.406	1	0.295	0	0.519	1	0.038	0	1	0.317	0.302
Brent Spence Corridor Project	2	1.00	1.00	-	-	-	-	0.429	1	0.250	0	0.889	0	0.571	0	0.875	0	0.250	0	2	NA	NA
US 181 Harbor Bridge Project	2	1.00	1.04	1064.50	2105.00	1066.00	2195.00	0.933	1	0.000	0	1.000	0	0.545	0	1.000	1	0.167	0	1	NA	NA
Loop 202 South Mountain Freeway	2	0.99	1.02	1746.52	1470.00	1733.01	1500.00	0.924	1	0.133	0	0.937	1	0.556	0	0.933	1	0.200	0	1	NA	0.366

Figure A-2 Project Performance and Centrality Measures Data Part 2

Table A-1 Variable Name List

PT	Procurement Type
CP	Cost Performance
SP	Schedule Performance
IC	Initial Cost
ID	Initial Duration
AC	Actual Cost
AD	Actual Duration
GSB	GC/SPV Betweenness
SGSB	Significance GC/SPV Betweenness
DB	DOT Betweenness
SDB	Significance DOT Betweenness
GSC	GC/SPV Closeness
SGSC	Significance GC/SPV Closeness
DC	DOT Closeness
SDC	Significance DOT Closeness
GST	GC/SPV Total-Degree
SGST	Significance GC/SPV Total-Degree
DT	DOT Total-Degree
SDT	Significance DOT Total-Degree
NPA	Number of Public Agencies
UTC	USDOT TIFIA Centrality
BBC	Banks/Bondholders Centrality

Appendix B: Project Stakeholder Network Diagrams

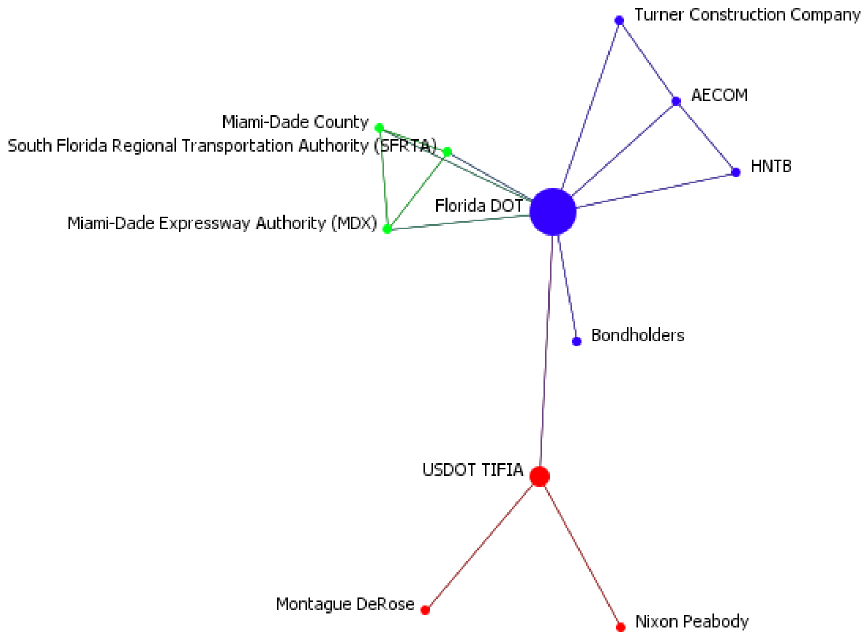

Figure A-3 Miami Intermodal Center Network Diagram

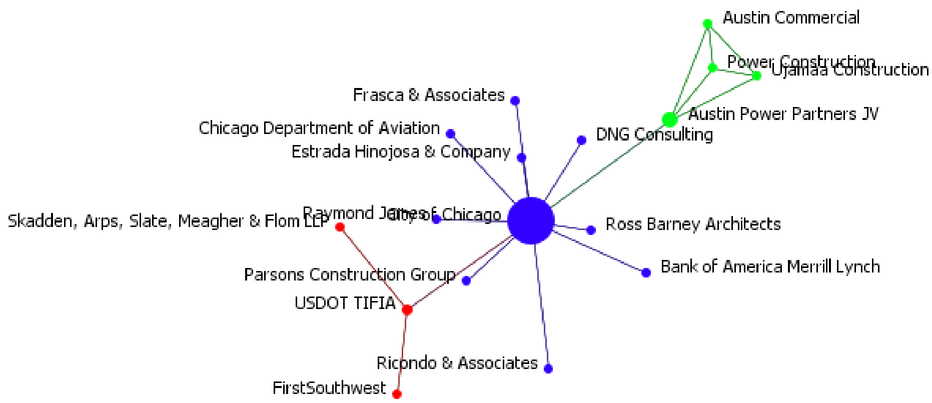

Figure A-4 Chicago O'Hare Con- RAC Network Diagram

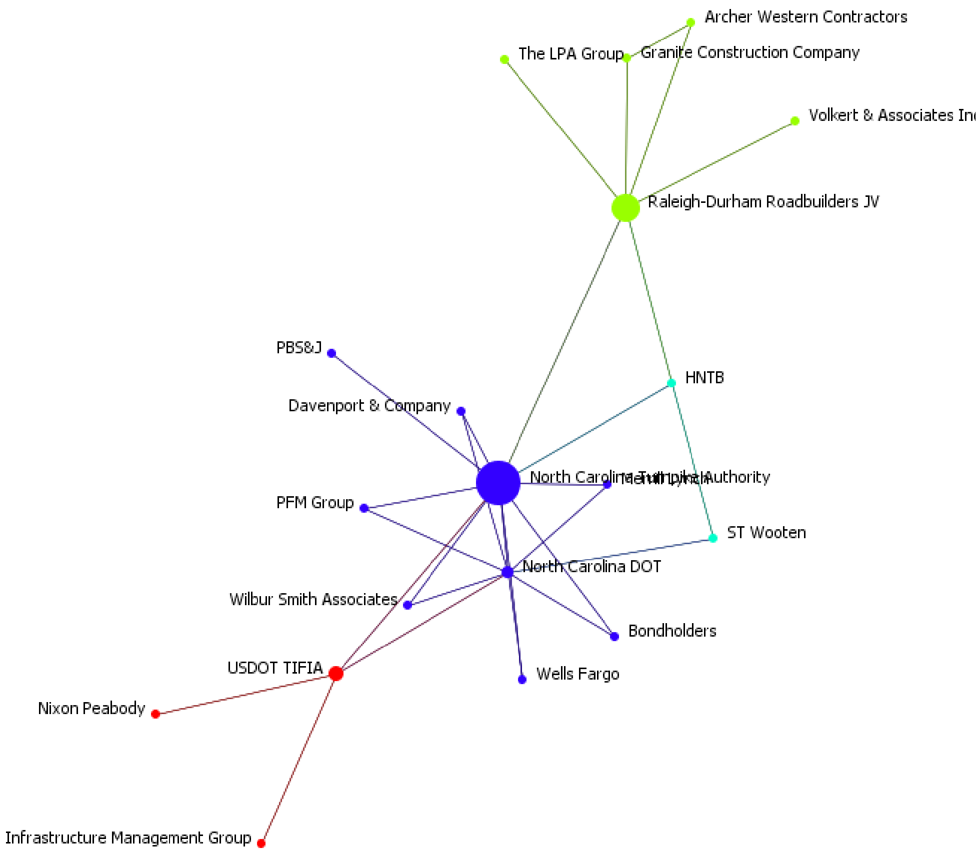

Figure A-5 Triangle Expressway Network Diagram

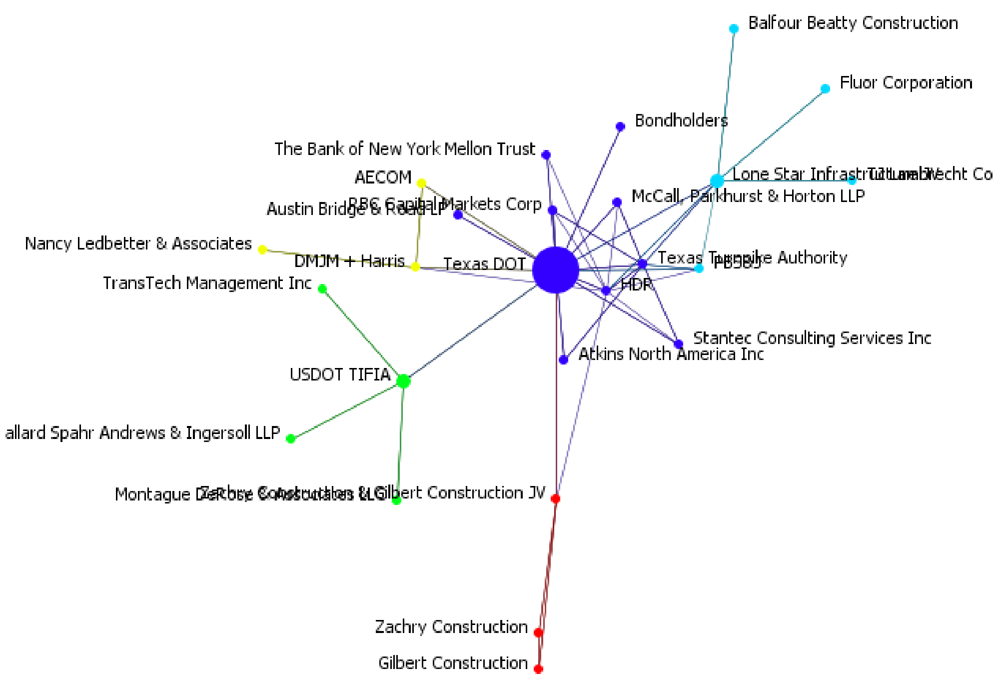

Figure A-6 Central Texas Turnpike System Network Diagram

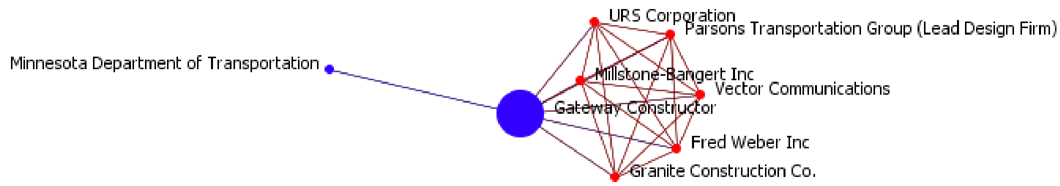

Figure A-7 I-64 from Spoede Rd. to Sarah St.

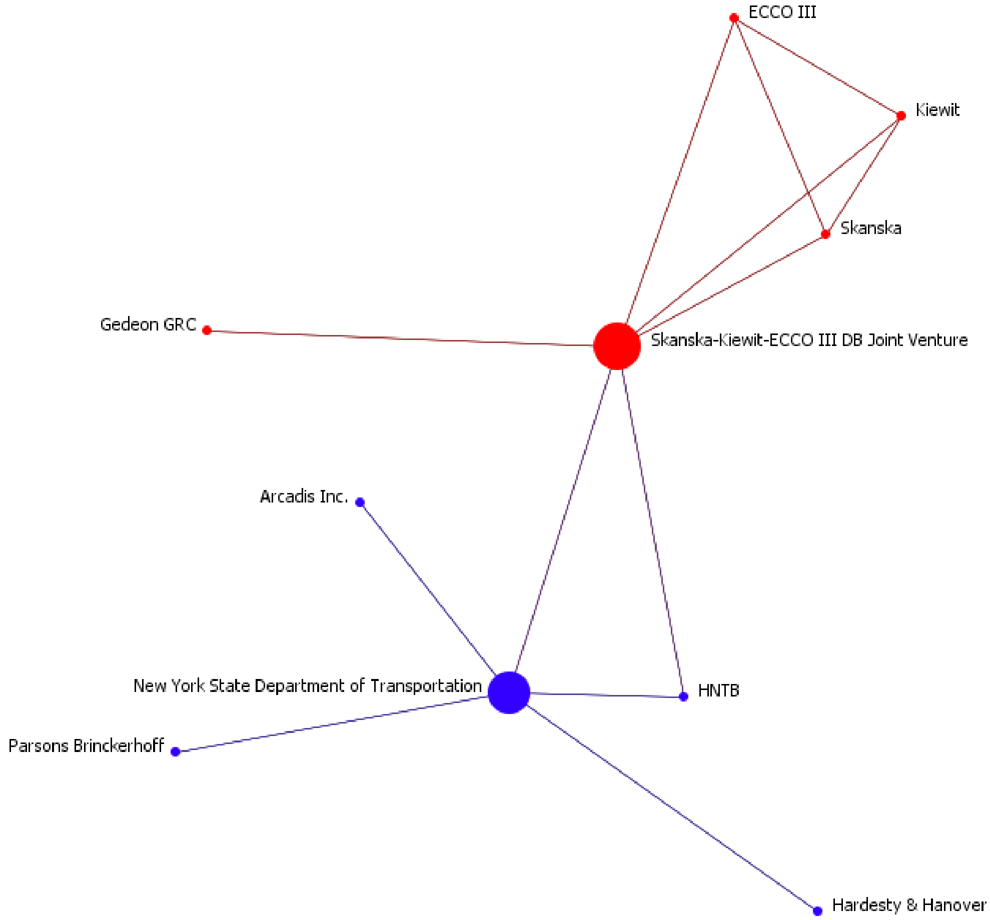

Figure A-8 Kosciuszko Bridge Replacement Network Diagram

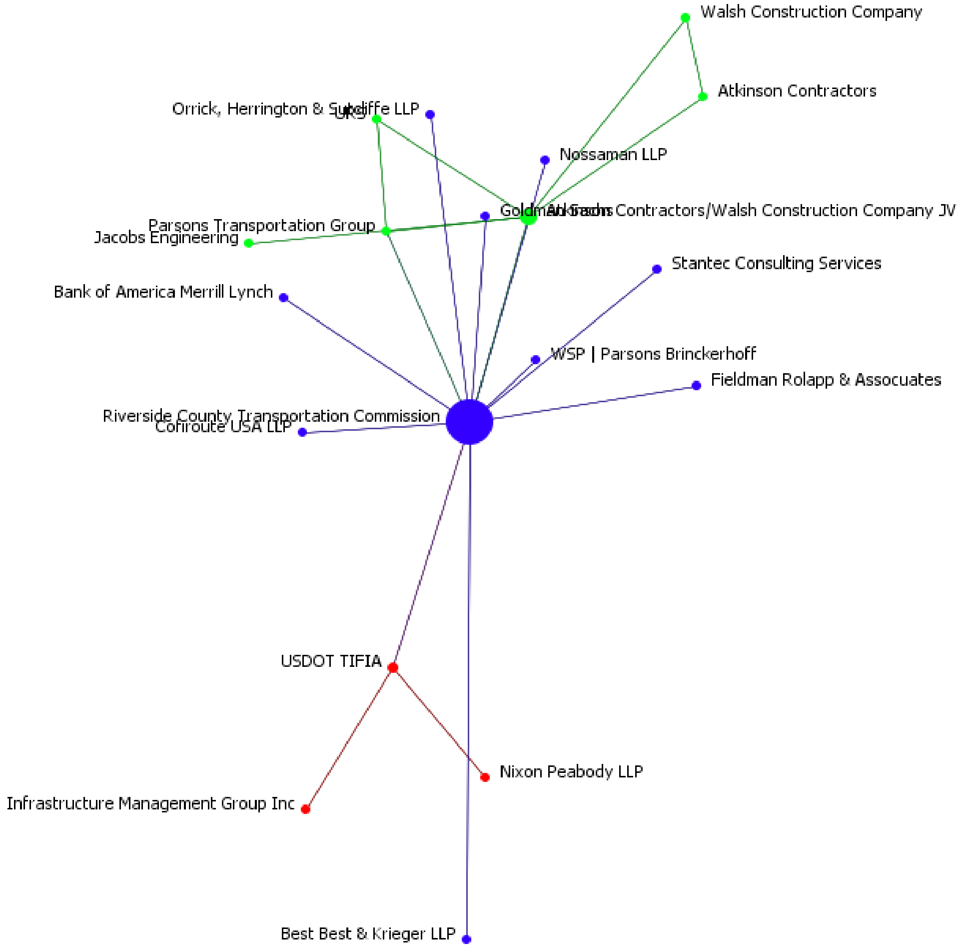

Figure A-9 SR-91 Corridor Improvements Network Diagram

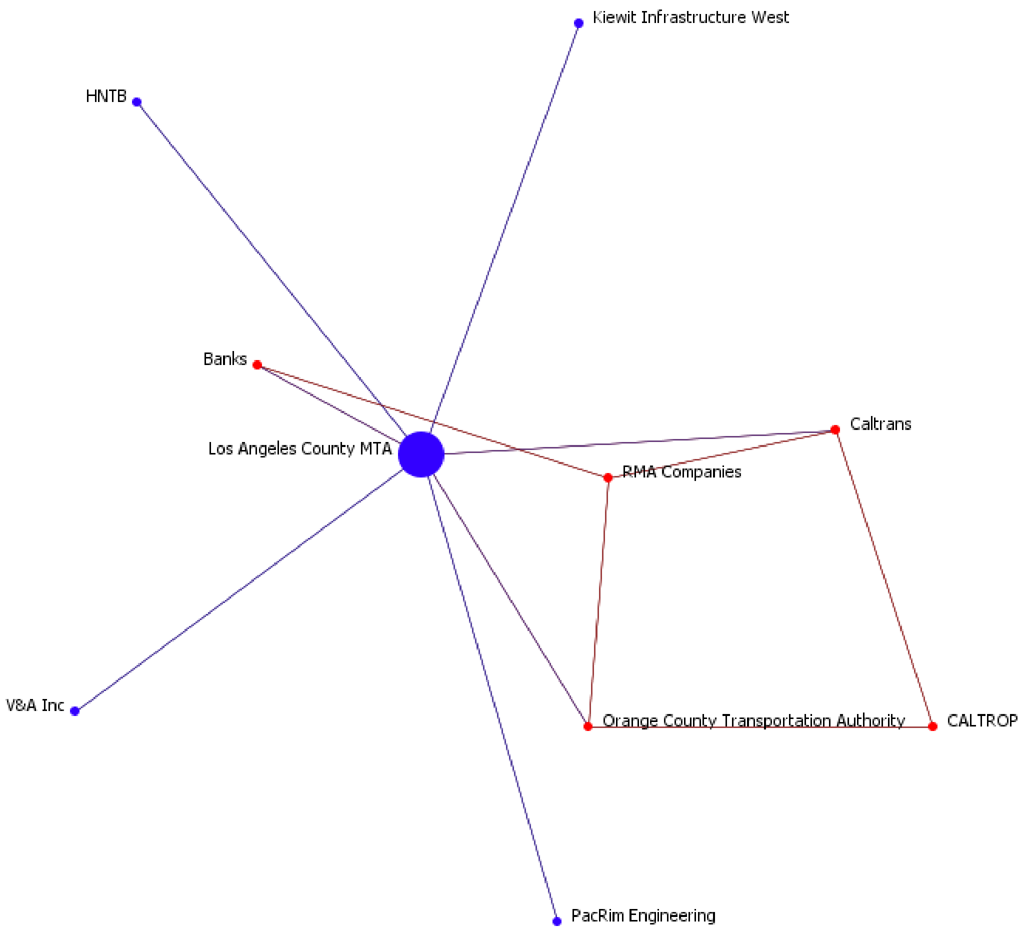

Figure A-10 I-405 Sepulveda Pass Widening Network Diagram

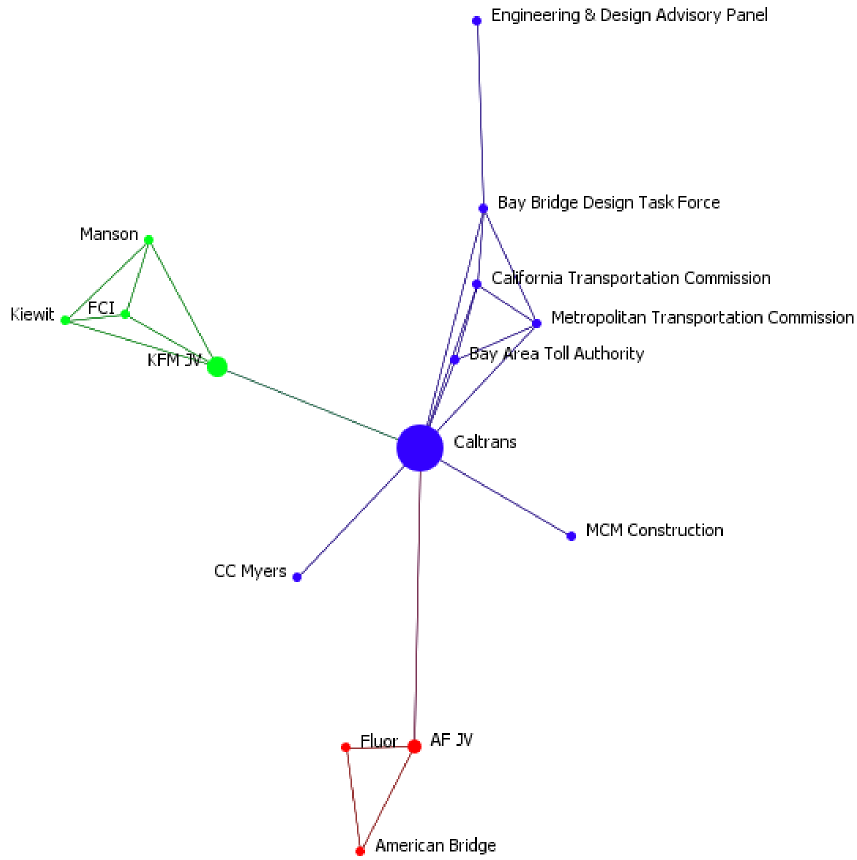

Figure A-11 I-80/San Francisco-Oakland Bay Bridge Network Diagram

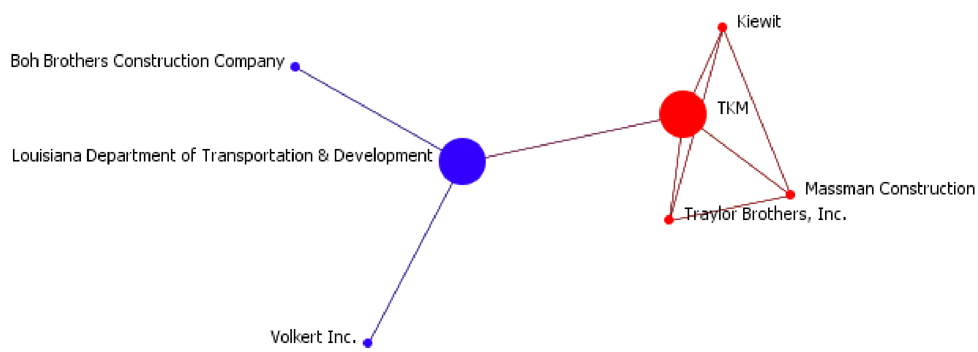

Figure A-12 I-10 Twin Span Structures Network Diagram

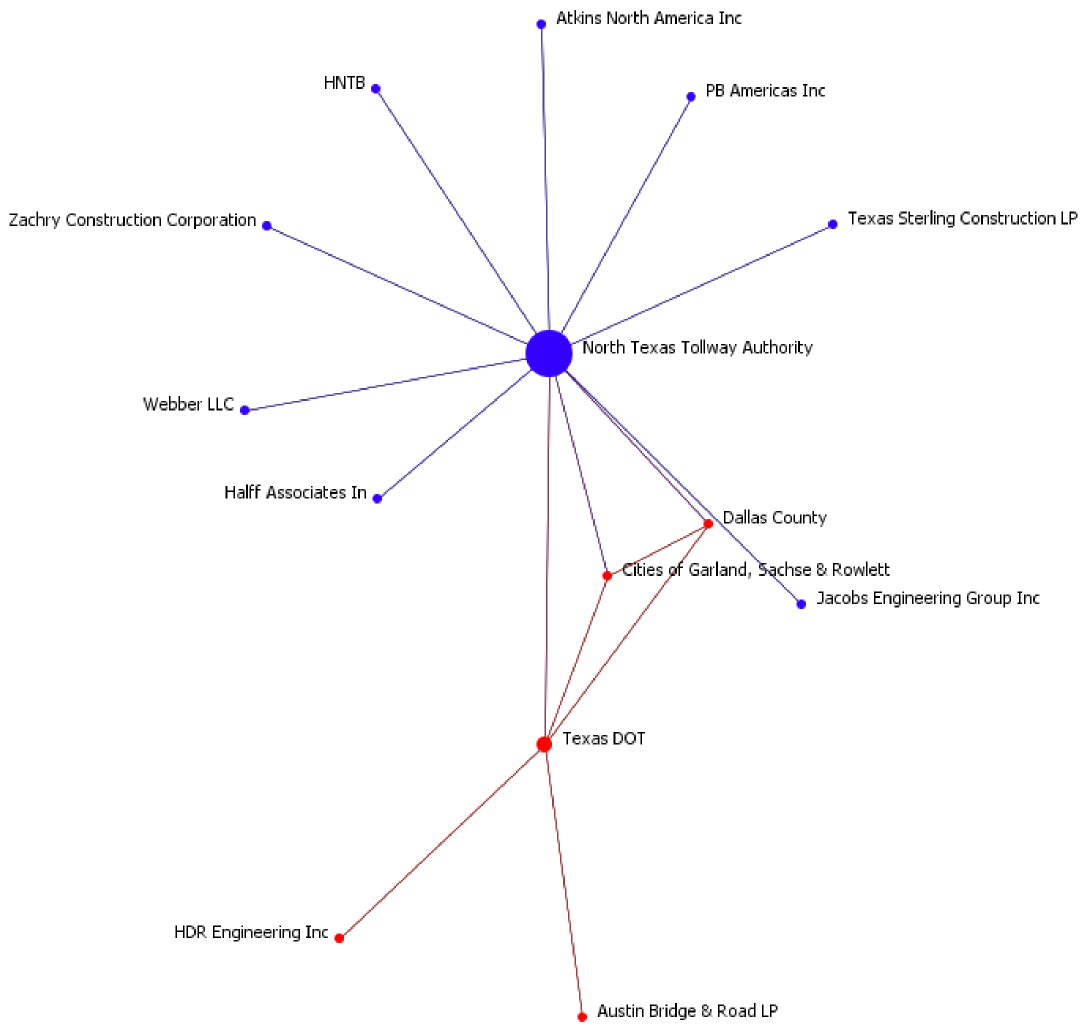

Figure A-13 PGBT Eastern Extension Network Diagram

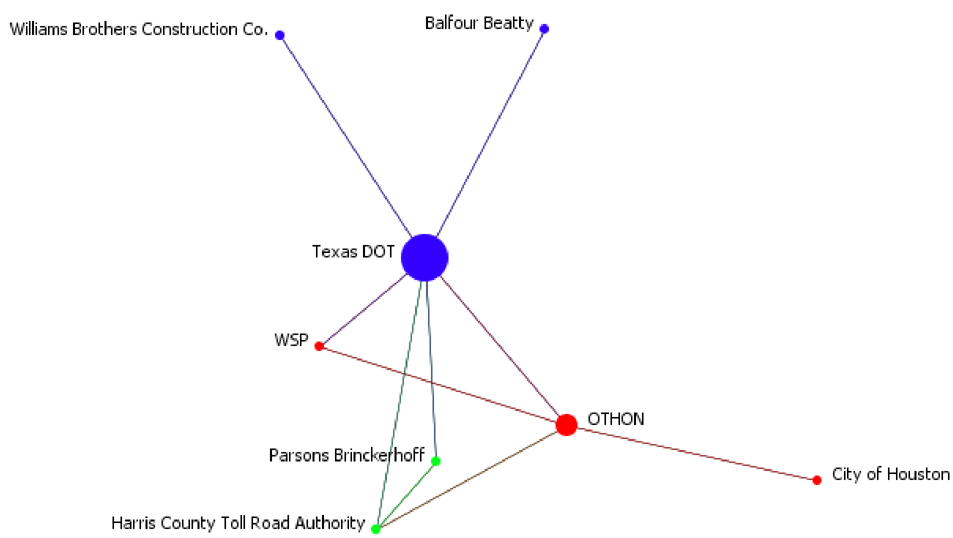

Figure A-14 I-10 Katy Freeway Reconstruction Network Diagram

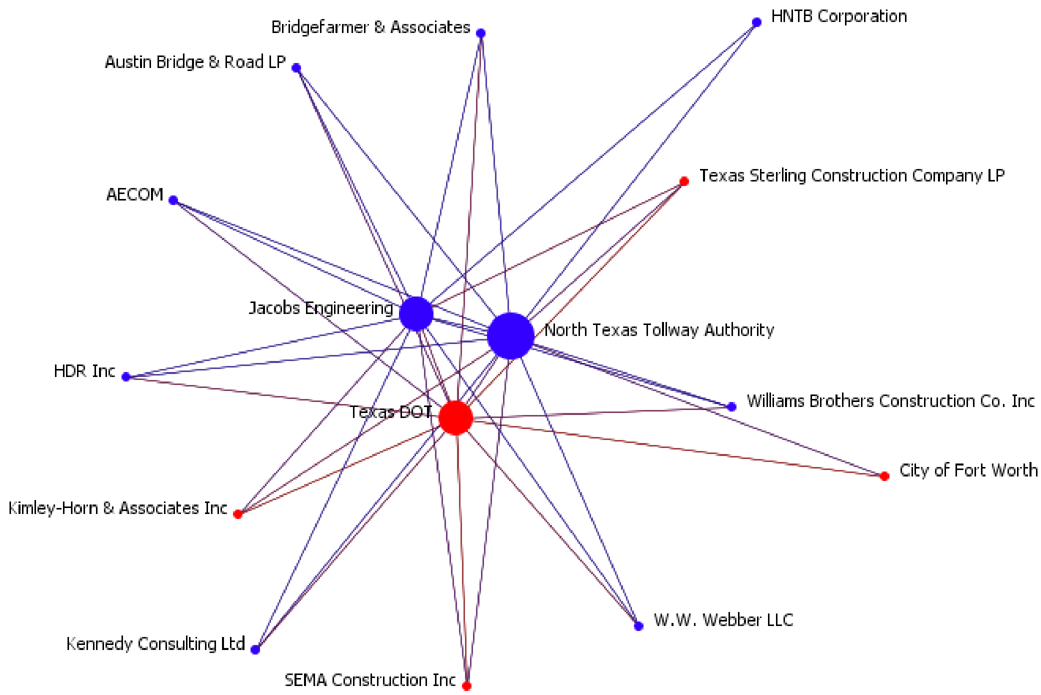

Figure A-15 Southwest Parkway (SH 121) Network Diagram

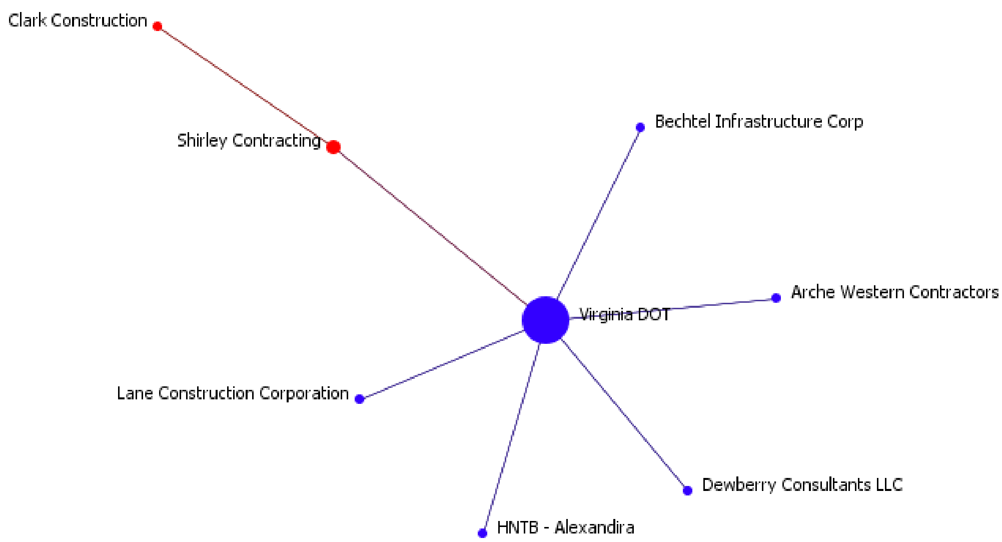

Figure A-16 I-95/I-395/I-495 Springfield Interchange Network Diagram

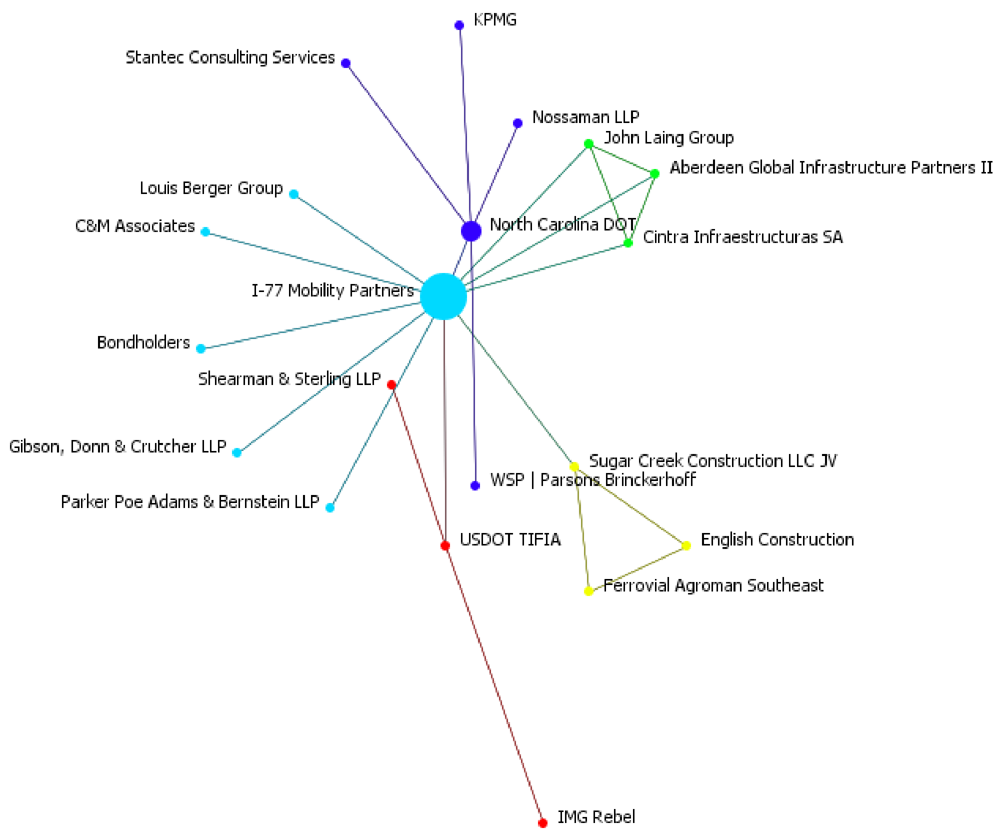

Figure A-17 I-77 Express Lanes from Exit 11 to Exit 36 Network Diagram

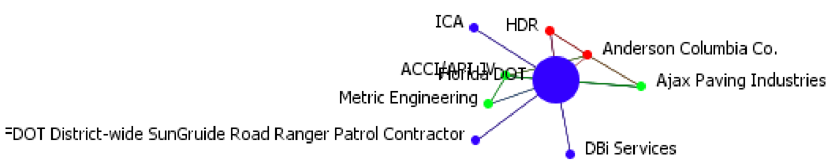

Figure A-18 I-75 from GG Parkway to SR-80 (iROX) Network Diagram

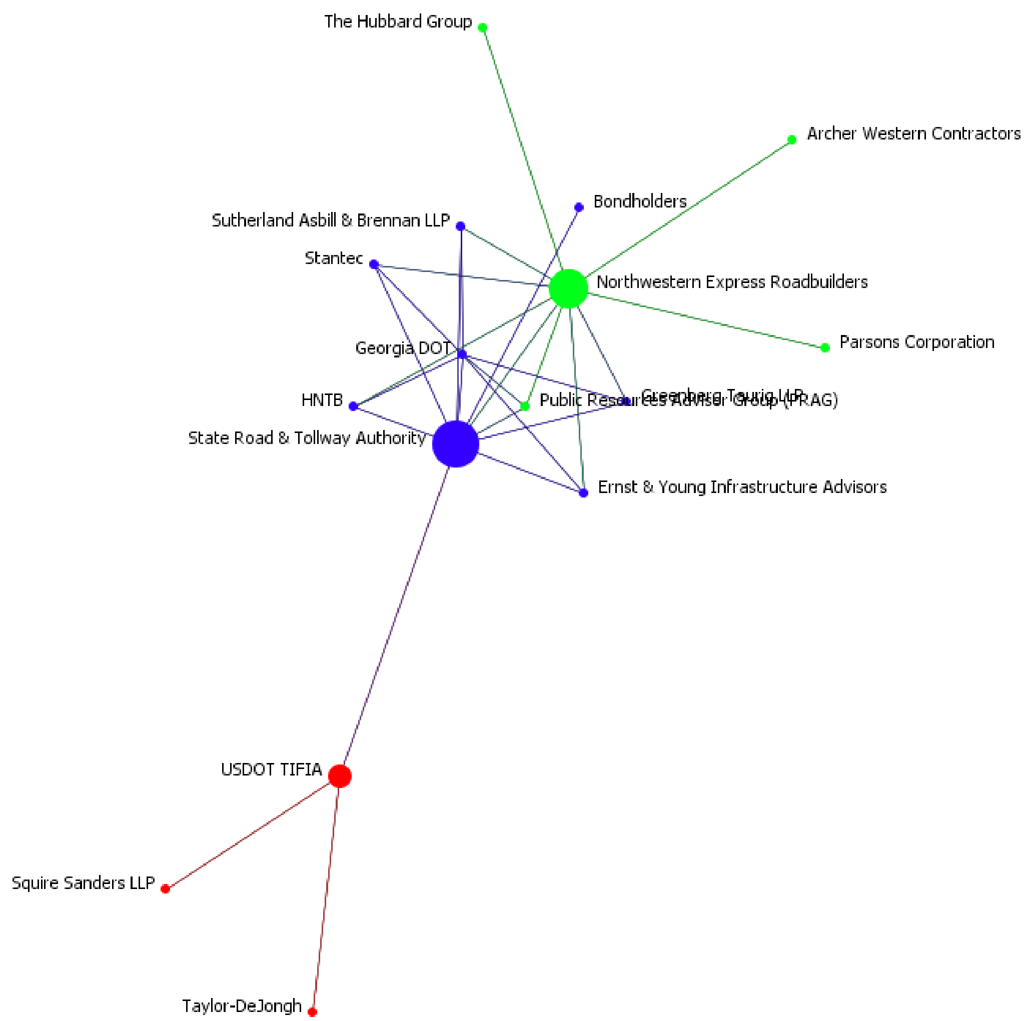

Figure A-19 Northwest Corridor (I-75/I-575) Network Diagram

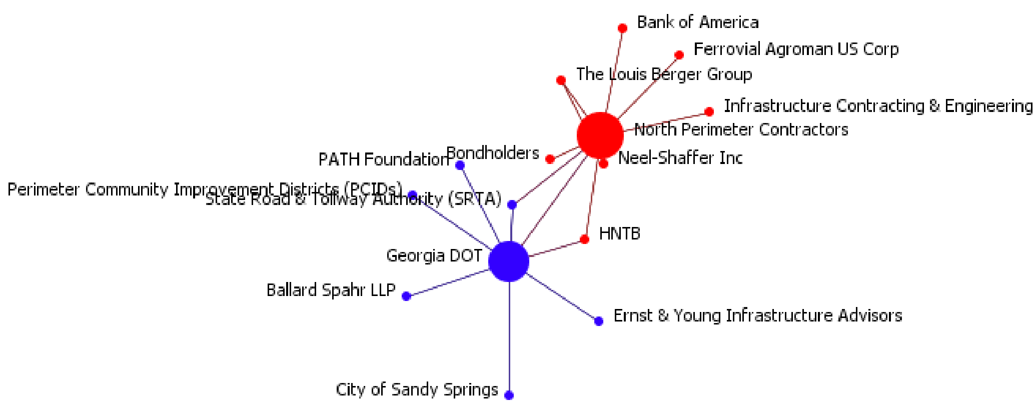

Figure A-20 I-285/SR 400 Interchange Network Diagram

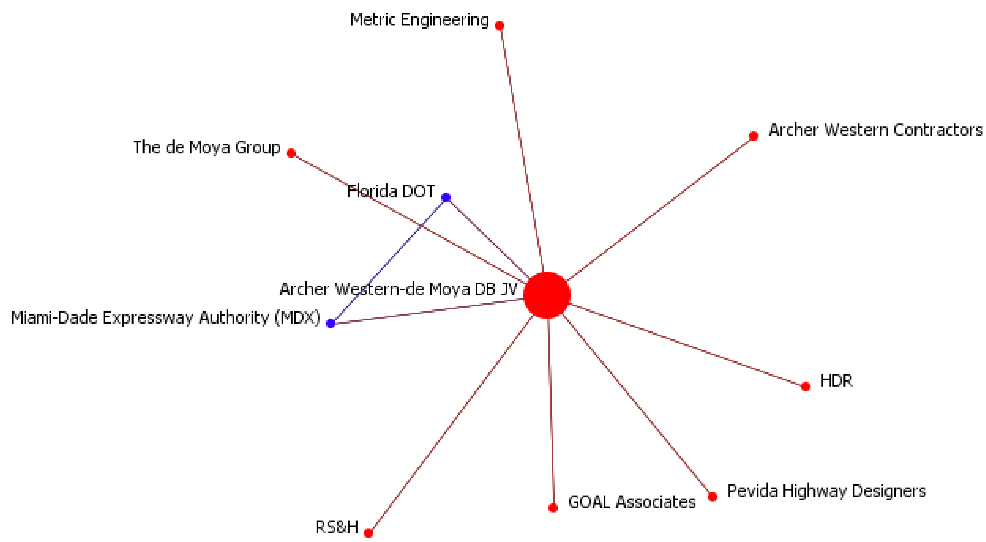

Figure A-21 I-395 Reconstruction Network Diagram

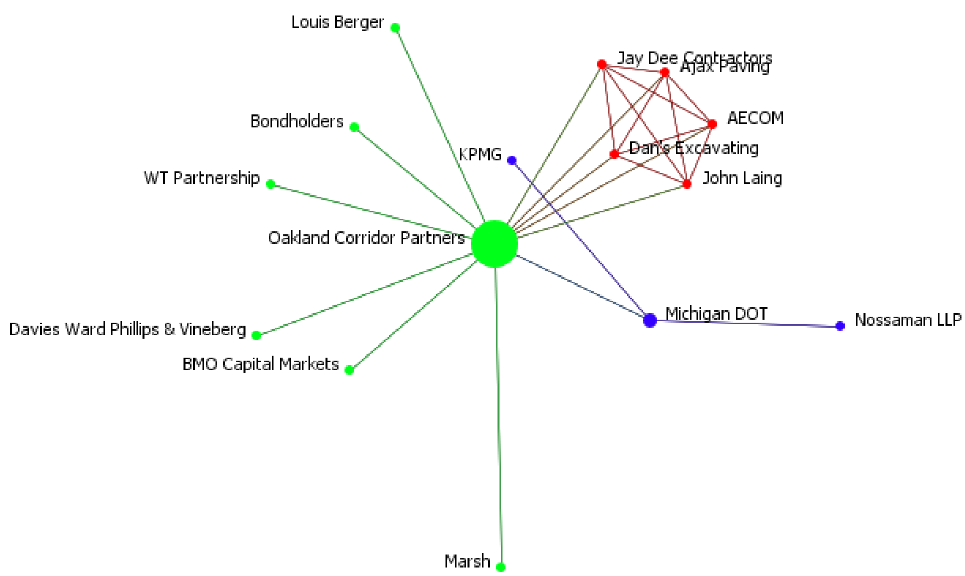

Figure A-22 I-75 Modernization Segment 3 Network Diagram

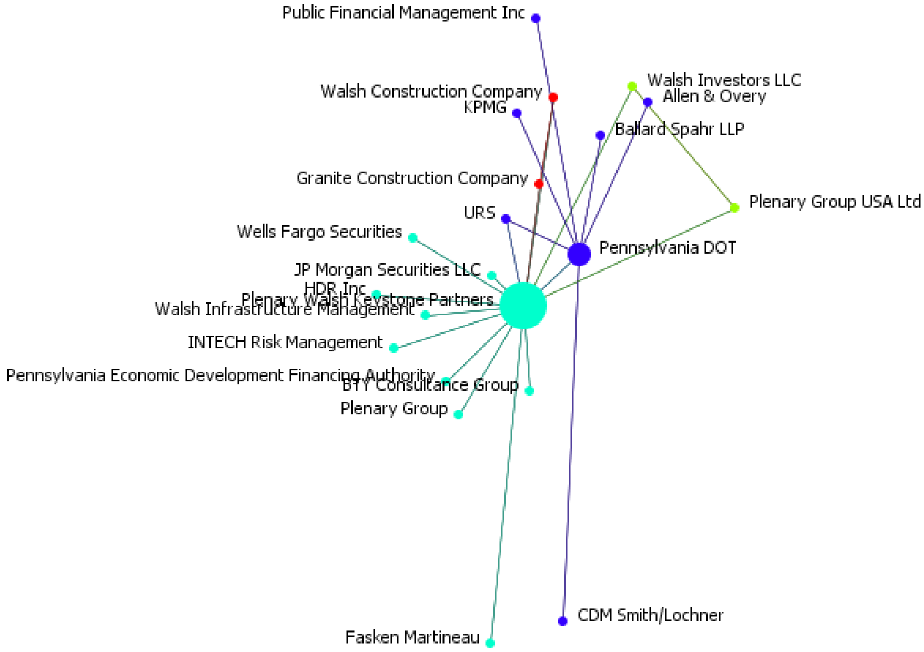

Figure A-23 Commonwealth PA Rapid Bridge Replacement Network Diagram

Appendix C: SPSS Analysis

Examples of output directly from SPSS software used for analyzing the data.

GC/SPV Betweenness & Closeness

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.034[a]	.001	-.028	.23868	2.536

a. Predictors: (Constant), GC_SPV_Closeness, GC_SPV_Betweenness

b. Dependent Variable: Cost_Performance

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.005	2	.002	.040	.961[b]
	Residual	3.931	69	.057		
	Total	3.935	71			

a. Dependent Variable: Cost_Performance

b. Predictors: (Constant), GC_SPV_Closeness, GC_SPV_Betweenness

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1.066	.108		9.901	.000		
	GC_SPV_Betweenness	.002	.107	.003	.021	.983	.825	1.212
	GC_SPV_Closeness	-.047	.176	-.035	-.265	.792	.825	1.212

a. Dependent Variable: Cost_Performance

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	GC_SPV_Betweenness	GC_SPV_Closeness
1	1	2.822	1.000	.01	.02	.01
	2	.145	4.408	.11	.91	.04
	3	.033	9.217	.88	.06	.96

a. Dependent Variable: Cost_Performance

DOT Betweenness & Closeness

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.094[a]	.009	-.020	.23776	2.557

a. Predictors: (Constant), DOT_Closeness, DOT_Betweenness

b. Dependent Variable: Cost_Performance

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.035	2	.017	.310	.735[b]
	Residual	3.900	69	.057		
	Total	3.935	71			

a. Dependent Variable: Cost_Performance

b. Predictors: (Constant), DOT_Closeness, DOT_Betweenness

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	VIF
1	(Constant)	.987	.105		9.415	.000		
	DOT_Betweenness	.064	.116	.082	.551	.583	.644	1.553
	DOT_Closeness	.024	.194	.018	.121	.904	.644	1.553

a. Dependent Variable: Cost_Performance

Collinearity Diagnostics[a]

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions (Constant)	DOT_Betweenness	DOT_Closeness
1	1	2.835	1.000	.01	.02	.01
	2	.136	4.570	.17	.72	.01
	3	.029	9.839	.82	.26	.98

a. Dependent Variable: Cost_Performance

Appendix D: Project Data Profile

Table A-2 Project Types

Project Name	Project Type	State
Loop 202 South Mountain Freeway	Beltway	AZ
SR-91 Corridor Improvement/HOT lanes initial project	Highway Widening/Managed Lanes	CA
I-405 Improvement Project (SR-73 to I-605)	Highway Widening/Managed Lanes	CA
Gerald Desmond Bridge Replacement	Bridge	CA
I-405 Sepulveda Pass Widen and HOV	Highway Widening/Managed Lanes	CA
I-80/San Francisco-Oakland Bay Bridge (E	Bridge	CA
SR-52 Extension	Highway Widening/Managed Lanes	CA
I-215 San Bernardino North Corridor Project	Highway Widening/Managed Lanes	CA
SR-4 (East) Widening Project	Highway Widening/Managed Lanes	CA
Doyle Drive / Presidio Parkway Project	Major Highway/New Highway	CA
I-70 East	Highway Reconstruction/Rehabilitation (Major Highway)	CO
Miami Intermodal Center (MIC)	Intermodal Station	FL
Connector - I-4 to Lee Roy Selmon Expressway	Connector	FL
SR 826/SR 836 Interchange Reconstruction	Interchange	FL
(iROX) I-75 from GG Parkway to SR-80, D/	Highway Widening/Managed Lanes	FL
I-395 Reconstruction	Highway Reconstruction/Rehabilitation (Major Highway)	FL
I-4 Ultimate W/Managed (Tolled) Lanes	Highway Widening/Managed Lanes	FL
I-595 Corridor Improvements	Highway Widening/Managed Lanes	FL
Port of Miami Tunnel & Access Improvement	Tunnel	FL
Northwest Corridor Project (I-75/I-575)	Major Highway/New Highway	GA
I-285/SR 400 Interchange Project	Interchange	GA

O'Hare Con-RAC	Intermodal Station	IL
Circle Interchange	Interchange	IL
Louisville-Southern Indiana Ohio River Bridge- EEC	Bridge	KY
I-10 Twin Span Structures	Bridge	LA
Central Artery/Ted Williams Tunnel	Tunnel	MA
Intercounty Connector	Connector	MD
I-75 Modernization Segment 3	Highway Widening/Managed Lanes	MI
New Mississippi River Bridge	Bridge	MN
I-64, from Spoede Rd. to Sarah Street	Highway Reconstruction/Rehabilitation (Major Highway)	MO
Triangle Expressway, Western Wake Freeway	Major Highway/New Highway	NC
Monroe Expressway	Major Highway/New Highway	NC
I-77 Express lanes from Exit 11 to Exit 36	Highway Widening/Managed Lanes	NC
Goethals Bridge Replacement	Bridge	NJ & NY
Kosciuszko Bridge Replacement	Bridge	NY
Tappan Zee Hudson River Crossing/New NY Bridge	Bridge	NY
Willis Avenue Bridge	Bridge	NY
Portsmouth Bypass	Beltway	OH
Brent Spence Corridor Project	Bridge	OH
Commonwealth of PA Rapid Bridge Replacement	Bridge	PA
Central Texas Turnpike	Major Highway/New Highway	TX
IH 35E Managed Lanes (Dallas & Denton)	Highway Widening/Managed Lanes	TX
Bergstrom Expressway - US 183 from US 290 to SH 71	Highway Widening/Managed Lanes	TX
SH 99 Grand Parkway Segment H & I-1	Major Highway/New Highway	TX
SH 99 Grand Parkway Segment F-G	Major Highway/New Highway	TX
PGBT - Eastern Extension	Highway Access/Extension	TX
I-10/Katy Freeway Project	Highway Reconstruction/Rehabilitation (Major Highway)	TX
Southwest Parkway (SH 121)	Major Highway/New Highway	TX
SH 288 Toll Lanes	Highway Widening/Managed Lanes	TX
Midtown Express (SH 183 Managed Lanes Project)	Highway Widening/Managed Lanes	TX

LBJ Freeway	Major Highway/New Highway	TX
North Tarrant Express (Segment 1&2A)	Highway Reconstruction/Rehabilitation (Major Highway)	TX
North Tarrant Express (Segment 3A&3B)	Highway Reconstruction/Rehabilitation (Major Highway)	TX
SH 130 Segments 5 & 6	Highway Access/Extension	TX
US 181 Harbor Bridge Project	Bridge	TX
I-15 Corridor Salt Lake County	Highway Reconstruction/Rehabilitation (Major Highway)	UT
Thimble Shoal Tunnel	Tunnel	VA
I-95/I-395/I-495 Springfield Interchange	Interchange	VA
Transform 66 Outside the Beltway	Highway Widening/Managed Lanes	VA
Capital Beltway high occupancy toll (HOT	Beltway	VA
I-95 HOT/HOV Lanes, Northern Segment	Highway Widening/Managed Lanes	VA
Midtown Tunnel/Downtown Tunnel/Martin Lu	Tunnel	VA
I-95/Woodrow Wilson Bridge	Bridge	VA & MN
SR 99: Alaskan Way Viaduct Replacement P	Major Highway/New Highway	WA
SR 520, Medina to SR202: Eastside Trans	Highway Reconstruction/Rehabilitation (Major Highway)	WA
SR 520, I-5 to Medina: Bridge Replacement	Bridge	WA
SR 520 - Pontoon Construction Project	Bridge	WA
I-43/I-94/I-794 Marquette Interchange	Interchange	WI
Zoo Interchange	Interchange	WI
I-94 North-South	Highway Reconstruction/Rehabilitation (Major Highway)	WI
Tri-County Freeway, USH 10/441	Major Highway/New Highway	WI
I-41 Reconstruction	Highway Reconstruction/Rehabilitation (Major Highway)	WI

Bibliography

Ahsan, K., & Gunawan, I. (2010). Analysis of cost and schedule performance of international development projects. *International Journal of Project Management*, *28*(1), 68–78. https://doi.org/10.1016/j.ijproman.2009.03.005

Atkin, B., & Skitmore, M. (2008). Editorial: stakeholder management in construction. *Construction Management and Economics*, *26*(6), 549–552. https://doi.org/10.1080/01446190802142405

Atkinson, R. (1999). Project Management: Cost, Time and Quality, Two Best Guesses and a Phenomenon, it's Time to Accept Other Success Criteria. *International Journal of Project Management*, 17(6), p. 337-342.

Baratta, A. (2006). The triple constraint: a triple illusion. *Paper presented at PMI® Global Congress 2006*—North America, Seattle, WA. Newtown Square, PA: Project Management Institute.

BBC (2014). Influence of Stakeholders on Business Objectives. Retrieved from: http://www.bbc.co.uk/bitesize/higher/business_management/business_enterprise/business_contemporary_society/revision/10/

Beaty, C., Ellis, D., Epps, J., Glover, B., & Norboge, N. (n.d.). *Assessing the Costs Attributed to Project Delays*. 37.

Bryde, D. (2008). Perceptions of the impact of project sponsorship practices on project success. *International Journal of Project Management*, *26*(8), 800–809. https://doi.org/10.1016/j.ijproman.2007.12.001

Cadini, F., Zio, E., & Petrescu, C. (2008). Using Centrality Measures to Rank the Importance of the Components of a Complex Network Infrastructure. *CRITIS*.

Chinyio, E., & Olomolaiye, P. (2010). Introducing Stakeholder Management. In *Construction Stakeholder Management* (pp. 1–12). https://doi.org/10.1002/9781444315349.ch1

Chung, K. S. K., & Crawford, L. (2016). The Role of Social Networks Theory and Methodology for Project Stakeholder Management. *Procedia - Social and Behavioral Sciences, 226*, 372–380. https://doi.org/10.1016/j.sbspro.2016.06.201

Clough, R. H., Sears, G. A., Sears, S. K. (2000). Construction Project Management Fourth Edition. New York, New York: John Wiley & Sons, Inc.

Cox, A. and Thompson, I. (1997). Fit for purpose' contractual relations: determining a theoretical framework for construction projects. *European Journal of Purchasing & Supply Management*. Volume 3 (September 1997. pp. 127-135.

Deguire, M. (2014). Stakeholder 2 Stakeholder networking. *Paper presented at PMI® Global Congress 2014*—North America, Phoenix, AZ. Newtown Square, PA: Project Management Institute.

Freeman, Linton C. (1979). Centrality in social networks I: Conceptual clarification. *Social Networks*, 1(3), pp. 215-239.

Freeman, R. E., Harrison, J. S., & Zyglidopoulos, S. (2018, August). Stakeholder Theory by R. Edward Freeman. https://doi.org/10.1017/9781108539500

Hall, M., Holt, R., & Purchase, D. (2003). Project sponsors under New Public Management: lessons from the frontline. *International Journal of Project Management*, *21*(7), 495–502. https://doi.org/10.1016/S0263-7863(02)00054-6

Jackson, M. O. (2008). Social and Economic Networks. *Princeton University Press*. pp. 62-72.

Khan, A., Skibniewski, M., & Cable, J. (2017). *Understanding Project Stakeholder Psychology*. 17.

Lemes Alarcão, A. L., & Sacomano Neto, M. (2016). Actor centrality in Network Projects and scientific performance: an exploratory study. *RAI Revista de Administração e Inovação, 13*(2), 78–88. https://doi.org/10.1016/j.rai.2016.03.002

Lienert, J., Schnetzer, F., & Ingold, K. (2013). Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes. *Journal of Environmental Management*, *125*, 134–148. https://doi.org/10.1016/j.jenvman.2013.03.052

Low, S. P., Chuan, Q. T. (2006). Environmental Factors and Work Performance of Project Managers. *International Journal of Project Management*, 21 (1), pp. 24-37.

Mead, S. P. (2001). Using Social Network Analysis to Visualize Project Teams. Newton Square, PA, USA: *Project Management Institute 2001*, Vol. 32 No. 4, pp. 32-28.

Meredith, J. R., Shafer, S. M., Mantel, S. J. Jr., (2017). Project Management in Practice, Sixth Edition. Lexington, KY, USA: *John Wiley and Sons, Inc*. pp. 37.

MindTools.com. (2018). Stakeholder Analysis. Retrieved from: https://www.mindtools.com/pages/article/newPPM_07.htm

Naoum, S. and Egbu, C. (2015). Critical review of procurement method research in construction journals. *Procedia Economics and Finance*. Volume 21 (2015). pp. 6-13.

Pinto, J. K., Slevin, D. P. (1988). Critical Success Factors Across the Project Life Cycle. *Project Management Journal*, 19 (3), pp. 67-75.

Prell, C., Hubacek, K., & Reed, M. (2009). Stakeholder Analysis and Social Network Analysis in Natural Resource Management. *Society & Natural Resources*, *22*(6), 501–518. https://doi.org/10.1080/08941920802199202

Project Management Institute. (2013). *A Guide to the Project Management Body of Knowledge (PMBOK® Guide), Fifth Edition*. Newtown Square, PA, USA: *Project Management Institute*, pp. 392-415.

Project-Management.com. (2017). What is Stakeholder Analysis? Retrieved from: https://project-management.com/what-is-stakeholder-analysis/

Pryke, S. D. (2004). Analysing construction project coalitions: exploring the application of social network analysis. *Construction Management and Economics*, *22*(8), 787–797. https://doi.org/10.1080/0144619042000206533

Quiggin, J. (1996). Private Sector Involvement in Infrastructure Projects. *Australian Economic Review*, *29*(1), 51–64. https://doi.org/10.1111/j.1467-8462.1996.tb00915.x

Ramsey, D. W., & El Asmar, M. (2015). Cost and Schedule Performance Benchmarks of U.S. Transportation Public-Private Partnership Projects: Preliminary Results. *Transportation Research Record*, *2504*(1), 58–65. https://doi.org/10.3141/2504-07

Rowley, T. J. (1997). Moving Beyond Dyadic Ties: A Network Theory of Stakeholder Influences. *Academy of Management Review*, *22*(4), 887–910. https://doi.org/10.5465/amr.1997.9711022107

Scott, J. P. (2000, March 25). Social Network Analysis: A Handbook, Second Edition*. Sage Publications Ltd*. ISBN: 0761963391. pp. 85-102.

Scott, J. P., Carrington, P. J. (2011). The SAGE Handbook of Social Network Analysis. *Sage Publications Ltd*. ISBN: 1446250113. pp. 11-25

Sharma, R. (2010). *What is the Salience Model?* Retrieved from: http://www.brighthubpm.com/resource-management/81274-what-is-the-salience-model/

Shrestha, P. P., Migliaccio, G. C., O'Connor, J. T., & Gibson, G. E. (2007). Benchmarking of Large Design–Build Highway Projects: One-to-One Comparison and Comparison with Design–Bid–Build Projects. *Transportation Research Record: Journal of the Transportation Research Board*, *1994*(1), 17–25. https://doi.org/10.3141/1994-03

Singh, H. (2017, September 2). The Salience Model for Stakeholder Classification. Retrieved May 16, 2019, from DEEP FRIED BRAIN website: https://www.deepfriedbrainproject.com/2017/09/salience-model-for-stakeholder-classification.html

Social networks and project management performance. (n.d.). Retrieved May 13, 2019, from https://www.pmi.org/learning/library/social-networks-project-management-performance-6418

Sutterfield, J. S., Friday-Stroud, S. S., & Shivers-Blackwell, S. L. (2006). A Case Study of Project and Stakeholder Management Failures: Lessons Learned. *Project Management Journal*, *37*(5), 26–35. https://doi.org/10.1177/875697280603700504

Svendsen, A.C., Laberge, M. (2005). "Convening Stakeholder Networks: A New Way of Thinking, Being and Engaging". Convening Stakeholder Networks: A New Way of Thinking, Being and Engaging Author(s): Ann C. Svendsen and Myriam Laberge Source: The Journal of Corporate Citizenship, No. 19 (Autumn 2005), pp. 91-104 Published by: Greenleaf Publishing Stable URL: https://www.jstor.org/stable/10.2307/jcorpciti.19.91

The President and Fellows of Harvard College. (2019). "*Basic Guidelines for Contracts and Contract Risk Management*" Retrieved from: https://rmas.fad.harvard.edu/basic-guidelines-contracts-and-contract-risk-management

The Triple Constraint. (n.d.). Retrieved May 11, 2019, from https://www.pmi.org/learning/library/triple-constraint-erroneous-useless-value-8024

UpCounsel. (2019). "*Contractual Relationship: Everything You Need to Know*". Retrieved from: https://www.upcounsel.com/contractual-relationship

Wang, X., & Huang, J. (2006). The relationships between key stakeholders' project performance and project success: Perceptions of Chinese construction supervising engineers. *International Journal of Project Management, 24*(3), 253–260. https://doi.org/10.1016/j.ijproman.2005.11.006

Watt, A. (2014). *5. Stakeholder Management.* Retrieved from: https://opentextbc.ca/projectmanagement/chapter/chapter-5-project-stakeholders-project-management/