

# Mapping the R&D Knowledge Network

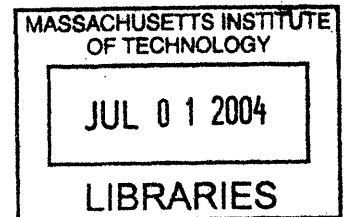
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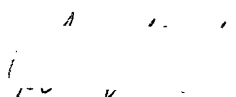
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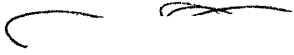
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# Mapping the R&D Knowledge Network

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Management of Technology

## Abstract

Knowledge networks have received a significant amount of attention in the past few decades as people look beyond corporate governance and resource-based approaches to uncover sources of competitive advantage. While this area of research is useful for organizations in general, it is especially pertinent to R&D organizations where knowledge flow is the critical enabler for breakthrough innovation.

The proposed thesis will examine the drivers of knowledge flow and how it impacts the performance of Functional Centers and its subunits. The core of this research focuses on a medium-sized R&D firm in Singapore. This work is divided into the following steps:

- Develop a structured interview for gathering ideas from senior managers
- Create and execute a survey to assess the knowledge network
- Process and analyze the results

This thesis will investigate the following questions:

- What are the various approaches people use to form their working networks and which approaches generate the most contacts and which methods generate the most *useful* contacts.
- Does strong intra-center/subunit connectivity negatively impact inter-center/subunit connectivity with people from other groups?
- How does the presence of people with strong networks within the centers affect the performance of the group? Do the managers of these people recognize their value/contribution and how does it affect the usefulness of these connectors?
- How does the duration of a bond between two people affect the quality of its social and work-related interactions?
- How does the willingness to build cross-level bonds (managers and junior engineers) impact the performance and efficacy of managers hence their workgroups?

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My 12 months at Sloan @MIT has been a pilgrimage to understanding that greatness of mind alone is insufficient. I have come to understand that greatness comes about only through the confluence of greatness of mind, character and purpose. During my time here I have had the privilege of working and interacting with many of such people who I will always hold up as my heroes; people whom I hope to emulate.

To the class of MOT 2004 who had contributed greatly to my learning and it has truly been my privilege to be part of the family; the last one before we are amalgamated with the Sloan Fellows program.

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# **Chapter 1 Introduction**

## **1.1 Overview of Social Network Analysis**

One of the goals of Social Network Analysis (SNA) is to investigate how organizations can achieve higher performance whether it is in terms of innovation or other measures by leveraging the knowledge networks of people. The discussion here will focus on the role of communications in organizations and its impact on performance. There have been a lot of studies on the topic of organizational learning and social network analysis over the past 30 years and this research attempts to build on what has been done before and aims to add to the wealth of knowledge that is currently available.

Traditional thinking on drivers of innovation and performance tends to focus on internal factors such as the capabilities and processes within companies for creating and commercializing technology. While these topics are important, it does not address the impact of its people on organizational performance. While the role of corporate governance, the resources of a company and other external factors may be important, much more needs to be done to maximize the most valuable asset any organization could have and that is its people.

This study gives an overview of the current areas of studies being conducted on SNA and looks at the communication patterns of a medium sized R&D firm in Singapore. By analyzing the communication patterns of engineers and scientists across its 15 Centers, it tries to form conclusions on the pattern of social behaviors and how it affects the flow of knowledge and its impact on performance.

## **1.2 The Role of Interaction**

In discussing the creation of knowledge, it is useful to view it using the model proposed by Nonaka. In his model knowledge is created from the Socialization Process which entails tacit to tacit communication. By virtue of the form in which the new knowledge is created, it

requires people to people interaction and cannot be transferred wholly via documentation. It is with this understanding in mind that this thesis topic of *Mapping the R&D Knowledge Network* comes about.

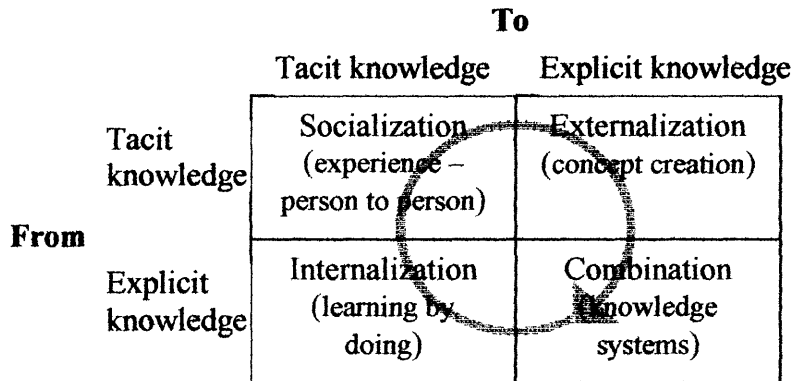


Figure 1 The model for creation of New Knowledge (Nonaka and Takeuchi)

The importance of communication in producing information can be supported by Morton’s (1971) acknowledgement that our present total knowledge of systems has become too complex for a single person to grasp it all. In order to create new knowledge, people need to specialize into ever narrower fields in order to push the forefronts of knowledge. However these knowledge needs to be synthesized with other specialized knowledge in order to create new technology, products and services. Such an inter-relatedness of purpose highlights the ever increasing need for communication among higher specialized individuals.

Interactions also play a role in retaining knowledge within an organization. Walsh and Ungson developed one of the few models specifically targeted to organizational memory. Their model parallels Draft and Huber’s (1987) learning frames in defining information processing and interpretive systems. They stated that “an organization is a network of intersubjectively shared meanings that are sustained through the development and use of a common language and everyday social interactions” (Walsh & Ungson, 1991). It is through this process of sharing (along with information collection mechanisms such as organizational reports and accounts) that the collective organizational memory exceeds that of the individual.

### **1.3 The role of Diversity in Social Network Analysis**

There is much research done to investigate the effects of structural and demographic diversity on knowledge sharing and ultimately its impact on performance. The research performed by Cummings (2003) suggests that external knowledge will be more strongly associated with performance when work groups are more structurally diverse. He listed four structural diversities and they are geographic location of group members, functional assignments of group members, managers whom group members reported to and finally the business units that members come from. This work draws on previously suggested notion that unique knowledge is more valuable than knowledge sources shared by everyone. While the conclusion of this study was that diversity is good, he acknowledged that there are costs as well. For example, geographical diversity may make intra-group communication more difficult due to the reduction of informal contact. This problem may be exacerbated in R&D organizations where a lot of new knowledge is by nature tacit and therefore requires a large amount of face-to-face communication among members. In addition, cross-functional groups may encounter difficulties in bridging their different “thought worlds” (Dougherty). Such conflicts can be expected when there is diversity in an organization as suggested by Pelled (1996). Despite all this, he believes that the benefit outweighs the cost, although he further acknowledged that additional evidence is needed on conflict, coordination, and cohesiveness. This work done fits nicely with what Pelled did when she identified and categorized the various types of demographic diversities and their impact.

In investigating the effects of demographics on performance, Pelled found data that indicated that group diversity was positive correlated to turnover. However the literature on the effect of diversity on task performance was ambivalent. There has been literature that showed a positive correlation between increase in diversity and performance, a negative correlation between increase in diversity vs increase in performance, as well as studies linking it to both. In view of this lack of a theory that could adequately explain both turnover and the mixture of cognitive task performance, she offered a model to provide a tool to correct this deficiency.

Pelled's work attempts to segment demographic diversity into a 2x2 matrix which separates those of high visibility vs those of low visibility and on the other dimension, those that are job-related and those that are not. In investigating the effects of diversity, she adopted the terminology used by Guetzkow and Gyr in defining task related conflicts as substantive conflicts and non-task related, emotion-based conflicts as affective conflicts. She used turnover and cognitive task performance as measures to qualify the effects. She further developed a systems dynamic model that attempts to explain how the effect of the types of diversity and group longevity affects turnover and cognitive task performance. This paper was interesting in that it attempts to segment the various types of diversity and provides a model in which to view its impact on both task performance and turnover. The model is comprehensive and compelling and Pelled was able to find other research that supported her model. In summary this paper showed that not all forms of conflicts are negative and not all forms of diversity are positive. The model is shown in the figure below. Note that the two variables are not symmetrical items. Her model states that job-related demographic diversity leads to more substantive conflicts, however all forms of highly visible demographic diversity whether job-related or not will lead to affective conflict. One problem with the model is that while she acknowledged that occasionally substantive conflicts could also lead to affective conflict, the model does not reflect this.

Both forms (structural and demographic) of diversity result in a condition termed *communication impedance or mismatch* (Allen 1969) between areas or groups. This usually occurs when there is a lack of a shared coding scheme or language which is expected in diversity unless there exists a strong communication system and the parties have previously undergone a strong socialization process. This socialization process is one of the parameters that Social Network Analysis (SNA) attempts to address.



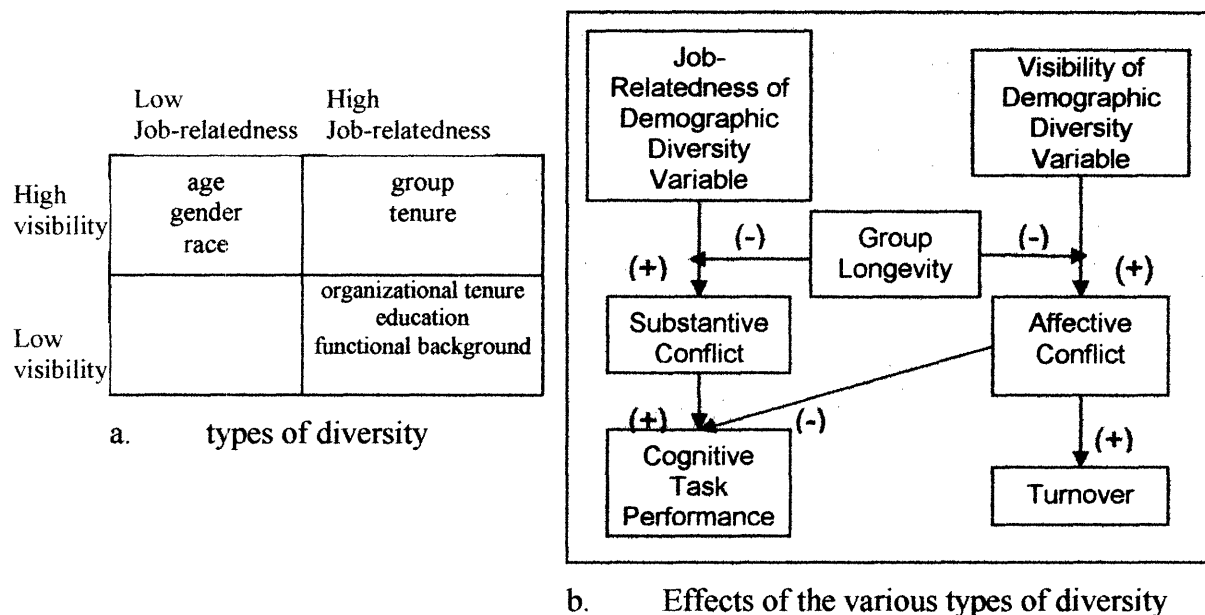


Figure 2 The models proposed by Pelled on demographic diversity

#### 1.4 Social Capital and Networks

In a paper by Cummings and Cross (2003), it was suggested that groups constrained by structural properties such as hierarchy, core-peripheral and leader structural holes will perform worse than groups with a more integrative structure. Results obtained from subsequent studies of 182 work groups in a global organization appear to support these hypotheses. Though there does not appear to be a typical integrative structure for high-performing groups, sufficient ties among members to facilitate information flow, without over-reliance on one member, does seem important. The results suggest an important link between structural properties of work group and performance. However further work by Gargiulo suggests that managers with networks rich in structural holes enjoy comparatively early promotions or higher bonuses, which are assumed to reflect their superior ability to add value to their organizations. The reasoning offered here is that by not being part of a cohesive and embedded network gives them a high level of social capital. This implies that network closure does not help, but rather hinders organizational coordination. This is a result of

obligations that result from highly cohesive networks that managers may have difficulties extricating themselves from. Given a limited amount of time and energy, an obligation to maintain relationships that are no longer advantageous may hinder the ability to cultivate new relationships necessary to maintain the value of the manager's social capital.

This problem is magnified when the manager's role or task changes necessitating a realignment of the composition of his network to the new task environment. There is often a need to balance between the legitimacy and support offered by being part of a cohesive network and retaining the flexibility to adapt one's network as required by the change in roles and needs. While this may seem to run counter to what Cummings and Cross indicate, it does not invalidate what has previously been suggested. Instead it provides an occasion when the benefits of having structural holes outweigh the costs of retarded information flow as well as the other benefits associated with having highly integrative structures.

While there has been many articles that describe networks and their effect on organizations, Krackhardt and Hanson (1993) analyzed networks by identifying three different forms of networks each of which has different characteristics. The first is the advice network which shows the prominent players in an organization on which others depend to solve problems and provide technical information. Second is the trust network which maps the people who share delicate political information and back one another in a crisis. Lastly there is the communication network which reveals the people who talk about work-related matters on a regular basis. These networks are often not mutually exclusive; neither did the paper indicate that they are correlated. Because these networks show the most influential players in the day-to-day operations of a company, the authors suggest that they are useful to examine when a company is considering routine changes. Trust networks often reveal the causes of non-routine problems such as poor performance by temporary teams. The authors suggest that companies should examine trust networks when implementing a major change or experiencing a crisis. The communication network can help identify gaps in information flow, the failure to generate new ideas and the inefficient use of resources. They should also be examined when productivity is low. There is no ideal network for any of these, what matters is the fit, whether networks are in sync with company goals.

A study by Cross and Prusak analyzed and identified four common role-players (refer to Appendix B for further explanation of these terms) whose performance is critical to the productivity of any organization. First, there are the central connectors, who link most people in an informal network with one another. Second there are the boundary spanners, who connect an informal network with other parts of the company or with similar networks in other organizations. Third there are the information brokers that keep the different subgroups in an informal network together. If they didn't communicate across the subgroups, the network as a whole would splinter into smaller, less effective segments. Such a lack of communication effectiveness may lead to inefficiencies caused by redoing what has previously been done, ie reinventing the wheel within an organization. Finally, there are peripheral specialists, who provide specialized expertise. Besides identifying groups of people, the authors also suggest that through Social Network Analysis (SNA), people can identify where they need to build more or better relationships, and senior executives can coach them appropriately. Four focuses were found helpful to help managers improve their connections. The first is the extent to which managers seek out people within or outside of their functional areas. Second is the degree to which hierarchy, tenure, and location matter to the managers' social relationships. Third is the length of time managers have known their connections. And fourth is the extent to which managers' personal networks are the result of interactions that are built into their schedules rather than ad-hoc encounters in the hallways. Social Networks cannot be aligned with organizational goals through random interventions and off-site activities such as company social events etc. Rather executives need to openly and systematically work with informal networks, this gives it the legitimacy that will encourage the groups to become more effective.

In order to leverage off the competitive advantage that Social Networks provides, it is important to understand some misconceptions. The time and resources available to any single person is limited hence there are only so many people he or she can maintain meaningful relations with. According to Cross, Nohria, & Parker (2003), there are several misconceptions associated with the use of SNA. The first is that more communication always results in better networks. Due to the limited resources that a person has, it is more important

to focus on quality rather than quantity. Therefore one should focus on who knows what; by working with networks that start from what people know, managers can intervene to sustain informal groups without adding the burden of more and potentially useless communications. The second myth is that everyone should be connected to everyone else. However Cross et al. points out that an indiscriminate increase in connectedness can be a drag on productivity, as people get bogged down maintaining all their relationships. To correct for this, managers should target areas where cross-boundary collaboration is lacking but important. These gaps can be analyzed using SNA. The third myth is that there is nothing that can be done to aid informal networks, this is not true and Cross et al. in his paper described ways in which these impediments can be overcome.

### **1.5 Organizations in the Context of Networks**

Tushman describes an organization in general and an R&D organization in particular as an information processing system. In such a system, oral communication is seen as a particularly effective medium for the transfer of information. It is an efficient medium for the exchange of ideas, information, and concepts since it permits rapid feedback, recoding, and synthesis of complex information. It was also found to be more current and efficient than more formal information media. Finally, the importance of oral communication as an information medium is accentuated in R&D settings since technology (as opposed to science) is difficult to document. This is congruent to Nonaka's notion of tacit to tacit communications. However the author also qualifies that oral communication is effective only when there is a shared coding scheme or language, or where the actors are sufficiently alike in background or perspective that they can rapidly develop a common language. This may refer to the possession of technical currency to understand what is being said or the cultural understanding to understand the nuances of what is being said. It is not that communication between areas with different coding schemes and problem orientations is directly associated with lower quality of information; rather, it is that these highly differentiated areas are simply less effective in supplying information or feedback because of a *communication impedance or mismatch* (Allen T.J. & Cohen S. 1969) between the areas. The results of this study points

to the conclusion that the more successful project teams tailor their communication patterns to fit the information processing demands of their work as opposed to a one size fits all approach. These results are complementary to organizational design literature, and suggest that the more effective managers can actively manage or design communication patterns.

In a study by Allen et al (2002), he investigated the effect of geographic separation on communication among engineers and scientist and made the following observations. First, it is no surprise that engineers at different sites are unlikely to communicate frequently. Second, engineers in different buildings on the same site are almost as unlikely to communicate as those at different sites, this observation is reinforced by the well known observation of the notoriously bad communication among the faculty on most college and university campuses. Third even if engineers are located within the same building but at different floors, if they have no organizational relationship they are just as unlikely to communicate than if they were in different buildings.

Allen etc. further suggested in this study that there is always a need for three types of technical communication in an R&D organization. Type I communication accomplishes coordination among tasks and activities. This is usually achieved by forming project teams. Type II communication provides information about developments in rapidly changing technologies and is mostly managed by departments. Type III communication provides inspiration, stimulating creativity and often functioning as the initial source of new product ideas. There is no organization forms designed to manage Type III communication. This type of communication often occurs between people who are working in different departments, on different projects and drawing on different disciplines. It is this cross-disciplinary, cross-functional communication that allows the development of unusual combinations of ideas that lead to creativity and innovation. This type of communication relies heavily on chance encounters, hence is seriously reduced by geographic dispersion. Besides geographic ties, the two other means of creating organizational bonds is via project teams and departmental organization. These are usually better means of maintaining communication than just geographical closeness. Managers can therefore manage these bonds and barriers to improve communication between members in an organization.

Allen discovered that engineers and even scientists obtain a major portion, usually most of their technical information through colleague contact. While journals and reports are important to the dissemination of technical information (explicit to explicit transfer of knowledge using Nonaka's model), most such knowledge reaches the practitioners through face-to-face contact with colleagues.

In order to facilitate such an exchange of information, workgroups need to be organized in a manner that maximizes the chances of such interactions taking place. However there is a dichotomy between the needs of the markets hence customers and the need to maintain current and up-to-date in an engineer's specialty. To keep abreast of customers requirements requires teams to be organized in projects and co-located as such, however such an arrangement would be detrimental to the specialists' knowledge base. Organizing groups according to specialty would in turn be detrimental to meeting customers' needs as in complex developments, project based organization may be necessary for constant coordination.

To determine which is the best way to organize depends on the level of communication and coordination required as well as the rate at which knowledge changes at either end. In summary teams or groups should be organized where coordination and interaction is more critical and where the rate of change of knowledge is more rapid. The key here is to determine which axis requires more coordination.

## **Chapter 2      Thesis Objectives**

### **2.1    *Main Task***

This thesis examines the drivers of knowledge flow and how it impacts the performance of Functional Centers and their subunits. The core of this research focuses on a medium-sized R&D firm in Singapore.

By leveraging on the availability of computing resources today, this study attempts to gather data regarding connectivity in the entire organization and look into the interconnectivity that exists to answer the following questions.

- (i)    What are the various approaches people use to form their working networks.
- (ii)    Which approaches generates the most *useful* contacts.
- (iii)    How does strong intra-center/subunit connectivity and inter-center/subunit connectivity with people from other centers impact performance?
- (iv)    How does the presence of people with strong networks within the centers affect the performance of the center? Do the managers of these people recognize their value/contribution and how does it affect the usefulness of these connectors?
- (v)    How does the willingness to build cross-level bonds (managers and junior engineers) impact the performance and efficacy of managers hence their centers?

### **2.2    *The R&D Organization***

This organization is multi-disciplinary in nature and performs research in many different technologies for different applications. It can be regarded as a conglomerate of research centers as its 15 centers operates fairly autonomously. While cross-center teams are often formed, it is usually as a result of the ‘buying’ of expertise from the other centers. Ownership

of projects with some exceptions always resides within a particular Center. This organization by functional expertise is in agreement with the work by Allen (1997) whereby groups ought to be organized according to functional expertise when technologies changes quickly. This allows the individual staff to maintain their technical currency in a changing environment by interacting and learning from people with complementary skills. Being an R&D organization, its work inherently involves fairly fast changing technologies.

There has been recently a drive towards innovation as a means of value creation. As such several programs have been put in place by the top management to pursue the generation of new ideas and funds were set aside for the centers to propose projects to research and develop new products. The attitude of the staff with regards to this strategic orientation is unclear and some of the data gathered subsequently may offer some hypothesis on this subject. The amount of time per staff set aside for innovation activities will be used as a measure for center performance subsequently. The assumption here is that the more innovation activities/staff carried out, the better the center performance. This hypothesis will be tested subsequently.

Individual centers perform their R&D activities for their customers and use an activity-based accounting method to bill their customers. As such the size of the center is proportional to its ability to generate revenue. However if the center in question is unable to fully utilize its manpower resources, it becomes a liability to the organization. This revenue generation ability will be used later as another means of performance measurement.

In order to motivate and reward its staff for outstanding performance, there exist several different award mechanisms as well. These awards involve a sum of money either paid to the individual or to the team that performs *par excellent*. Given that there are different categories for both team and individuals, a method was used to normalize them and another performance measure based on awards garnered was developed. These measurements of performance will be used to correlate performance with the various attributes of the centers.

The demography of this organization is fairly typically of an R&D organization whereby about 75-80% of its staff are graduates with science or engineering degrees and about half of



these graduates have post-graduate degrees. 75-80% of its staff is male and the organization is fairly young as a whole with the median age of around 30-35 years old. Due to the very specialized nature of the work and its multi-disciplinary business model, it is difficult (though not impossible) for staff to change centers and it does not happen very frequently. As such a staff with a very long tenure at the organization may have stayed in the same center for his or her entire career; this often results in a very strong loyalty towards their respective centers. More often than not managers are also promoted from within.

### **2.3 Methodology**

In order to answer the five questions above, an on-line survey was prepared and administered on the company's Intranet. Using an on-line survey enabled me to reach out to all the employees (including the corporate staff) of the company and collect responses from them in an efficient and timely manner. The aim of the survey is to find out about the communication patterns within an organization consisting of several independent functional units. This company performs research and development in many different technological areas and is organized into 15 Centers.

To answer the survey the respondent is required to login whereby his name will be captured by the system. For this survey I was not able to create a drop-down list for the names of people that the respondent communicates with. This resulted in several ambiguities that needed to be pre-processed and corrected subsequently. While several reassurances were given that the survey would be kept strictly confidential and that processing will only be performed externally without any data being revealed to any other fellow staff, several people have expressed reservation at revealing such information. This is the inherent risks that a survey of this nature faces especially in a conservative Asian culture and society.

For such surveys, it is also important to design the questions in a manner that is unambiguous and not easily misunderstood. The answers solicited should also be easily quantifiable by the respondents and I avoid asking vague and fuzzy questions. The questions that were asked in the survey are:

- Who are the people you interact with regularly within your Center?
- Who are the people you interact with regularly outside your Center but within the organization?
- Who are the people you interact with regularly outside the organization?
- To what extent do you share task relevant knowledge about work topics with these people?
- To what extent do you socialize or chat about non-work related or personal topics with these people?
- To what extent do you discuss new ideas or potential innovations for the organization with these people?
- How frequently do you interact with these people using the following media; face to face, telephone, email and SMS.
- Describe a moment of inspiration or insight that sparked innovation, who was involved and how did this person affect you?
- Gives us some background about yourself.

The aim of these questions is to solicit data from the respondents that will help me answer the questions posed in chapter 2.1. The actual survey format is in Appendix A.

In order to include some added perspective to the survey, a discussion was held with several of the center heads to solicit their views on Social Network Analysis and their perceived usefulness of it. The discussions in general were honest as well as insightful, the topics discussed includes the unique aspects of their respective centers. Some centers are more focused on development work and are hence more secretive in nature, whereas those centers that perform mainly research work are less secretive. This may have an impact on the level and quality of communication within and outside of the centers. There is one center that performs services to the other centers and this is important as they would have very strong networks but their performance will not be correlated to networks in the same way. All these insights will be used during the discussion phase of this thesis.

## Chapter 3 Survey Results

### 3.1 Survey Response Rate

The online survey generated a response rate of approximately 25%. There were many reasons for this low rate and among them are that the survey was conducted in a manner that did not allow me to send frequent reminders. Also as this was the first time such a study was conducted and the staff was quite unsure about the implications of revealing information as intimate as their personal networks. From discussions with various managers in the organization, it was revealed that such a response rate was common within the context of its organizational culture. The breakdown of the data collected is shown in the table below.

Center	Number of Responses	Staff size
1	69	147
2	17	74
3	16	70
4	8	33
5	15	68
6	10	67
7 <sup>1</sup>	4	47
8	11	65
9	9	43
10	7	54
11	18	82
12	10	71
13	18	86
14	20	67
15	15	94

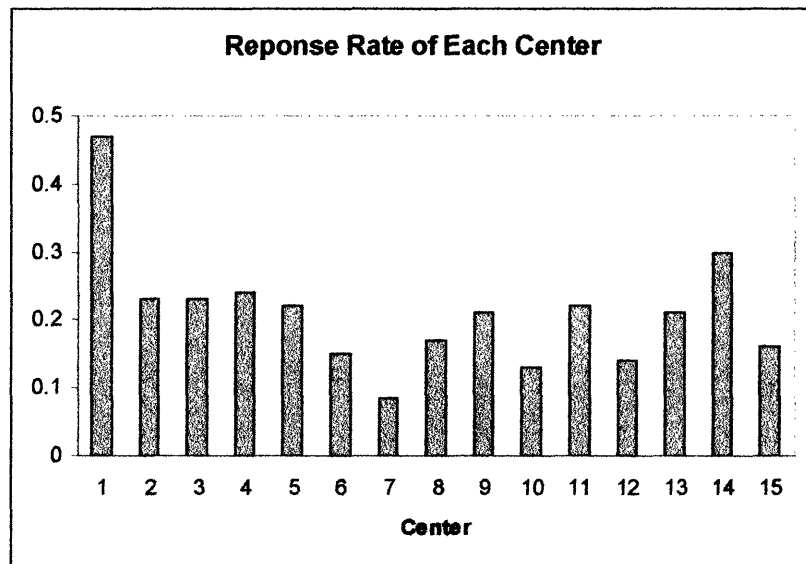


Figure 3 The Response Number and Rate for Each Center

<sup>1</sup> Center 7 and 9 were new additions to the organization having been merged from another organization. For this reason these 2 centers will be ignored for most of the analysis.

Demographic data was not available for me to determine the distribution of responses across the organization, but from anecdotal feedback given by the managers, such surveys typically generate more responses from the younger and more junior engineers and scientists.

### **3.2 *How are Networks Formed***

Figure 4 shows how networks are formed within the organization. As expected, most networks are formed within the context of projects. This is not only because project work brings people in contact with many different people, but projects also give the individual a basis for frequent communication with others. This shows that most of the people that an individual communicates with on a regular basis do so within a project. The distant second avenue which networks are formed is by being in the same physical location. This is because being in the same location reduces the effort required to communicate.

Figure 4 also shows that committee work and special assignments do not result in many regular contacts made. This is probably a result of both the lesser number of people encountered in this manner as well as people not keeping in contact after such work has been completed. Since an individual can only afford to maintain a limited amount of ties, ties formed during committee work are often not sustained since the reason for communication is not maintained beyond the context of the committee. Hence after the termination of the committee, contacts that did not migrate towards actual project work or social ties will simply disappear.

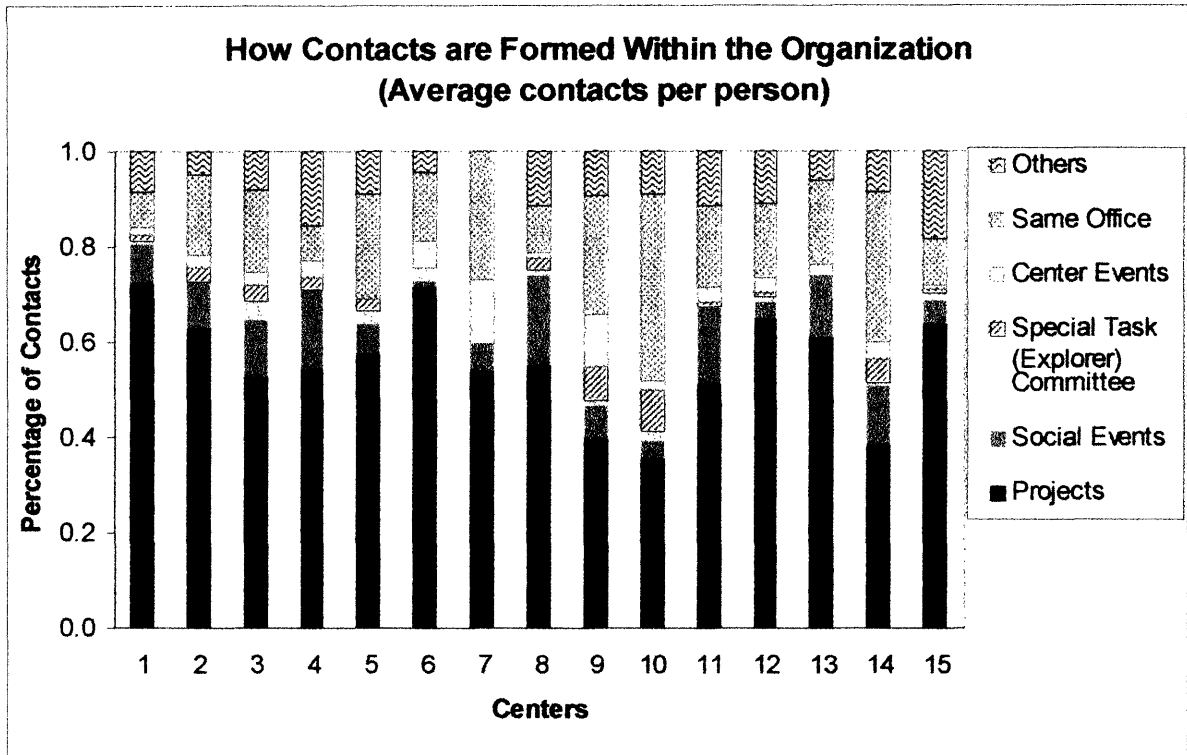


Figure 4 Plot of How Internal Networks are Formed

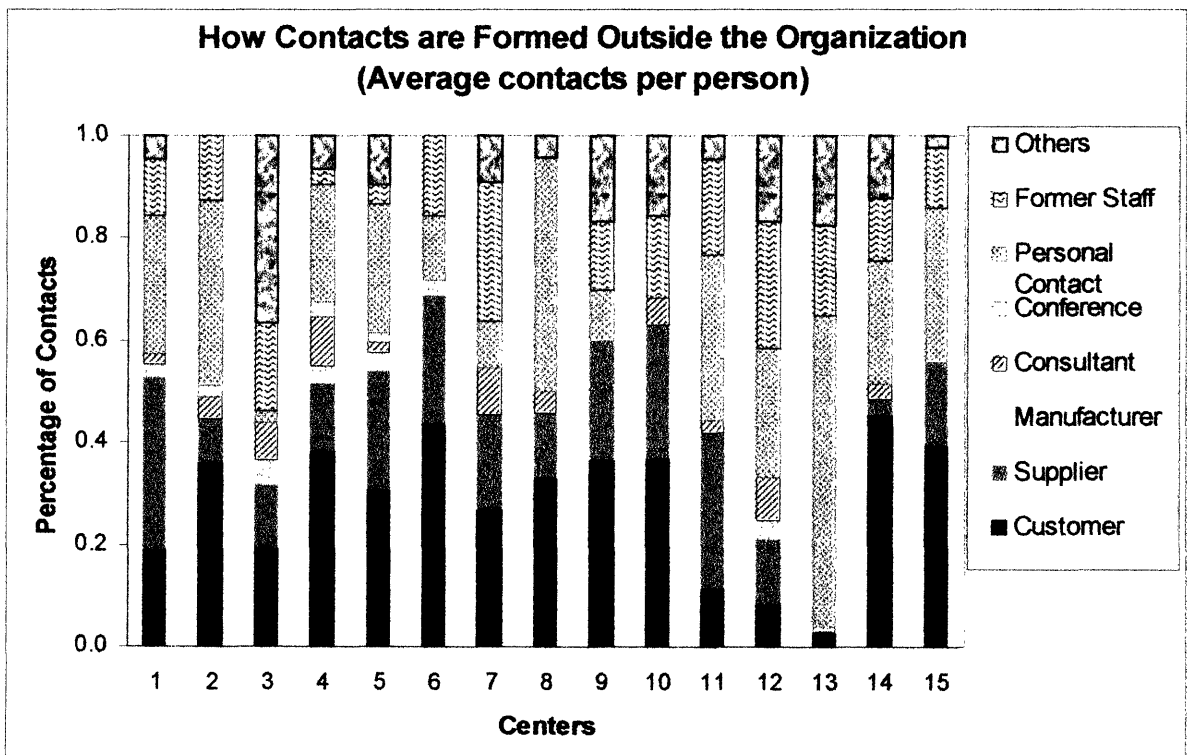


Figure 5 Plot of How External Networks are Formed

The graph in figure 5 shows communication that occurs with people outside the organization. The number of respondents here were quite small therefore data robustness is doubtful. Once again the data suggests that communication occurs within the context of a need. In this case the two main avenues for communication were with customers and suppliers. The 2 unexpected results were contacts made during conferences and those with former staff. It was quite unexpected that despite the frequency at which staff attended conferences very little meaningful contacts were made, it may imply that the main purpose for staff to attend conferences is to keep abreast of latest technological developments and not for making contacts. This is pertinent because it shows a classic example of encountering many different people but not developing meaningful and lasting relationships. This highlights the importance of management incorporating a framework to legitimize and encourage the formation of such networks (Cross and Prusak).

The second interesting finding was contacts maintained with former staff. This represents a very important source of contacts and source of knowledge regarding the industry or area of research. The data shown on the next table supports this statement in that about half of the interactions with former staff are of technical importance.

### ***3.3 Approaches that Generate the Most Useful Networks***

While the previous section discusses the formation of networks, this section discusses the importance of the networks formed via the various means. The strengths of the networks have been sub-divided along the 3 categories and they are Technical, Social and Innovation Networks (Krackhardt and Hanson 1993).

Looking at the strengths of internal networks (networks within the organization), contacts formed in the context of projects yielded the strongest Technical networks; however it also yielded moderately strong Social networks and surprisingly weaker Innovation networks. This was surprising since it was reasonable to expect that people will be more willing to admit that they have stronger Innovation networks than Social networks. This observation

helps to validate the honesty of the responses. For contacts made with people within the same office, it shows Technical networks that are almost as strong (as those formed via projects) and Social networks that are significantly stronger. Since staffs from each Center are usually located in close proximity<sup>2</sup> and since they are likely to be of the same specialization, a lot of technical discussions occur among them. The strength of their Social networks are in agreement with the common observation of strong correlation between physical proximity and liking; therefore social interactions.

In looking at contacts formed through Social interactions, the data suggests that most of these networks did not translate into strong Technical or Innovation networks. However, communications relating to Technical is stronger than Innovation. The reason could be that while these people share common interest or have an affinity for each other, they may be of different specialization hence have little basis for technical discussions.

The other sources of network formation also suggest that Innovation networks are not of a high priority among staff except for those formed under Special Tasks. This observation is however skewed as the purpose of these special task groups was to generate innovative ideas and provide recommendations.

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<sup>2</sup> The centers are usually organized in a few subunits and while the entire center may not always be located together, the various subunits usually are.

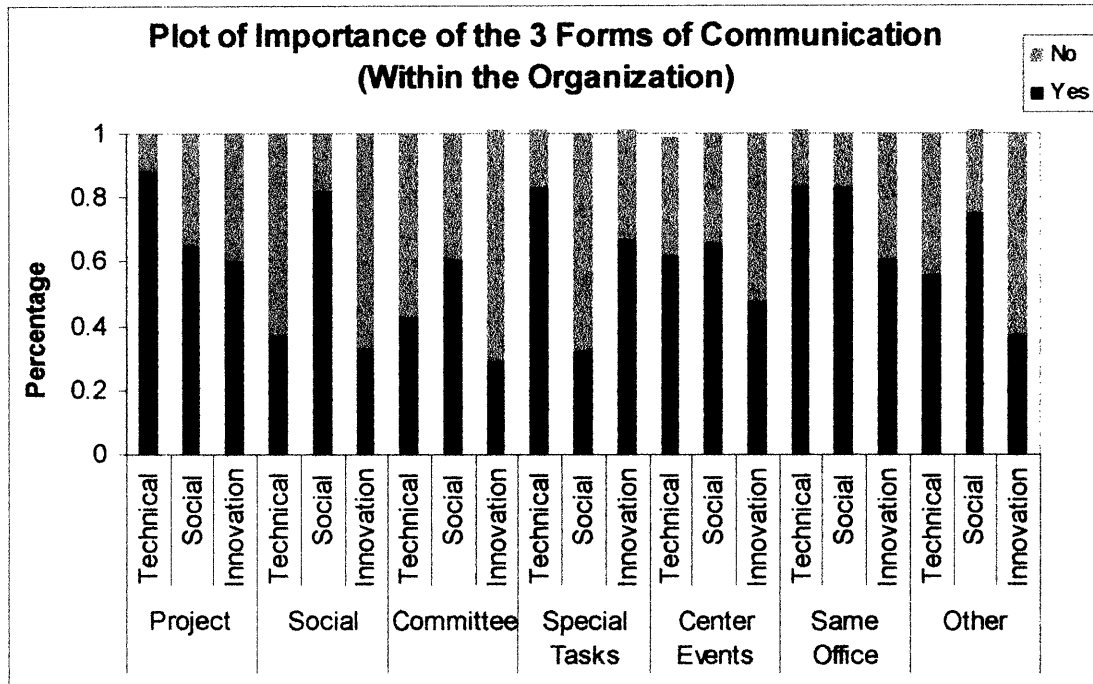


Figure 6 How Internal Contacts are Formed and its Resulting Communication Frequency

In looking at networks formed outside the organization, there is very weak communication in the area of innovation, implying that staff only seek to discuss innovative ideas within the organization. Most of the communication with customer and supplier are Technical; it is not in the culture for staff to discuss innovations with the customers since the prevailing *modus operandi* here is simply to meet customer's requirements. Personal networks are used almost exclusively for social purposes only and there was very little cross-over to technical discussion. This implies that staff rarely leverage off their personal networks to obtain technical information. This might be a result of confidentiality requirements of the organization. However this argument (not the reasoning as confidentiality is very important in the organization) weakens when one observes communication with former staff. Here the amount of technical communication remains quite strong even though from a confidentiality stand point this should not be the case since this former staffs are no longer part of the organization<sup>3</sup>. As of now there is not a good explanation for this phenomenon except that

<sup>3</sup> One possible explanation for this is that these former staff moved on to affiliated organizations and are hence at liberty to discuss technical matters. However the data available is unable to confirm or refute this.



perhaps with former staff there is less of a barrier to communication or they have moved into adjacent or complementary organizations.

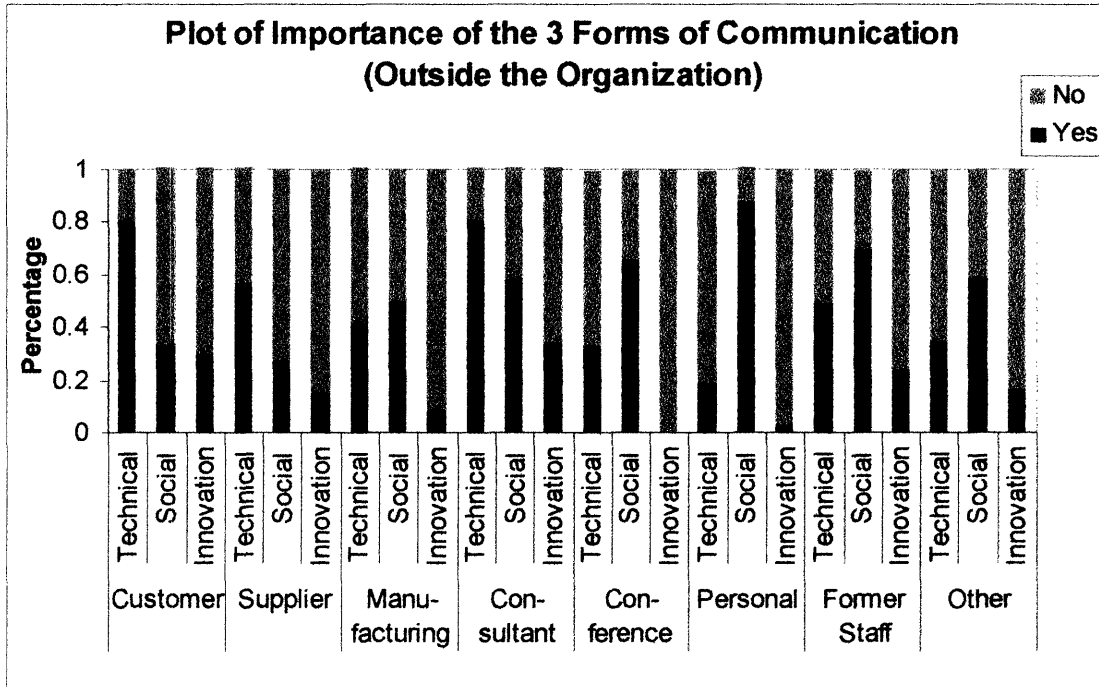


Figure 7 How External Contacts are Formed and its Resulting Communication Frequency

### 3.4 Impact of Intra-Center and Inter-Center Connectivity

In observing the impact of intra-center and inter-center connectivity, Technical and Innovation networks were investigated separately. The measure used to describe this was the E-I index as introduced by Krackhardt and Stern (1988).

$$E - I \text{ index} = \frac{EL - IL}{EL + IL}$$

where

EL = the number of external links

IL = the number of internal links

The index score ranges from -1.0 to 1.0. As the E-I index approaches 1.0, all the links are external, as the E-I index approaches -1.0, all links are internal. The data for within the organization (Technical Networks) shows most indices between -0.25 to -0.7 except for center 3 as depicted in figure 8. This means that most communications exist within the centers. Center 3 is unique as they provide services mainly for the other centers; hence they have a large ratio of contacts with staff from other centers.

E-I Index		
Center	Within Org.	Outside Org.
1	-0.43	-0.63
2	-0.48	-0.46
3	-0.14	-0.53
4	-0.40	-0.33
5	-0.38	-0.46
6	-0.39	-0.30
7	-0.54	-0.74
8	-0.66	-0.72
9	-0.26	-0.24
10	-0.30	-0.24
11	-0.47	-0.67
12	-0.43	-0.57
13	-0.67	-0.50
14	-0.58	-0.62
15	-0.68	-0.57

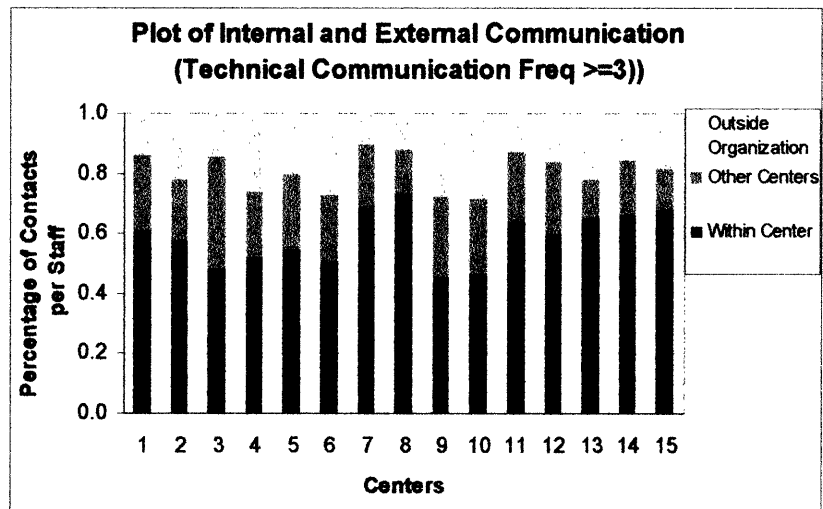


Figure 8 Plot for Ratio of Internal vs External Links for Links with Technical Communication  $\geq 3$

The data for Innovation Networks (as shown in figure 9) is similar to that for Technical Networks. This is unsurprising as most communication occurs internally, however what is interesting is that the indices for within the organization were not too different from those outside the organization for some of the centers. This could either be due to strong collaboration with external parties which equal that with members from other centers. However it is more likely due to strong networks that exist within the centers.

The reasoning for this could be explained by how the organization is structured. It is organized according to technical specialization; as such most of the important discussions

will occur within the centers. Since the organization is engaged in very specialized research and development, most of the staff has very tight specialization. This reduces the likelihood of finding an answer to a problem outside the center if it could not be found within.

A lot of the communication that occurs beyond the center occurs because of the nature of the project. This form of communication is often quite different from that which occurs within the center. While staff may discuss about specific technical problems with their peers in their own groups<sup>4</sup>, communication with people outside their groups usually involve more of interface issues. Hence the amount of inter-center communication a group or a center has is influenced by the degree of interface that their work requires.

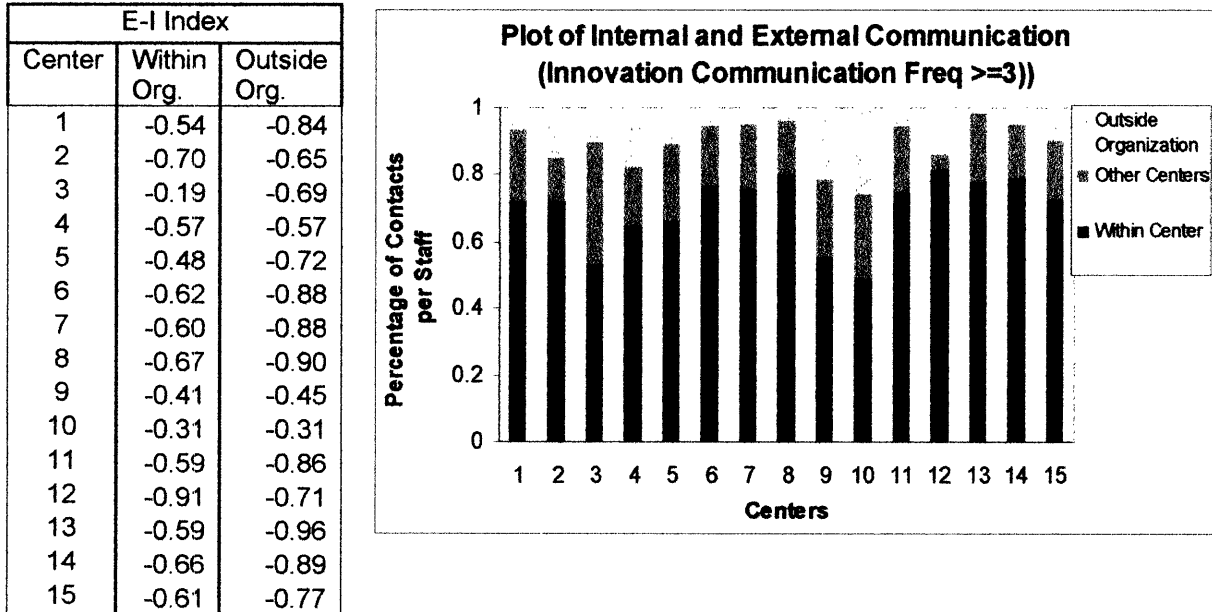


Figure 9 Plot for Ratio of Internal vs External Links for Links with Innovation Communication  $\geq 3$

<sup>4</sup> Centers are usually further divided into specialist groups of the same specialty.

### **3.5 Impact of People With Strong Networks on Center Performance**

In developing a measure of people with strong networks, two sets of data were developed. The first set did not normalize the strength of networks with regards to the size of the centers. This is because in measuring the performance of the centers, it is the presence of the actual number of such people that matters and not the normalized number. However this may not give the true picture hence a second set of data normalizes the data against the size of the centers and the impact of both are observed.

The number of people with 6 or more contacts pointing in (people who pointed to them as a contact) was tabulated for each center and an aggregate score was calculated based on the following formula:

$$\text{Aggregate Factor} = \sum_i \text{NumberofContacts}_i$$

Where

- i : the person with strong networks
- NumberofContacts : Number of people who mentioned them

Not surprisingly center 1 has the highest factor, mainly because they are the largest. Centers 7, 8 and 9 do not have people with strong networks at all. The impact these ‘gatekeepers’ have on the performance of the centers will be discussed in the next chapter. There are usually 2 reasons for people to point at these gatekeepers, first they could be technical experts who others (even those outside their centers of domain expertise) turn to for technical advice. Second, these people might be project managers of very large projects that require the expertise of several different centers.

Center	Raw number	Normalized
1	153	1.04
2	15	0.20
3	42	0.60
4	19	0.57
5	28	0.41
6	6	0.09
7	0	0.00
8	0	0.11
9	0	0.34
10	6	0.08
11	28	0.08
12	6	0.20
13	7	0.18
14	13	1.04
15	17	0.20

Figure 10 Table of Staff with Strong Networks

### 3.6 Impact of Cross-Level Communication on Performance.

This section measures the quantity of cross-level communication that is occurring within the individual centers. The formula used to calculate the ratio was:

$$\% \text{Crosslevel (Technical Freq} \geq 3) = \frac{C\_Sup + C\_Sub}{C\_Total}$$

Where

$C\_Sup$  = Contact with a Superior

$C\_Sub$  = Contact with a Subordinate

$C\_Total$  = All Contacts with a Superior, Subordinate or Peer

*For all contacts that meets the criteria for Technical Frequency  $\geq 3$*

This ratio aims to observe the degree of managerial involvement that occurs within each center. The assumption here is that the more managerial involvement there is, the more aware managers are and hence more likely to resolve potential problems before they occur. In the next chapter, this ratio will be used to compare against performance. The aim of this is to

observe the correlation between managerial involvement and performance. Various different criteria considered were used to observe for differences in communication regarding Technical matters and those regarding Innovation matters.

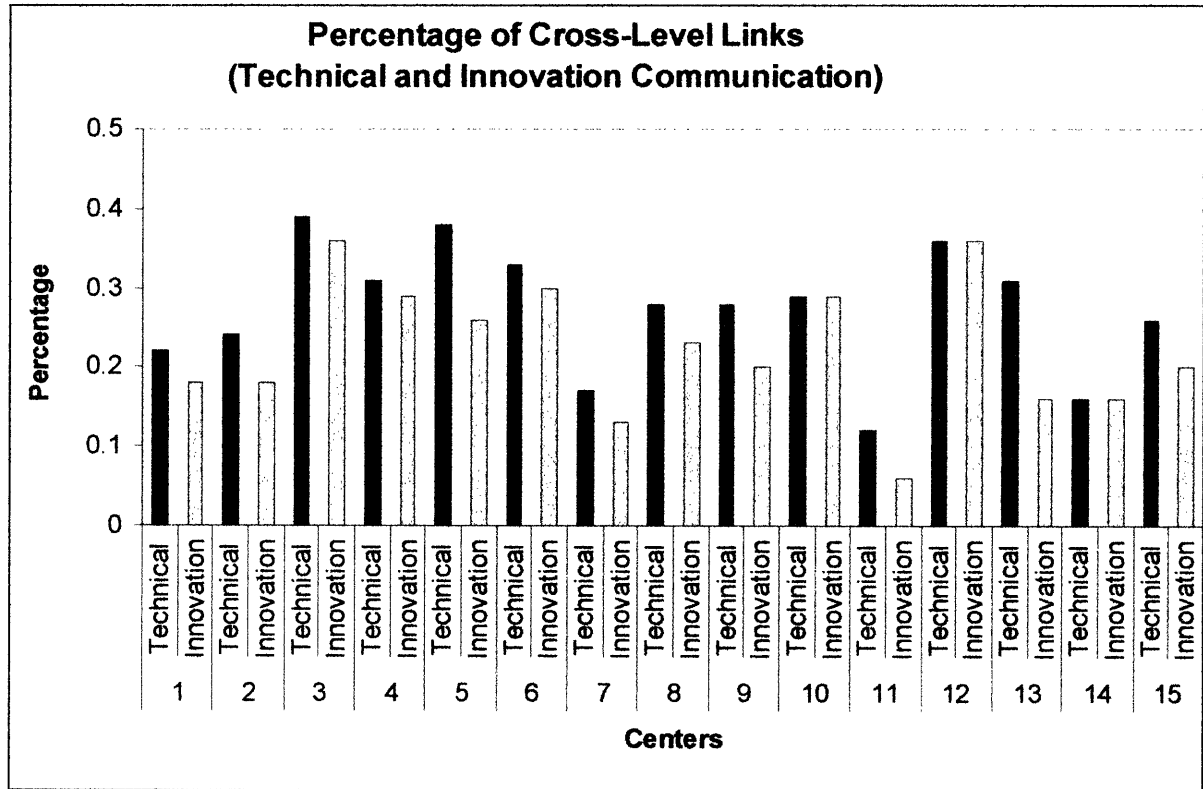


Figure 10 Plot for Percentage of Cross-Level Links for Each Center with a Communication Frequency  $\geq 3$

### 3.7 Performance Measures Used.

There are five performance measures used here and they have been generated (based on available data) as a means to observe the impact of the various quantities extracted above on performance. These measures have been created for this study as the organization does not have a formal measure to rate the performance of the centers preferring a more egalitarian system. Regardless the five measures that were created as a proxy for performance measurements are believed to be good substitutes. They are used separately as opposed to

being used as a single consolidated metric because each measures a different performance metric and demonstrates the success of the centers at a different aspect of achievements. Centers 7 and 9 were excluded as data for these 2 centers are not available. Some of the numbers are normalized with respect to the largest figure among all the centers measured. The purpose of this is to standardize the format of the graphs (such that all data resides between 0 and 1) and also to protect the confidentiality of the data.

The Innovation Activity metric shows the amount of resources the center was able to secure from management to perform Innovative research. The assumption here is that the more Innovative a center is the more effort it places on such activities and in turn they are rewarded with more resources from the corporate. This measure is normalized with respect to the number of staff each of the center has.

The Manpower Utilized metric shows the amount of resources that each center has been able to secure from its customers to perform its regular activities. The assumption here is that the better performing centers would be able to secure more funding since they have been able to meet customer's needs hence are able to win more contracts. It is a ratio of the total funding secured vs the total amount of Manpower that each center has.

The Revenue metric shows the contribution to the company's bottom line in excess of the cost of its manpower. The reason here is that the Manpower Utilized metric is insufficient as it may penalize centers that are large, despite the fact that if these centers are able to effectively utilize all their manpower, their contribution to the organizations' revenue is larger than that of a smaller center. The organizations' revenue generation model is one of cost plus markup of manpower. Hence the more engaged manpower a center has, the more it contributes to the overheads of the organization.

The Awards Garnered metric shows a composite of the amount of awards that each center has garnered over the past 5 years. As there are various different types of awards given over the past 5 years coupled with changes in names of awards and criteria, the normalizing factor used here was the monetary value of the award. This performance is quite robust as it is a direct endorsement from upper management as well as the various center heads.

The Awards Normalized is the total prize money received by members of each center. The difference between Awards Garnered and this is that Awards Garnered allocates all the points to the center that led the project. However project teams invariably consist of members from other centers, hence this measure sums up the total monetary award garnered by the staff from each center regardless of whether the project belongs to the center or not. This measure may not accurately reflect the dynamism of the centers as the cap on the value of an award is the same regardless of the size of the team. There were several project teams in the larger centers that were disproportionately large; hence it skews the data on award per staff. This is the reason why both sets of measures are used as opposed to just one or the other.

Center	Innovation Activity per staff	MP Utilized	Revenue Contribution	Awards Garnered	Awards Normalized
1	0.00	1.00	1.00	1.00	0.69
2	0.46	0.80	0.30	0.20	0.25
3	0.00	0.85	0.29	0.30	0.42
4	1.00	0.94	0.20	0.25	0.51
5	0.51	0.92	0.36	0.25	0.34
6	0.49	0.91	0.36	0.55	0.56
8	0.66	0.62	0.11	0.50	1.00
10	0.06	0.84	0.25	0.15	0.24
11	0.63	0.82	0.39	0.55	0.42
12	0.34	0.83	0.26	0.95	0.93
13	0.11	0.89	0.42	0.75	0.51
14	0.14	0.85	0.31	0.30	0.22
15	0.00	0.91	0.49	0.60	0.42

Figure 11 Plot for Various Performance Measures Used in Analysis



## Chapter 4 Analysis of Results

The results of the survey were presented in Chapter 3 and now the data will be examined to look for patterns and correlations. It is important to note that while correlations may be observed from these regressions, it is difficult to tell by just looking at the numbers the direction of causality. Here is where my previous conversations with some of the managers at the company become useful, giving me a sense of what is actually happening. Numeric data is often preferred to anecdotal evidence but to have a good sense of the data, the latter is often crucial.

We will first look at the correlations between the control variables such as interaction, relationships etc and the performance measures previously identified. Next we shall look at the correlations between several control variables themselves to look for interesting patterns. All the regressions here are based on the centers. At the time of the survey, centers 7 and 9 were new inclusions to the organization hence performance data were not available. As such they were excluded in the regression model; hence only 13 centers were used. Due to the dominant nature of center 1, the regressions were also performed with and w/o the dominant center. The numbers in parenthesis are the results without the dominant center.

### 4.1 Correlation of Control Variables vs Performance

(Correlation w/o dominant center is in brackets)	<b>Innovation Activity</b>	<b>MP Utilized</b>	<b>Revenue</b>	<b>Awards Garnered</b>	<b>Award per Staff</b>
<b>Innovation Activity</b> Allocation of manpower for innovation activities	1.00	(-0.084)	(-0.462)	(-0.116)	(-0.317)
<b>MP Utilized</b> Manpower utilization rate	(-0.084)	1.00	(-0.583)	(-0.084)	(-0.513)
<b>Revenue</b> Contribution to bottom line of the organization	-0.223	0.649**	1.00	(0.257)	-0.338
<b>Award Garnered</b> Sum of subjective value of awards	(-0.116)	(-0.084)	(0.257)	1.00	(0.077)
	-0.223	0.192	0.585**		0.67**

<b>Award per Staff</b> Award per given staff	(0.316)	(-0.513*)	(-0.462)	(0.672)	1.00
	<b>0.22</b>	<b>-0.338</b>	<b>-0.006</b>	<b>0.67**</b>	
<b>External_Internal T (inside)</b> Ratio of inter & intra center communication with Technical_Freq >=3	(-0.013)	(0.264)	(-0.221)	(-0.424)	(-0.243)
	<b>-0.032</b>	<b>0.262</b>	<b>-0.046</b>	<b>-0.320</b>	<b>-0.22</b>
<b>External_Internal T (outside)</b> Ratio of communication within center and outside the organization with Technical_Freq >=3	(0.069)	(0.572*)	(0.063)	(-0.327)	(-0.357)
	<b>0.151</b>	<b>0.359</b>	<b>-0.216</b>	<b>-0.414</b>	<b>-0.4</b>
<b>External_Internal I (inside)</b> Ratio of inter & intra center communication with Innovation_Freq >=3	(-0.324)	(0.203)	(0.063)	(-0.604**)	(-0.094*)
	<b>-0.324</b>	<b>0.205</b>	<b>0.063</b>	<b>-0.475*</b>	<b>-0.47*</b>
<b>External_Internal I (outside)</b> Ratio of communication within center and outside the organization with Innovation_Freq >=3	(0.031)	(0.187)	(-0.314)	(-0.464)	(-0.263)
	<b>0.078</b>	<b>0.091</b>	<b>-0.281</b>	<b>-0.469*</b>	<b>-0.29</b>
<b>Strong_Networks</b> The number of people with 6 or more connections pointing in	(-0.057)	(0.349)	(0.272)	(-0.347)	(-0.435)
	<b>-0.322</b>	<b>0.535*</b>	<b>0.886**</b>	<b>0.439</b>	<b>0.09</b>
			<b>**</b>		
<b>Networks_Norm</b> Strong_Networks normalized to the size of the center	(0.235)	(0.452)	(0.06)	(-0.469)	(-0.367)
	<b>-0.099</b>	<b>0.614**</b>	<b>0.676**</b>	<b>0.162</b>	<b>-0.061</b>
<b>Cross Level Technical</b> Ratio of cross-level communication vs all communication within a center involving Technical_Freq >=3	(-0.081)	(0.237)	(-0.179)	(-0.08)	(0.303)
	<b>-0.002</b>	<b>0.099</b>	<b>-0.281</b>	<b>-0.058</b>	<b>0.24</b>
<b>Cross Level Innovation</b> Ratio of cross-level communication vs all communication within a center involving Innovation_Freq >=3	(-0.069)	(0.147)	(-0.415)	(-0.011)	(0.316)
	<b>-0.006</b>	<b>-0.043</b>	<b>-0.35</b>	<b>-0.109</b>	<b>0.26</b>

\* p<0.1  
\*\*p<0.05  
\*\*\*p<0.01  
\*\*\*\*p<0.001

Figure 12 Plot of Correlation between Performance and Various Factors

We shall first analyze the correlations with the dominant center included. In looking at the correlation between the various performance measures, it is interesting to observe a negative correlation between Innovation and 3 of the other performance measures MP Utilization, Revenue and Award Garnered. However Revenue has a strong positive correlation with both MP Utilized as well as Award Garnered. This seems to suggest that Innovation Activity is a poor proxy for performance measurement and is in fact counter to good performance. The reason for this observation will be discussed subsequently but for now it will not be used in our discussions.

The correlation between internal-external links and Awards Garnered shows a strong negative relationship and it starts to become statistically significant for the Innovation Networks. This implies that the more inward looking a center becomes ( $E_I$  index tends to -1) the better the center performs. There is a strong reason here; as suggested by Tushman, effective communication is often possible only when there is a shared coding scheme or language that may be granted by having the necessary technical currency. However in the case of this organization, the different centers are mainly working on different and at times unrelated technologies. The result is a communication mismatch that is greater than the benefits that may be derived from structural diversity. In such an environment, strong intra-center links might be preferred. The work by Farris also points to innovative groups being highly cohesive and more inward looking.

In looking at the correlation between centers with people having Strong Networks and performance, a very strong and statistically robust correlation is observed between having such people and MP utilization. The correlation between having such people and Awards Garnered is also strongly positive although statistically not as significant. This clearly shows that there is strong correlation between having 'gate keepers' within centers and performance. Even if the strength of networks is normalized with regards to the size of the centers, correlation between Revenue and MP utilization is still very strong.

In looking at Cross Level Communication (CLC), it is surprising to see that there is almost no correlation between Awards Garnered and amount of CLC that is occurring. CLC can be

viewed as the involvement of the managers in the day to day tasks that goes on within a center; the definition of CLC used in the data acquisition is whenever a staff says that he or she spoke to someone of a different level, that link is considered a CLC link. This reflects the awareness that managers have in the activities that occur within the Center. Aggregating it across the center and dividing it by the total number of links within a center gives us the CLC ratio. This seems to imply that managerial awareness or involvement has no bearing on the performance of centers. This seems counter-intuitive to what is expected, since strong managerial presence is suppose to result in better performance as they are in a better position to manage. Farris (1973) gave an explanation that there are actually two separate effects at play here. On one hand when the supervisor in a sub-unit is highly competent, increased levels of involvement will result in an improvement in performance. Whereas if the opposite were true and the supervisors are not competent, then an increase in managerial involvement may actually result in a decrease in the performance of his or her sub-unit. Taking these two effects together and assuming that the organization has a mixture of both types of supervisors, the aggregate would be the canceling of both trends resulting in no correlation being observed. Unfortunately data for this effect is not easily available hence it cannot be easily examined.

The correlation that experiences a significant change after removing the dominant center are highlighted in bold. To investigate its impact, the regression plots are computed and displayed next. There are three reasons for the dominance of the center; first this center is the largest center within the organization and is about 50% larger than the next largest center. Second this center is also the organizations top performer with its members enjoying more prestige and faster promotions than comparative members of most other centers. Third this center also has the highest response rate for the survey with a return of about 40% compared with the organization wide response rate of 25%.

In further examining the table in figure 12, the graph of the correlation between factors with a correlation index of greater than 0.4 is plotted below. For the purpose of the discussion in this section, we shall ignore relationships with a correlation index of less than 0.4. If the

correlations with and without the dominant center are significantly different, both trends are shown as well, else only the trend that include the dominant center is shown.

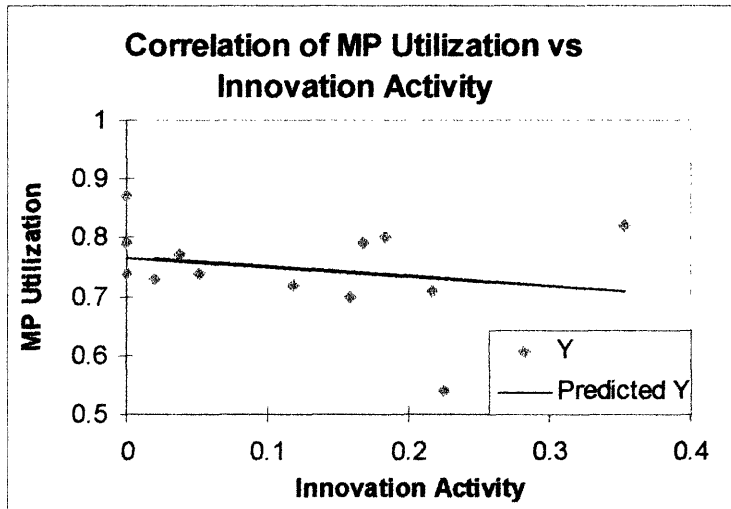


Figure 13 Plot of Correlation between Manpower Utilization vs Innovation Activity

Figure 13 shows a slope with a slight negative gradient. This implies that the more innovation activity a center engages in, the lower its manpower utilization rate. This clearly indicates that one of these performance measures is unsuitable and it is the Innovation activity metric. It could also mean that the less busy centers typically have more time for innovation activities and in fact requires funding for such activities to keep its staff fully loaded.

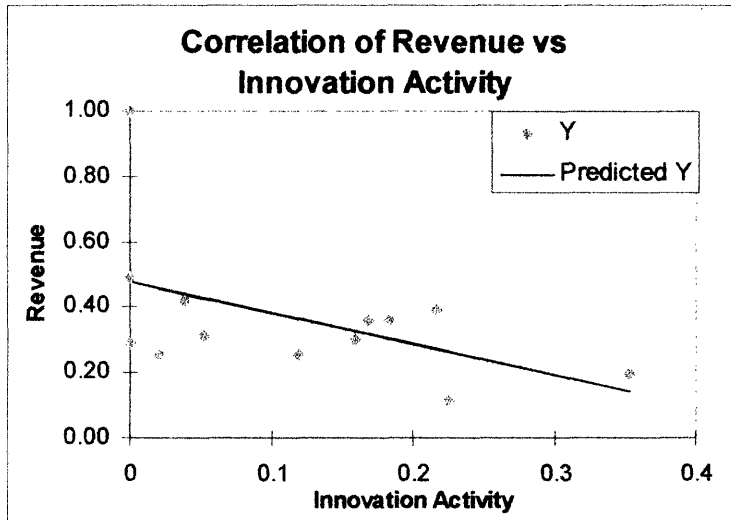


Figure 14 Plot of Correlation between Revenue Generation vs Innovation Activity

Figure 14 again shows a negative gradient between 2 performance measures. This confirms that Innovation activity is a poor metric to use as a performance measure.

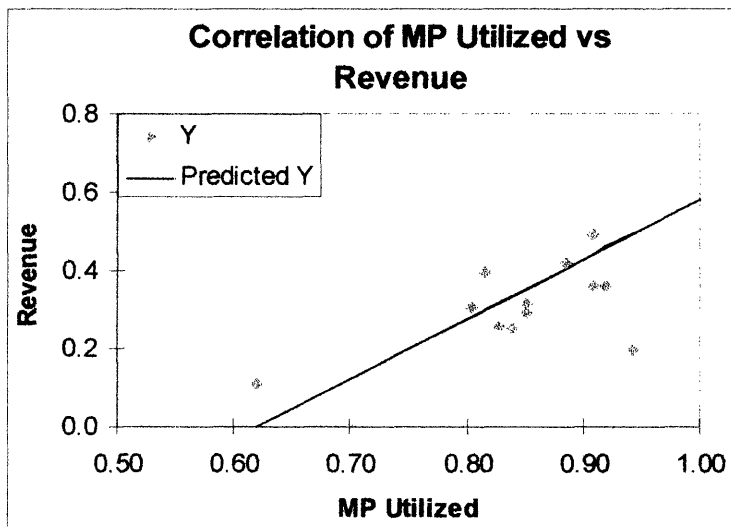


Figure 15 Plot of Correlation between Manpower Utilization vs Revenue Generation

Figure 15 shows a strong positive gradient depicting a strong positive relationship between Revenue and Manpower Utilization. This is to be expected since higher Manpower Utilization is directly translated into more revenue although it does not show the effects of size. This is why the correlation between these two plots is not a perfect 1 which is expected

if the two metrics are perfectly correlated. In short, having a MP Utilization rate of 1 does not guarantee that the Revenue contribution will be large since it does not take into account the size of the center which is critical when calculating Revenue generation.

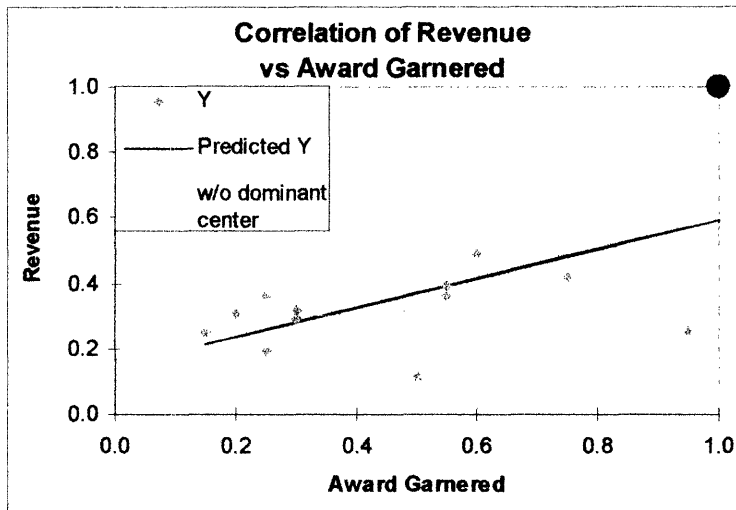


Figure 16 Plot of Correlation between Revenue Generation vs Awards Garnered

Figure 16 shows a strong positive relationship between Revenue and Award Garnered. This is intuitive since a center that is doing good work deserving of awards would also likely generate a healthy stream of revenue for the organization. The single point at the top right-hand corner clearly depicts a dominant center. This dominant center is helped by its size and its efficacy in fulfilling its role. For a relatively well-run organization like this, size can be regarded as an effective indicator to the likely performance since it has to be justified by the value it produces. In other words the more effective (or greater contribution to the activities of the organization) a center is the more projects and activities it can generate which in turn would require more staff to carry out those activities. In examining the plot, ignoring the dominant center reduces the gradient of the slope of the correlation. The correlation also reduces from 0.585 ( $p < 0.05$ ) to 0.257 when the dominant center is ignored.

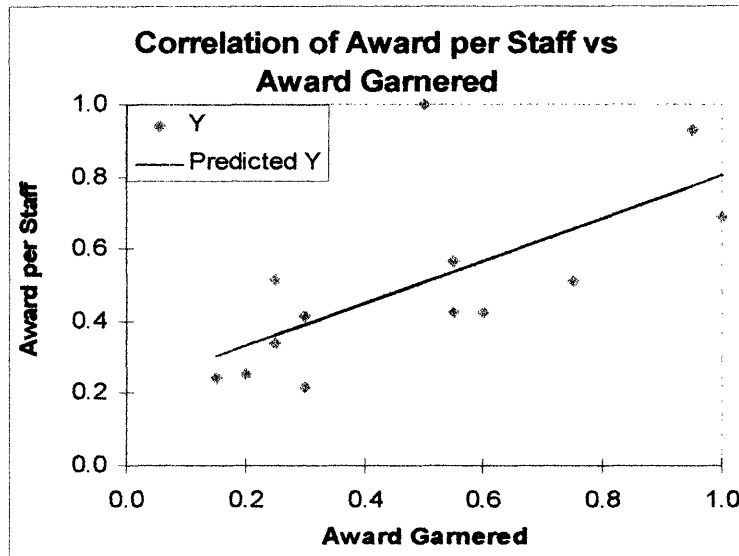


Figure 17 Plot of Correlation between Award per Staff vs Awards Garnered

Figure 17 shows a strong positive relationship between Award per Staff and Award Garnered. Note that the correlation is not perfect; for example, one of the centers scored the highest on Award per Staff but only average in Award Garnered. This could be because some of the centers play a larger support role, this means that their staffs are often involved in award winning projects but the center which they belong to do not lead most of these projects. While the Award Garnered metric may give an indication of the performance of a center, the Award per Staff metric gives an indication of the value-add of a center to the entire organization.



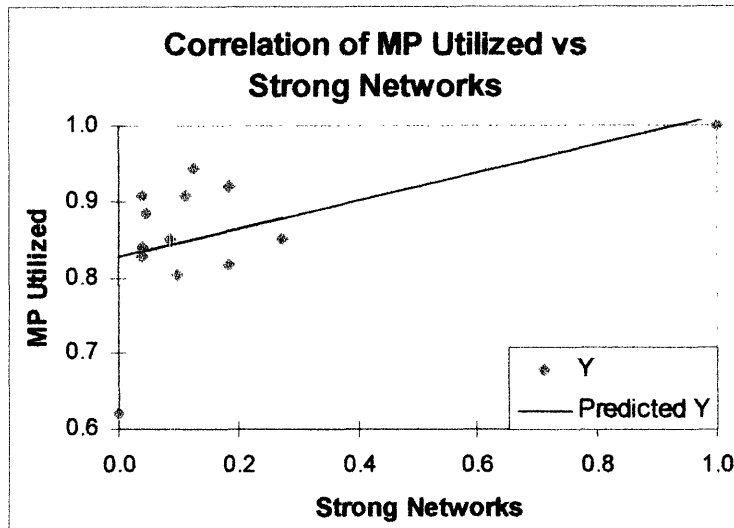


Figure 18 Plot of Correlation between Manpower Utilization and Strength of Networks

Figure 18 shows a positive relationship between Strong Networks and Manpower Utilized. The graph shows a center that scores highest on both measures implying a very dominant center; this center played a disproportionate part in influencing the trend line. Another possible explanation to this trend is that centers with people who have strong networks are better at securing the confidence of potential customers,<sup>5</sup> and hence projects.

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<sup>5</sup> Both internal customers by providing services to the other centers and external customers that brings revenue directly into the organization.

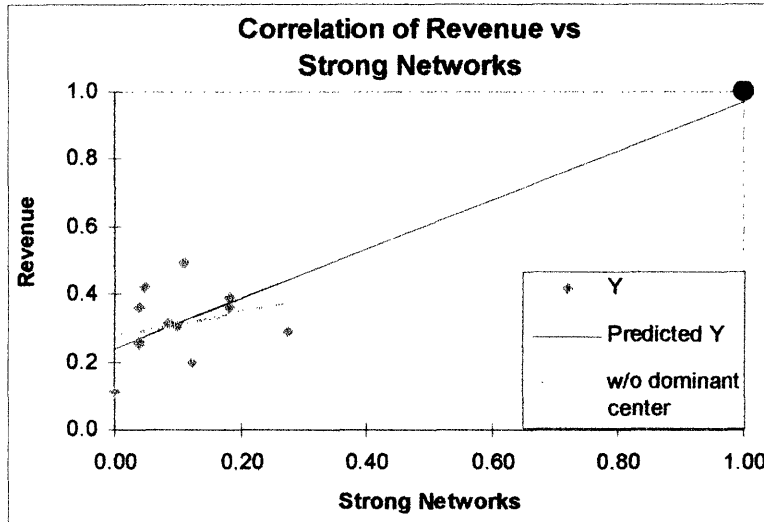


Figure 19 Plot of Correlation between Revenue and Strength of Networks

Figure 19 shows a positive relationship between Strong Networks and Revenue. Once again the graph shows a center that scores highest on both measures implying a very dominant center. This graph is related to that of figure 18 and they share similar reasoning. In examining the plot, ignoring the dominant center reduces the gradient of the slope of the correlation. Most importantly, the correlation also reduces from 0.886 ( $p < 0.001$ ) to 0.272 when the dominant center is ignored. The reason is clear as the outlying point is so far out that it forces the trend line to cut across it predicting a high correlation in the process. In reality, the data does not fit a linear trend in any way, but the dominant data point obscures the fact. However the original trend may still be true but the data does not reveal it due to insufficiency of survey data.

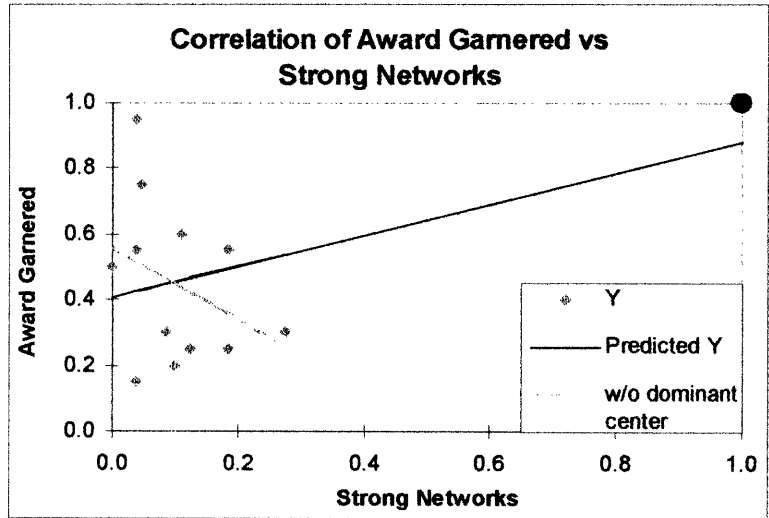


Figure 20 Plot of Correlation between Awards Garnered and Strength of Networks

Figure 20 shows a positive relationship between Award Garnered and Strong Networks. However this correlation is not very strong and it is largely supported by the dominant nature of the center that occupies the top positions for both measures. In examining the plot, ignoring the dominant center changes the gradient of the slope of the correlation dramatically. The graph shows that these numbers do not mean much as the data points do not fit either predictions very well. The data appear more random than correlated and this is largely due to the insufficiency of the data collected.

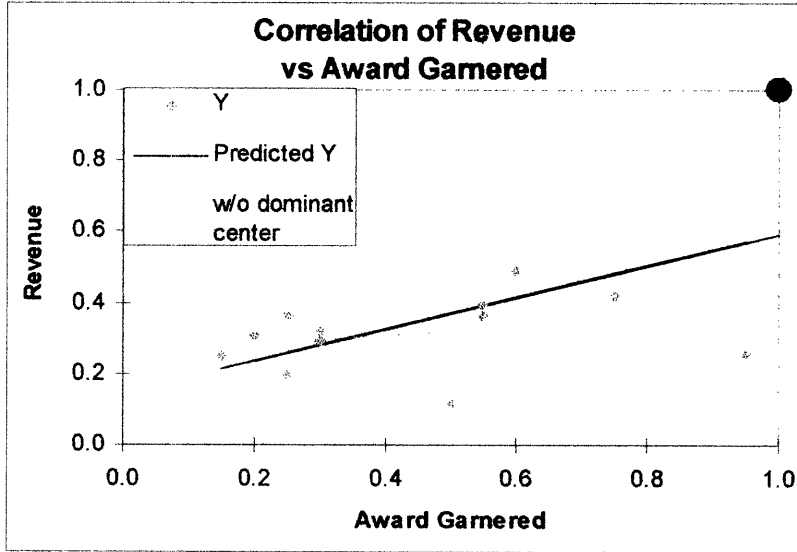


Figure 21 Plot of Correlation between Revenue and Awards Garnered

Figure 21 above shows that an increase in Award Garnered correlates positively with Revenue generation which is not surprising since they both represent good performance. However ignoring the dominant center reduces the gradient of the slope of the correlation. The correlation also reduces from 0.585 ( $p < 0.05$ ) to 0.257 when the dominant center is ignored.

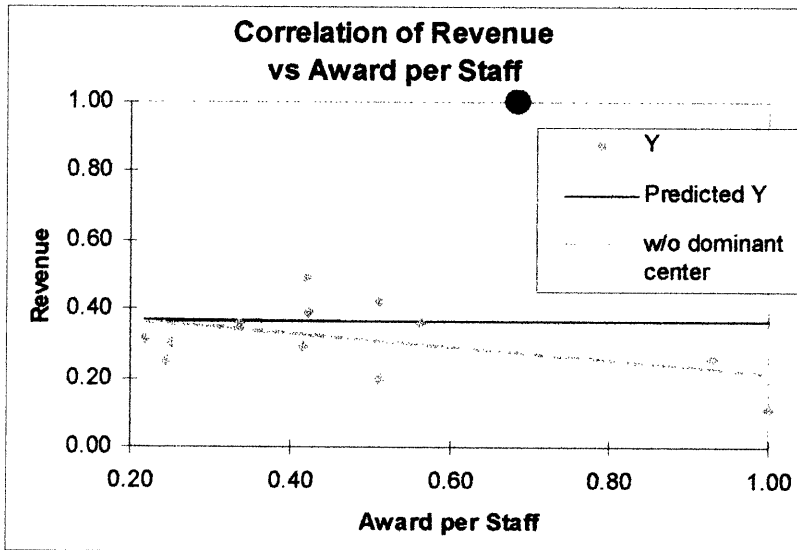


Figure 22 Plot of Correlation between Revenue and Award per Staff

In examining the plot of Revenue vs Award per staff, ignoring the dominant center shifts the gradient of the slope of the correlation from almost neutral to negative. The correlation also increases from -0.338 to -0.513 ( $p < 0.1$ ) when the dominant center is ignored, and here the data clearly appears to better fit the predicted trend. This trend is quite unexpected but it is probably due to some centers playing a very strong support role. This result in the center not leading any award winning teams but its members contributes in many of those projects belonging to other centers. This explains the differences between figure 21 and figure 22.

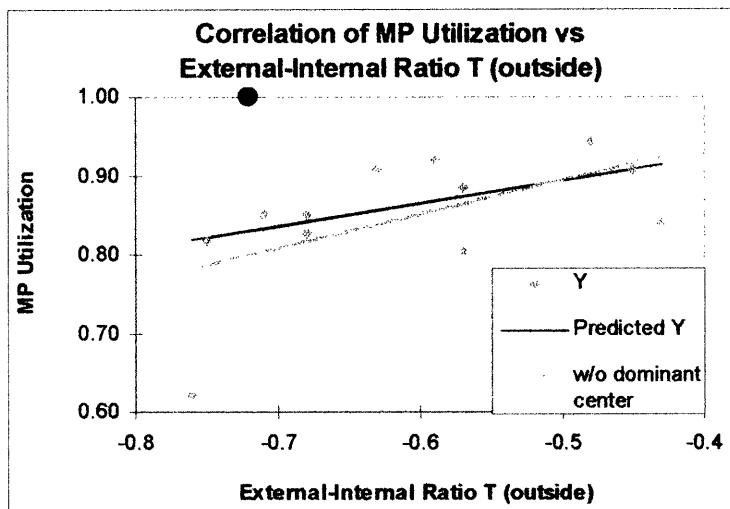


Figure 23 Plot of Correlation between MP Utilization and External-Internal Ratio Technical (outside the organization)

In examining the plot in figure 23, ignoring the dominant center increases the gradient of the slope of the correlation and increases the correlation from 0.359 to 0.572 ( $p < 0.1$ ). The graph actually shows a fairly reasonable fit when the dominant center is ignored.

What this sub section shows is the impact of one dominant center on the various correlation results. What this suggests is that the culture and organization of this center is significantly different from the rest of the organization. From my understanding from talking to the staff and managers there, this dominant center is essentially one of the main drivers for a lot of the research activity within the organization and is also the biggest revenue generator. Another interesting point is that while all the other centers are organized around technologies, this center is largely organized around a product range. Unfortunately there is insufficient survey data for me to conclude if the behavior of the organization will be more or less accurately

described if this center was ignored. As such the outcome of the set of data presented here is ambiguous at best and we are unable to form good conclusions.

## 4.2 Correlation of Control Variables

This section examines the relationship between the various control variables. While chapter 4.1 examines the correlation of various control variables with performance, this chapter will examine the correlation among various other control variables. This will give us some insights into the communication behavior of staff in the organization.

	<b>Years Known</b>	<b>Tech_Freq</b>	<b>Social_Freq</b>	<b>Inno_Freq</b>	<b>Sched_F2F</b>	<b>Informal_F2F</b>	<b>Phone</b>	<b>Email</b>	<b>Location</b>
<b>Years Known</b>	1.00	-0.04 **	0.18 ****	0.03 **	0.00	-0.02	0.12 ****	0.05 ***	0.01
<b>Tech_Freq</b> Frequency of technical comm..		1.00	0.11 ****	0.57 ****	0.41 ****	0.43 ****	0.36 ****	0.45 ****	-0.37 ****
<b>Social_Freq</b> Frequency of social comm..			1.00	0.28 ****	0.23 ****	0.33 ****	0.22 ****	0.32 ****	-0.22 ****
<b>Inno_Freq</b> Frequency of Innovation comm.				1.00	0.38 ****	0.42 ****	0.30 ****	0.33 ****	-0.27 ****
<b>Sched_F2F</b> Face to face comm.					1.00	0.49 ****	0.50 ****	0.42 ****	-0.31 ****
<b>Informal_F2F</b> Chanced face to face comm....						1.00	0.43 ****	0.50 ****	-0.55 ****
<b>Phone</b> Comm. by phone							1.00	0.63 ****	-0.20 ****
<b>Email</b> Comm. by email								1.00	-0.30 ****
<b>Location</b> Location of person									1.00

\* p<0.1  
 \*\* p<0.05  
 \*\*\* p<0.01  
 \*\*\*\* p<0.001

Figure 24 Table of Correlation for various control factors

Looking at figure 25, it can be seen that there is a much stronger relationship between Technical and Innovation communication than Technical and Social. In essence Technical and Innovation are very much related, however Social communication requires one to have a liking for the other. For the case of Innovation, this is less a requirement.

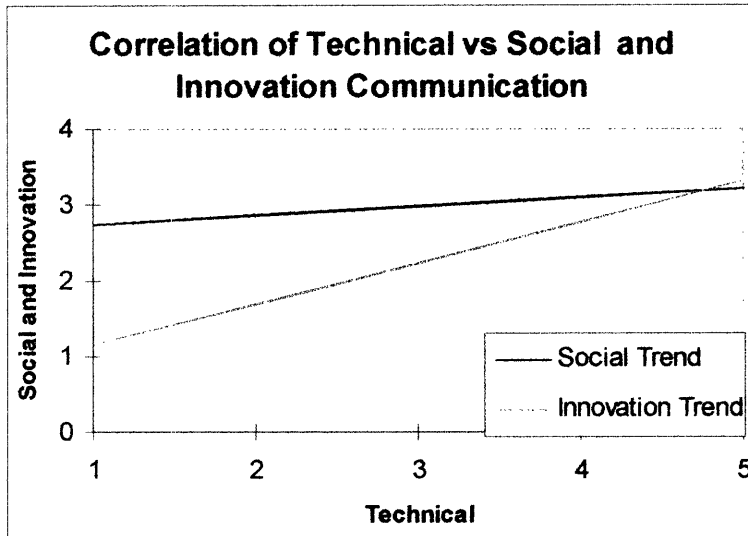


Figure 25 Plot of Correlation between Technical and Other Forms of Communication

As Location becomes closer, the frequency of all these 3 forms of communication increases<sup>6</sup> as well. However from the table the suggested relationship appears quite weak; this is because the relationship is not a linear one. As Allen (1977) suggested, the frequency of communication decays exponentially as distance increases. This appears to be the case here (46% of all networks are with people within the same office).

In observing all the channels of communication used with respect to Location, a correlation was observed<sup>7</sup>. This correlation is probably due to more networks being formed and more communication taking place as a result of location. The case of Informal F2F, it shows both the effect of more networks formed and the effect of proximity on this channel of

<sup>6</sup> The correlation shows that as Location becomes closer, ie. number gets smaller, the frequency of all three forms of communication increases which is why a negative number is depicted.

<sup>7</sup> The correlation shows that as Location becomes closer, ie the number gets smaller, the frequency of the channels of communication being used increases.

communication (observe that it has a steeper slope than the others). Being in the same location greatly increases the likelihood of serendipitous meetings hence Informal F2F communications. Figure 26 shows the reduction in frequency of all channels of communication with distance. The informal F2F slope is slightly steeper than the rest since occasions for it is lower. However the only slight difference in slope suggests that the effect of simply not communicating with someone further away is greater as opposed to simply not using a particular channel. In an R&D environment such as this, face to face communication is sometimes absolutely essential and a premium is often put on obtaining answers to questions immediately. It also helps that being organized and co-located functionally, most of the technical experts that a staff may require is usually just a few cubicles away.

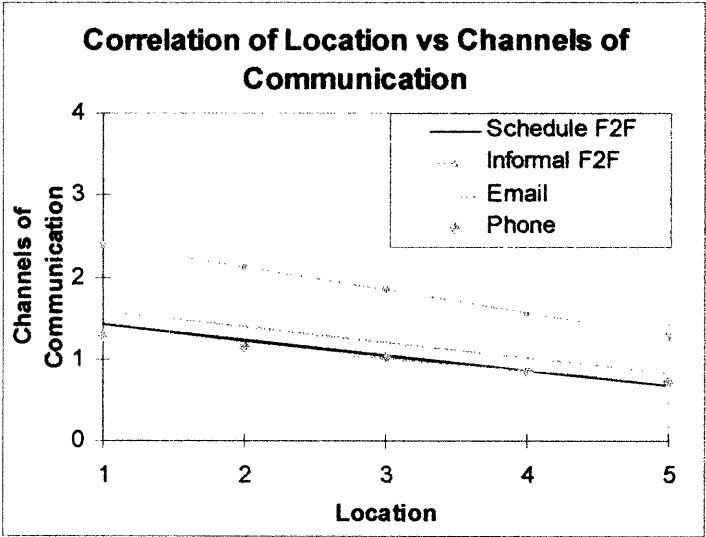


Figure 26 Plot of Correlation between Channels of Communication and Location

### 4.3 Discussion

The aim of this thesis is to answer some questions; the first question is “What are the various approaches people use to form their working networks?” From the data gathered, 56% of all regular internal (within the organization) contacts were made during project work, 18% due



to being in the same office<sup>8</sup> and 9% from social events. From a policy point of view, if management desires to ensure a high level of integration between several functional groups for strategic reasons, mechanisms could be put in place to encourage this. One method is to encourage project teams to be formed with different people from the same functional groups whenever possible. While this may result in lower efficiency in the beginning<sup>9</sup>, having this cross familiarity with members from both sides would encourage greater cross pollination of ideas. For external contacts, 28% of them are customers, 23% are personal contacts, 17% are suppliers and 14% former staff. These exogenous factors are usually not within the control of management although they can be an important source of ideas and inspiration.

The second question is “Which approaches generates the most *useful* contacts”. According to figure 6, contacts made during projects and by being in the same office generate the most useful contacts (Looking at the Technical and Innovation communication frequency). This is due to the specialize nature of its R&D work; contacts are usually useful only when the contact has the correct technical currency to contribute to the knowledge and solution relevant to the person involved. People involved in the same projects obviously have the required technical currency and due to the co-locating structure of functional expertise, the contacts made within the office are often people of the relevant expertise. This accounts for the usefulness of the contacts. It is interesting to note that the Innovation score is consistently below the Social score across all except for those formed under Special Tasks<sup>10</sup>. There are two possible reasons for this; first, the idea of innovation is quite vague and staff understanding of the difference between Technical and Innovation communication is quite undifferentiated. This results in people “under-declaring” the amount of innovation that is actually going on. Second, the engineers and scientist are often working on immediate and pressing deadlines hence the focus is usually on solving technical problems at hand to meet customer requirements. Innovation is regarded as an ad-hoc activity to be done when there is additional time. Communication with people outside the organization shows a pattern that is

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<sup>8</sup> Due to the functional delineation of the organization, these people are likely to be also of the same technological expertise.

<sup>9</sup> More socialization would have to take place if there were no prior relationships.

<sup>10</sup> Usually the purpose of these special tasks is to generate innovation, thus this skew. Also these special task teams usually have a shorter duration which results less socialization taking place which explains the lower level of Social communication.

rather focused. Staff usually talks to customer mainly about work and personal contacts are mainly for social purposes.

The third question is “How does strong intra-center/subunit connectivity and inter-center/subunit connectivity with people from other center impact performance”. Figure 8<sup>11</sup> and figure 9 shows the average contacts that staff have with people within the centers, within the organization and outside the organization. Both graphs show a large number of contacts within the centers. Looking at the correlation tables in figure 12, there is not a clearly positive or negative trend observed. However in looking at the trends of Innovation communication versus performance based on Award Garnered, there is actually a suggestion of a negative correlation (for both contacts within the organization and those outside). This seems to imply that tight internal cohesion within the center is better for performance as is defined in this thesis. However it is important to point out that this is only as true as how performance was defined in this study. The long term strategic impacts of having a good mix of inter and intra-center cohesion unfortunately cannot be ascertained from this study. One problem is that this survey is based on data collected within the past year, whereas the accumulation of effort that resulted in those awards occurred many years ago. Therefore there is this time lag that we are unable to quantify.

The fourth question is “How does the presence of people with strong networks within the center affect the performance of the center? Do the managers of these people recognize their value/contribution and how does it affect the usefulness of these connectors?” and the answer is shown in figure 18, 19 and 20<sup>12</sup>. One possible explanation to this trend is that centers with people who have strong networks are better at securing the confidence of potential customers and hence projects. The other is simply people with strong networks have access to timely and important information that plays a large role in solving problems. In our study the direction of causality is not clear.<sup>13</sup> From my communication with some of the managers,

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<sup>11</sup> Figure 8 shows contacts with which there are a high degree of Technical communication and figure 9 shows contacts with which there are a high degree of Innovation communication.

<sup>12</sup> The lack of data prevents us from confirming this, however this is what the data that is available suggests.

<sup>13</sup> Do these people have access to a lot of useful information because of their extensive networks or do they have an extensive network because they have access to information hence attracts people to them.

there does not appear to be a formal system in place to recognize or reward these people. However these people would probably be rewarded indirectly from the impact they generate by being in award winning teams or simply being given more resources to do interesting work.

The last question was “How does the willingness to build cross-level bonds (managers and junior engineers) impact the performance and efficacy of managers hence their centers?” Looking at the correlation of all the various performance measures and percentage of cross-level bonds, no statistically significant relationship was observed. This seems to suggest that managerial involvement does not positively impact the performance of the center. Besides what was discussed in chapter 4.1, in the context of this organization<sup>14</sup>, it is possible that staffs who are consistently high performers usually require very little managerial involvement. As such high performance centers may consist of high performing individuals who require minimal managerial involvement. So the net result is a lower level of managerial involvement and a higher level of performance observed. While this reasoning seems plausible, the question remains as to whether the center would have performed even better if these high performers were better managed. From my interactions with the staff and some of the managers, this hypothesis of high performers is unlikely since high performers usually want to be recognized. As such they would logically seek out the managers to discuss their successes. More data and targeted questions would be required to isolate these different effects to arrive at a satisfactory answer. However to attempt to gather data to make such inference may be difficult given the prevailing organizational culture.

In analyzing the performance measures to use, the metrics used for innovation appears to be somewhat negatively correlated with the other measures for performance. There are 2 possible reasons and they relate to the direction of causality; first is whether the resources spent on innovation is high because of the lack of resources for ‘regular’ projects? Or the focus on innovation and the activities related resulted in a scaling back on commitment to regular projects. Interestingly, the year which the data was gathered happened to be a lean

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<sup>14</sup> This organization consists of many of the best and the brightest in the country with a large percentage of the staff being granted highly prestigious scholarships to pursue tertiary or post-graduate degrees.

year where the customers for most of the centers scaled back on its R&D expenditures. At the same time there was a general slow-down in new hires and a scarcity of revenue generating projects. These events suggest that the resources that many of the centers sought were a result of its difficulty in fully loading its staff. This is not to say that the resources allocated to these innovation projects were squandered, but rather a dearth of revenue generating projects afforded some of the experienced staff time and opportunity to pursue more risky and innovative initiatives.

## Chapter 5 Conclusion

This study analyzed the responses from over 247 survey returns with a total of 2691 contacts reported for the 15 centers within the organization. While this number is fairly large, the total number of respondents represented only 25% of the total strength<sup>15</sup> of the organization. While the preliminary survey of the data obtained showed a reasonable representation of people across the demography, I did not have accurate staff demographic data to ascertain conclusively the robustness of the data. The gathering of data was quite difficult in this thesis because of cultural reasons as well as confidentiality requirements from the organization. Such a study of network is fairly new and several feedback from staff indicated that they found the questions intrusive. Perhaps over time as the value of this becomes more apparent, the level of resistance to such a survey would reduce.

The other difficulty encountered in this study was the lack of available formal data on the performance of the various centers. Several proxies were generated to overcome this, however these metrics may not be what the staff have been motivated to achieve although they may be nonetheless fairly good proxies.

This study was able to answer the various questions it set out to answer and while the data gathered is not as robust as might be desired, it does give a good indication of how social networks are made and maintained in this organization. It showed that contacts are usually made in the context of a need, and it is usually during the course of a project or a need for technical advice. The functional structure and business focus<sup>16</sup> of this organization also reduces the value of functional diversity in networks since most of the desired technical expertise that staff may require usually resides within the center they are from. This observation forms the main thrust for the conclusion and that is the data suggests an organization that is primarily focused on building functional depth and expertise. But it lacks the focus on product developments that requires cross-functional teams. This organization

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<sup>15</sup> Not including corporate staff.

<sup>16</sup> Each center is typically responsible for securing its own projects and funding, therefore customer needs that do not fit into the particular profile of anyone of the functional centers will have difficulty finding a champion.

seems to be still in a stage of technology build-up and have yet to move on to development of total products and solutions to meet customer's needs. Quoting from a conversation with a customer, "...My feeling is that ... (the organization)... was at a stage when they were trying to build up their technology expertise, but lately they have been trying to be more customer focused ...". As the organization moves towards focusing on customers and developing and delivering solutions<sup>17</sup> instead of technology, a positive correlation should start to appear between the E-I index and performance. The value of an organization should be greater than the sum of its parts (in this case centers) else the individual centers ought to function autonomously as it would increase the nimbleness of the centers and reduce its overheads. And there is no better place to observe if this is the case than by observing the cross-functional communication that is taking place.

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<sup>17</sup> Since the organization is organized functionally, a solution based on customer's need would require more cross center heavy-weight teams (Clark & Wheelwright) necessitating more cross center interaction.

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# APPENDIX A Knowledge Network Assessment

Welcome,  
FirstName  
Surname

Knowledge Network Assessment

Introduction

This Knowledge Network Assessment should take approximately **15 minutes** to complete. It is being administered by **Professor Jonathon Cummings** at MIT's Sloan School of Management. Your individual responses are confidential and will not be shared with fellow employees. Professor Cummings will analyze the data and provide results to the organization. The results will be used to assist the organization in understanding key elements of knowledge sharing and successful performance.

We strongly encourage you to complete the Knowledge Network Assessment, since the perspective of each participant is necessary for drawing valid conclusions. To start, click on the "**Begin the Assessment**" link below. Please complete this assessment by **January 31, 2004**

Thank you,  
**Sponsor**

## Begin the Assessment

Page	Title	Description
1	Network Information	Information about people you interacted with on a regular basis over the past 3 months.
2	Interaction Network	Information about your network interaction, such as who you shared task-relevant knowledge with about work-related topics.
3	Communication Frequency	Information about frequency of communication with each person in your network through face-to-face, phone, email, and SMS.
4	Key Moment	Information about a "key moment" that occurred during the past 3 months, such as an interaction with someone who exposed you to unique knowledge.
5	Background Information	Information about you, used to account for your past experiences in the organization.

### **Confidentiality Note**

Your responses are **confidential** and will **not** be shared with your fellow employees. In addition, your responses will be stored in a password-protected database separate from your name in order to ensure the privacy of the information you provide. All results will be reported back to the organization in aggregate, which means that your responses will not be identifiable to anyone other than Professor Cummings without your consent.

Network Information

Your network consists of people you interacted with on a regular basis over the past 3 months. This includes people inside of your Centre (Step #1 below) as well as others outside of your Centre (Step #2 below) or outside of DSO (Step #3 below).

**Step #1: People inside of your Centre**

Please indicate each person's relationship category, years known, location relative to you, and how you met.

Person (Surname, Firstname)	Relationship Category	Years Known	Location	How you met	If "other" state how you met...
Person 1	acquaintance	< 1 year	same room	regular projects	
Person 2	acquaintance	< 1 year	same room	regular projects	
Person 3	acquaintance	< 1 year	same room	regular projects	
Person 4	acquaintance	< 1 year	same room	regular projects	
Person 5	acquaintance	< 1 year	same room	regular projects	
Person 6	acquaintance	< 1 year	same room	regular projects	

**Step #2: People outside of your Centre, Inside of DSO**

Below are blanks for naming up to five people not listed above who are *outside of your Centre but inside of DSO*. (Please type first and last name)

Person (Surname, Firstname)	Relationship Category	Years Known	Location	How you met	If "other" state how you met...
	acquaintance	< 1 year	same room	regular projects	
	acquaintance	< 1 year	same room	regular projects	
	acquaintance	< 1 year	same room	regular projects	
	acquaintance	< 1 year	same room	regular projects	
	acquaintance	< 1 year	same room	regular projects	

**Step #3: People outside of DSO**

Below are blanks for naming up to five people not listed above who are *outside of DSO*. (Please type first and last name)

Person (Surname, Firstname)	Relationship Category	Years Known	Location	How you met	If "other" state how you met...
	acquaintance	< 1 year	same country	customer	
	acquaintance	< 1 year	same country	customer	
	acquaintance	< 1 year	same country	customer	
	acquaintance	< 1 year	same country	customer	
	acquaintance	< 1 year	same country	customer	

If you have any questions regarding this assessment, please contact [Jonathon Cummings](#).

**Confidentiality Note**

Your responses are **confidential** and will **not** be shared with your fellow employees. In addition, your responses will be stored in a password-protected database separate from your name in order to ensure the privacy of the information you provide. All results will be reported back to DSO in aggregate, which means that your responses will not be identifiable to anyone other than Professor Cummings without your consent.

Interaction Network

Below is a list of all people from the previous page. An interaction network characterizes the types of interactions you had with them.

Please indicate the extent to which, *during the past 3 months*, you interacted with them...

Person	... to share task-relevant knowledge about work topics	... to socialize or chat about non-work or personal topics	... to discuss new ideas or potential innovations for DSO
	1 = never      3 = sometimes      5 = a lot	1 = never      3 = sometimes      5 = a lot	1 = never      3 = sometimes      5 = a lot
<b>Person 1</b>	☺ 1 2 3 4 5	☺ 1 2 3 4 5	☺ 1 2 3 4 5
<b>Person 2</b>	☺ 1 2 3 4 5	☺ 1 2 3 4 5	☺ 1 2 3 4 5
<b>Person 3</b>	☺ 1 2 3 4 5	☺ 1 2 3 4 5	☺ 1 2 3 4 5
<b>Person 4</b>	☺ 1 2 3 4 5	☺ 1 2 3 4 5	☺ 1 2 3 4 5
<b>Person 5</b>	☺ 1 2 3 4 5	☺ 1 2 3 4 5	☺ 1 2 3 4 5
<b>Person 6</b>	☺ 1 2 3 4 5	☺ 1 2 3 4 5	☺ 1 2 3 4 5

[Previous Page](#)      [Next Page](#)

If you have any questions regarding this assessment, please contact [Jonathon Cummings](#).

**Confidentiality Note**

Your responses are **confidential** and will **not** be shared with your fellow employees. In addition, your responses will be stored in a password-protected database separate from your name in order to ensure the privacy of the information you provide. All results will be reported back to DSO in aggregate, which means that your responses will not be identifiable to anyone other than Professor Cummings without your consent.

Communication Frequency

For each person, please indicate **how frequently you communicated** with them *during the past 3 months* through face-to-face, phone, email, and SMS. For face-to-face communication, please distinguish between scheduled (e.g., planned meetings or discussions) and informal (e.g., spontaneous meetings or discussions).

Person	Scheduled Face-to-face	Informal Face-to-face	Phone	Email	SMS
<b>Person 1</b>	quarterly	quarterly	quarterly	quarterly	quarterly
<b>Person 2</b>	quarterly	quarterly	quarterly	quarterly	quarterly
<b>Person 3</b>	quarterly	quarterly	quarterly	quarterly	quarterly
<b>Person 4</b>	quarterly	quarterly	quarterly	quarterly	quarterly
<b>Person 5</b>	quarterly	quarterly	quarterly	quarterly	quarterly
<b>Person 6</b>	quarterly	quarterly	quarterly	quarterly	quarterly

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If you have any questions regarding this assessment, please contact [Jonathon Cummings](#).

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Your responses are **confidential** and will **not** be shared with your fellow employees. In addition, your responses will be stored in a password-protected database separate from your name in order to ensure the privacy of the information you provide. All results will be reported back to DSO in aggregate, which means that your responses will not be identifiable to anyone other than Professor Cummings without your consent.

Key Moment

A key moment -- or Ah Ha! moment -- with someone during the past 3 months is the source of inspiration or insight that sparked innovation. A key moment with someone could have exposed you to unique knowledge, allowed you to combine knowledge in new ways, or permitted you to discover the reuse of knowledge.

Thinking back on knowledge sharing *during the past 3 months*, **please describe one key moment** with someone which you believe was most influential for innovation (please include their **Surname and Firstname**).

Person (Surname, Firstname):

"Key Moment" Description:

Please characterize the key moment you have described above:

- |   |  |
|---|--|
| <b>Knowledge Sharing</b>                                | <b>Geographic Location</b>                             |
| <input type="checkbox"/> exposure to unique knowledge   | <input type="checkbox"/> someone within building       |
| <input type="checkbox"/> combine knowledge in new ways  | <input type="checkbox"/> different building            |
| <input type="checkbox"/> discover reuse of knowledge    | <input type="checkbox"/> different country             |
| <b>Organizational Structure</b>                         | <b>Hierarchical Status</b>                             |
| <input type="checkbox"/> someone within Centre          | <input type="checkbox"/> someone in lower hierarchy    |
| <input type="checkbox"/> different Centre               | <input type="checkbox"/> equivalent level in hierarchy |
| <input type="checkbox"/> different DSO                  | <input type="checkbox"/> higher in hierarchy           |
| <b>Communication Media</b>                              | <b>Contact Initiation</b>                              |
| <input type="checkbox"/> primarily through face-to-face | <input type="checkbox"/> I contacted person            |
| <input type="checkbox"/> through phone                  | <input type="checkbox"/> person contacted me           |
| <input type="checkbox"/> through email                  | <input type="checkbox"/> made contact by chance        |

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If you have any questions regarding this assessment, please contact [Jonathon Cummings](#).

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Background Information

In order to account for individual differences, some of the questions below ask about **your** past experiences in DSO.

Technical Seniority in DSO:  
AE

Hierarchical level in DSO:  
technical staff

Gender:  
female

Age:  
15-20 years old

DSO work experience:  
<1 year

Industry work experience:  
<1 year

National origin:  
Singapore

Educational experience:  
ITE

Primary language you speak fluently:  
Chinese

Number of different Centres you have had work assignments/positions in:  
1

Office Location:  
D BIK SP

Number of projects worked on during the past 3 months:  
1

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