# ORGANIZATIONAL NETWORK ANALYSIS

# IN A TRANSPORTATION

# AGENCY

By

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The members of the Committee appointed to examine the dissertation/thesis of KRISTINA HAMMER find it satisfactory and recommend that it be accepted.

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Abstract

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Organizational Network Analysis, or ONA, is a tool that has been developed to aid organizations in the identification and visualization of how information is shared between employees. Using ONA, management can make informed decisions about who should work with whom, and which employees should meet to discuss ideas in order to cultivate innovation.

The purpose of this research is to introduce the concept of ONA and to apply the methods of ONA to the engineering world, specifically in a transportation agency, and by so doing, to discover where information sharing is occurring and where it is impeded.

Ninety-four employees in two different networks of a state transportation agency were surveyed, using validated survey questions, and the data was analyzed using standard methods of ONA which are discussed in detail in the text.

Network maps were created for both networks graphically displaying how information is shared between employees at every efficiency level. A number of employees within the transportation agency were found to be key in determining the information sharing efficiencies of

others. One network was found to be at risk for serious knowledge loss and breakdown in communication if several key individuals were removed. Both networks were found to have overall effective ratings of information transfer.

Based upon the research, it was concluded that the concepts form Organization Network Analysis can be beneficially applied to transportation agencies. Valuable information was gained by the transportation agency as to how information is actually shared by the employees of the network, and measures could be taken to improve specific areas where information sharing was not as efficient as desired. The anticipated results of the project are more balanced connectivity across both networks, more ties from the members on the periphery, and in general, more productive information sharing.

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# INTRODUCTION

It is universally recognized that information sharing is important for cultivating a productive organization. People need to collaborate productively and utilize social resources to produce innovation and creativity. For some companies, information sharing is not an issue, information flows from person to person, and work is done effectively. For other companies, however, information sharing does not occur as freely. Whether because of personal bias, internal structure, geographic separation, or any other reason, information transfer and sharing is not efficient. This can cause loss of revenue, failure to be innovative, and potentially even loss of valuable knowledge. Organizational Network Analysis (ONA) is a tool that can be used to analyze information sharing structures, and can aid concerned management in making informed decisions to improve information flow.

ONA can answer many important questions about networks, such as how cohesive is the network? Do hierarchy, formal structure, or function group silos limit employees? How well do employees know the expertise of others in the network, and how accessible is that expertise? Which employees are acting as bottlenecks, and which are acting as agents? Where does information sharing breakdown occur? Are some members of the network overly connected? Are some members not connected enough? Is there potential for dramatic knowledge loss and network fracturing if a small handful of people leave? Possessing the ability to answer these questions will greatly increase an executive's productivity when trying to create a more profitable organization.

Using ONA, management can make informed decisions about who should work with whom, and which employees should meet to discuss ideas in order to cultivate innovation. In

their book *The Hidden Power of Social Networks*, Rob Cross and Andrew Parker (2004) observe the following:

> Even in small, contained groups, executives are often surprised by patterns of collaboration that are quite different from their beliefs and from the formal organization chart. […] Rather than leave the inner workings of a network to chance, executives can leverage the insights of a social network analysis to address critical disconnects or rigidities in networks and create a sense-and-respond capability deep within the organization. (p. 7).

The overall health of a network can be greatly improved by making a few well placed adjustments to the network after ONA has revealed which key people need to be better connected and which people are overly connected, creating a bottleneck in information flow. Increasing the connectivity of peripheral people will both increase the potential for profitable collaboration and decrease the reliance on those people who have become bottlenecks to information flow due to the networks over reliance on their expertise.

ONA has been utilized in many sectors of the professional world, however it has been slow to infiltrate into the engineering community. The ability to communicate effectively is commonly stressed as a trait that engineers tend to lack, and as such, engineering firms may start at a slight disadvantage when it comes to information flow. Using ONA, engineering firms might be able to identify people who are creating information sharing breakdowns and create strategies to improve the flow of information. By being aware of their assets, engineering firms can play to their strengths and place individuals who excel in information sharing in positions that require it more.

Another example of how ONA can be beneficial to the engineering community is through knowledge retention. As the older generation of engineer moves towards retirement, the potential for knowledge loss becomes greater. Engineers who have been working in the industry for decades have learned the most efficient way to solve problems and can arrive at a solution more quickly than a new engineer might be able to. These skills save the engineers, and therefore the engineering firms, time and money on projects, and if those engineers are allowed to retire without passing their expertise on to the younger generation, the engineering firms have essentially lost not only time and money, but also a valuable resource. Cross, et al. state it this way, "Given the rapid turnover many companies experience today, it is important to find ways to help people become better connected so the organization can get the true benefit of their expertise more quickly" (2001, p. 112). (Wenger, McDermott, & Snyder, 2002) (Wenger, Communities of Practice, 1998) ONA can allow firms to identify whether their older engineers do work with their younger engineers, or whether more formal means of information sharing should be established, such as a mentorship program or increased project collaboration.

Collaboration is one final example of the usefulness of ONA. Engineering projects are multi-faceted, and therefore require input from various groups within an engineering firm. Through collaboration, a safe and efficient design can be proposed more quickly than if the project was repeatedly passed between the assorted engineers for individual input and change. Using ONA, firms can see how engineering groups work together, and where relationships need to be fostered in order to promote more collaboration. Firms can also identify where collaboration is already occurring, and can make a conscious effort to encourage those engineers to work together more. According to Cross & Parker (2004), people rely on those they know and trust

more than outside sources of information, so beneficial collaboration could occur between people who were already aware of the expertise of the others in the group. A way to foster this collaboration is through what Wenger, McDermott, and Snyder term "communities of practice". In to their book Cultivating Communities of Practice, Wenger, et al. define communities of practice as "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (2002, p. 4). These communities of practice help employees group together around common areas of work, and foster productive collaboration. In his earlier book, Communities of Practice, Wenger states, "Communities of practice are the locus of 'real work'. Their practices are where the formal rests on the informal, where the visible counts on the invisible, where the official meets the everyday" (1998, p. 243). Again, Wenger, et al. support the idea of collaboration by saying, "Having others who share your overall view of the domain and yet bring their individual perspectives on any given problem creates a social learning system that goes beyond the sum of its parts" (2002, p. 34). Collaboration, through communities of practice, or otherwise, can help an organization reach goals more quickly and effectively.

These are only a few examples of how organizational network analysis can be beneficial to the engineering community. The Virginia Department of Transportation has already utilized ONA and found it to be an excellent tool for recognizing areas where information sharing was inhibited and where improvements could be made. Transportation agencies can be especially susceptible to information sharing breakdown due to the geographic separation of their offices. According to Cross, Thomas, & Light, "the likelihood of collaborating with someone decreases substantially the farther one is from that person. Although collaborative tools such as e-mail, instant messaging

and video conferencing can bridge some gaps, proximity still frequently dictates people's networks. Often this means that people allow proximate others – not those with the best expertise – to influence their thinking" (2006, p. 13).

The use of ONA has not been widely adopted for engineering agencies, therefore this paper will discuss in more detail what ONA is, how data can be collected and analyzed, specific benefits from analysis, and finally it will conclude with a case study illustrating the principles outlined. The goal of the research presented in this paper is to demonstrate how ONA can be beneficial in analyzing and improving communication and information sharing patterns in organizations, and to illustrate the use of ONA in a case study on a transportation agency. The following are more specific goals for the research:

ONA Theory

- Introduce common network measures
- Demonstrate various methods of analysis
- Illustrate ways ONA can be useful to engineering agencies

Case Study

- Introduce survey for acquiring data
- Show how ONA can be applied to a transportation agency
- Present specific results from ONA

## NETWORK MEASURES

There are a number of network measures associated with ONA that are useful in a variety of contexts to understand and analyze a network. Network measures are used to analyze the nature of the actual relationships between people, which emerge from the survey data. The data can be manipulated in many ways to obtain numerous useful pieces of information. A few of the network measures are defined in Table 1 below. The network measures used most frequently are discussed in more detail. Prestige, Distance, Closeness, and Centrality were not used in the case study, and are therefore only mentioned briefly.

Table 1. Network measure descriptions. (Knoke & Yang, 2008),(Wasserman & Faust, 1994).

| Network Measure | Definition | Importance |
|---|---|---|
| Closeness | How immediately an actor can interact with others by communicating directly or through very few intermediaries | Indicator of how quickly interaction can occur between actors |
| Indegree | The number of people who go to an actor for information | Indicator of an actors possession of information or resources |
| Outdegree | The number of people an actor goes to for information | Indicator of an actors knowledge of information or resources others possess |
| Connectedness | The summation of an actors Indegree and Outdegree | Indication of the ease with which and actor can communicate with other members of the network |
| Betweenness | The extent to which other actors lie on the shortest distance between pairs of actors | Indicator of control over information exchange or resource flow within the network |
| Prestige | The extent to which a social actor within a network "receives" or "serves as the object" of relations sent by others in the network | Emphasizes inequalities in control over resources, as well as authority and deference accompanying such inequalities |
| Distance | The length of the shortest path between two actors | Indicator of how directly communication occurs |
| Centrality | The extent to which a node connects to all other nodes | Indicator of extensive involvement in relationships with other actors |

Indegree is the first network measure that will be discussed in more depth. Indegree is the number of people who *go to* an individual for information. Typically people in more supervisory positions tend to have a high Indegree since those employees lower on the chain of command need approval for many actions they take and rely on senior employees for information. This is an instance of possibly poor Indegree, since having too many employees needing approval from one individual can create a bottleneck in information flow. Leaders, however, may not understand the effect hierarchy has on a network since their days may be spent making quick decisions and they may not be aware that peripheral people may wait weeks for a response to a question (Cross & Parker, 2004). Cross & Parker find this to be especially true in professional services. "In many kinds of professional services work, there is often not a single right answer but many plausible ones. Those in power often dictate the correct course of action and can quickly create networks that are overly reliant on them" (2004, p. 27). Indegree can be used to easily pinpoint those people who are most often sought out for information and who may be inadvertently acting as a bottleneck to the actors seeking information or decisions from them.

Conversely, Outdegree is the number of people and individual *goes to* for information. Outdegree can be used to indicate which people within the network know of the desirable proficiencies of others. Tom Allen of MIT found that engineers and scientists were roughly five times more likely to turn to a person for information than to an impersonal source, according to a decade's worth of studies on the subject (Cross & Parker, 2004). Furthermore, it has been found that even if a person containing the sought out knowledge on a subject works within the network, if the seeker does not have a direct relationship with that person, information transfer may not occur(Cross & Parker, 2004). One example in Cross & Parker's book describes a Research and

Development company that had tried to promote collaboration by creating a virtual problem-solving space and using online resumes to pinpoint certain expertise. However, this organization still found that people relied on "those they knew and trusted, and not on a database of self-proclaimed experts" (p. 16). The individuals with a high Outdegree may be those most aware of the expertise of others. Outdegree can also indicate the individuals who may be too reliant on others for information. This reliance may be due to a person's relatively short tenure in their current job position, to their being a newly hired employee, or to some other reason. Awareness of these individuals is important in order to ensure, if their high Outdegree stems from less desirable reasons, that steps can be taken to create more self-reliance in order that other individuals within the network are not overly burdened with requests for information.

Indegree and Outdegree can be combined into one single term, Connectedness. For example, Hilary has eight co-workers who routinely go to her for information on their projects, while Hilary, being more senior in the organization, only goes to David and Carrie when she needs information. Hilary's Indegree would be eight, her Outdegree would be two, and her Connectedness would be ten. The criteria on which Indegree, Outdegree, and Connectedness are considered acceptable vary depending on the organization being analyzed. A small company might expect to see, on average, lower values for these terms of measurement than would a large national or international company, simply because a small company has fewer employees. For example, an actor in a company with 16 total employees could have a maximum connectedness value of 30, while an actor in a company with several thousand employees could easily have a connectedness value in the hundreds. Well-connected people generally fall into one of two

categories, central connectors and bottlenecks. Cross & Parker (2004) point out that more connectivity is not always better.

> In networks of any size, it is not possible for everyone to be connected to everyone else, nor is it desirable. An indiscriminate increase in connections can be a drag on productivity. A crucial benefit of network analysis often comes from discovering excessive relationships. This discovery can help managers develop ways to alleviate overburdened people and decrease time-consuming connections (pp. 8-9).

When overly connected people are slowing the work of others it is crucial for organizations to take action to reduce their demand. This can be done through the formation of subgroups, where more people with the necessary expertise come into contact with one another, or through reallocating some of the more minor responsibilities of an overly connected person, allowing them to have more time to focus on their areas of expertise(Cross & Parker, 2004).

However, high connectivity does not always indicate a bottleneck. Highly connected people can be very beneficial to a network by making connections between groups that might not otherwise be made, or by providing quick feedback to those seeking information. It is important for executives to be aware of those members in order to ensure that gaps in the network will not be created if those individuals leave. These actors, sometimes referred to as central connectors, often have high levels of expertise in one or several areas, according to Cross & Thomas (2009), and therefore make day-to-day work possible for many others in the network. Losing a central connector can be extremely detrimental to a network. In order to reduce the impact of the departure of central connectors, “organizations need to develop the collaborative skills of everyone in the network and then help position emerging connectors in the center of the network

by assigning them to critical and relevant projects" (Cross & Thomas, 2009, p. 172). Another action to take to ensure the retention of organizational memory held by the central connectors is to create informal pairings of centrally connected members with more peripheral members. Cross & Thomas use an example of a pharmaceutical company that needed scientists to work together to interpret data. The company paired junior scientists with central scientists, allowing the junior scientists to receive real-time feedback, as well as develop connections with others throughout the company. In this way companies can ensure that valuable knowledge is not lost and that the younger generation of employees is making important connections with employees who possess expertise.

The next term of measurement is Betweenness. Suppose two people within a network are not directly connected to one another, but information could be transferred from one to the other through a string of intermediate people who are *between* the two people. Those intermediate people would thus have a Betweenness value attributed to them. Unlike the measurement terms previously discussed, Betweenness is based upon the probability of information sharing, rather than a directly measured number of people. To calculate Betweenness then, it is assumed that information will travel along the shortest route, or geodesic, between two people, *j* and *k*, regardless of which individuals lie along that route. If there is more than one geodesic, it is also assumed that each geodesic is equally likely to be used, represented by the variable $g_{jk}$. The total number of geodesics linking the two actors, *j* and *k*, that contain an individual is given by $g_{jk}(n_i)$. The probability that an individual, *i*, lies on a geodesic between two others can then be calculated using the equation $g_{jk}(n_i) / g_{jk}$. The Betweenness value then, is the sum of these estimated probabilities divided by all the pairs of actors except the *i*th actor as shown in the equation below:

$$C_B(n_i) = \Sigma\, g_{jk}(n_i) / g_{jk}$$

for *i* distinct from *j* and *k*. This index is a sum of probabilities, which counts how "between" each of the actors is (Wasserman & Faust, 1994). Also unlike the other terms of measurement, Betweenness is standardized to have a value between 0 and 1, where a value of 0 indicates that an individual does not lie between any others in the network, and a value of 1 indicates that an individual lies on every shortest route between others in the network, as illustrated below in Figure 1 (Wasserman & Faust, 1994). This star diagram shows person 1 having a Betweenness value of 1, while persons 2 through7 each have Betweenness of 0.

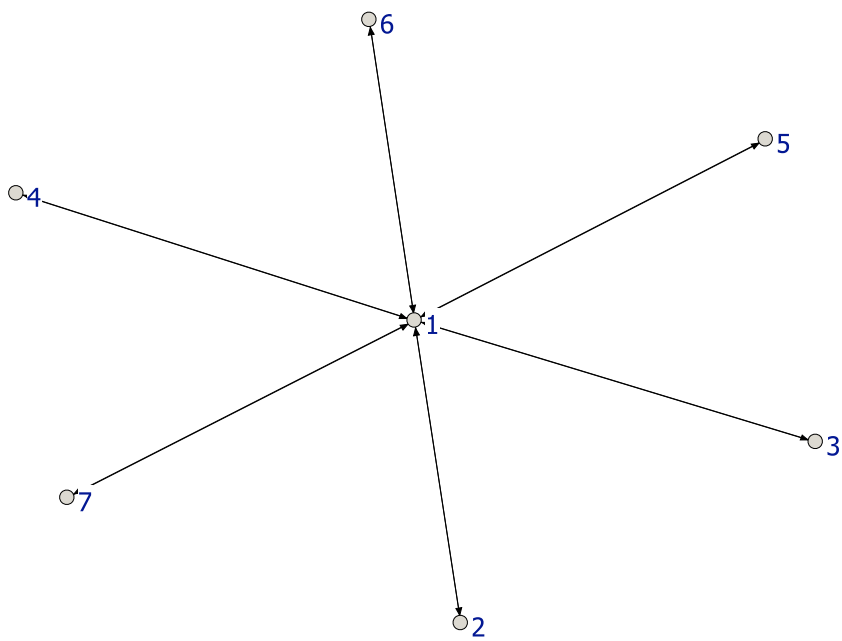



Figure 1. Star diagram illustrating Betweenness.

A more common example of Betweenness can be understood by considering a Real Estate Agent. One group of people, buyers, needs to know the other group of people, sellers. Buyers may know other buyers, and sellers may know other sellers, but buyers and sellers may not know each other. The Real Estate Agent works to connect the buyers to the sellers so that real estate

transactions can occur. This is illustrated below in Figure 2, where person 1 is the “agent” between the buyer group, in gray, and the seller group, in black. This type of separation can happen easily in companies that are spread over several regions. One region may only have communication to another region through one person.

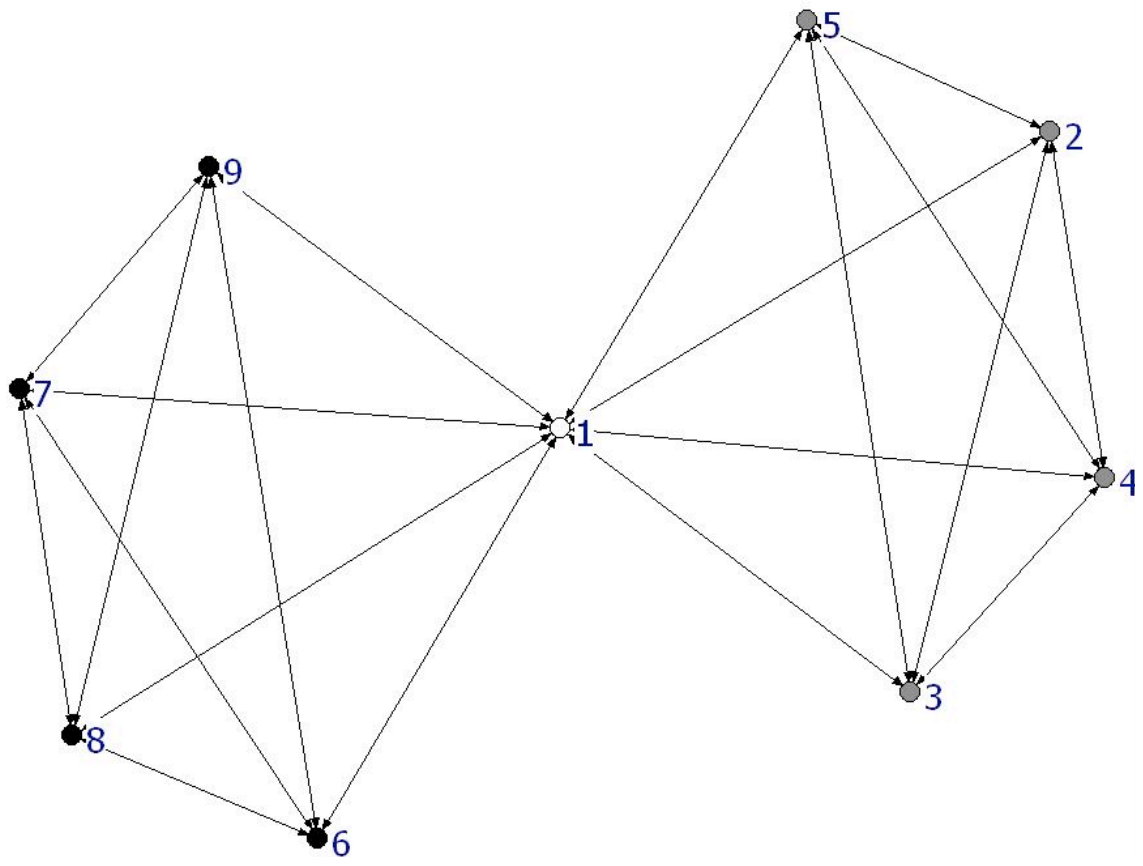



Figure 2. Betweenness diagram illustrating communication agents.

Betweenness values can be used to indicate which actors in the network are brokers between groups of people. According to Cross & Thomas (2009) “[brokers] may not have the most connections in a network, but by virtue of their relationships across subgroups, they have a unique understanding of the political dynamics and of the resources and expertise embedded in a

network" (p. 173). Knowing who the brokers are in a network can help executives to reduce network fragmentation between subgroups.

Each of these network measures is important for executives and employees to be aware of in order to maintain a strong network. Being able to identify how various members of the network are being sought out by their peers allows executives to gain a better understanding of how information sharing really occurs in the company. Each of the network measures can provide insight into how information sharing is occurring; however Indegree, Outdegree, Connectedness and Betweenness quickly provide understanding of how the network members truly interact.

## DATA COLLECTION

In order to calculate the network measures, data must first be collected. This data is essentially a list of which individuals every member of the network goes to for information, how effective that person is in providing information, and whether there was any kind of profitable gain from the interactions. Other data that is necessary for conducting ONA are personal attributes such as an individual's tenure in the company, their job function, and their perception of how well the network upholds important business values.

The fastest way to collect the necessary data is to survey the members of the network. The survey used to gather information necessary to conduct the organizational network analysis was developed at the University of Virginia under Rob Cross and Andrew Parker. Access to the survey requires membership in the Network Roundtable, an organization started by Cross & Parker to explore the business applications of network analysis. Membership also grants access to multiple webinars and online resources that explains how the survey works, and how to utilize its power to the best advantage. The survey is made up of several parts, each uniquely customizable for the specific organization being analyzed. The specific parts of the survey are the personal information section, the cultural values section, the personal network section (including the expertise section) the energy network section, and the bounded network section. Each of these will be discussed in the coming paragraphs.

The personal information section of the survey can be used to establish categorical statistics for the respondents, such as Job Function, Tenure, Region, Age, Sex, etc. These categories can be used when looking at the network maps to distinguish between different groups of people. This will be discussed later when describing the network maps.

The cultural values section asks respondents to rate various office environment values as they currently are within their work environment, and how they ideally should be. These values include such things as innovation and change, empowerment of employees to act, participation and open discussion, predictable performance outcomes, etc. The information gathered from this question set can be used to determine the respondents' opinion of the office environment in which they work, and how satisfied they are with that environment.

A personal network consists of all individuals to whom a person goes for information to get their work done, whether or not that person is within their network. A personal network could include contacts made during previous employment, personal friends, other business contacts made outside of the organizational network, or co-workers within the organizational network. In the survey, each respondent was asked to list up to 15 people to whom they turn for information. The respondents were further asked to identify whether the individuals within their personal networks collaborate with one another, or if they would be likely to collaborate with one another if the situation presented itself. By asking this question, ties can be made between people who may be part of the organizational network, but fail to respond to the survey or between people who are not part of the bounded network. The next question in the personal network section asks the respondent to indicate the primary benefit they receive from each member of their personal network. This information further allows insight into the nature of the personal network relationships. As another part of the personal network section, respondents were asked to list three skills or kinds of expertise that are important for them to be effective in their work, to rate themselves on their proficiency in that skill or expertise, and to indicate the extent to which each person in their personal network helps them with each skill or expertise.

The next section of the survey deals with the energy in networks. The questions in this section ask about the respondents' own attitudes at work, and offer suggestions to help improve these attitudes. This section of the survey is geared towards offering immediate feedback to each employee to initiate a change in approach to dealing with networks. The energy section of the survey does not provide much immediate information for network analysis, however it can be useful for understanding each respondent's viewpoint.

The final, and most analytically useful, part of the survey is the bounded network section. The bounded network is the formally established network of employees being surveyed for the network analysis. This network can be comprised of any portion of the employees within the organization with common interest, such as a group of people who are integral to a core process within the organization or those who all serve a critical function (Cross & Parker, 2004). When surveying a bounded network, each respondent is provided with a list of names for every other member of the network.

The main reason for using the survey developed by the Network Rountable is that the questions in the survey have been validated. In general, validity refers to the degree to which a tool captures what it is intended to measure. Thus by using the validated questions, the results obtained from the survey can be trusted to accurately represent the information being sought out. The use of valid survey questions is especially important for the bounded network questions, as these are the questions on which the network maps are primarily based.

The first question in the bounded network section asks respondents to indicate the extent to which the other individuals in the bounded network are effective in providing them information that helps them learn, solve problems and do their work. The names of each of the

other individuals in the bounded network are listed, and for each name the respondent can choose either that they do not know the person or have not worked with them on any relevant projects, or that they are ineffective, somewhat ineffective, somewhat effective, or effective at providing information. Respondents must select an answer for each person in the bounded network. Four subsequent questions are then asked about the individuals the respondents indicated they knew, i.e. the individuals who were given an effectiveness rating. These questions asked if interactions with the individuals resulted in better quality of work, time saved, reduced project costs, and if the respondent receives clear direction from each individual. The responses to the bounded network questions, especially the first "information" question, act as the basis for the network maps, which graphically depict the relationships in the network.

Another important aspect of data collection is personal interviews. Interviews conducted after the survey results have been analyzed can help executives to understand the motivation behind how individuals answered the survey questions. For example, if a network had a member who was generally rated as effective, but who generally rated the others in the network ineffective, interviewing that individual could provide insight into how much personality had an effect on the results. Interviews can also provide clarity for the cultural values section of the survey. Interviewers might be able to ask respondents about particular answers in order to be able to develop a plan of action to change the network values to be more favorable to employees. No interviews were conducted for the case study in this paper.

## DATA ANALYSIS

Once the survey data has been collected, it can be analyzed through the use of network analysis software that can calculate the network measures previously discussed and create network maps. Both maps and calculations are necessary in order to fully understand how the network operates. Through calculations, executives can compare numerical values for Connectedness, Betweenness, etc., and network maps can be used to quickly show which individuals are more central to the network and which are more peripheral.

Programs such as UCI Net can be used to calculate each individual's Indegree, Outdegree, Connectedness, Betweenness, etc. These values can be compiled into summary tables in a spreadsheet so that they can be easily viewed and understood. Being able to see the values for each of the members of the network can aid executives in understanding the typical values for their network, and they can thus compare each network member to the norm for the network. Having numerical values to reference while analyzing the network maps can also be helpful since network maps do not provide specific values. The calculated numbers and the maps should be used together when analyzing the network.

NetDraw is a computer program used to create network maps, which can be manipulated to show various levels of connectivity. Nodes are used to represent people, and lines are used to indicate the connections between the nodes, with arrows pointing out the direction that the communication goes. For example, Figure 3 on the next page displays an example of a one-way relationship, where person 1 goes to person 2 for information, but person 2 does not go to person 1 for information. In this diagram, person 1 has an Outdegree of 1 and an Indegree of 0, while person 2 has an Outdegree of 0 and an Indegree of 1. Figure 4 shows a relationship where both

person 1 and person 2 go to each other for information. In Figure 4, both person 1 and person 2 have an Outdegree of 1 and an Indegree of 1.

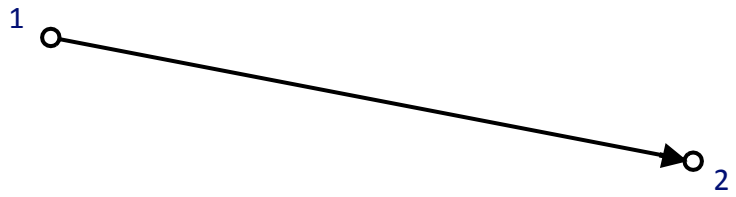



Figure 3. One way communication between person 1 and person 2.

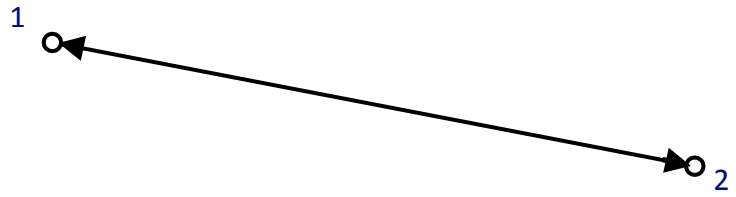



Figure 4. Two way communication between person 1 and person 2.

Additionally, nodes can be labeled with names, colors, shapes and sizes to represent various pieces of personal information, such as function, tenure, region, etc. Figure 5 on the following page displays a fictional network with ten employees who work in three different regions and perform two different functions. The nodes are shaded to represent the different regions, shaped to represent the functions, and sized to indicate the employee's tenure in the organization. Three important pieces of information can be gathered simply by looking at the node representing a person. Individual employees can be isolated and their direct network, or egonet, can be analyzed to see to whom they are connected. These egonets generally contain the individual being studied, or ego, the members of the network who are directly connected to the ego, and the secondary members of the network who are indirectly connected to the ego. Figure

6 displays a sample egonet for person 40. There are 12 other individuals in his network who are either directly or secondarily connected to him.

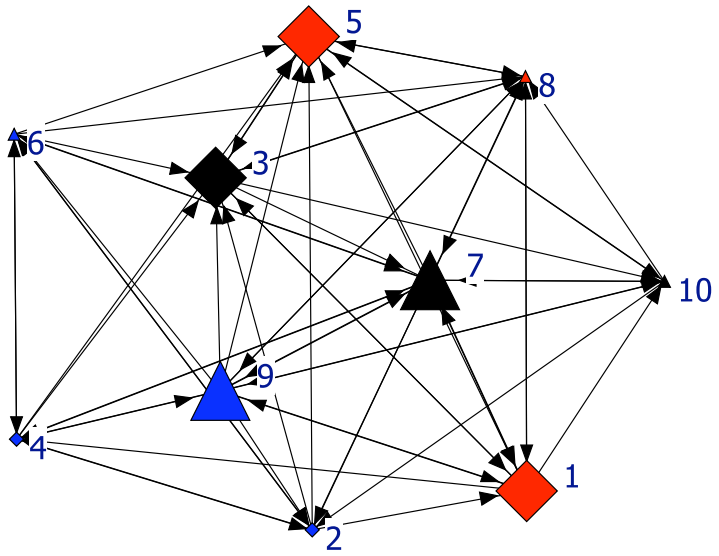



Figure 5. Using node size, shape, and shade to represent information.

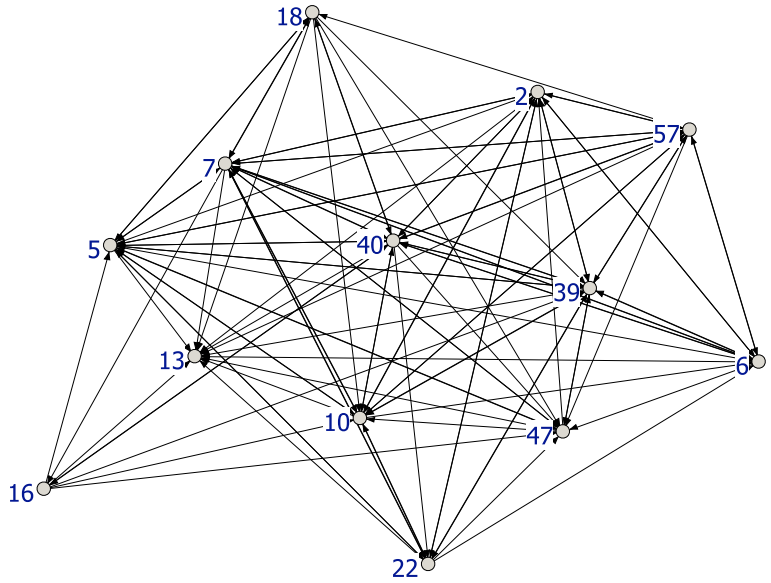
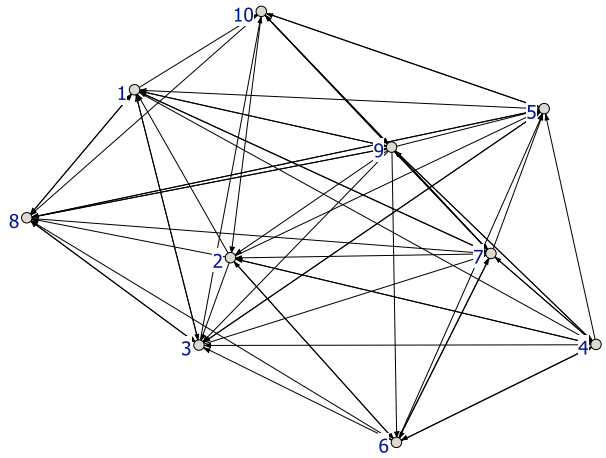



Figure 6. Egonet for person 40.

Using NetDraw, maps can be created based on the strength of interaction between people, i.e. ineffective, somewhat ineffective, etc. Figure 7 and Figure 8 show how maps can vary depending on the connection strength being mapped. These maps are of a fictional network.



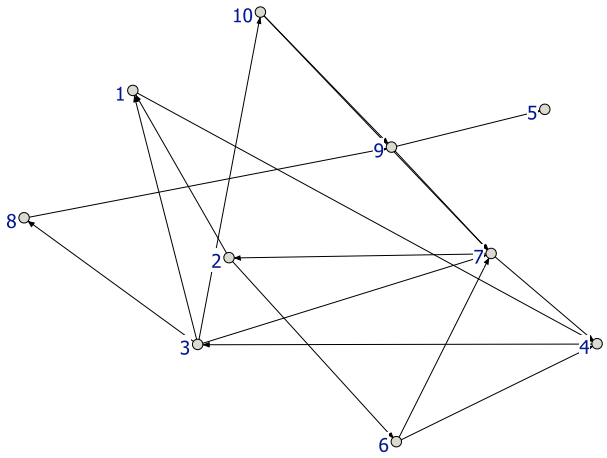




Figure 7. Every connections within the network. Figure 8. Connections representing strengths 3 and 4.

Having the lines on the map represent the connection strength allows the organizations to assess the attitude that respondents have toward the others in the network; whether they rate the others as generally effective or generally ineffective. Another way that the maps can be manipulated is through the elimination of certain nodes and their corresponding connections. It is easy for people to become overly connected in an organization, and network maps can show the hole that would be created if these individuals left the company. For example, if person 1 was removed from the map shown in Figure 2, the network would become completely separated into two distinct groups as shown in Figure 9. In reality, this kind of complete separation would be highly unlikely to occur, however something similar might happen if overly connected people within a network were to be removed. The separation can affect both overall company performance and profitability adversely since information sharing may not take place as rapidly.

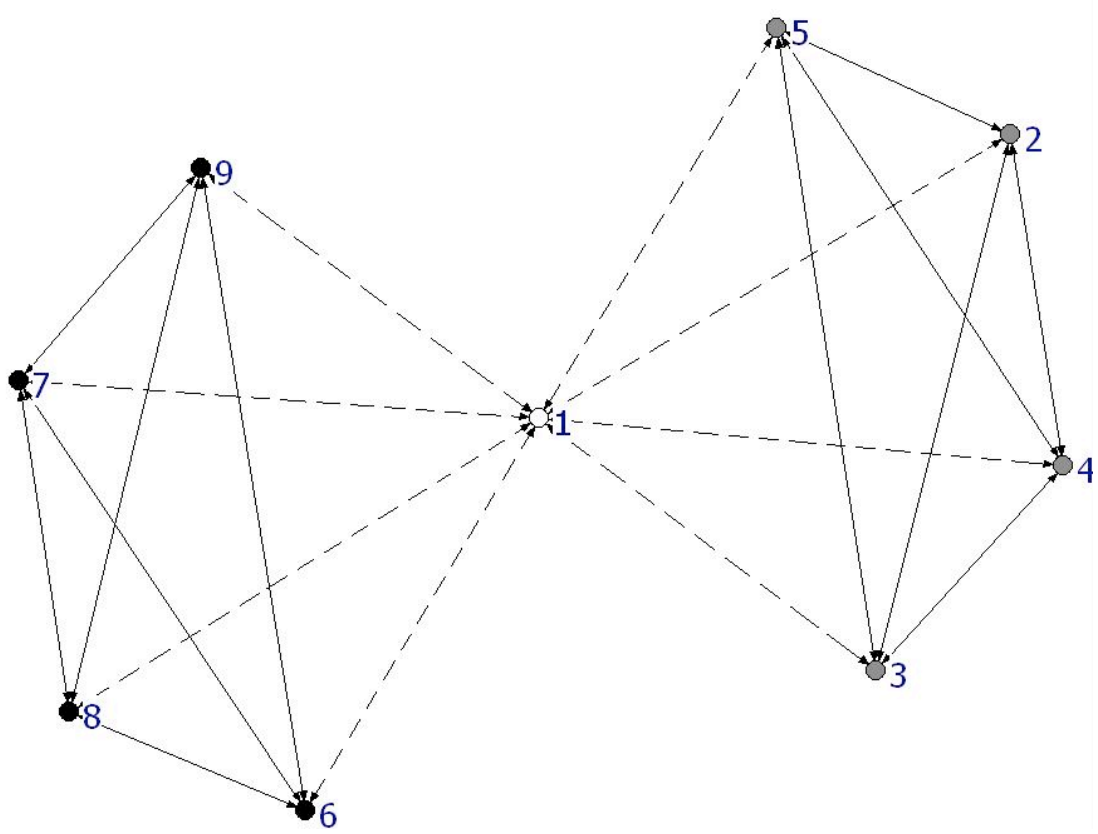



Figure 9. Fragmented network due to the removal of a highly connected employee.

Each network has its own set of challenges and difficult areas, so a generalized prescription for analysis cannot be proposed. Some networks are highly fragmented and have only a few members connecting the different areas, acting as brokers, while other networks are fairly well connected, but have a few members who are too highly connected, causing bottlenecks to occur. In the first example, creating more connections between the different areas would keep the network from becoming completely fragmented if the brokers left. In the second example, the best solution might be to delegate some of the highly connected members secondary responsibilities to others so that they can focus on the areas in which they have the most expertise. Each network must be subject to a detailed analysis in order to find the most effective

solution for the networks problems. However, the following case study provides a detailed look at an ONA for two networks within a state transportation agency.

## CASE STUDY

The network analysis was conducted for two networks within a state transportation agency spread throughout several cities; Network A was made up of 60 people and Network B consisted of 84 people. Each network contained individuals from each of the various offices. Some of the respondents were members of both Network A and Network B, but were asked to complete the survey twice, once for each network. The interaction between Network A and Network B was not analyzed for this study.

The survey given to the employees consists of the questions shown in Appendix A. Networks A and B had completion rates of 58% and 72% respectively. Ideally this percentage would be higher, allowing for every piece of available information to be gathered. The results from the data may vary slightly due to the low response rate, however the responses represent the majority of the members in both networks, so the response rate is not a cause for great concern. The data was then exported for analysis. Each network was analyzed separately, since the two networks represented vastly different areas relating to transportation.

The responses to the last four questions of the survey, asking about time saved, money saved on projects, quality of direction, and overall quality of work, were analyzed for reliability, and a Chronbach's alpha value of 0.848 was obtained. Essentially, this means that if a respondent indicated that a particular person was generally effective, the respondent would also say that the person also generally saved them time, the person generally saved them money on projects, that they received clear direction from that person, and that the overall quality of their work was improved due to interactions with that person. This means that for future surveys only one of the five questions would need to be asked, and the responses to that question could be extrapolated

for the other four questions. This also means that analysis of the networks could validly be conducted based on the responses to one of those questions. For the case study in this paper, the responses to the effectiveness question were used for analysis.

The first step for analysis was to calculate the network measures for the members of the two networks. Once the values were calculated and input into a spreadsheet, maps were created for the networks. Each network was unique in many aspects, and so separate analyses had to be conducted.

Network A was composed of 60 individuals and had four function groups, Advisory, Core Team, Leadership Team, and Technical. On the following network maps, the functions are represented by the shapes circle, square, triangle, and diamond, respectively. In order to preserve the privacy of the individuals within the network, numbers have been assigned to each individual. In order to make the analysis simpler, the male pronoun will be used for every individual, regardless of his or her actual sex. Since only 58% of the members of Network A responded to the survey, actual Indegree and Outdegree values will be lower than the actual number, however the general trends are reliable as a majority of the network is represented in the data. Table 2 provides a more detailed description of each of the functions in Network A.

Table 2. Network A function descriptions.

| **Function** | **Description** |
|---|---|
| Advisory | Develop, advise and/or set policy related to Network A activities for the department. |
| Core Team | Provide technical information on their area of expertise for Network A activities. Work together to gather information and develop recommendations to respond to legislative and policy requirements. |
| Leadership Team | Assist in the development of policy and procedures. Facilitate implementation of Network A activities within their areas of responsibility. |
| Technical | Provide technical information on their area of expertise for Network A activities on an as needed basis. |

The first network map analyzed was the map representing all of the “ineffective” responses to the survey question, “How effective is each individual in providing you information to get your work done”. As shown in Figure 10, individual 40, who is one of the directors within Network A, has 9 arrows pointing towards others, indicating that he views these others as ineffective. Additionally, he has 2 arrows pointing inward, indicating that there are 2 individuals who find him ineffective at providing information. One of the people who individual 40 found to be ineffective is person 22, who is a manager in Network A. An interesting observation of this map is that two directors in Network A find individual 22 to be ineffective, while individual 22 finds 4 other people in that function to be ineffective. The majority of the individuals in this network are not included on this map, indicating that most people found the others to be better than ineffective at providing information, which is a positive sign for the network. Additionally, person 29 has 4 incoming arrows, the most of any individual in Network A, with person 5, person 49, and person 58 each receiving 3 arrows indicating ineffective information sharing.

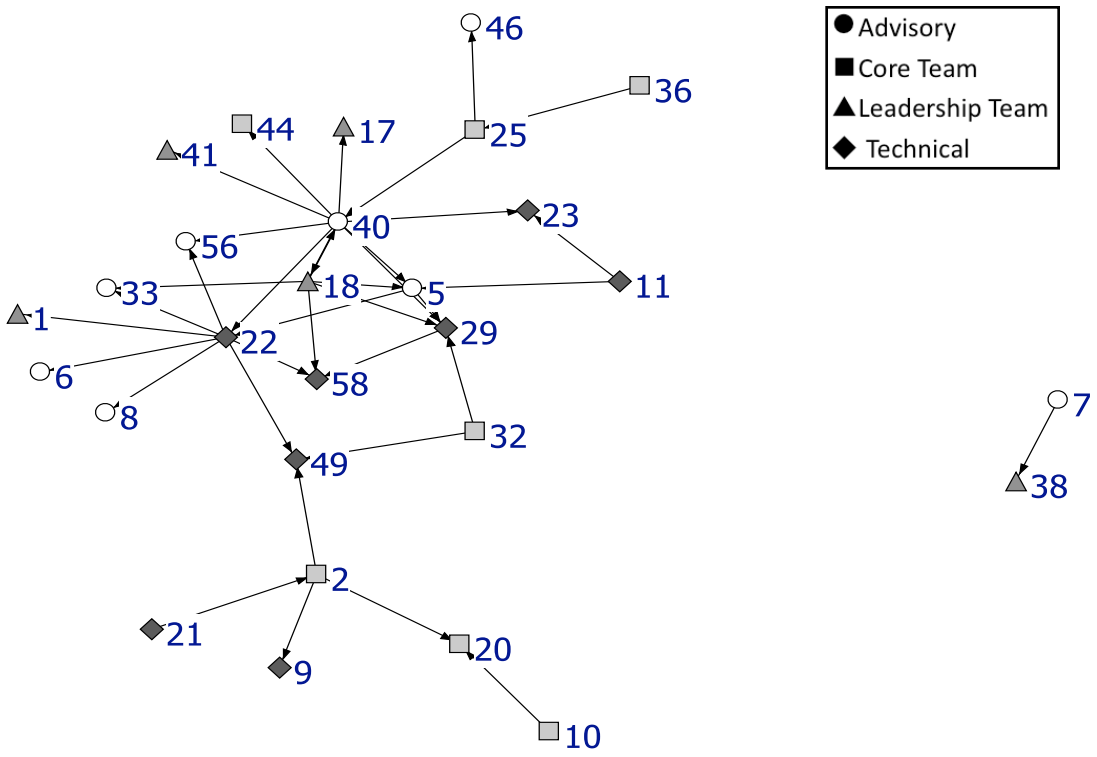



Figure 10. Network map showing responses of "Ineffective".

The next map to be analyzed, shown in Figure 11, is the map showing all the responses of “somewhat ineffective” to the same survey question. Again, individual 40 has 16 outgoing arrows, indicating that there are a number of people whom he finds to be somewhat ineffective at providing information. The average number of outgoing arrows for this connection level is 4 arrows. The people most often identified as somewhat ineffective in providing information are person 2 with 8 incoming arrows, persons 5, 6, and 49 with 7 incoming arrows, and person 55 with 6 incoming arrows. The average number of incoming arrows for this connection level is 3 arrows. In order to try to improve the network, person 40 could be interviewed and asked why he rated the others as somewhat ineffective. According to the network map, Individual 40 is central to the network, meaning that the other individuals in the network somewhat revolve around him,

and that he is an integral part of the network. His high level of centrality would indicate that some measures should be taken to ensure that others' information sharing with him would improve in the future. Another central individual in this map is person 55. Again, he has 6 incoming arrows, showing that others find him to be somewhat ineffective at providing information. Similar steps should be taken to ensure that his information seeking habits improve to become more effective to others. Person 2, the program leader for Network A, is on the periphery of the map, which is surprising, since he is one of the more senior people in the network. However, since Figure 11 shows more negative responses to the survey, the peripheral position that individual 2 holds is not considered troubling. It is important to be aware of the fact that person 2 does have 8 incoming arrows, the most of any individual in the network, so steps should be taken to ensure that his information sharing becomes more effective.

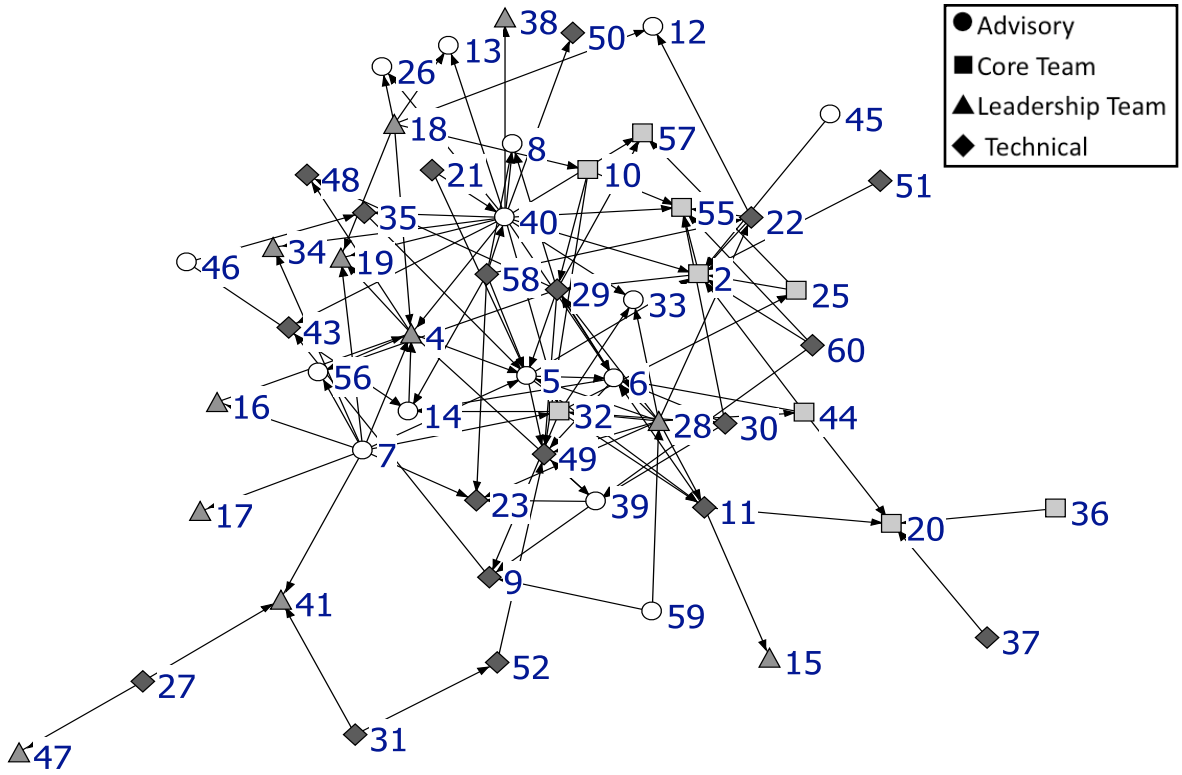



Figure 11. Network map showing responses of "Somewhat Ineffective".

Figure 12 presents a map of all of the connections resulting from responses of “Somewhat Effective” to the information question. This level of response had the highest number of connections (387 connections) of any of the answers, indicating that most people considered others to be somewhat effective in providing information (“effective” had 381 connections, “somewhat ineffective” had 117 connections, and “ineffective” had 37 connections). Having the greatest number of connections for this response level indicates that Network A is healthy in that most people indicate that they are able to get the information they need from others in a fairly effective manner.

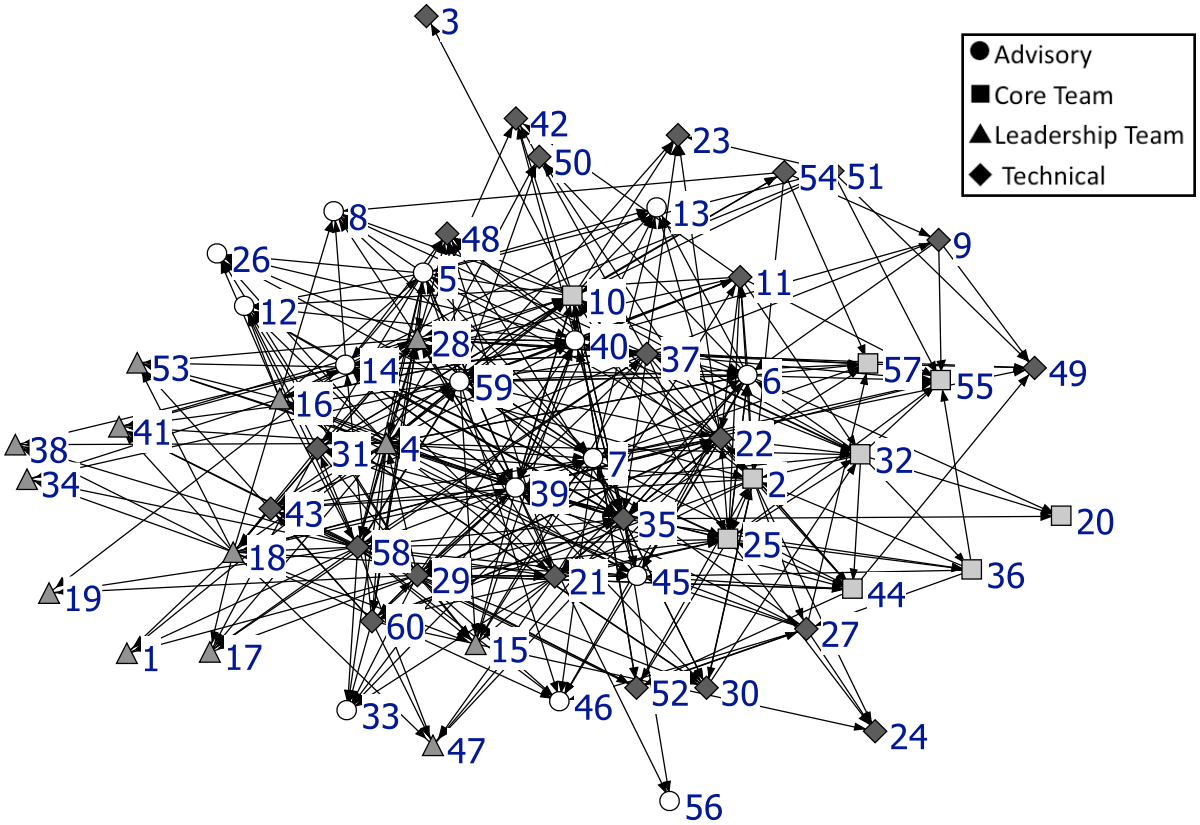



Figure 12. Network map showing responses of "Somewhat Effective".

Within this Network A there appears to be vulnerability at the connection level of somewhat effective. If the three most connected people, (persons 2, 7, and 39) who represent

approximately 5% of this network, were to be taken out of the network, because of retirement, layoffs, etc., a hole would be created in the network map, as shown in Figure 13. More than 20% of the total number of connections (78 of 387) in this map would be lost if these three people were gone. This hole indicates that if those three people were removed, a breakdown in information sharing and access could occur. An important note about those three people is that they are all part of the advisory function, and each one is a director within one of the departments of the agency. Having people so high up in the agency being the most connected could potentially lead to a bottleneck. If these individuals are responsible for approving too many decisions that could be handled by lower ranking individuals, they may not have time to handle the bigger issues that require their expertise.

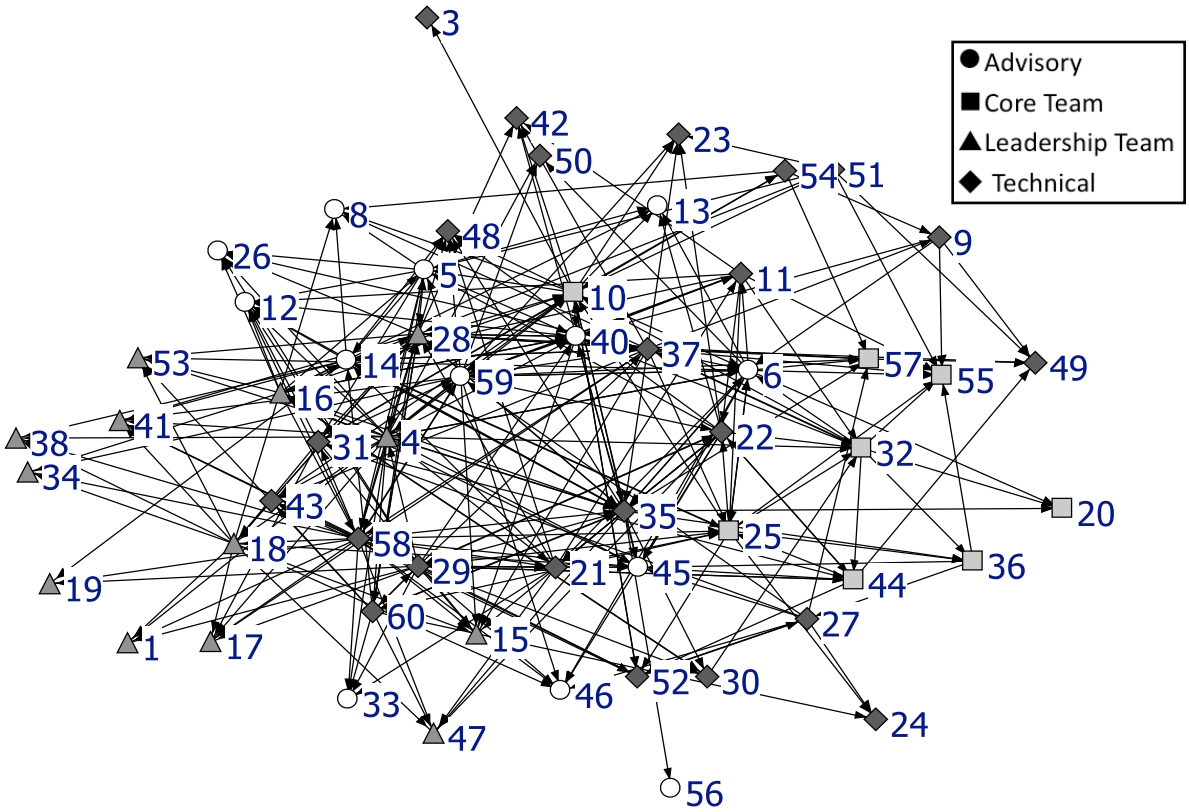



Figure 13. Network map showing the hole left by removing the three most connected members of Network A.

The map in Figure 14 indicates the responses of “Effective” to the information question. There are still a good number of connections, 381, for this response level, which indicates that there are many individuals who both find others effective and are found to be effective in providing others with information. The fact that the number of connections for the “somewhat effective” and “effective” responses is much higher than for the “somewhat ineffective” and “ineffective” responses indicates that network A as a whole tends to have good information sharing. Individual 57 has 32 connections pointing away from him, indicating that he finds many others to be effective in providing information, however only 9 people found him to be effective. In the time which passed between when the survey was distributed to Network A and when the analysis of the results took place, person 57 was relocated to another position, so the lack of effective information provided by him is no longer an issue for the network. Person 2, who is the program leader for Network A, was found to be effective at providing information by 11 other people, while he found 23 people to be effective. His numbers are above the average of 7 connections in and 10 connections out.

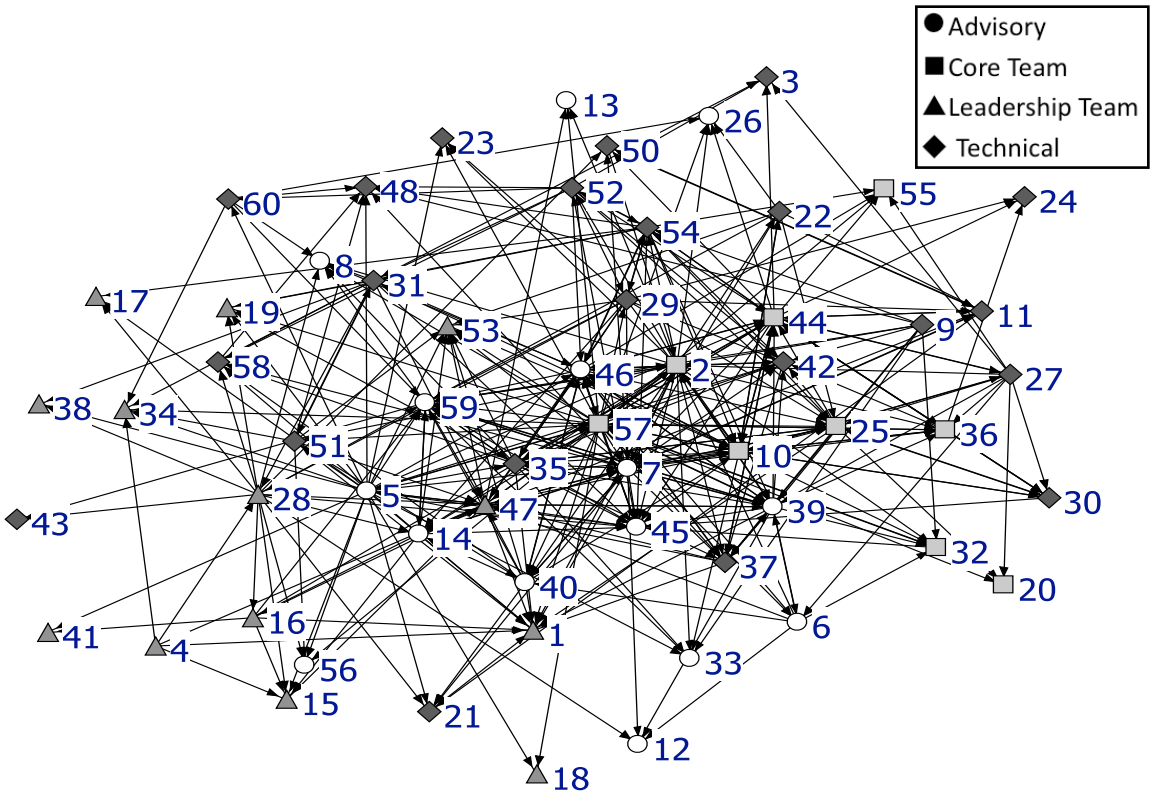



Figure 14. Network map showing responses of "Effective".

An interesting thing about Figure 14 is that most of the members of the leadership function are peripheral to the network. This indicates that they are not centrally connected to the other members of the network and are therefore not sought out as much for information, nor do they seek others out, which might seem surprising, since they are in fact the leaders of the department. However, their time is spread more broadly than just Network A, so the peripheral position is not alarming.

The Network map displaying all of the connections for Network A is shown in Figure 15 below.

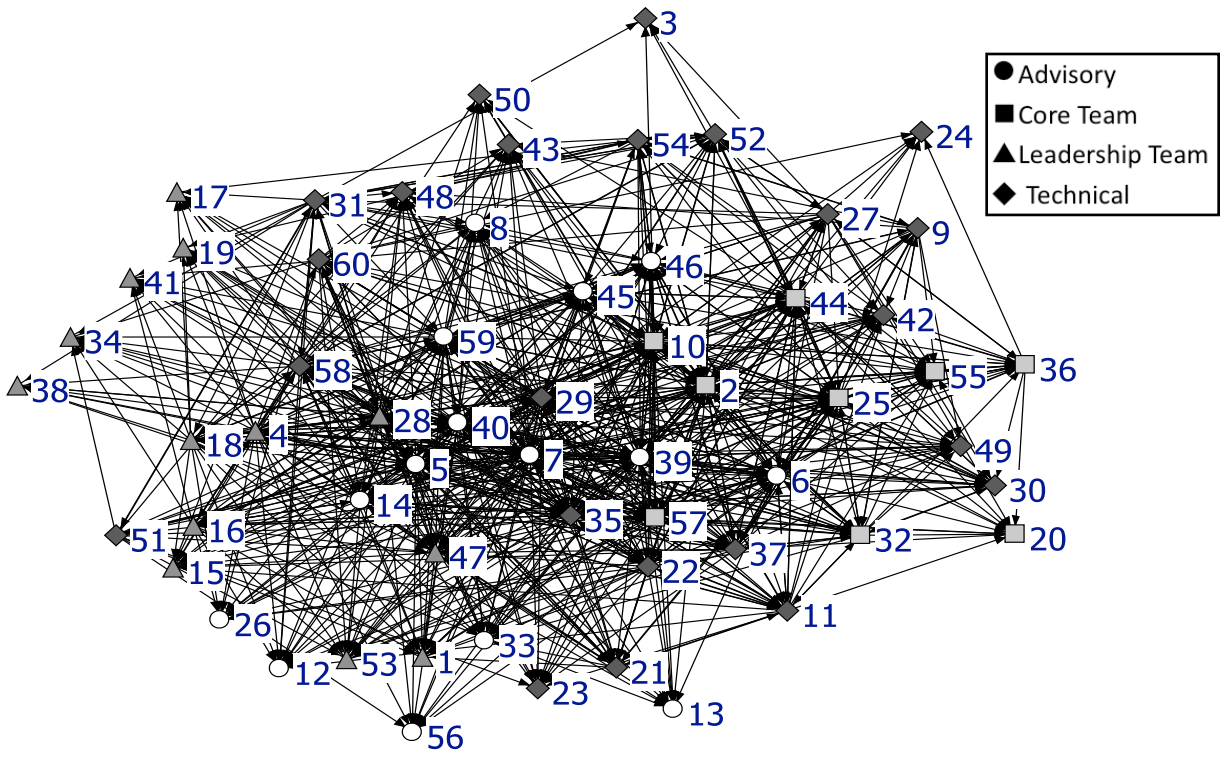



Figure 15. Network map showing all connections for Network A.

This map shows 922 of the possible 3540 connections between the various members of the network. In other words, approximately 26% of the possible connections for the network actually exist, according to the responses to the survey. However, not every member of the network completed the survey, so the number of actual connections could be higher. There are clearly some changes that should be made to the network in order to increase the number of the connections, as well as improve the effectiveness of the information sharing. However, every member of the network is connected to at least one other member of the network, so there are no individuals completely excluded from information sharing. It is important to be aware of how productive the existing communication is, as well. Actions taken to improve the network should be considerate of the level to which productivity needs to increase.

Also of interest are the maps showing where information sharing does *not* occur. Figure 16 displays the responses of "I do not know this person" for the information question. Every line on the map indicates where a person does not know another person, or knows them but has not worked with them on an issue relating to Network A. Compared to Figure 15, Figure 16 shows a large number of connections (1438 vs. 922). This indicates that people within Network A are more likely to not have worked with others on a project related to Network A or to not know others than they are to have worked with them or know them.

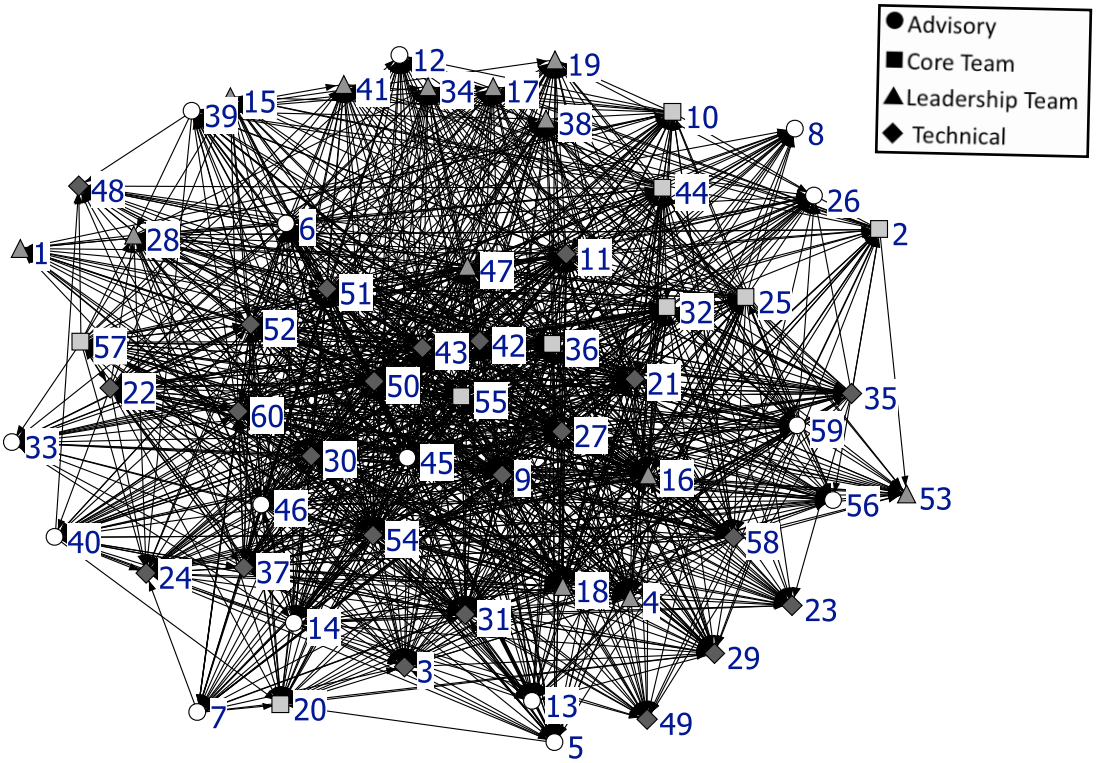



Figure 16. Network map showing which individuals do *not* know others.

The individuals who reported that they had not worked with other individuals in the network for the different functions are displayed in Figures 17-20 below. The lines on these maps represent when people do *not* know each other. Thus, the more lines on the map, the less information sharing is occurring. The technical function, especially, has a large number of lines

between the different individuals. This is true for both Network A and Network B. Some possible reasons for this are that the individuals in the technical function perform more specialized duties, and therefore are not as reliant on each other, and this could be exacerbated by the fact that, like every other function, the individuals in the technical function are located all around the state, so face-to-face contact is somewhat impeded.

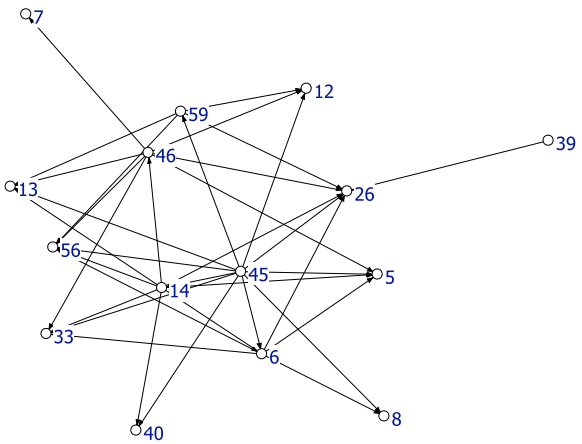



Figure 17. Advisory function.

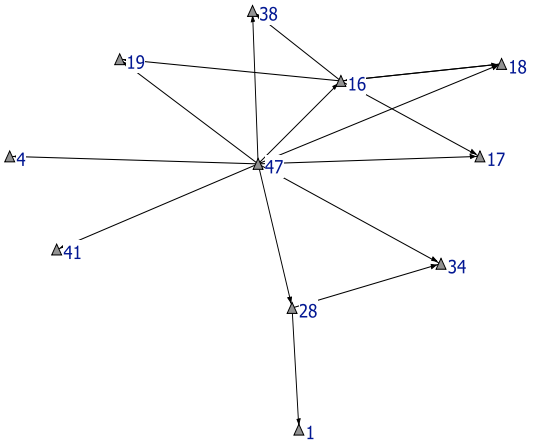



Figure 19. Leadership Team function.

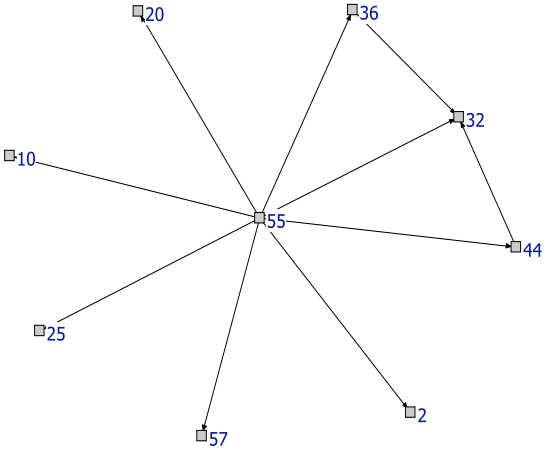



Figure 18. Core Team function.

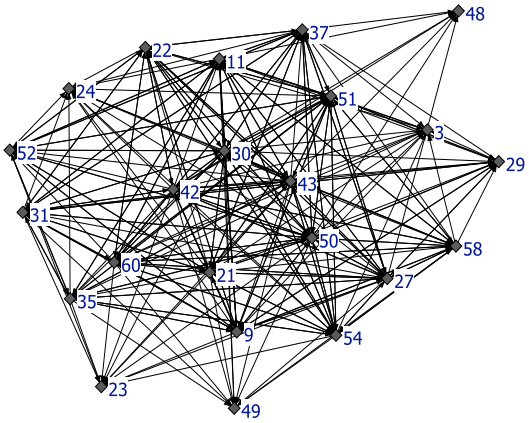



Figure 20. Technical function.

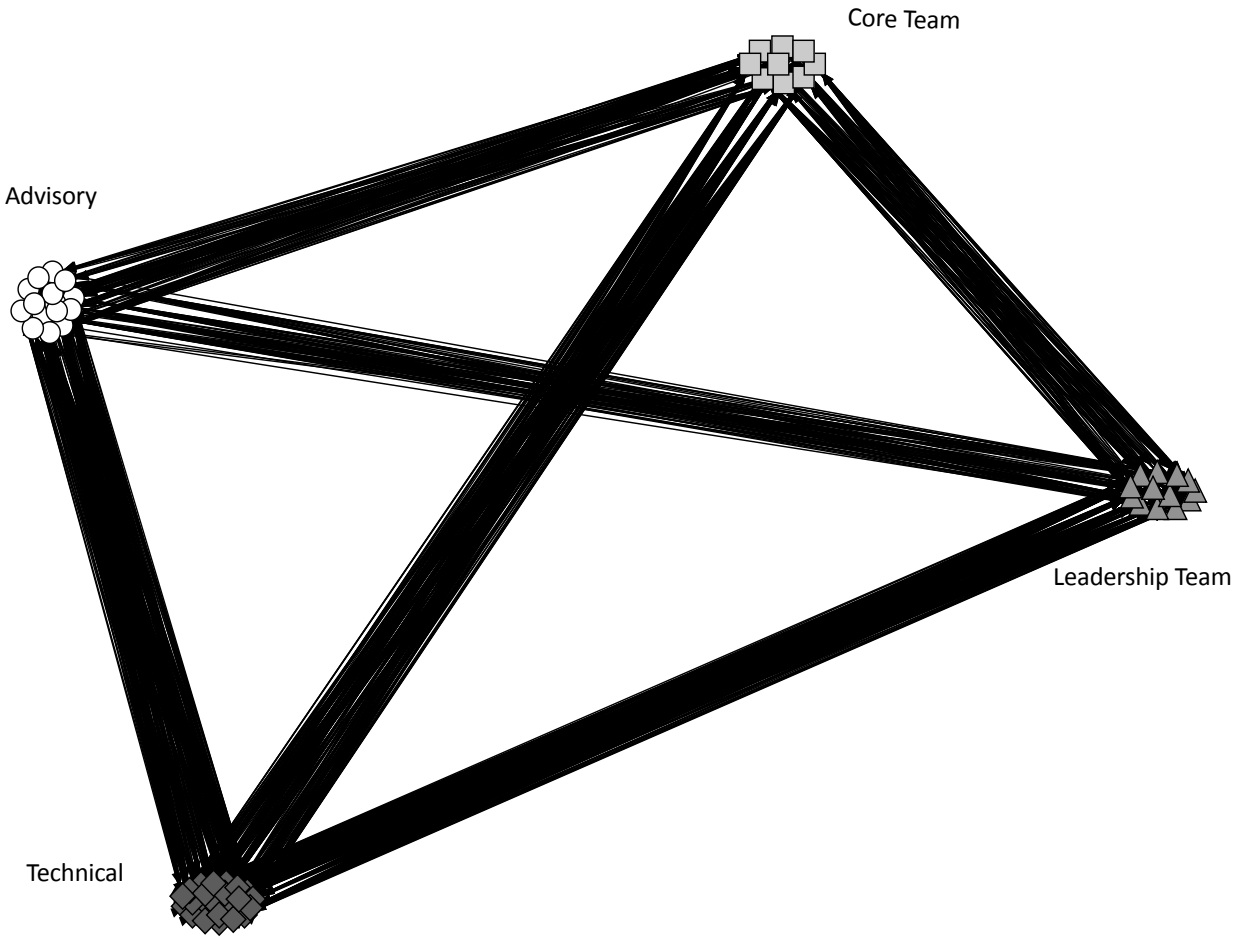



Figure 21. Network map showing lack of connection between functions in Network A.

Figure 21, above, illustrates the lack of connection that exists between each of the four different function groups in Network A. As in Figures 16-19, the lines on Figure 21 represent where individuals do not know others or have not worked with others on projects related to Network A. The number of lines on these diagrams are not inflated by network members who did not respond to the survey. Non-respondents are only included in the maps if a survey respondent indicated that they had not worked with or did not know a non-respondent. This is another area where improvement could be made. The simplest solution to this problem is increase the

awareness that each member of the network has of what people in the other functions does; eventually leading toward an awareness of what expertise others have individually.

The effective and ineffective connectivity of each individual was calculated. Essentially this represents how many times an individual listed another person as either somewhat effective or effective or as somewhat ineffective or ineffective versus how many times the individual was listed in either of those categories. Appendix B contains a complete table of all individuals Indegree, Outdegree, Connectedness, and the effective and ineffective connectedness values. Two interesting findings from the tabulated data are from person 5 and person 40. Person 5 has equal numbers of effective and ineffective Indegree ratings, but has 36 effective Outdegree ratings. Essentially this means that while other people in the network tend to find person 5 a neutrally effective source of information, person 5 finds over half of the other people to be either somewhat effective or effective at providing information. Person 40 has a generally effective rating for Indegree, but has a majority of ineffective Outdegree ratings, indicating that while people in the network tend to find him effective at providing information, person 40 generally does not find others to be effective sources of information. The findings for person 40 could be particularly important as it could indicate that he may be frustrated that others in his network do not seem to provide information as effectively as he does. Addressing this point in an interview could allow the network executives to possibly avoid having person 40 become overly frustrated with his work environment. Other helpful actions to address this problem could be to identify the kind of information that person 40 tends to seek out and then to identify which individuals in the network are most likely to possess that information and to ensure that person 40 is aware of those individuals.

A similar analysis was conducted for Network B, which is composed of 84 individuals in 5 function groups. The functions for Network B are Government-to-Government Relations, represented by the circle, Policy and Procedure represented by the square, Project Development represented by the upward pointing triangle, Technical represented by the diamond, and Liaison/ Coordinator represented by the downward pointing triangle. Network maps were created for Network B, and each one was analyzed in a similar manner to Network A. Since only 72% of the members of Network B responded to the survey, actual Indegree and Outdegree values will be lower than the actual number, however the general trends are reliable as a majority of the network is represented in the data. Table 3 provides a more detailed description of each function in Network B.

Table 3. Network B function descriptions.

| **Function** | **Description** |
|---|---|
| Government to Government Relations | Involved in government to government relationship building and maintenance including negotiations, policy development and problem solving. |
| Policy & Procedures | Involved in procedure development, policy development and problem solving for Network B activities as it relates to the their area of expertise. Provide technical advice on this subject within the department. |
| Technical | Provide technical information on their area of expertise for Network B activities on an as needed basis. |
| Liaison/Coordinator | Develop, collate, and guide Network B policy and procedures within the department. Serve as the experts on Network B process and procedures within the department. Serve as a liaison. |
| Project Development | Assist in development and funding of transportation projects that occur. |

The first network map, shown in Figure 22, represents all of the responses of “ineffective” to the survey question of how effective is each individual in providing information. Person 10 is very central to this network map with 9 incoming and 12 outgoing ratings of ineffective, only 1 of which is mutual. The average number of outgoing ineffective ratings for Network B is less than 1,

so person 10 stands out as identifying ineffective information sharing. Person 10 holds a fairly central role in Network B and is connected to almost 80% of the network, so it makes sense that if ineffective information sharing was occurring that he would be able to identify it. Interviewing person 10 and asking why he rated each individual as ineffective at providing information could obtain valuable information for network improvement. Person 5 has the second highest number of ineffective ratings for Network B, with 6 incoming arrows, half of which are from others within his function. He did not identify any others as ineffective at providing information. It could be beneficial to know why the other people in the network see Person 5 as ineffective at providing information. There are a total of 44 connections for the response of "ineffective" in Network B, totaling less than 1% of the total possible connections for the network, and over 3% of the existing connections. Combined with the "somewhat ineffective" ratings discussed in the next paragraph, over 11% of the existing connections for Network B are some degree of ineffective.

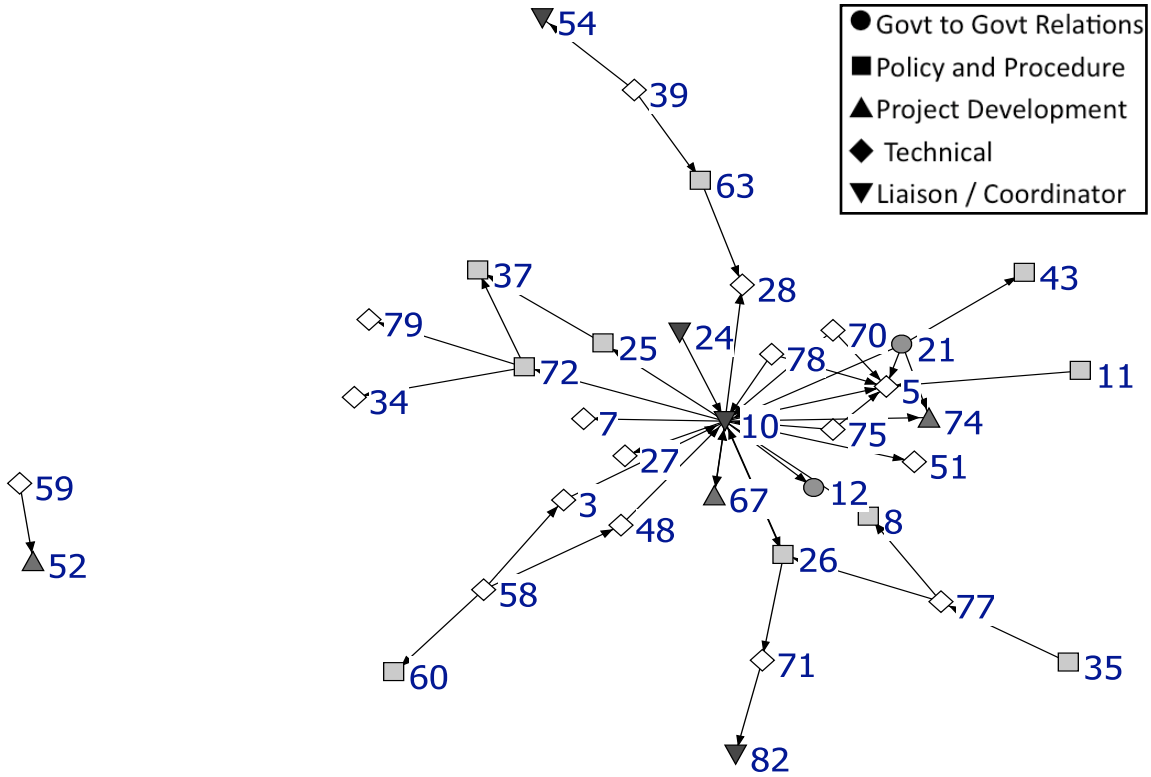



Figure 22. Network map showing responses of "Ineffective".

The next network map analyzed presents the responses of “Somewhat Ineffective” (Figure 23). The key observations from this map are that person 10 is again the most connected individual with 10 outgoing and 6 incoming arrows. Persons 11, and 28 are also fairly well connected with a total of 13 and 14 connections, respectively. Thirty-one of the members of the Technical function are represented on the map (exactly half of all people on the map), either being identified as somewhat ineffective, or identifying others as somewhat ineffective.

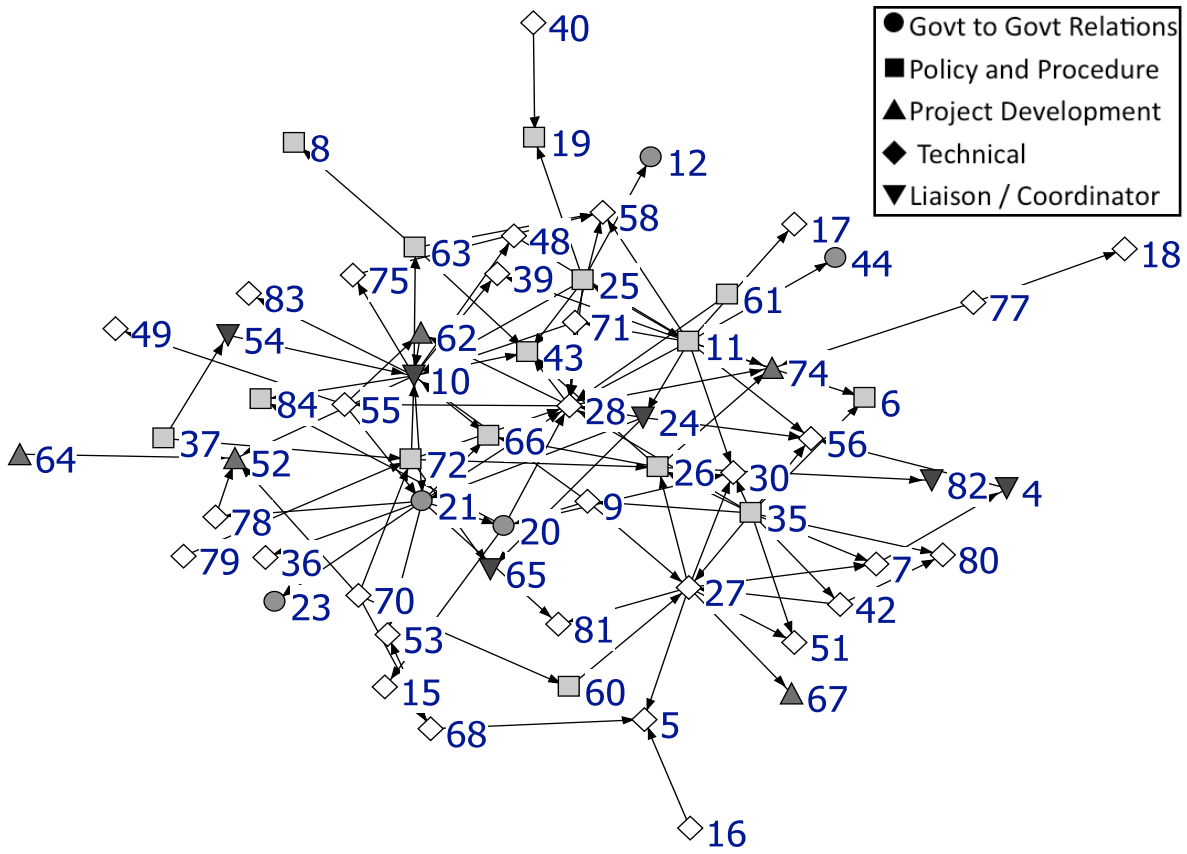



Figure 23. Network map showing responses of "Somewhat Ineffective".

The next network map, shown in Figure 24, representing responses of “Somewhat Effective” gives some more useful information. The first thing to be noted is that person 33, who did respond to the survey, is not included in the map. He neither indicated anyone as somewhat effective nor was he indicated by anyone else as somewhat effective at providing information. This indicates that all of his connections are either more effective or less effective than the “somewhat effective” level. Three individuals, person 15, person 29 and person 69 are all extremely peripheral on the map, which indicates that even though they are connected to others in the network at this effectiveness level, they are not central to the network information flow. Additionally, each of those individuals is only connected to one other person in the network.

Person 35, on the other hand, is very central to the network with 36 connections indicating that he finds others and is found by others to be somewhat effective at providing information. Person 11 is equally as connected on this map, which is to be expected as that individual holds a very central role in Network B. It is important to note that there are 457 connections at the somewhat effective level, more than at both of the ineffective levels combined, indicating that in general, people in Network B tend to find each other more effective than ineffective. The connections at the somewhat effective level represent approximately 34% of the total number of existing connections for Network B, but only represent roughly 6.5% of the total number of possible connections for the network.

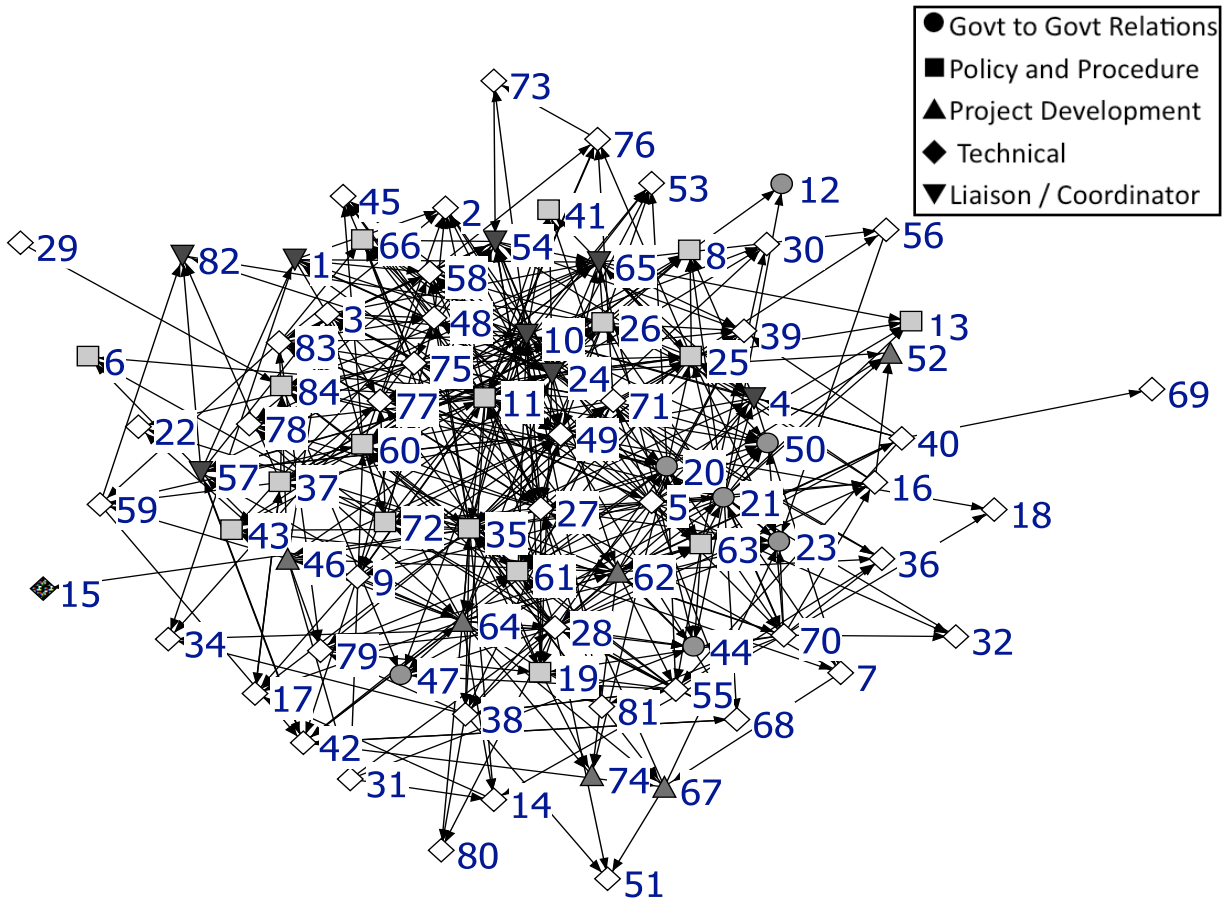



Figure 24. Network map showing responses of "Somewhat Effective".

The network map shown in Figure 25 indicates all of the responses of “Effective” for Network B. This map includes everyone in the network, which indicates that effective information transfer is occurring. Persons 10 and 72, both of whom hold high positions in the network, are central on this map, having 17 and 16 incoming arrows respectively, which would indicate that they are effective information sharers. They are not the most highly connected people on the map, however. Persons 54 and 60 both have 26 incoming effective ratings, indicating that they are the most effective at providing information for the network of all individuals in Network B. In total there are 728 connections at this effectiveness level, representing over 54% of all existing connections for the network, but still only slightly over 10% of the total possible connections. Since this map represents the most positive response to the survey question, having over half of the total connections for the network occur at this effectiveness level indicates that information is being passed between individuals. Combining the “somewhat effective” and “effective” responses results in over 88% of the connections in the network. An interesting observation is that all of the Project Development function members are on the periphery of the map, possibly meaning that these people in particular should be more connected to others in the network. They are generally only involved in the network when a project is taking place in their geographic area, so their membership within the network is intermittent. Thus their peripheral placement may not be cause for consternation.

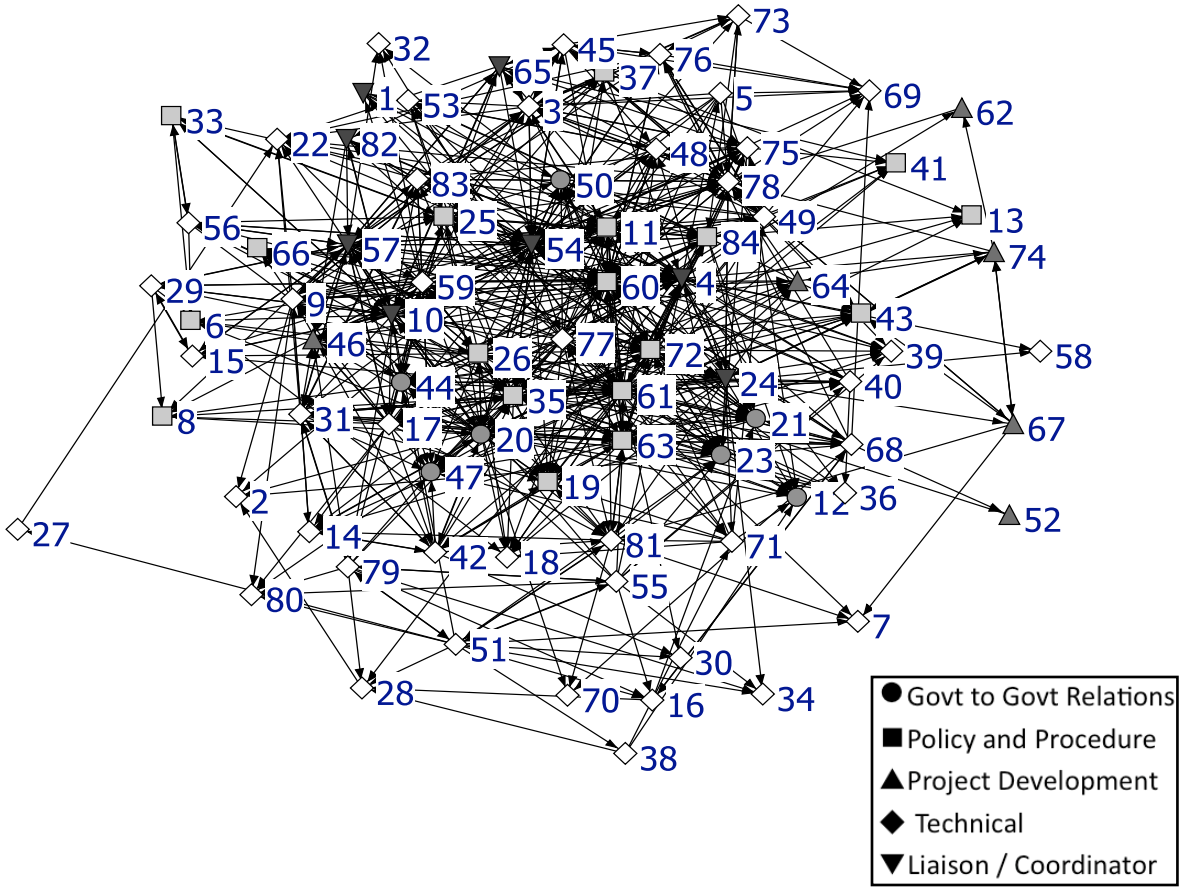



Figure 25. Network map showing responses of "Effective".

Figure 26 displays all of the connections between every member of Network B. Every member of the network is connected to at least 3 other individuals, indicating that no one is left entirely unconnected. The fact that the lines are so dense in the middle of the map indicates that a large number of connections exist between the members of the network who are most central. The most connected individuals in the network are persons 10, 11, 35, 54, 60 and 61, but they are not all the most central people. This indicates that though they represent the people with the highest number of connections, they are not the most sought after people, possibly because of being overly connected. Figure 27 shows the same map with the 6 most connected people,

approximately 7% of the network members, removed. These 6 people correspond to about 18% of all existing connections in the network. While there are definitely fewer connections across the center of the map, there does not appear to be any large holes in the network. This lack of holes is a good indication that the network is healthy, and that information has routes to people other than through the most connected individuals.

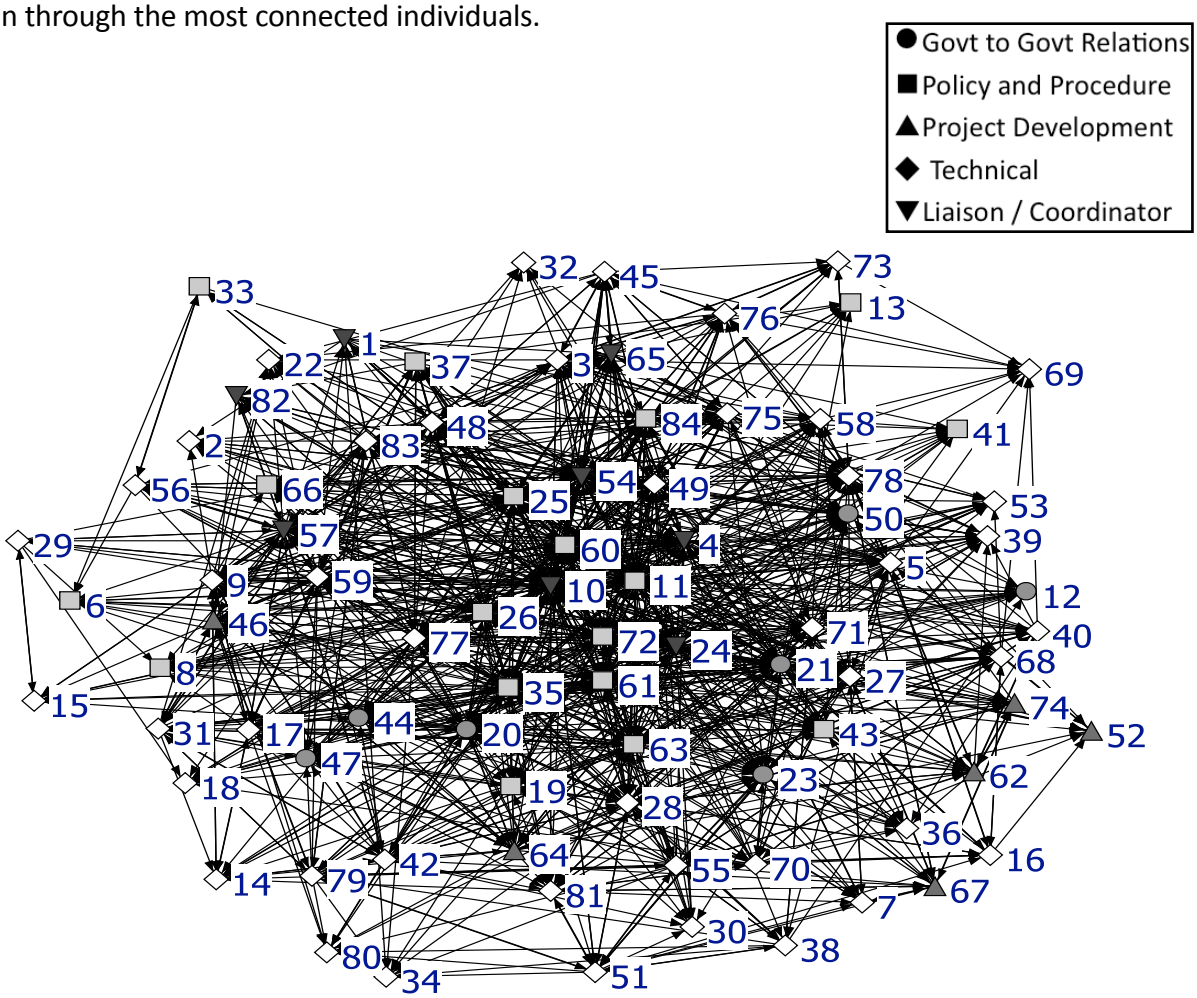



Figure 26. Network map showing all connections for Network B.

An additional positive note for Network B is that no one individual is connected only to the most connected people. In other words, when the most connected individuals are removed from the network, no one is left without any means of getting information. One negative observation

for the network, though, is that all of the individuals in the Technical function are periphery to the network. It may not actually be a problem, but it is something that would need to be brought to the attention of the network executives, nonetheless.

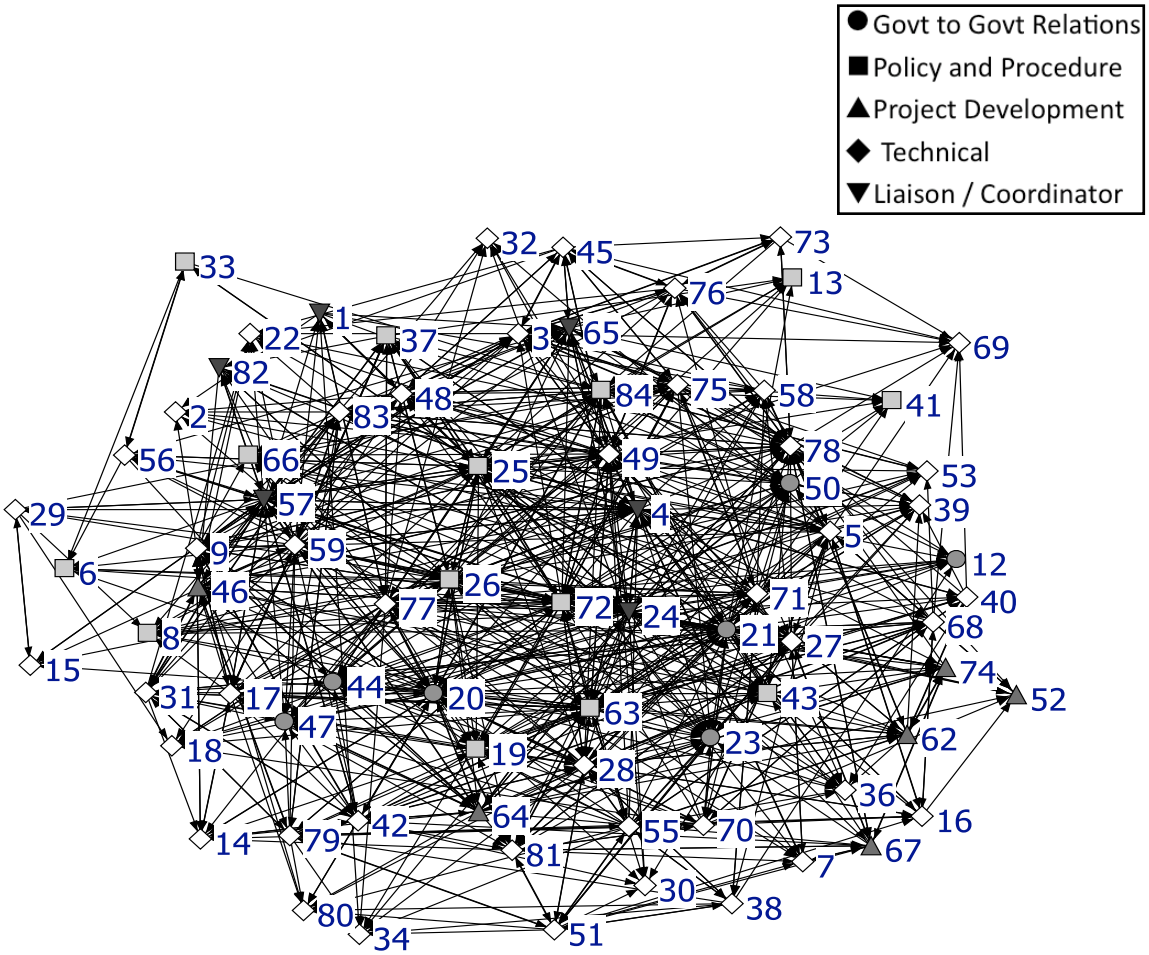



Figure 27. Network map showing the hole left by removing the 6 most connected people in Network B.

The map for Network B in Figure 28 displays all of the connections that do not exist between people. The lines on Figure 28 represent answers of “I do not know this person” to the survey question asking about the effectiveness of information flow. Not surprisingly, the majority of the central people on this map are members of the Technical function. While it cannot be expected that every person within a network know every other person in the network, the density

of the lines is worth consideration and examination by executives. Figures 29 through 32 show which individuals in each of the different functions do not know the others or have not worked with the others on network related projects. There is no map created for the Government-to-Government Relations function because every member of that function knew every other member of the function.

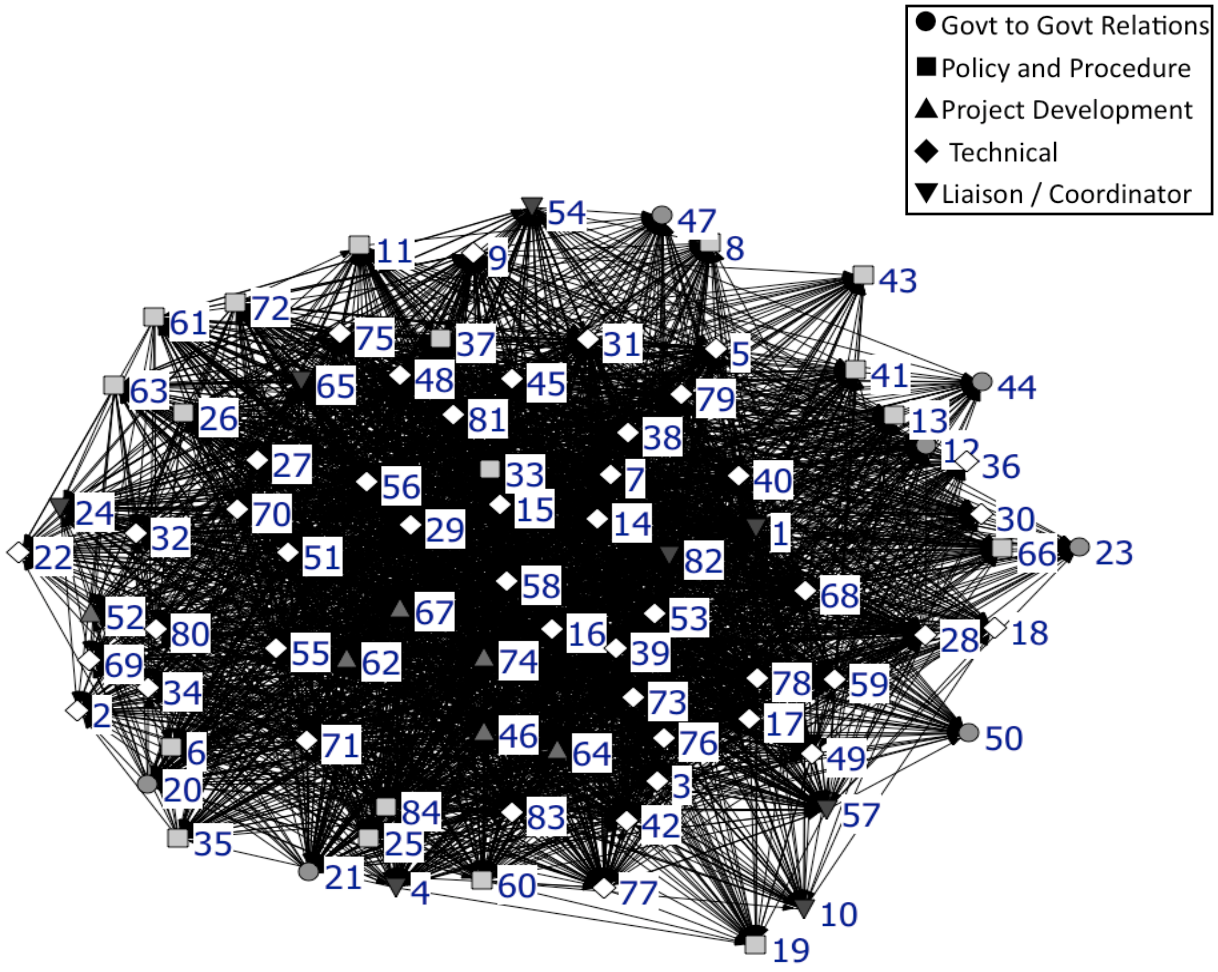



Figure 28. Network map showing which individuals do *not* know others.

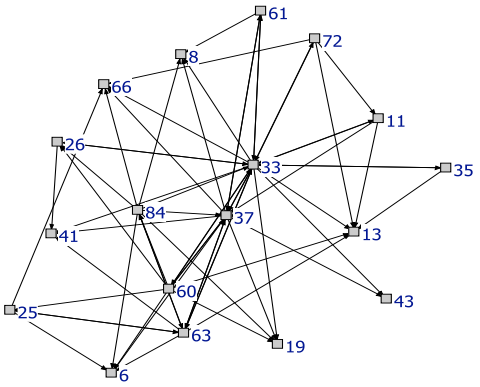



Figure 29. Policy and Procedure function.

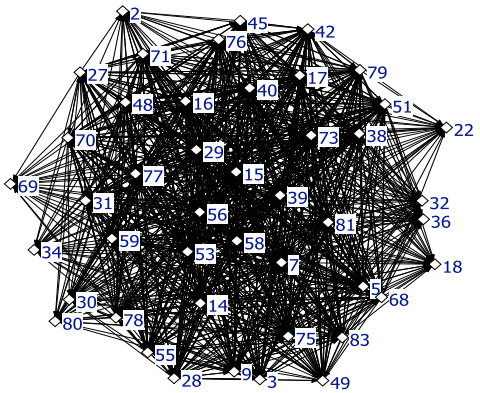



Figure 31. Technical function.

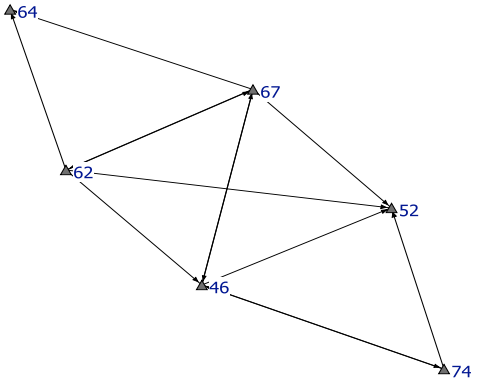



Figure 30. Project Development function.

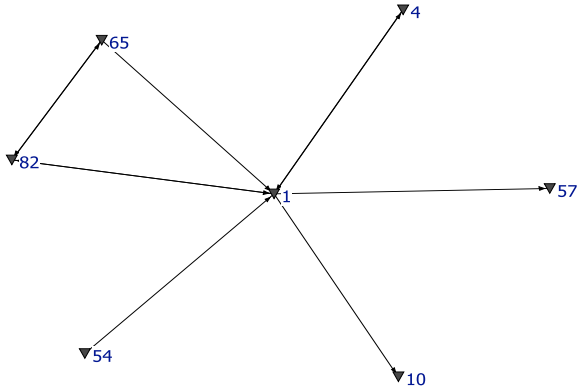



Figure 32. Liaison/Coordinator function.

The function with the fewest connections is the Technical function. This might be due to the fact that the technical people are mostly self-reliant, and do not need to communicate with others in their function, but some investigation into why there are so few connections would still be beneficial. Whether or not these individuals need to seek out information from other people in their specific function, it is important for them to be aware of who other technical people are, in case the occasion ever did arise that they needed information. One especially interesting

observation is that person 1, in the Liaison/Coordinator function, is completely unknown by half of his network. Figure 33 illustrates the lack of connection between each of the functions in Network B. Again, the largest number of connections is between the Technical function and each of the other functions (almost 60% of all connections) and the number of lines on the map represent only those individuals who responded to the survey.

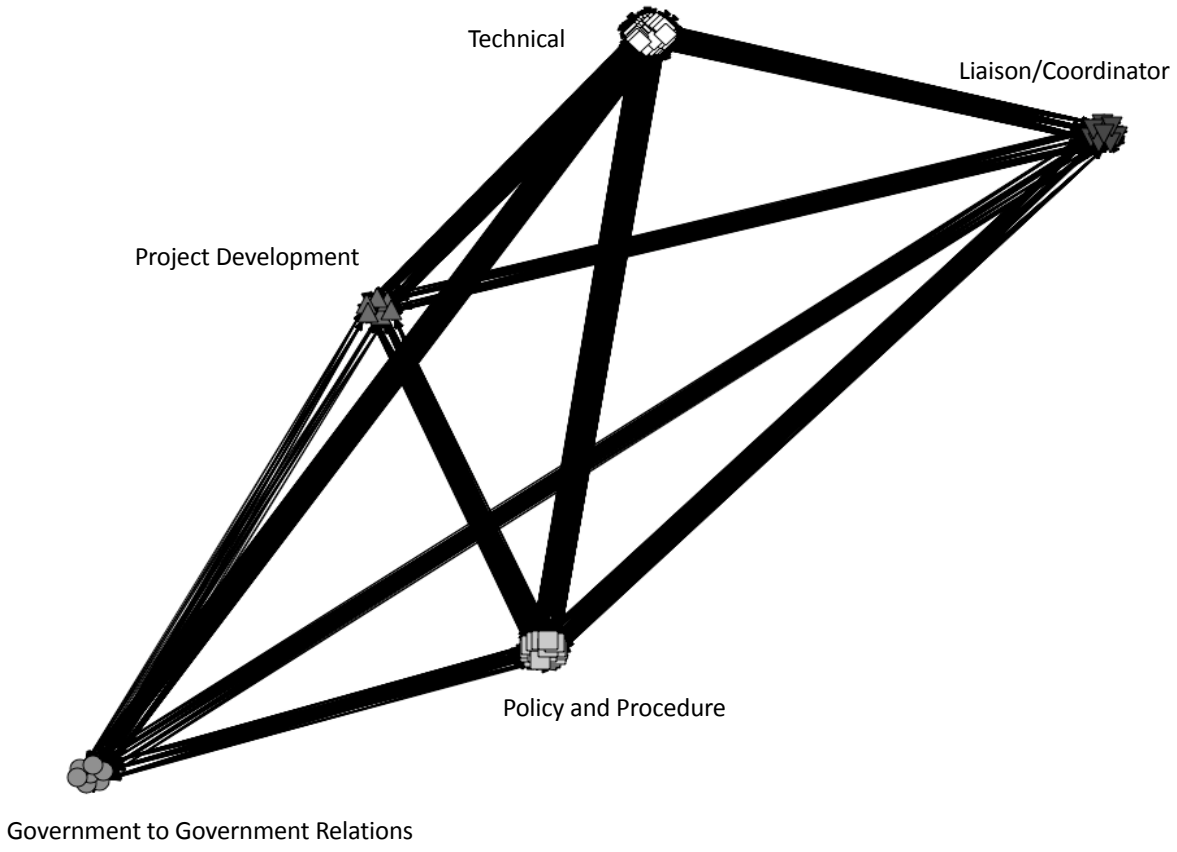



Figure 33. Network map showing lack of connection between functions in Network B.

As with Network A, the individual numerical results for every person in Network B have been tabulated and can be found in Appendix C. One interesting effective/ineffective rating anomaly is that person 5 has 2 effective Indegree ratings and 9 ineffective Indegree ratings, but has 29 effective Outdegree ratings and 0 ineffective Outdegree ratings. In other words, person 5

tends to find others effective at providing information, but is generally found to be ineffective himself at providing information to others. In general, the people in Network B tend to have mutual effective/ineffective opinions of each other's ability to provide information.

To summarize the results from the case study, further information from Person 40 in Network A and Person 10 in Network B could help the networks identify why others are ineffective at providing information. For both networks, the majority of the information sharing has been labeled as either "somewhat effective" or "effective". In Network A, the top 5% most connected people represent 20% of the network connections, and their removal could prove to be very detrimental to the network, so steps should be taken to ensure they stay in the network, and that information can be transferred between network individuals apart from them. In both networks the members of the Technical function are poorly connected to both others in their function and other members of the networks in general. It should be determined if this lack of connection and centrality is actually a problem, or if it is acceptable because of the duties the members of this function perform. According to the numbers, both networks have far fewer than the possible number of connections that could exist in the two networks, however both networks had non-respondent members, and new connections are made as employees tenure increases, so the number of missing connections is not a completely reliable indication of the health of either of the networks. A better measure of the health of the network would be to determine the level of productivity of the information being shared.

## CONCLUSION

Organizational Network Analysis is a tool that has been adapted to many business spheres including Finances, Communication, IT, and Government, but it has only had limited exposure in the engineering world through the Virginia Department of Transportation. Rob Cross, one of the individuals at the forefront of ONA research, has worked with over 120 companies to conduct ONA, none of which were engineering companies. However, through the work done in this study, it is evident that the methods of ONA are applicable to engineering fields. Engineers are not exempt from the necessity of information sharing, and efficient information sharing is key for the efficient use of company time and money.

A key finding from this research is the fact that even though individuals work together and should, in theory, be sharing information with one another, they may not be, as shown by the high number of missing connections (only 26% of the possible connections exist for Network A, and only 19% for Network B). Additionally, executives and management may think that information flows along certain paths or between certain individuals, when it does not. In speaking to the Transportation Agency executives, some surprise was expressed when they found that certain individuals were connected closely to other individuals. Organization Network Analysis is valuable for discovering where the holes in information flow are, and allowing the executives, management, and individuals themselves to work toward more beneficial information flow, based on an accurate picture of where information transfer is really occurring. Knowing that Network A is susceptible to losing 20% of their connections with the removal of only 5% of their employees may prove to be very beneficial to the network.

In order to draw appropriate conclusions from the data, those conducting the analysis must know the interpersonal frictions which are present between the individuals being mapped. Some of the information transfer dysfunction may be due to inadequate knowledge of the other individuals within the network, but some of it is also due to personality conflicts or personal opinions of the other individual. Without an adequate knowledge of those invisible barriers to information sharing, erroneous conclusions might be drawn, and the proposed actions to remedy the breakdown may not be appropriate. Some of the missing connections within the network, which were not due to the lack of response, were "not surprising" to the Agency executives when the data was presented to them.

The networks of individuals should be viewed as a living organism; changing one small part of the network will have an effect on the rest of the network. Changing one individual's duties or position within the network will cause the rest of the network to shift and compensate for the change. This can be either beneficial or detrimental to the network. The tools in ONA can be extremely helpful in depicting how the network would be effected if one member were to be relocated to a different position or set of duties. Shortly after conducting the ONA for the Transportation Agency, one of the more senior members of the Agency was removed from the networks, and so some of the problems in information flow were abated.

Future research, which would bolster the work done in this project, could include personal interviews with members of the transportation agency. These interviews could be useful in determining the individuals motivation in answering the questions, and revealing their rationale for the ratings they gave others, from which information necessary to implement useful changes in the network could be garnered. A second survey after the interventions and communities of

practice have been implemented within the agency would help to determine where changes actually occurred, and which plans for improvement actually produced their desired results.

Additional applications of research with ONA could include its application to an engineering design firm setting. The formal engineering firms would greatly benefit in the aspects of collaboration and time saved, as well as aiding in increased productivity and profitability. Higher education is another place that ONA could be expanded to. Knowing if and how students interact with one another could aid faculty in fostering a more effective learning environment, and could aid in student retention by creating an environment where student's self-efficacy could be bolstered.

The results obtained for the case study presented in this paper are specific to the group of people studied herein. ONA results vary depending on the group of people being analyzed, however, by gaining knowledge of information sharing patterns, executives, faculty, managers, and employers will be better equipped to make decisions about their employees. To date, there is very limited research done on the application of Organization Network Analysis in an engineering setting. The research in this paper shows that despite outside appearances, some people are not as well connected as they might seem, others are too connected, and within everyone there is potential for profitable information sharing.

# APPENDIX A

## COMPLETE LIST OF SURVEY QUESTIONS

| Survey Section | Questions |
|---|---|
| **Personal Information** | What is your function within the network? |
| | How long have you worked in your functional group? |
| | How long have you worked at the organization? |
| **Cultural Values** | Please assess the extent to which each characteristic below is and should be valued currently within your network |
| | Participation, open discussion |
| | Empowerment of employees to act |
| | Assessing employee concerns and ideas |
| | Human relations, teamwork, cohesion |
| | Flexibility, decentralization |
| | Expansion, growth, and development |
| | Innovation and change |
| | Creative problem solving processes |
| | Control, centralization |
| | Formality, structure and routines |
| | Stability, continuity, order |
| | Predictable performance outcomes |
| | Task focus, accomplishment, goal achievement |
| | Direction, objective setting, goal clarity |
| | Efficiency, productivity, profitability |
| | Outcome excellence, quality |
| **Personal Network** | Please indicate up to 15 people you turn to for information to get your work done in your network. |
| | To what degree do these people either currently collaborate on projects or would be likely to collaborate when the opportunity arose? |
| | Please indicate at least one of the primary benefits that you currently receive from each person |
| | Please indicate up to 3 skills or kinds of expertise that are important for you to be effective in your work. |
| | Please rate your ability for the skills or expertise |
| | To what extent do you learn by seeking each person below out for information or advice regarding your skills or expertise? |
| **Energy Networks** | I strike and effective balance between tapping people in my network to get work done and connecting with these people on a personal level |
| | I maintain an appropriate balance between what I ask for and what I contribute to those in my network. |
| | I consistently follow through on the commitments I make to people in my network |
| | I am committed (and show this commitment) to principles or goals that are larger than my own self interest |
| | In meetings and one-on-one conversations I effectively engage others in realistic possibilities that capture their imaginations and hearts |
| | I fully focus my attention in meetings and one-on-one conversations and show my interest in others and their ideas. |
| | I create room for others to be a meaningful part of conversations or make sure they see how their efforts will contribute to an evolving plan in the future. |
| | When I must disagree with someone's plan or a course of action I do so in a way that focuses attention on the issue at hand and not the individual contributing the idea. |
| | I maintain an effective balance between pushing toward a goal and welcoming new ideas that improve on a project or process for getting to a goal. |

**Bounded Network**

Please indicate the extent to which the other people in the network are effective in providing you with information that helps you to learn, solve problems, and do your work.

The quality of my work within this network is better as a result of interactions with this individual

I save time on my projects within this network as a result of interaction with this individual

I have made decisions on my projects within this network that have reduced project costs as a result of interaction with this individual.

I receive clear direction of work tasks I need to accomplish within this network as a result of interaction with this individual

## APPENDIX B

## TABLE OF RESULTS FOR NETWORK A

| ID | Connectedness | Indegree | Effective Indegree | Ineffective Indegree | Outdegree | Effective Outdegree | Ineffective Outdegree | Overall Effectiveness | Function |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 20 | 20 | 19 | 1 | 0 | 0 | 0 | 3.5 | Leadership Team |
| 2 | 69 | 27 | 18 | 9 | 42 | 37 | 5 | 3.5 | Core Team |
| 3 | 5 | 5 | 5 | 0 | 0 | 0 | 0 | 3.5 | Technical |
| 4 | 44 | 12 | 7 | 5 | 32 | 27 | 5 | 3.0 | Leadership Team |
| 5 | 63 | 20 | 10 | 10 | 43 | 36 | 6 | 3.0 | Advisory |
| 6 | 46 | 22 | 14 | 8 | 24 | 21 | 3 | 3.0 | Advisory |
| 7 | 69 | 21 | 21 | 0 | 48 | 37 | 11 | 4.0 | Advisory |
| 8 | 20 | 20 | 16 | 4 | 0 | 0 | 0 | 3.5 | Advisory |
| 9 | 20 | 6 | 2 | 4 | 14 | 13 | 1 | 2.5 | Technical |
| 10 | 61 | 26 | 25 | 1 | 35 | 30 | 4 | 3.5 | Core Team |
| 11 | 31 | 14 | 11 | 3 | 17 | 12 | 5 | 3.0 | Technical |
| 12 | 16 | 16 | 14 | 2 | 0 | 0 | 0 | 3.5 | Advisory |
| 13 | 12 | 12 | 10 | 2 | 0 | 0 | 0 | 3.0 | Advisory |
| 14 | 44 | 21 | 17 | 4 | 23 | 22 | 1 | 3.5 | Advisory |
| 15 | 17 | 17 | 16 | 1 | 0 | 0 | 0 | 3.5 | Leadership Team |
| 16 | 29 | 7 | 6 | 1 | 22 | 20 | 1 | 3.0 | Leadership Team |
| 17 | 11 | 11 | 9 | 2 | 0 | 0 | 0 | 3.0 | Leadership Team |
| 18 | 33 | 8 | 7 | 1 | 25 | 14 | 11 | 3.5 | Leadership Team |
| 19 | 13 | 13 | 9 | 4 | 0 | 0 | 0 | 3.0 | Leadership Team |
| 20 | 12 | 12 | 6 | 6 | 0 | 0 | 0 | 3.0 | Core Team |
| 21 | 25 | 13 | 13 | 0 | 12 | 8 | 3 | 3.0 | Technical |
| 22 | 44 | 14 | 10 | 4 | 30 | 20 | 10 | 3.0 | Technical |
| 23 | 15 | 15 | 9 | 6 | 0 | 0 | 0 | 3.0 | Technical |
| 24 | 7 | 7 | 7 | 0 | 0 | 0 | 0 | 3.5 | Technical |
| 25 | 46 | 23 | 21 | 2 | 23 | 19 | 4 | 3.5 | Core Team |
| 26 | 14 | 14 | 12 | 2 | 0 | 0 | 0 | 3.0 | Advisory |
| 27 | 26 | 6 | 6 | 0 | 20 | 18 | 2 | 3.5 | Technical |
| 28 | 56 | 15 | 14 | 1 | 41 | 31 | 10 | 3.5 | Leadership Team |
| 29 | 60 | 17 | 9 | 8 | 43 | 35 | 8 | 2.5 | Technical |
| 30 | 22 | 12 | 11 | 1 | 10 | 7 | 3 | 3.5 | Technical |

| ID | Connectedness | Indegree | Effective Indegree | Ineffective Indegree | Outdegree | Effective Outdegree | Ineffective Outdegree | Overall Effectiveness | Function |
|---|---|---|---|---|---|---|---|---|---|
| 31 | 30 | 8 | 8 | 0 | 22 | 20 | 2 | 3.0 | Technical |
| 32 | 35 | 15 | 12 | 3 | 20 | 12 | 8 | 3.5 | Core Team |
| 33 | 18 | 18 | 13 | 5 | 0 | 0 | 0 | 3.0 | Advisory |
| 34 | 12 | 12 | 10 | 2 | 0 | 0 | 0 | 3.0 | Leadership Team |
| 35 | 57 | 21 | 19 | 2 | 36 | 35 | 1 | 3.5 | Technical |
| 36 | 22 | 10 | 10 | 0 | 12 | 10 | 2 | 3.5 | Core Team |
| 37 | 41 | 14 | 14 | 0 | 27 | 26 | 1 | 3.5 | Technical |
| 38 | 9 | 9 | 7 | 2 | 0 | 0 | 0 | 3.0 | Leadership Team |
| 39 | 66 | 27 | 24 | 3 | 39 | 36 | 3 | 3.5 | Advisory |
| 40 | 64 | 21 | 17 | 4 | 43 | 18 | 25 | 3.5 | Advisory |
| 41 | 13 | 13 | 9 | 4 | 0 | 0 | 0 | 3.0 | Leadership Team |
| 42 | 19 | 18 | 18 | 0 | 1 | 1 | 0 | 3.5 | Technical |
| 43 | 14 | 14 | 12 | 2 | 0 | 0 | 0 | 3.0 | Technical |
| 44 | 48 | 23 | 21 | 2 | 25 | 22 | 3 | 3.5 | Core Team |
| 45 | 34 | 27 | 27 | 0 | 7 | 6 | 1 | 3.5 | Advisory |
| 46 | 40 | 22 | 21 | 1 | 18 | 16 | 2 | 3.5 | Advisory |
| 47 | 34 | 23 | 22 | 1 | 11 | 11 | 0 | 3.5 | Leadership Team |
| 48 | 19 | 19 | 17 | 2 | 0 | 0 | 0 | 3.0 | Technical |
| 49 | 16 | 16 | 6 | 10 | 0 | 0 | 0 | 2.5 | Technical |
| 50 | 11 | 9 | 8 | 1 | 2 | 2 | 0 | 3.5 | Technical |
| 51 | 20 | 3 | 3 | 0 | 17 | 15 | 1 | 3.5 | Technical |
| 52 | 26 | 10 | 9 | 1 | 16 | 15 | 1 | 3.0 | Technical |
| 53 | 18 | 18 | 18 | 0 | 0 | 0 | 0 | 3.5 | Leadership Team |
| 54 | 26 | 8 | 8 | 0 | 18 | 18 | 0 | 3.5 | Technical |
| 55 | 21 | 21 | 15 | 6 | 0 | 0 | 0 | 3.0 | Core Team |
| 56 | 11 | 11 | 6 | 5 | 0 | 0 | 0 | 3.0 | Advisory |
| 57 | 53 | 20 | 17 | 3 | 33 | 33 | 0 | 3.5 | Core Team |
| 58 | 44 | 15 | 12 | 3 | 29 | 23 | 6 | 3.0 | Technical |
| 59 | 51 | 23 | 23 | 0 | 28 | 26 | 2 | 3.5 | Advisory |
| 60 | 27 | 8 | 8 | 0 | 19 | 16 | 3 | 3.0 | Technical |

## APPENDIX C

## TABLE OF RESULTS FOR NETWORK B

| ID | Connectedness | Indegree | Effective Indegree | Ineffective Indegree | Outdegree | Effective Outdegree | Ineffective Outdegree | Overall Effectiveness | Function |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 18 | 7 | 7 | 0 | 11 | 11 | 0 | 3.5 | Liaison/ Coordinator |
| 2 | 13 | 13 | 13 | 0 | 0 | 0 | 0 | 3.5 | Technical |
| 3 | 37 | 21 | 20 | 1 | 16 | 15 | 1 | 4.0 | Technical |
| 4 | 61 | 22 | 21 | 1 | 39 | 37 | 1 | 4.0 | Liaison/ Coordinator |
| 5 | 40 | 11 | 2 | 9 | 29 | 29 | 0 | 2.5 | Technical |
| 6 | 12 | 12 | 10 | 2 | 0 | 0 | 0 | 3.5 | Policy and Procedures |
| 7 | 13 | 10 | 7 | 3 | 3 | 2 | 1 | 3.5 | Technical |
| 8 | 17 | 17 | 14 | 3 | 0 | 0 | 0 | 3.5 | Policy and Procedures |
| 9 | 40 | 20 | 19 | 1 | 20 | 17 | 3 | 4.0 | Technical |
| 10 | 102 | 40 | 25 | 15 | 62 | 39 | 22 | 3.0 | Liaison/ Coordinator |
| 11 | 84 | 32 | 31 | 1 | 52 | 38 | 13 | 3.5 | Policy and Procedures |
| 12 | 15 | 15 | 13 | 2 | 0 | 0 | 0 | 3.5 | Gov to Gov Relations |
| 13 | 8 | 8 | 8 | 0 | 0 | 0 | 0 | 3.5 | Policy and Procedures |
| 14 | 16 | 12 | 12 | 0 | 4 | 4 | 0 | 3.5 | Technical |
| 15 | 11 | 8 | 7 | 1 | 3 | 3 | 0 | 3.5 | Technical |
| 16 | 15 | 8 | 8 | 0 | 7 | 6 | 1 | 3.0 | Technical |
| 17 | 32 | 15 | 14 | 1 | 17 | 17 | 0 | 4.0 | Technical |
| 18 | 13 | 13 | 12 | 1 | 0 | 0 | 0 | 3.5 | Technical |
| 19 | 26 | 26 | 24 | 2 | 0 | 0 | 0 | 3.5 | Policy and Procedures |
| 20 | 65 | 22 | 20 | 2 | 43 | 39 | 4 | 3.5 | Gov to Gov Relations |
| 21 | 56 | 21 | 18 | 3 | 35 | 22 | 12 | 3.5 | Gov to Gov Relations |
| 22 | 15 | 15 | 15 | 0 | 0 | 0 | 0 | 4.0 | Technical |
| 23 | 26 | 26 | 25 | 1 | 0 | 0 | 0 | 3.5 | Gov to Gov Relations |
| 24 | 65 | 16 | 15 | 1 | 49 | 43 | 5 | 3.5 | Liaison/ Coordinator |
| 25 | 55 | 24 | 22 | 2 | 31 | 24 | 6 | 3.5 | Policy and Procedures |

| ID | Connectedness | Indegree | Effective Indegree | Ineffective Indegree | Outdegree | Effective Outdegree | Ineffective Outdegree | Overall Effectiveness | Function |
|---|---|---|---|---|---|---|---|---|---|
| 26 | 58 | 17 | 12 | 5 | 41 | 35 | 6 | 3.0 | Policy and Procedures |
| 27 | 38 | 16 | 11 | 5 | 22 | 15 | 7 | 3.0 | Technical |
| 28 | 48 | 21 | 10 | 11 | 27 | 22 | 5 | 3.0 | Technical |
| 29 | 12 | 5 | 5 | 0 | 7 | 7 | 0 | 4.0 | Technical |
| 30 | 11 | 11 | 7 | 4 | 0 | 0 | 0 | 3.5 | Technical |
| 31 | 28 | 11 | 11 | 0 | 17 | 17 | 0 | 4.0 | Technical |
| 32 | 7 | 7 | 7 | 0 | 0 | 0 | 0 | 3.0 | Technical |
| 33 | 8 | 3 | 3 | 0 | 5 | 5 | 0 | 3.5 | Policy and Procedures |
| 34 | 9 | 9 | 8 | 1 | 0 | 0 | 0 | 3.0 | Technical |
| 35 | 87 | 30 | 30 | 0 | 57 | 45 | 12 | 3.5 | Policy and Procedures |
| 36 | 14 | 14 | 13 | 1 | 0 | 0 | 0 | 3.5 | Technical |
| 37 | 26 | 10 | 8 | 2 | 16 | 14 | 2 | 3.5 | Policy and Procedures |
| 38 | 15 | 7 | 7 | 0 | 8 | 8 | 0 | 3.0 | Technical |
| 39 | 22 | 20 | 18 | 2 | 2 | 0 | 2 | 3.5 | Technical |
| 40 | 21 | 6 | 6 | 0 | 15 | 14 | 1 | 4.0 | Technical |
| 41 | 12 | 12 | 12 | 0 | 0 | 0 | 0 | 3.5 | Policy and Procedures |
| 42 | 31 | 12 | 11 | 1 | 19 | 17 | 2 | 4.0 | Technical |
| 43 | 24 | 24 | 18 | 6 | 0 | 0 | 0 | 3.0 | Policy and Procedures |
| 44 | 26 | 26 | 25 | 1 | 0 | 0 | 0 | 3.5 | Gov to Gov Relations |
| 45 | 25 | 11 | 11 | 0 | 14 | 14 | 0 | 4.0 | Technical |
| 46 | 32 | 17 | 17 | 0 | 15 | 15 | 0 | 4.0 | Project Developme nt |
| 47 | 23 | 23 | 23 | 0 | 0 | 0 | 0 | 3.5 | Gov to Gov Relations |
| 48 | 34 | 19 | 17 | 2 | 15 | 13 | 2 | 3.5 | Technical |
| 49 | 52 | 24 | 23 | 1 | 28 | 28 | 0 | 4.0 | Technical |
| 50 | 22 | 22 | 22 | 0 | 0 | 0 | 0 | 3.5 | Gov to Gov Relations |
| 51 | 22 | 9 | 6 | 3 | 13 | 13 | 0 | 3.0 | Technical |
| 52 | 11 | 11 | 9 | 2 | 0 | 5 | 0 | 3.0 | Technical |
| 53 | 17 | 11 | 6 | 5 | 6 | 0 | 0 | 3.0 | Project Developme nt |
| 54 | 75 | 38 | 36 | 2 | 37 | 36 | 1 | 4.0 | Liaison/ Coordinator |

| ID | Connectedness | Indegree | Effective Indegree | Ineffective Indegree | Outdegree | Effective Outdegree | Ineffective Outdegree | Overall Effectiveness | Function |
|---|---|---|---|---|---|---|---|---|---|
| 55 | 31 | 7 | 6 | 1 | 24 | 21 | 3 | 3.0 | Technical |
| 56 | 20 | 11 | 7 | 4 | 9 | 9 | 0 | 3.5 | Technical |
| 57 | 57 | 25 | 25 | 0 | 32 | 32 | 0 | 4.0 | Liaison/ Coordinator |
| 58 | 21 | 15 | 11 | 4 | 6 | 3 | 3 | 3.5 | Technical |
| 59 | 45 | 13 | 13 | 0 | 32 | 31 | 1 | 4.0 | Technical |
| 60 | 67 | 37 | 35 | 2 | 30 | 29 | 1 | 4.0 | Policy and Procedures |
| 61 | 70 | 24 | 24 | 0 | 46 | 44 | 1 | 3.5 | Policy and Procedures |
| 62 | 22 | 11 | 9 | 2 | 11 | 10 | 1 | 3.0 | Project Developme nt |
| 63 | 64 | 26 | 24 | 2 | 38 | 34 | 4 | 3.5 | Policy and Procedures |
| 64 | 36 | 13 | 13 | 0 | 23 | 22 | 1 | 4.0 | Project Developme nt |
| 65 | 36 | 17 | 15 | 2 | 19 | 19 | 0 | 3.5 | Liaison/ Coordinator |
| 66 | 19 | 19 | 16 | 3 | 0 | 0 | 0 | 3.5 | Policy and Procedures |
| 67 | 18 | 9 | 7 | 2 | 9 | 8 | 1 | 3.0 | Project Developme nt |
| 68 | 29 | 11 | 10 | 1 | 18 | 16 | 2 | 3.5 | Technical |
| 69 | 10 | 10 | 10 | 0 | 0 | 0 | 0 | 4.0 | Technical |
| 70 | 25 | 6 | 6 | 0 | 19 | 13 | 6 | 4.0 | Technical |
| 71 | 37 | 12 | 9 | 3 | 25 | 21 | 4 | 3.0 | Technical |
| 72 | 65 | 27 | 23 | 4 | 38 | 30 | 7 | 3.5 | Policy and Procedures |
| 73 | 12 | 6 | 6 | 0 | 6 | 6 | 0 | 4.0 | Technical |
| 74 | 20 | 13 | 7 | 6 | 7 | 6 | 0 | 3.0 | Project Developme nt |
| 75 | 41 | 14 | 13 | 1 | 27 | 24 | 3 | 4.0 | Technical |
| 76 | 24 | 12 | 12 | 0 | 12 | 12 | 0 | 4.0 | Technical |
| 77 | 54 | 15 | 14 | 1 | 39 | 34 | 4 | 3.5 | Technical |
| 78 | 47 | 26 | 25 | 1 | 21 | 18 | 3 | 4.0 | Technical |
| 79 | 25 | 9 | 8 | 1 | 16 | 15 | 1 | 2.5 | Technical |
| 80 | 11 | 11 | 9 | 2 | 0 | 0 | 0 | 3.5 | Technical |
| 81 | 28 | 16 | 14 | 2 | 12 | 12 | 0 | 3.5 | Technical |

| ID | Connectedness | Indegree | Effective Indegree | Ineffective Indegree | Outdegree | Effective Outdegree | Ineffective Outdegree | Overall Effectiveness | Function |
|---|---|---|---|---|---|---|---|---|---|
| 82 | 18 | 11 | 9 | 2 | 7 | 7 | 0 | 3.5 | Liaison/ Coordinator |
| 83 | 36 | 16 | 15 | 1 | 20 | 20 | 0 | 3.5 | Technical |
| 84 | 39 | 18 | 16 | 2 | 21 | 20 | 0 | 3.5 | Policy and Procedures |

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