Border-Crossing Knowledge Networking Among Multinational Firms: The Case of R&D Facilities

by

Ali Shirvani-Mahdavi

Submitted to the Department of Urban Studies and Planning in Partial Fulfillment of the Requirements for the Degree of
Doctor of Philosophy in Urban and Regional Studies

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ABSTRACT

I use social network methods, to (1) describe the extent of knowledge networks of R&D researchers at three facilities of a large Multinational Enterprise (MNE), dubbed AMBE Corp., located in Brazil, Canada, and China; (2) to analyze the role of personal attributes in the manner in which the individuals utilize their knowledge resources; and (3) to determine the influence of other internal and external factors that affect the respondents' knowledge networks. There are two knowledge networks under analysis are, (1) Knowledge Networks for Problem Solving, and (2) Knowledge Networks for Central R&D Innovation. The third network, Communication Tools for Knowledge Networking, examines the communication tools that support the above knowledge networks. The descriptive results show that although the respondents in the three facilities utilize a different mix of knowledge resources, they do a relatively effective job of bridging the gap between AMBE's global knowledge resources, particularly that of AMBE's Central R&D, with the external knowledge resources. In all three facilities, the external knowledge networking is conducted through specialized gatekeepers, with the exception of knowledge networking.

The quantitative results show that personal attributes influence knowledge networks differently. For problem solving, all of the personal attributes, with the exception of gender, influence the groups so that they have different knowledge-networking profiles, with none of the groups having more extensive knowledge networks than their comparison groups. However, for Central R&D innovation networks, personal attributes affect the knowledge networks so that men, managers, and respondents with more than 15 years of tenure, have more extensive knowledge networks, which is expected, given their additional knowledge resources. The respondents' urgency in looking for the relevant knowledge is the primary explanation for this difference between the two networks. This difference in knowledge networking among the different groups did not result in more similar knowledge networking, within each group, implying that there are additional factors that influence the networks. These factors are, (1) respondents' personal, job-related, and social resources; (2) resource distribution among R&D facilities; (3) management initiatives; (4) level of trust; and (5) facilities' histories and mandates, and how they are influenced by government policies. This study contributes to the current literature on globalization of R&D, knowledge management, and social network theory.

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This study is funded partially by the Laboratory for Energy and Environment (LFEE), and the Martin Family Society of Graduate Fellows for Sustainability, at MIT. In order to insure the confidentiality of the respondents who participated in this study, and to adhere to MIT's strict standards on using social surveys, this study was approved by MIT's Committee On the Use of Humans as Experimental Subjects (COUHES), Application Number, 2952. This study has certainly been a collaborative effort. First and foremost, I would like to thank all the respondents who participated in the surveys and personal interviews. Clearly, without their cooperation, honesty, and opinions, I could not have completed this study. I would also like to give my sincere gratitude to AMBE's Corporate R&D managers, as well as the directors and managers of the facilities in Brazil, Canada, and China. They showed me incredible courtesy and made me feel extremely welcomed in their countries, offices, and laboratories. At MIT, I would like to thank Professor Martin Rein for reviewing my dissertation proposal, and for his helpful suggestions regarding the overall scope of the study. I would especially like to thank Professor David Marks for his generosity and advice, not only during the completion of this study, but throughout my tenure at MIT. My gratitude also goes to Karen Gibson, and the entire staff at LFEE, for providing me with the resources to meet with my committee on a regular basis. However, my deepest gratitude goes to my Committee, who supported and guided me through an amazing learning process. I would like to thank Dr. Joanne Kauffman for staying on the Committee, and providing me with her amazing insight into writing a dissertation, despite the changes in the scope of the project and her departure from MIT. I would also like to give my sincere gratitude to Professor Eleanor Westney, for steering me onto the right path every time I started wandering from the topic at hand, and for providing me with knowledge so deep and clear that even I could understand it. In addition, I like to thank

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Finally, I would like to send my love and gratitude to my family. To my sister whose support, love, and belief in me transcended my own worst fears; to my brother, who kept me focused and energized by believing in me; and to my mother, who is still asking me every day what is it that I study. To My son, Beck, whose smile brightens my day, even in the middle of the night; to my daughter, Eden, whose sense of humor had me chuckling even as I was making yet another network map; and to my wife, Melanie, who kept me grounded, sane, and loved, through three years of multi-tasking. It is not an overstatement to say that without her, I would have rolled over and gone to sleep a long time ago. I would like to dedicate this dissertation to my late father, Mr. Hossein Shirvani-Mahdavi, who passed away nine months before I completed this study. Although, he never witnessed the completion of this study, I know he appreciated the fact that I was on the final stages of a path that I started so many years ago. I have no idea whether he sees or knows that I am done, but I do know that I miss him tremendously; thank you for giving me the sense of curiosity that has sustained me throughout these years.

CHAPTER 1: INTRODUCTION

1.1 Introduction

What role does personal attributes such as job position and tenure, as well as, culture and language, play in the way that individuals share knowledge in a firm? What impacts do factors, such as, resource allocation, informal social networks, trust, and facilities' histories and mandates have on the extent of individuals' knowledge networks? How do they affect the functioning of knowledge networks for innovation within firms? Can understanding of their role help multinational managers improve knowledge sharing across decentralized international R&D-unit boundaries, and thereby further promote innovation? These questions lie at the heart of this thesis, which is aimed at better understanding of the drivers of knowledge flows, and communication streams in geographically decentralized R&D organizations. By analyzing and understanding the impediments and facilitators of knowledge flow and communication streams, geographically decentralized R&D organizations may be able to manage and integrate their diverse knowledge sources more effectively. This is particularly significant in an era where the importance of electronic communication tools (E tools) is putting more emphasis on virtual and distant teamwork, and less on co-located and proximate problem solving.

In order to explore the above questions, I conduct a case study of a large, innovative MNE (dubbed AMBE for confidentiality reasons) with a long history of global R&D operations, as well as innovative product and technology development. After a number of discussions with AMBE's R&D management, we agreed that the most important and relevant R&D networks within AMBE to study were, (1) Knowledge Networks for Problem Solving, and (2) Knowledge Networks for Central R&D Innovation, for the employees of three global facilities, located in Brazil, Canada, and People's Republic of China (China). These two knowledge networks

correspond very well with the two primary job responsibilities of AMBE's R&D employees, which are, (1) to provide technical assistance and product enhancements to AMBE's customers, and (2) to be engaged in, and provide input into, AMBE's global product development and innovative research, most of which originates from AMBE's central R&D operations. In addition, because of the emerging importance of electronic communication, and virtual tools for effective knowledge networking, I examine their roles in supporting the above knowledge networks through my analysis of Communication Tools for Knowledge Networking (*CTKN*).

In order to conduct this study, I draw on literature from organizational models and globalization of R&D (e.g., Williamson 1985; Nadler and Tushman 1997; Stopford and Wells 1972; Westney 1998; Ghoshal and Nohria 1993; Granstrand, Hakanson, and Sjolander1992), studies of knowledge networks (e.g., Farace, Monge, and Russell 1977), proximity (e.g., Gertler 1995, 2001; Zeller 2002), and the evolving role of communication tools (Antonelli, Guena, and Steinmueller 2000; Plymale and Hartgrove 1999). The structure of this chapter is as follows. In Section 1.2, I provide additional background information on this study. In Section 1.3, I discuss my research approach, design, and the central propositions of this study. In Section 1.4, I describe the structure of the study, and I conclude the chapter in Section 1.5.

1.2 Study Background

Although the United States remains the world's Science and Technology (S&T) leader, a collection of trends in indicators of U.S. S&T competitiveness paints a more differentiated picture. Previously, the lower paid, labor-intensive U.S. industries fell victim to global competition; by the 1980s, however, U.S. high-tech industries also found intense foreign competition, especially from Japan and Europe, in markets they once dominated. And in the 1990s, competition opened on yet another front as several of the newly industrialized

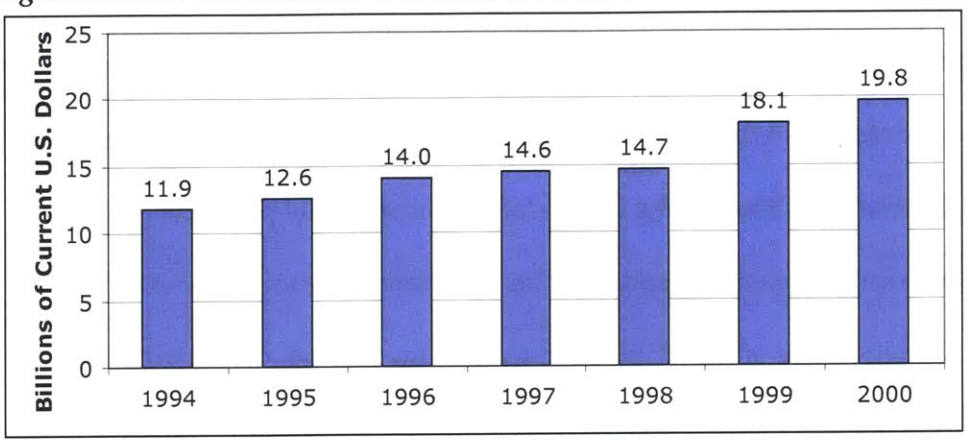
economies (NIEs) posed new challenges for U.S. producers. For example, since 1973, R&D performance in Japanese manufacturing industries grew at a higher annual rate than in the United States; since 1980, it has grown faster than in all other industrialized countries. In Science and Engineering (S&E) research output, as measured by publications in the world's key journals, the U.S. share continues to decline, indicative of the development of cutting-edge research capabilities elsewhere. Although the U.S. balance in intellectual products trade remains positive, it is showing signs of a gradual decline (National Science Board 2004).

Furthermore, the U.S. share of the global high-technology market, measured as the percentage of global industry shipments, declined from a high of 33 percent in the early 1980s to below 30 percent in 1991, where it has since held steady, and, the U.S. high-technology exports declined from 23 to 19 percent of the world's total during the 1990s (National Science Board 2004). Finally, even as larger proportions of U.S. citizens avail themselves of higher education, United States lost the advantage it held for several decades, as the country offering by far the most widespread access to higher education. Starting in the late 1970s, and accelerating in the 1990s, other countries built up their postsecondary education systems, and a number of them now provide a first-level college degree to at least one-third of their college-age cohort, and there is evidence that many countries are trying to increase production of degrees in natural sciences and engineering (National Science Board 2004).

Confronted with this global dispersion of S&T activities, major MNEs in Organization of Economic Co-operation and Development (OECD) countries, particularly those in the United States, began to locate their R&D facilities in these emerging regions, where they could tap into these growing networks of knowledge and expertise. To illustrate, Figure 1.1 shows that the amount of R&D spending by U.S. MNEs in foreign countries increased from $11.9 billions in

1994 to $19.8 billion dollars in 2000, for an increase of over 70 percent (National Science Board 2004).

Figure 1.1: U.S. Owned R&D Overseas, 1994-2000



Source: *Science and Technology Indicators 2004.*

The above shift in R&D investments created new challenges for both home and host-countries policy-makers, as well as, MNEs' management. The challenge to the home country is the continued erosion and flight of national expertise, technological know how, and innovative capacity. For host countries, the policy makers needed to insure that their scientists and researchers were included in the MNEs' knowledge networks and value chains, so that the hosting of these R&D facilities could lead to the establishment of local innovation clusters. Host-country governments are eager to attract the R&D facilities of MNEs by investing in basic infrastructure, and technical education, in their desire to see the local employees engage in MNEs' border-crossing and local knowledge networks. Finally, the challenge for MNEs' management is to make certain that the additional investments in locating an R&D facility in host countries, pay dividend by tapping into these emerging local knowledge networks, which are comprised not only of their technically-educated employees, but also, customers, suppliers, and other firms and R&D facilities.

One of the critical areas where the interactions of local knowledge resources and MNEs' global knowledge networks can be beneficial to both the innovation process within the MNE and to host-country policymakers, is through enhanced development of environmental innovations. There are two reasons why this should be the case. First, the combination of world-class innovative capabilities of large MNEs, with the knowledge of local environmental scientists who are familiar with their local and regional environmental problems, could result in innovative solutions to otherwise intractable problems. Second, MNEs could benefit from this collaboration, because the end result may be the development of products with a potentially large customer base. This is because, for MNEs, if markets exist, they undertake even radical change to satisfy them. All the companies monitor their customers' willingness to pay for environmental attributes. Firms track global trends in resource scarcity, environmental regulations, voluntary product standards, and customer environmental priorities and needs, so they can respond rapidly to emerging markets.

So the key question is whether there is any evidence that MNEs engage in these beneficial border-crossing knowledge networks. I examined this question in an earlier study of knowledge networks for environmental innovations among the R&D scientists of geographically dispersed facilities of a large MNE. In both the previous and current study, I focus on the knowledge networks themselves, rather than on the role of policy-makers and their interactions with MNEs, because of the importance of these networks to both MNEs and host-country governments and policymakers. Without the effective utilization of these knowledge networks, most of the benefits associated with these globalization efforts may not be realized. In my previous study, the knowledge network under analysis was Knowledge Network for Environmental Innovation, and the knowledge sources were those of suppliers, customers, universities or other local firms or facilities. Knowledge networks for Environmental

Innovations are important, both because they contribute to the development of environmentally friendly technologies, but more relevant to this study, because the knowledge itself is complex and often requires input from multiple sources and stakeholders. My previous study showed large differences in the extent and level of knowledge networks among the geographically dispersed facilities. However, through my personal interviews with the key actors in these knowledge networks, I came to the conclusion that personal attributes, such as position, tenure and gender, as well as culture and language, may play a significant role in the way that individuals share their knowledge, and influence the extent and efficacy of their knowledge networks.

The impetus behind the current study came from my previous research, and the key questions that were left unanswered at the end of that project became the basis for this study. The most important of these questions was to understand why employees at these R&D facilities did not utilize all the knowledge resources they had at their disposal. Despite the change in focus from Knowledge Networks for Environmental Innovation, to Knowledge Networks for Problem Solving, and Knowledge Networks for Central R&D Innovation, there is evidence in the literature that there are some similarities between Knowledge Networks for Environmental Innovation and other business-related R&D knowledge networks. For example, analysts discuss the growing importance attached to networks that link actors for a variety of R&D functions, including the development of environmental innovations. As such, institutional theorists work from the principle that organizations are in complex relationships with other actors in society, responding to their pressures and signals through a range of repertoires, including market forces, policy devices, and regulation (DiMaggio and Powell 1991; Oliver 1991), some of which lead to organizational change directed toward innovation in general and environmental innovation in particular (Carley and Christie 1993; Jennings and

Zandbergen 1995). These ideas about knowledge and organizational networks suggest that sustainable development will involve networks of organizational and individual actors forming and reforming action-learning collaborations that lead to social and technological innovations and adaptations (Roome 1998).

However, there are also major differences between two networks. As I stated above, both Knowledge Networks for Problem Solving and Knowledge Networks for Central R&D Innovation are formed to support the specific job tasks of AMBE's R&D employees. Knowledge Networks for Environmental Innovation, on the other hand, does not correspond to any of the *mandated* tasks of the AMBE R&D employees. As such, whatever shape Knowledge Networks for Environmental Innovation networks take within AMBE, they will have more of an informal and temporary characteristic to them than either of the two knowledge networks under analysis in this study. This can be due to the fact that MNEs, such as AMBE, have not yet understood, or learned how, to embed environmental goals into their structure the way they have, say, health and safety. However, that is not to say that AMBE could not have robust Knowledge Networks for Environmental Innovation, formed for projects that have an environmental component to them, or through communities of practice of scientists and engineers who have a special interest in environmental innovations outside of their formal job requirements. These networks could tap into multiple internal, local, and global knowledge resources, and may very well contribute to the knowledge reservoir of environmental innovation within AMBE.

Knowledge Networks for Environmental Innovation remain an important topic to study, not only because they are critical in the development and promotion of environmental technologies, but also because the environmental-innovation process involves the creation and dissemination of very complex knowledge across multiple actors, such as suppliers, customers,

academia, and government agencies, who could be geographically dispersed across multiple locations, which are characteristics of most R&D knowledge networks.

1.3 Research Propositions, Approach, and Design

My objectives in this study are, (1) to determine the extent of knowledge networking of individuals in globally dispersed R&D facilities with their global, local, internal, and virtual knowledge resources; (2) to examine the relative importance of the underlying factors that influence the extent and efficacy of these internal, external, and border-crossing knowledge networks among researchers in these facilities; and (3) to show that personal characteristics of individual and the attributes of their facilities, influence the scope and effectiveness of their knowledge networks, both directly through the individuals' informal and formal networks, and indirectly, through the tools individuals utilize to facilitate the flow of their communication. These objectives lead directly to the following three propositions.

1.3.1 Research Propositions

Research Proposition 1: As I showed above, one of the most important aspects of MNEs' efforts to globalize their R&D efforts is their participation in the local knowledge networks of the relevant sources of knowledge and expertise in the host countries. These networks provide the MNEs and local stakeholders with valuable insight and expertise that is beneficial to all of the members of these networks. At the same time, although these facilities are located in geographically dispersed locations, they are still part of a 'network' of MNEs' global R&D facilities. As such, these facilities are at the center of knowledge networks that connect robust global, MNE-specific knowledge, with extensive local knowledge resources. In this sense, these facilities span the gap in the knowledge network that exists between the local knowledge sources, and the MNEs' global knowledge resources (Burt 1992). These gaps, which Burt (1992)

termed structural holes, present an opportunity to these global facilities to broker the flow of information between global and local knowledge resources, making their roles extremely important in the border-crossing knowledge networks. In social network analysis, the idea of an organization, such as an R&D facility, filling the gap presented by a structural hole is quite unique. In fact, in majority of cases, it is the entrepreneurial and opportunistic actors in social or knowledge networks that span these structural holes (Burt 1992). As such, the overall effectiveness of these facilities is dependent on their robust knowledge networking with *both* local knowledge resources that are external to the MNE, and global knowledge resources that are internal to the MNE. It is important to note that the networking can take place through specialized gatekeepers who can expose the facilities to these knowledge resources in an efficient manner, or through the utilization of electronic communication tools, or virtual knowledge repositories. As such, my first proposition is:

> *In order for MNEs to fully realize the benefits of their R&D globalization efforts, they must have robust knowledge networking with both their global, internal knowledge resources, as well as with their local, external knowledge resources.*

Research Proposition 2:

The advantages of heterogeneous groups of interactions are well established in both social theory and network analysis (Burt 1982; Walker, Kogut and Shan 1997). Individuals with a broad network range are exposed to more experiences, different competencies, and added opportunities for discussion and debate, than those with narrower networks range. From this perspective, "innovation occurs at the boundaries between mind sets, not within the provincial territory of one knowledge and skill base" (Leonard-Barton 1995, p. 62). By having access to a diverse set of activities, experiences, and collaborators, individuals can broaden the resource and knowledge base on which they draw. This is especially important in the R&D arena, where the complexity and multi-faceted nature of problems and their solutions require diverse sets of

skills and backgrounds (Powell and Owen-Smith 1998). When relationships are deepened, greater commitment and more thorough knowledge sharing should follow.

This poses two important questions. First, do individuals have the capacity to establish and manage broad and expansive networks that span geographies, as well as, competencies and positions in the supply chain and the regulatory environment? Second, what personal characteristics, and resources, increase the individuals' knowledge-networking capacities? For example, as their tenure within their firms and facilities increase, individuals may have incentives to develop deep and/or diverse collaborations with a wider array of partners than they had before. Establishing formal ties across multiple disciplines, countries, and interested parties, requires time, which makes the tenure of individuals very important. New employees need to build credibility with fellow employees, customers, suppliers, and regulators, to overcome initial reservations toward new contact persons. In summary, the more experienced individuals become at collaboration, the more they will establish a reputation for being reliable partners so that others will perceive them as unlikely to act opportunistically.

In reality, there are two types of tenure individuals can draw upon for their knowledge-networking activities. The first is the amount of time an individual has been with the firm (*firm tenure*), and the second is the amount of time the individuals has been working at a particular facility within the firm (*facility tenure*). Increased firm tenure gives individuals the opportunity to be exposed to more diverse knowledge sources across the firm, making it a more relevant attribute when discussing border-crossing networks. Facility tenure, on the other hand, allows individuals to create strong, localized knowledge networks, which can expose individuals to expansive local, and facility-wide knowledge resources. Regardless, increased tenure levels can have a positive effect on the extent of both local and border-crossing knowledge networks.

Another aspect of increased tenure level that can have a direct impact on individuals' knowledge networks is that employees with longer tenure may also be those employees in management positions. As such, individuals' positions alone could also influence the shape and extent of their knowledge networks by giving them access to individuals, both within and outside the firm that is otherwise not available to individuals outside management positions.

The above arguments suggest that individuals in positions of power, as well as those with long tenure, play a critical role in binding networks together, deepening, extending, and reshaping these networks for innovative activities and problem solving. Alternatively, an inner circle of key participants may dominate the knowledge networks, and these centrally positioned individuals can reap great rewards from their strategic locations in knowledge networks. Historically, this inner circle might well comprise an elite mix of male individuals from the facilities, their male colleagues from other facilities in the firm, research institutions, regulators, Non-Governmental Organizations (NGOs), and providers of other key resources who play a disproportionately important role. If this is in fact the case, then this discrepancy should be noticeable in the extent and diversity of internal and border-crossing knowledge networks among male and female individuals in these facilities.

Finally, as part of my previous research into the globalization of R&D facilities, I heard about anecdotal evidence that there is a strong relationship between individuals' culture and language, and the manner in which they use their social and knowledge networks (Shirvani-Mahdavi 2001, p. 172). A number of writings (Quinn and Holland, 1987; Fischer, 1988; Trompenaars, 1993; Hofstede, 2001; Bigoness and Blakely, 1996) conclude that cultural aspects are extremely important to consider in the processes of knowledge creation, sharing and utilization. By selecting respondents from three national facilities, I can examine the

relationship between culture, language, and knowledge networking. In this case then, location is a proxy for these attributes. The above discussion leads to my second research proposition:

> *There are underlying personal characteristics that affect the knowledge networking of R&D respondents, regardless of the network under analysis. These characteristics are gender, position, firm tenure, facility tenure, and location, which is a proxy for language and culture. The influence of these factors results in managers, men, and individuals with longer tenure to have more extensive knowledge networks, and for the respondents from the three facilities to have distinctly unique knowledge networks.*

Research Proposition 3:

The premise behind *Proposition 2* is that personal attributes affect individuals' knowledge networking, resulting in different knowledge networks for the individuals in the different groups. However, this does not imply that the individuals within the same group would have more similar knowledge networks. For example, through *Proposition 2*, I expect managers and employees to have distinctly different knowledge networks, with managers having access to, and utilizing more, of their available knowledge resources than employees. However, this proposition does not imply that all managers utilize the same knowledge resources, and exhibit the same knowledge-networking characteristics. The reason is that there are other internal and external factors that can also influence the extent of the individuals' knowledge networks. These factors and attributes include the respondents' social, personal and job-related resources, management initiatives, and facility characteristics. What these factors have in common is that they can influence the respondents' awareness, level of access, and rate of utilization of these knowledge resources. As such, my third proposition is:

> *There are internal and external factors, such as respondents' social, personal and job-related resources, management initiatives, and facility characteristics, which can influence the individuals' knowledge networks, resulting in dissimilar knowledge networks among individuals who have similar personal attributes.*

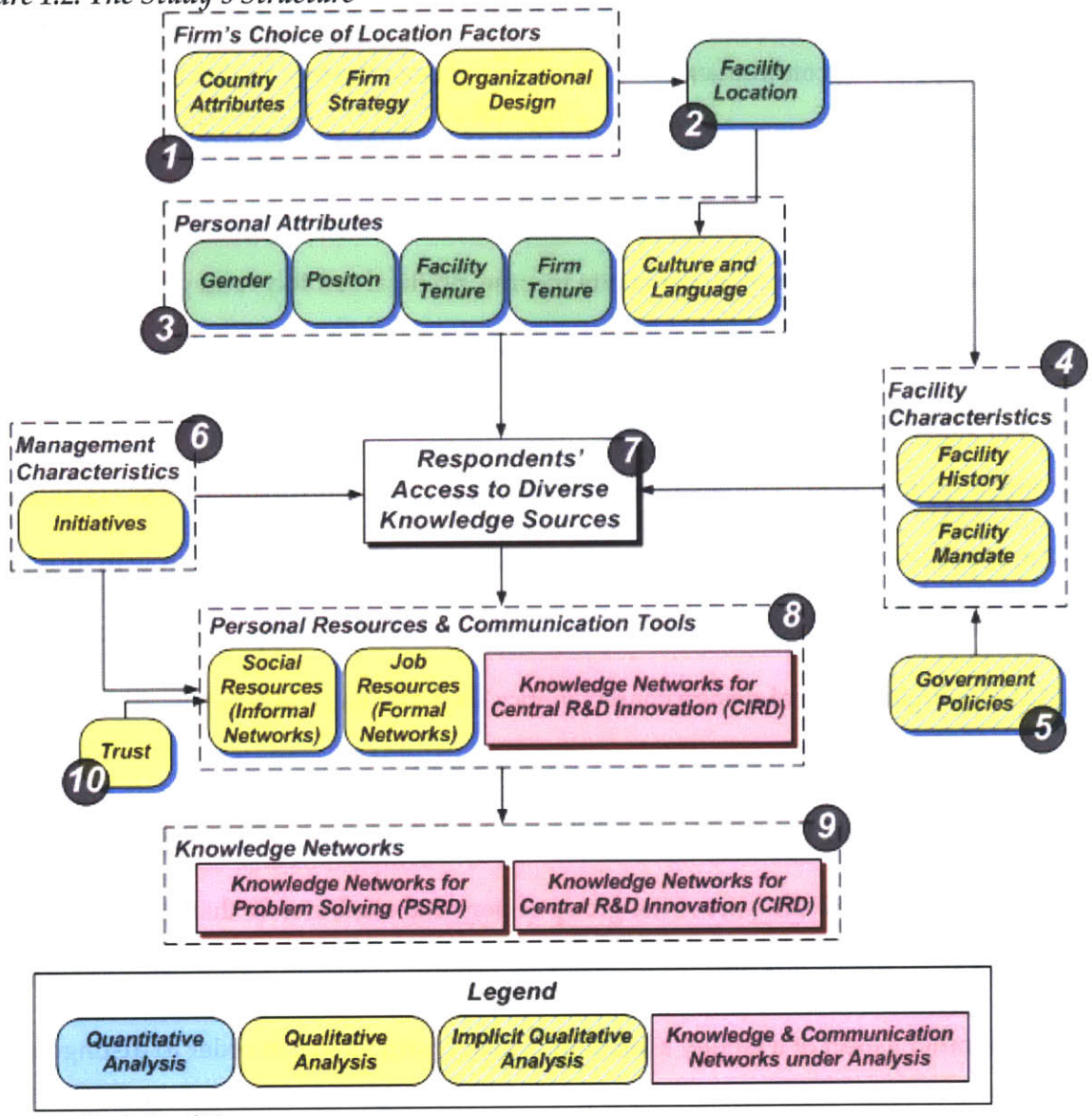
1.3.2 Research Approach

Figure 1.2 shows the association among the factors and attributes under analysis in this study, and their relationships to the two knowledge networks under analysis in this study, as well as their supporting communication tools. Starting from the top, the boxes in ① show the decision-making factors that determine the location of facilities among multinational firms. The most important of these are the host-country attributes, including the country's natural and intellectual resources, market size, per capita income, political stability, and geographical location. The second of these is AMBE's overall corporate strategy, including, but not limited to, its globalization plans. Finally, AMBE's organizational-design characteristics, and its management commitment to diversifying, decentralizing, and globalizing its R&D facilities, and their distribution of critical resources across these facilities, play a significant role in its decision to situate a facility in a foreign country. Of these qualitative factors, my main area of focus will be on AMBE's organizational-design characteristics, in particular AMBE's allocation of resources among its global, US, and Central R&D facilities.

As I stated above, I use the location of the facility ② as a proxy for language and culture of the respondents, which are part of the group of personal attributes ③ that, as I showed above, may have a strong influence on respondents' access to diverse knowledge resources ⑦. However, another aspect of a facility's location, which I term its *site*, in order to distinguish it from its role as a proxy for language and culture, can also influence respondents' level of access to different knowledge resources. The most important of these characteristics, the facilities' histories and mandates ⑥, are influential in the level of respondents' access to different knowledge resources. As such, the site of a facility influences its mandate, its relationship to other facilities and headquarters, the manner in which it evolves in the context of the firm's overall strategy, its history, its product portfolio, research agenda, and overall policies. All all

these, in turn, can have important effects on the manner in which the respondents in the facility utilize their knowledge resources, and utilize their communication tools.

Figure 1.2: The Study's Structure



Source: *Author's Rendition.*

Furthermore, host-country government policies can influence the way facilities function and evolve ⑤. Government policies are important in this context because they can affect facilities' mandates, for example through strict or relaxed enforcements of intellectual property rights, but also because through broader civil-society regulations, which can influence the manner in which respondents communicate with each other, and more importantly to their

colleagues in other facilities, and other knowledge-producing and consuming bodies, such as universities and NGOs.

Another factor, management initiatives ⑥, can also have a profound impact on the manner in which respondents utilize their knowledge resources, directly through their resource allocation, and indirectly, through initiatives that require more knowledge networking, and by designing projects that tap into specific knowledge resources. In addition, the level of trust ⑩ between and among respondents from different facilities can influence the utilization of the resources they have at their disposal. In particular, the level of trust would tend to favor the respondents' utilization of knowledge resources that are familiar, and disfavor those resources that are unfamiliar.

All of the above factors affect the respondents' level of access to different knowledge resources and the rate of their utilization. One of the key and reasonable assumptions I make in this study is that respondents cannot utilize knowledge resources they are not aware of or cannot access. Although access and awareness of all the available and relevant knowledge resources is a critical precondition in knowledge utilization, it is not sufficient in explaining the differences in knowledge networks. Once an individual becomes aware of a knowledge resource, it is the resources' level of usefulness, trustworthiness, and availability that turn them into practical and frequently-utilized tools for problem solving and innovative research. Finally, respondents' personal, social, job-related, and communication resources ⑨, turn knowledge resources to robust tools for knowledge networking for problem solving and Central R&D innovation.

1.3.3 Research Design

To conduct this study, I collected data from three R&D facilities of AMBE Corp. in Brazil, Canada, and China. I chose the facilities in these three countries for two reasons. First, they have distinctly different historical growth paths, and business mandates. Brazilian facilities' mandate and history closely mirror the geopolitical evolution of the Brazilian government's policies, which resulted in periods of tremendous growth and importance within AMBE, as well as episodes of limited contribution. Canadian facilities, on the other hand, experienced steady growth, and because of their proximity to the Central facilities, they have closely followed the direction of the U.S. Central facilities. Finally, the Chinese facilities came into operation much later than the Brazilian or Canadian facilities, but have been growing at an incredible pace and are slated to expand at a much more rapid rate than the facilities in the other two countries. The second reason I selected the facilities from the three countries is because of the differences in the respondents' history, language, and culture.

The primary motive in collecting quantitative data is to understand the extent and diversity of global knowledge networks among the employees of the three facilities, as well as, the effects of the respondents' personal attributes on their knowledge networks. This relates directly to *Propositions 1 and 2*. Alternatively, my purpose in conducting the qualitative personal interviews is to recognize some of the external factors behind the differences between shape and size of the knowledge and communication networks that I identify through the web surveys, which relates to *Proposition 3*.

I use two social network methods to analyze the importance of personal attributes in the shape and extent of the respondents' networks. Status measure is the social network tool to measure importance and popularity, and is the method I utilize to understand the importance of the different resources and tools, as well as to examine the extent of the respondents'

networks based on their personal attributes. I use the second tool, equivalence, to examine the level of similarity between the knowledge and communication networks of different groups of individuals. The principle behind equivalence analysis is that if there is a correlation between the underlying attribute and the shape and extent of the network, groups sharing that attribute should have larger equivalence scores than the population as a whole. In this case, a larger equivalence score means that the respondents have more similar networks than the population as a whole.

1.4 Structure of the Dissertation

In Chapter 2, I present the pertinent background literature on the most relevant drivers behind the globalization of R&D, that is proximity to sources of knowledge and expertise, as well as the organizational models that can support MNEs' efforts in globalizing their R&D operations. The third literature strand is on characteristics of knowledge, different types of knowledge networks, including local, internal, external, and border-crossing knowledge networks. Finally, I provide the background literature on the factors that influence individuals' knowledge networking, such as gender and position. In Chapter 3, I provide the background information on AMBE, including an overview of its technology portfolio, a historical analysis of its organizational-design characteristics, as well as, its R&D globalization activities, and relevant management initiatives. Chapter 4 is the methodology chapter, with sections on data gathering, research design, social analysis methods, and how these methods provide the tools by which I can use the data to answer the questions I pose in this study. In Chapter 5, I present the network maps and the results of the descriptive analysis for the networks for the three facilities, in addition to the descriptive gatekeeper analysis. Chapters 6 and 7 are the results and analysis chapters for communication tools and knowledge networks. In Chapter 7, I focus on

communication tools, and how personal and facility characteristics affect the level of usage and usefulness of communication tools. I also present the qualitative analysis that provides explanations for the results, both from the results of the personal interviews, as well as evidence from literature, in Chapters 6 and 7. I conclude the study in Chapter 8, by presenting an overview of the results, the contribution to literature and identification of future research needs.

1.5 Conclusion

The idea behind this study came from my research into informal social networks of R&D scientists working on environmental innovations for a large chemical company (Shirvani-Mahdavi 2001). The findings from my previous study showed that despite the management's initiatives to foster border-crossing knowledge networks, the most robust knowledge networking took place within the individuals' R&D facilities, and the extent of the border-crossing knowledge networks were limited (Shirvani-Mahdavi 2001). The key questions that were left unanswered at the end of that project became the basis for this study. As such, the purpose of this study is to, (1) show the extent of knowledge networking among the respondents from the three facilities with their global, local, virtual, and inter-facility knowledge resources; (2) test the relative importance of respondents' personal attributes, as well, as other internal and external factors, such as facilities' locations, and the utilization of their communication tools; and (3) the impact of these attributes and factors on the level of respondents' access to different knowledge resources, which affect the flow of knowledge among respondents of geographically dispersed R&D facilities of a large MNE. In Chapter 2, I present the relevant literature in order to provide the necessary foundation for the results and analysis chapters.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The trend for firms to globalize their research and development efforts is growing, and in every type of industry, outsourcing, alliances, consortia, partnership, and direct decentralizing of R&D around the globe, is now a commonplace pattern of conducting research and development. In Part I of this chapter, I explore the theoretical foundations, motivations for, and enablers of globalization of R&D. For this study, the most relevant driver for globalization of R&D is proximity to sources of knowledge and expertise. In this context, knowledge networking is of primary importance to successful globalization of R&D, and leads to the second part of this literature review, which is on the different types of knowledge networks that Multinational Enterprises (MNEs) utilize in order to tap into these diverse knowledge resources. The seminal research by Allen (1977) showed that the probability of two R&D professionals communicating with each other strongly depends on the physical distance separating those professionals. Additional research in this field concluded that the frequency of communication between a central research laboratory and a foreign subsidiary declines exponentially with physical distance (e.g. Hough 1972; Gertler 1995).

Combined, these studies show the importance of physical distance in knowledge networking among scientists in geographically dispersed R&D facilities. In this study, I question the validity of this *broad* conclusion by examining whether physical distance affects respondents' utilization of different knowledge resources equally. Furthermore, I analyze the influence of other underlying factors that diminish or increase the influence of physical distance in the manner in which individuals utilize their border-crossing knowledge resources.

In Part II, I present the literature review on the most pertinent aspects of the knowledge networks, including the factors that affect knowledge networking. For example, for the border-

crossing knowledge networks, I focus on those proximity characteristics that impede the flow of knowledge, such as physical, organizational, knowledge, relationship, and cultural distance. In this case, organizational distance refers to the degree of congruity between the organizational environments facing the two parties (Kostovo 1999), while knowledge distance refers to how large a gap exists between the source and the recipient in terms of their knowledge bases (Hamel 1991). Alternatively, relationship distance refers to the duration and quality of experience that the source and recipient have working together (Child and Rodrigues 1996). Finally, cultural distance refers the level of dissimilarity in the cultural background of the source and recipient (Gertler 1995). For the local knowledge networks, I concentrate on those features that facilitate the knowledge exchange, such as the importance of proximity, and its influence on learning regions. Finally, I focus on aspects of virtual knowledge networks, which replace and augment other types of knowledge networking, for example, through enhanced communication methods, and access to online documents and information. In Part III, I present the relationship between the global organizational models that I describe in Part I, with the type of knowledge networks these models require and utilize from Part II. I conclude this chapter by categorizing the knowledge networks that are under analysis in this study within the context of the literature that I present in this chapter.

2.2 Globalization of R&D

Along with proximity to sources of knowledge and expertise, the other strategic drivers behind globalization of R&D are shorter product development cycles, global competition, increased customer expectations, and technological risks (Boutellier, Gassman, and von Zedtwitz 1999). Input-oriented factors encompass drivers related to personnel, know-how and infrastructure. Physical proximity to markets and customers are output or product-oriented

factors. Furthermore, political and socio-cultural factors, such as local-content rules, technology acceptance, public-approval times, and regulations enforcing intellectual property rights in the host country, play an important role for MNEs to locate R&D abroad (Beckman and Fischer 1994). Direct cost advantages, such as labor costs, rarely influence the internationalization of R&D, but other economic efficiency-oriented factors, such as costs of coordination and transfer, as well as, critical laboratory size, do have an important impact. However, direct costs may become more important in the coming years, as other factors, such as, robust communication infrastructure, are no longer an issue in low labor-cost countries. Relevant to this study, the following five drivers are the most important factors behind MNEs' decisions to globalize their R&D operations.

(1) Proximity to Markets: Proximity to customers provides researchers with direct, unfiltered insight into customer needs, which, in turn, allows them to be more responsive in designing and developing their products for that particular market (Granstrand, Håkanson and Sjörlander 1992). MNEs' needs for continual testing and interaction with customer requirements necessitate the establishment of a local R&D facility.

(2) Proximity to Suppliers: In addition to proximity to markets, global R&D affords proximity to suppliers (Granstrand, Håkanson and Sjörlander 1992). This is particularly important in industries where there is a monopoly-monopsony relationship between the producer and the supplier, such as the automobile industry. This relationship allows the suppliers and the manufacturers to engage in joint R&D ventures in order to minimize risks and to satisfy diverse final-customer demand.

(3) Proximity to Sources of Knowledge and Talent: Technology development is very parochial, which results in an uneven distribution and concentration of technology development across the world. As such, to gain access to the output of these concentrated sources of technology,

firms have to be physically close to them, and participate in the local network of technology production (Granstrand, Håkanson and Sjörlander 1992). Given the difficulties of trading in technological know-how, in particular, the fact that MNEs often need to transfer people in order to share technological knowledge, the internal mechanism for creating laboratories close to the sources of knowledge can be more efficient than a pure market transaction through a contract, that is, buying technology (Granstrand, Håkanson and Sjörlander 1992).

(4) Stimulating Innovation: The blending of different educational systems, market environments, and customs in global R&D programs can generate new innovations. But even if the net effect is simply to avoid reinventing the wheel, MNEs are well served (Granstrand, Håkanson and Sjörlander 1992).

(5) Ability to Influence Research: MNEs can influence research agendas through close collaboration with learning institutions, and through funding the research that is part of their research agenda (Granstrand, Håkanson and Sjörlander 1992).

In addition to the above drivers, MNEs must consider the institutional environment of the host country where MNEs plan to operate their R&D operations. This consideration comes into play *after* MNEs have made the decision to globalize their R&D operations, and during the phase when they select the specific country to locate their R&D facilities. There is evidence in the literature that institutional checks, low incidence of corruption, and a political and economic environment that is generally considered low-risk, serve as effective proxies for a governmental climate that is respectful of private property rights, including intellectual property, which influences MNEs' choice of an international location (Lee and Mansfield, 1996; Seyoum, 1996). In this study, I examine the role of government policies that shape the facilities' history and mandate, and its impact on the knowledge networking of the individuals working in the facility, specifically through the case of Brazil.

2.3 Globalization Strategies for R&D: The Role of Organizational Models

R&D has been the last function of the corporation to go abroad, because managers of MNEs have considered the benefits of centralizing R&D to be very high. Therefore, I present geographic centralization as the base case with which to compare the other five-globalization strategies. Westney (1998) evaluated each strategy in terms of the criteria for a successful R&D function, and the comments on the advantages and disadvantages of each method are based on this evaluation. Table 2.1 shows the features of the six models of global R&D organizations.

The six R&D models presented in Table 2.1, range from the centralized R&D structures of *Home-Based R&D Unit* (Model 1), with its emphasis on concentrating all R&D activities in the home country, to the *Flexible Network Model* (Model 6), which focuses more on flexibility of assigning lead roles to R&D facilities on a project-by-project basis. The remaining four models scale the range between Models 1 and 6. As is apparent from Table 2.2, the advantages of the centralized models (Models 1 and 2) are low coordination costs, economies of scale, and reduced possibility of technology leakage. Alternatively, the advantages of the decentralized model (Models 3, 4, 5, and 6) are proximity to customers, access to expertise and diverse technical solutions, as well as flexibility. The disadvantages of the centralized model are ethnocentrism, distance from the customer, and inflexibility in applying technical solutions to diverse global problems, while those of the decentralized models, are high coordination costs, redundancy in infrastructure and capabilities, and the inability of small R&D labs to reach critical mass.

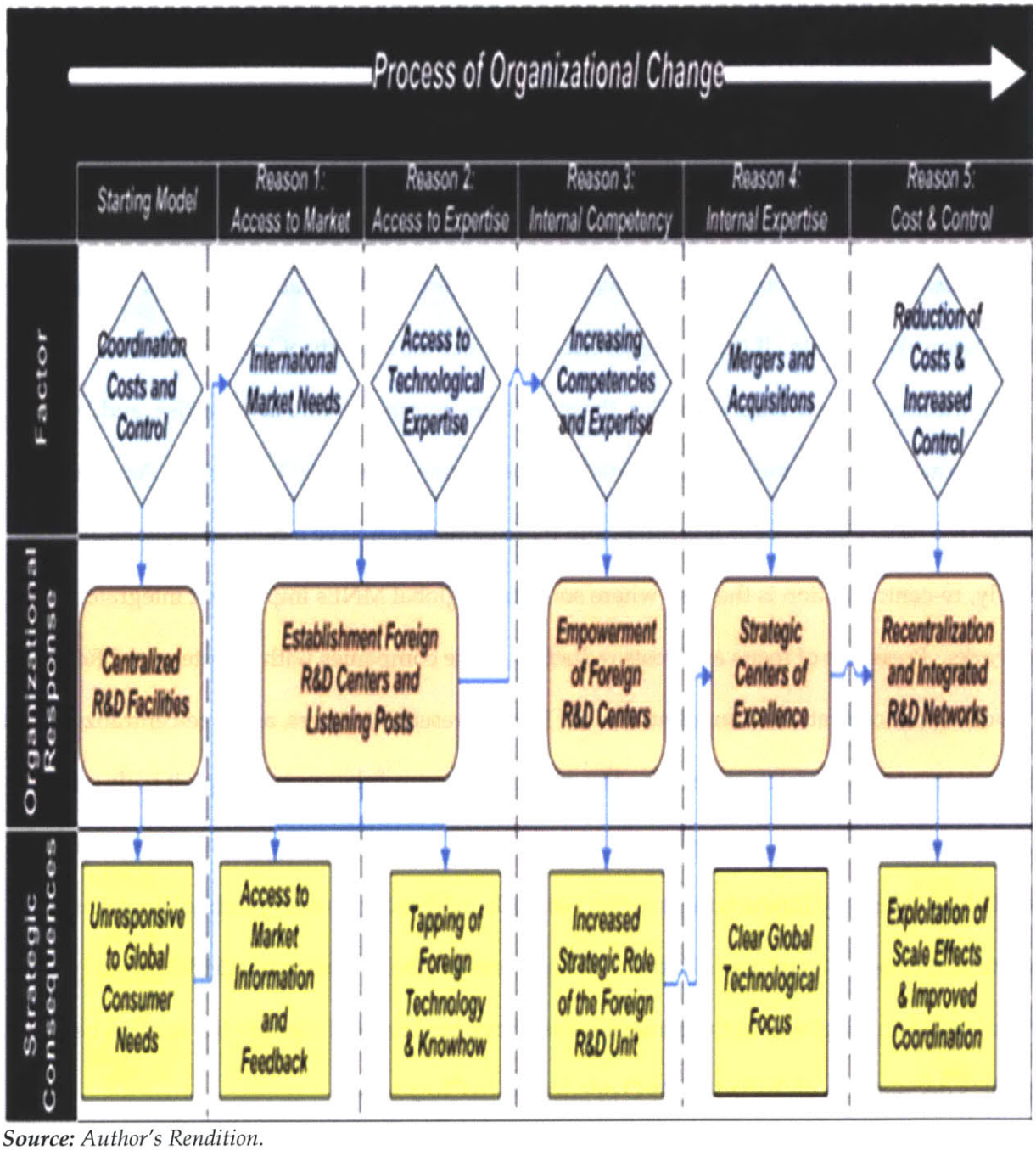
Table 2.1: Relevant Organizational Models for Globalization of R&D

Model	Features
1. Home-based R&D unit	• Concentrates all new technology development in home country. • Extends its reach outside the home country through alliances and technology organizations. • Emphasizes importance of sensor unit, dedicated to technology scanning, and technology acquisition.
2. Multiple-home bases	• Disperses the R&D functions geographically, at the level of multi-technology or multi-product business units, usually, in key lead markets.
3. World-wide lead center	• Identifies a center as the core location for a business and technology worldwide, and the management give it the responsibility for managing or coordinating the activities of technology development units in one or more countries.
4. Regional bases	• Identifies a single center in each major region, with the mandate of developing technology to support the business for the countries in that region, as well as, serving as a resource for the local use of technology developed in the other regional centers.
5. Regional technology headquarters	• Designates lead center in each region, which manages a network of dispersed local centers within that region, and coordinates activities with the other regional lead centers.
6. Flexible network	• Designates no unit permanently as the lead center, with the responsibility for managing and coordinating the activities of the other units in the network. • Assigns the leader role on a project-by-project basis to one of a set of geographically dispersed centers, or even shared across centers for some projects.

Source: Westney 1998.

According to Boutellier, Gassman, and von Zedtwitz (1999), there have been a number of principal reasons for organizational change among the R&D operations of MNEs, which I present in Figure 2.1. The first reason is external orientation, which refers to the fact that many companies with centralized R&D start globalization with product localization. The management in these companies realizes that their R&D processes must be aligned with international market needs better. As such, in order to incorporate expertise from foreign centers-of-innovation, the R&D center is opened to external information and feedback. The second reason is that of establishing listening posts. Companies establish these posts in areas of technological expertise, in order to tap into foreign technology and knowledge bases, which can become an important source of know-how. The third reason is the empowerment of foreign R&D, which is due to increasing competencies and technological strengths of geographically dispersed R&D units. In this case, companies that until recently exerted tight central control

Figure 2.1: Process of Organizational Change in Global R&D Facilities of MNEs



Source: *Author's Rendition.*

over their R&D sites, grant them more autonomy and empowerment. Consequently, the competencies and technological strengths of these R&D units increase as management assigns them strategic roles in the R&D network. This improves flexibility and fosters creativity in local units, and, as such, information flows freely, and each site follows a defined R&D mission.

The fourth reason is the integration of decentralized R&D sites. In this case, mergers and acquisitions among companies, as well as, strong local R&D capabilities, result in relatively autonomous R&D units. If the management recognizes the benefits of integration and interconnection of their R&D activities, these facilities become centers of expertise, and MNEs can introduce mechanisms for coordination of their international R&D activities. As a result, duplicated R&D efforts occur less often, and management can have a clear technological focus. Finally, re-centralization is the case where some truly global MNEs implement integrated R&D networks. Pressures of focus and costs reduction, force companies with an integrated R&D network to concentrate on a small number of leading research centers, and a re-centralization of decision in a few competency centers. The goal of this consolidation is to exploit scale effects and to improve coordination of globally-dispersed R&D activities by reducing the amount of parallel R&D, and by intensifying internal network and border-crossing technology transfer (Boutellier, Gassman, and von Zedtwitz 1999). I present the evolution of AMBE's R&D organizational model within the context of the above models, and identify the reasons behind AMBE's decisions to globalize its R&D operations in Chapter 3.

2.4 Characteristics of Knowledge Networks

Knowledge networks refer to networks whose mandates are to generate and disseminate knowledge, usually based on research that is both problem-based and theory-based (Clark 1998). Organizations can consider almost any collaborative activity involving the

sharing of information as a knowledge network. Such networks can arise instantaneously in response to a particular short-term need, or organizations can create them for long-term uses through a process of planned development, using rule-based formality and infrastructure. From this perspective then, there are two types of knowledge networks: formal and informal. Generally, informal networks are loosely structured, taking on whatever shape that best respond to their needs. Informal networks can rely on a range of media, such as telephone, e-mail, or voice, as appropriate. People can be added to the network at will, either by demand or by referral, or by self-selection in some informal networks. *The need to know* is the binding agent. These informal knowledge networks are case-driven: something has happened, or needs to happen, and so the network arises to deal with that particular case. Other informal networks are situation-driven. For example, those who work in a particular research arena can belong to an 'invisible college', sharing research results and information among each other. The flexibility and ad hoc nature of an informal network is both its best strength and its greatest weakness. In the context of this study, an example of an informal knowledge network is one that is formed for problem solving within a facility that does not involve the formal structure of a project.

In contrast, the most important feature of formal knowledge networks is their prescribed membership procedure, whether qualification- or rule-based, with an approval mechanism. For example, members of a research project belong to a formal knowledge network, because they are chosen specifically for the project and membership in the project is restricted to those members. H.C. Clark (1998) lists the following "ideal characteristics" of a formal knowledge network: (1) creates and disseminates knowledge for use beyond the membership of the networks; (2) maximizes the rate of knowledge creation; (3) provides recognizable direct benefits to participants; (4) supplies its members with a formal organization with a well-defined management structure; (5) provides a forum where the participants are invited, based on

criteria of merit or peer review; (6) endows the members of the network with a well-developed communication strategy; and (7) reduces the knowledge boundaries between sectors, such as those with academia and industry.

Knowledge content is another distinguishing feature of knowledge networks. There is a rich debate in knowledge-management literature on the distinctions between explicit and tacit knowledge. Most explanations revolve around what can be written down or made explicit in some fashion, and what cannot easily be recorded or shared (Cortada and Woods 2001). In the knowledge-management and knowledge-network context, explicit knowledge is often used almost interchangeably with information. The mapping and sharing of knowledge focuses primarily on individual's explicit knowledge, and its relation to organizational explicit knowledge, which is more commonly known as corporate memory (Cortada and Woods 2001).

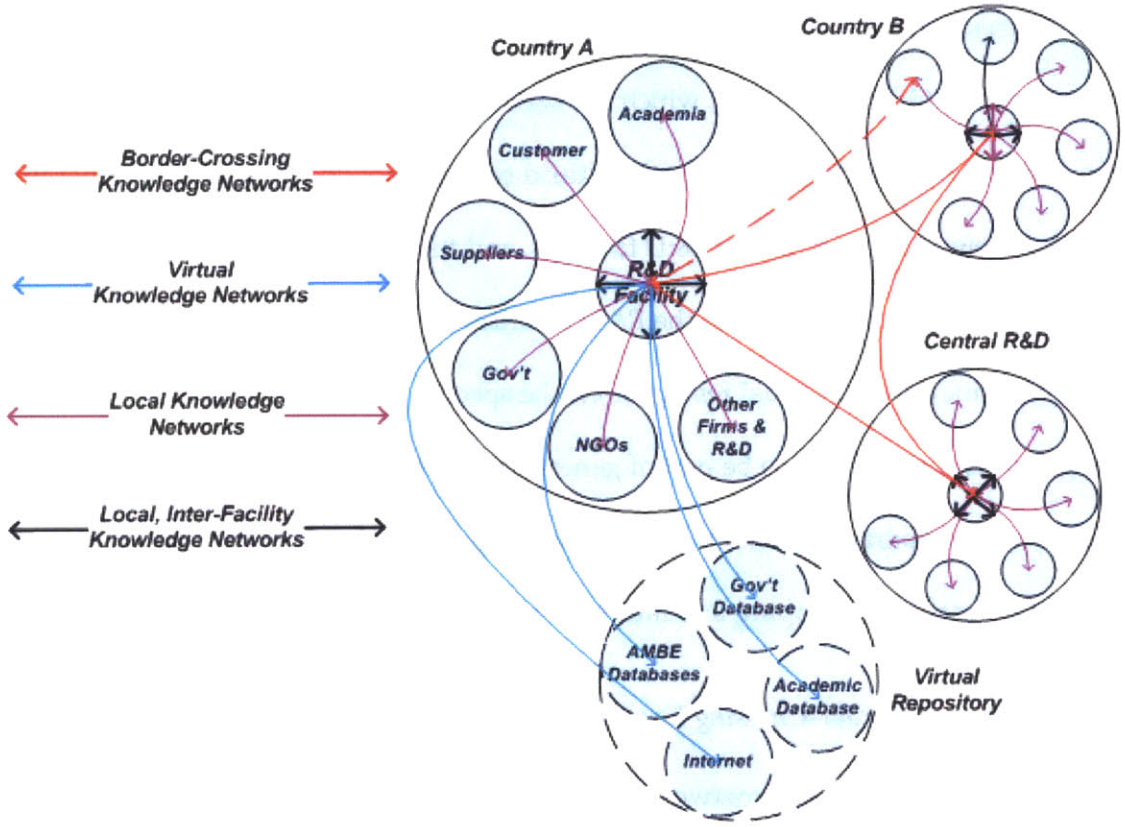
Tacit knowledge, on the other hand, is the understanding of how to do things. *It is created by doing*, by personal trial, error, reflection, and revision, but it is difficult to articulate what that 'how to' actually is. As such, the transfer of tacit knowledge is through shared processes (working together, mentoring, and so forth), in addition to the physical transmission of written or recorded content. In a network context, creating and sharing tacit knowledge requires collaborative work techniques, together with the establishment of long-term relationships and trust, both among the participants in the network and with those who will implement the research findings (Ryle, 1949; Polyani 1958, 1967; Reber, 1993).

2.5 Knowledge Resources and Networks

As stated earlier, MNEs' aspirations to be closer to local sources of knowledge and expertise are among the most important drivers behind their globalization of R&D. In this study, local knowledge resources refer to both the traditional sources of knowledge, such as

academia and other local R&D facilities, but also to suppliers, customers, government agencies, and other firms. Figure 2.2 shows the distinction between all the relevant knowledge networks, and their relationships with the R&D facility.

Figure 2.2: Distinctions between Local, Border-Crossing, and Virtual Knowledge Networks



Source: *Author's Rendition.*

As is apparent from Figure 2.2, there are two types of local knowledge networks: those that take place within the R&D facility (black line) and those that are external to the R&D facility but within the country where the facility is located (purple line). I consider the inter-facility knowledge networks to be local, because the majority of the employees of these R&D facilities are local scientists and engineers, and, as such, represent local knowledge sources. However, they are also different from external knowledge resources, because they are employees of AMBE, and, as such, AMBE expects them to contribute to its knowledge networks. One of the questions that I explore in this study is whether the firm also receives the

additional benefit of tapping into external knowledge networks by recruiting and hiring local scientists, or whether these local scientists do not carry any of these external-networking capabilities into the firm and facility with them.

Similarly, the border-crossing knowledge networks can be those involving the R&D facilities in different countries (solid red line), or, a much less prevalent type of border-crossing knowledge networks (dashed red line), which are between R&D facilities and suppliers or customers, in another country. More recently, a third type of knowledge network is emerging as an important source of expertise for R&D facilities, and those are virtual knowledge networks that connect the employees of the R&D facilities to the virtual repositories of knowledge (blue line). These virtual resources can be specific to the firm or they can belong to academia, government, or they can be part of general Internet resources. As such, although I treat these networks separately from the other knowledge networks, in reality, these networks represent another method of tapping into internal, external, and local knowledge resources.

2.5.1 Characteristics of Border-Crossing Knowledge Networks

Border-crossing knowledge networks refer to those networks where the contributing members of the network are located in different countries. The seminal research by Allen (1977) showed that the probability of two R&D professionals communicating with each other strongly depends on the physical distance separating those professionals. Thus, Allen found a five-percentage point likelihood of weekly communication between two engineers or scientists who are located 30 or more meters from each other. Observing this critical and very short distance of *30* meters, it is tempting to conclude that the problem of distance in international communication is a non-issue. However, one of the early studies in this field concluded that the frequency of communication between a central research laboratory and a foreign subsidiary,

further declines exponentially with physical distance (Hough 1972; Gertler 1995). The geographically nearest units communicated ten times more with the central research laboratory than the more distant units. In addition to physical distance, there are three other pertinent characteristics of border-crossing knowledge networks that can impede knowledge networking: (1) organizational distance, as reflected by the differences in the organizational practices and institutional environment where the knowledge is developed; (2) differences in the level of knowledge competence between the respondents in the different country facilities, and (3) the cultural differences between the members of the border-crossing knowledge networks. I discuss each of these in detail next.

1. Organizational Distance: Border-crossing knowledge networks must also confront organizational distance. Following Kostova (1999), organizational distance refers to the degree of congruity between the institutional environments facing the two parties. Accordingly, because knowledge is often meaning and value based, the success of knowledge transfer is determined by the transferability of meaning and value, in addition to the transferability of knowledge. Kostova's (1999) argument is consistent with the literature on the differences in organizational practices across countries (e.g., Graham 1985). According to Kostova, "the main ideas here are that (1) countries differ in their organizational characteristics; (2) organizational practices reflect the organizational environment of the country where they have been developed and established; and, therefore, (3) when practices are transferred across borders, they may not 'fit' within the institutional environment of the recipient country, which, in turn, may be an impediment to transfer" (p. 314). I examine the validity of this argument through my examination of three facilities with different organizational settings, which, in the case of Brazil, is strongly influenced by the evolution of Brazilian government's policy and the facility's history and mandate.

2. ***Knowledge Distance:*** Knowledge distance refers to how large a gap exists between the source and the recipient in terms of their knowledge bases. Hamel (1991, p. 97) found that organizational learning was enhanced when the knowledge gap between a source and a recipient was not so great to make the recipient unable to "identify, if not retrace, the intermediate learning steps between its present competence level and that of its partner." Also, Lane and Lubatkin (1998) found that a recipient that has a large knowledge gap between it and the source would be less likely to assimilate the source's knowledge. They developed the concept of 'relative absorptive capacity' to move the concept of absorptive capacity from an organizational basis to a relational basis. As such, it is the relative knowledge of the recipient with respect to the source's knowledge (i.e., the extent of the knowledge gap between the parties) that is important, and this is the relational concept.

Although, there can certainly be differences in knowledge capabilities between facilities within the same country, and this is certainly true of AMBE's R&D facilities, the significant difference in knowledge competence in AMBE's case is between the three facilities and Central R&D. Given this difference in the level of knowledge capabilities within AMBE, I can test the above theory by examining the extent of knowledge networking between the respondents and R&D facilities of similar knowledge capabilities, as well as with Central R&D.

3. ***Cultural Distance:*** Cultural distance refers to the duration and quality of experience that the source and recipient have working together. Researchers identify several culture-related factors that can affect knowledge-networking success. In a study of knowledge networking in international joint ventures, Child and Rodrigues (1996) find that knowledge transfer is facilitated when the parties hold similar social identities. Thus, one aspect of cultural distance is the degree of similarity of social identities of the members of the knowledge network. Their

research suggests that as social similarities of parties increase, so will their ease of communications, which allow for greater transfer success.

Furthermore, Schrader (1991) concluded that a strong positive relationship between recipient and source facilitates the trading of the transfer of information. Over time, as the parties develop an appreciation of their partners' social context, they establish their own social norms and expectations of one another, "thereby enabling the development of trust and with it the successful exchange of knowledge" (Roberts 2000, p. 38). Thus, the depth of experience of the parties in transferring knowledge, is critical in the knowledge-sharing success.

One of the main questions that I explore in this study is the importance of cultural distance in border-crossing knowledge networks among the respondents from the three facilities, with different cultural backgrounds. Of importance is whether cultural distance can be taken out of the context of the cultures under examination, or be treated as a generic factor in influencing the manner individuals utilize their border-crossing knowledge networks. I other words, in this study, I examine the validity of cultural distance as a broad impediment to border-crossing knowledge networking, by comparing their levels of among the respondents and other global R&D facilities.

2.5.2 *Local Knowledge Networks*

There is growing evidence in economic studies on externalities, of the relationship between knowledge networks and the spatial localization of knowledge. In their seminal study, Jaffe, Tajtenberg, and Hendersen (1993) analyzed patent-citation data pertaining to domestic university and corporate patents, to test the extent of localization of knowledge spillovers. At three different geographic levels (country, state, and Standard Metropolitan Statistical Area), they found evidence that patents citations tend to belong to the same geographic area as the

originating patent (the patent they cite), even after controlling for the existing concentration of patenting activity. Their findings indicated that knowledge localization exists in the aggregate. Because they did not analyze the variation of localization by region or technology, they left open the issue of whether the properties of technology and institutions, determine knowledge externalities. One obvious reason why knowledge should be localized is that skilled engineers who remain within the region hold it tacitly (Zander and Kogut 1995). As such, there is some evidence in the knowledge-networking literature that knowledge creation or dissemination tends to be localized.

There is further evidence of this idea in the literature on learning regions, which claims that proximity between actors is an important aspect in learning (e.g., Florida 1997). Learning regions are areas in which actors are interacting and learning. In such learning regions, there is a development of collective tacit knowledge that is linked to location because of functional and relational proximity (Keeble and Wilkinson 1999). Functional proximity deals with the separation in space and relations in terms of distance and time (Coenen, Moodysson, Asheim, and Jonsson 2003). Alternatively, relational proximity refers to the logics of adherence and similarity among interacting actors (Torre and Gilly 2000), which can alleviate some of the need for functional proximity (Gertler 1995, 2001). Specifically, relational proximity refers to societal factors such as language, institutional settings, cultural backgrounds, and more cognitive factors, such as technological experiences and perceptions (Guerrieri and Tylecote 1997; Zeller 2002). Relational proximity often coexists with functional proximity, but this does not necessarily connote a causal relationship.

In order for firms to exploit these external knowledge resources, they need to develop conduits or mechanisms that permit the absorption and use of this local external knowledge. Knowledge can be accessed through interactions and relationships of employees with those

outside the firm (Almeida and Kogut 1999), by hiring former employees of competitors (Almeida and Kogut 1999), and from public sources such as presentations at conferences, journals, books, and patents within an industry. Firms also access knowledge through their relationships with other companies (Zollo, Reuer and Singh 2002), suppliers (Takeishi 2001), universities and research institutions (Powell, Koput and Smith-Doerr 1996), industry associations (Hanssen-Bauer and Snow 1996) , and customers (Yli-Renko, Autio and Sapienza 2001).

Furthermore, there is ample evidence in the literature to support the claim that inter-facility knowledge networks should be quite extensive (e.g., Allen 1977; Becker and Steele 1995; Van den Bulte and Moenart 1997). Experimenting with different layouts, Allen (1977) found that communication increases by co-locating teams, and is further enhanced when groups work in non-territorial spaces. More recently, Becker and Steele (1995) identified collocation of all of Neon's development process under one roof, as being partly responsible for Chrysler cutting its development time from industry-average of 5 years, to 31 months. In duplicating Allen's study using social network methods, Van den Bulte and Moenart (1997) found that communication barriers among R&D teams were sizably lower after co-location. The authors found that not only were members of different teams much more likely to talk to one another once co-located, but R&D professionals were as likely to speak to a fellow researcher from another team, as to speak to a member of their own team (Van den Bulte and Moenart 1997).

The reasons why collocation improves communication flows and knowledge networking are the opposite of those that hinder knowledge networking in border-crossing knowledge networks. First, being located in different facilities decreases the probability that individuals meet by chance in their facilities. Second, it solidifies the separate thought worlds of different R&D facilities, encourages technical jargon, and heightens perceptions of

personality differences (Mazumdar 1995). Finally, the facility separation is often times accompanied by management and organizational differences. As such, managing the physical location of R&D scientists can be an important element in enhancing cross-functional information dissemination (Maltz and Kohli 1996).

The above literature makes it clear that there is localized knowledge and its importance and utilization can be deduced from, for example, patent citations, and that there are clear channels for accessing this knowledge, such as through informal social relationships. The questions that I examine in this study are whether the levels of knowledge networking within the facility and those with external local sources of knowledge, such as academia, are similar or distinctly different.

2.5.3 *Virtual Knowledge Networks*

There is a distinction between knowledge networks among individuals that are facilitated by electronic tools, such as e-mail, and knowledge networks that are between an individual and an electronic knowledge repository, such as a government or academic database. In the latter case, the source of the knowledge is an electronic tool, as well as the means of accessing the knowledge, which is what I discuss in this section. I also stress the utilization of communication tools, including electronic tools, to facilitate both types of knowledge networks, and I present those results in Chapter 7. In this Section, I present the literature review of virtual knowledge networks, in order to distinguish them from local and border-crossing knowledge networks.

The growing impact of virtual knowledge networks on R&D is manifest in its transformation of the processes by which R&D scientists and engineers acquire technical knowledge, develop new products and services, and connect with users. To make this point,

consider the following trends. More than 70% of businesses now use cyberspace for everything from finance to product development to virtual prototyping. Penetration in corporate research is even greater, as almost 90% of engineers now use the Internet for gathering procurement information, and almost 95% of researchers use the Internet in some form or another to improve their design and development work (rolandberger.com 2003).

In terms of general considerations of virtual knowledge networking among R&D scientists and engineers, Antonelli, Guena, and Steinmueller (2000) argue that the Internet impacts R&D primarily by altering, not the end-products, but the overall R&D process. Furthermore, they argue that the Internet is a critical medium for linking the development of information and new knowledge with its application. They contend that the Internet can be used to change the process of accumulating new knowledge. Furthermore, Internet can affect the pace and direction of subsequent technological convergence upon which the evolution of information and communication technologies rest.

There are four general categories of Internet functions that have potential benefits in the R&D process. The first is as communication tools, the most important of which is e-mail. The second is as connection tools, such as Telnet, which provide the capability to work interactively with a remote computer. Some services available through Telnet include databases, libraries, chat rooms, and bulletin boards. The third are transfer tools, such as File Transfer Protocols (FTPs), which allow individuals to move files and data from one computer to another, and enable members to download and upload information such as books, documents, and software. The fourth are access tools, such as the World Wide Web (www), which are a collection of standards and protocols used by individuals to access information available on the Internet, such as documents, images, video, and sound. All of the above Internet functions help facilitate and make possible the existence and effectiveness of knowledge networks. In this study, I

analyze the relative importance of the functions of virtual tools for the respondents from the three facilities, as well as the factors that influence their level of utilization and usefulness, and the extent of the virtual knowledge networks of the respondents from the three facilities.

2.6 Categorizing the Knowledge Networks under Analysis

There are two specific knowledge networks under analysis for this study. The first is Knowledge Network for Problem Solving (*KNPS*), used by the network participants as a resource to find solutions to the problems they encounter during the course of their work. The second is Knowledge Network for Central R&D Innovation (*KNCRDI*), which respondents utilize to find information about the cutting-edge innovation that takes place at the Central R&D facilities of AMBE Corp. Both of these knowledge networks can tap into local, border-crossing, or virtual knowledge sources. Although both of the above knowledge networks may have a formal and informal component to them, there is a propensity for each of the above networks to fall in the formal or informal knowledge network category. *KNPS* is formed on a much more ad-hoc basis by network members to satisfy their immediate needs, and where the communication between the respondents can be much more fluid and far less formal. On the other hand, primarily because of security reasons, *KNCRDI* requires many more formal rules of communication, and, as such, it cannot come into existence and dissolve as readily as *KNPS* networks, giving them more of a formal characteristic than the *KNPS* network.

2.7 Personal Attributes and Knowledge Networks

One of the long-standing findings in the social-sciences literature is the role of similarity in promoting voluntary interaction, and that communication is more likely to occur between people who are demographically similar, i.e., in homophilous relationships (e.g., Monge and Contractor 2000; McPherson, Smith-Lovin, Cook 2001; Wagner, Pfeffer and O'Reilly 1984;

Zenger and Lawrence 1989). For example, Zenger and Lawrence found that technical communication within an organization was related to age similarity, and both Ibarra (1992) and Leenders and Gabbay (1999) showed that gender similarity affects who communicates with whom. In general, people are more likely to have network ties, especially close ones, with those who are similar to themselves on a set of socially important attributes such as race, sex, education, and age (e.g., Marsden, 1988; Ibarra 1992).

Alternatively, research findings show the value of heterogeneity in the business environment, because it channels knowledge and information to those in diverse networks (Granovetter 1973). Network heterogeneity measures the diversity of persons in a respondent's networks, and "implies integration into several spheres of society," and analysts consider it to be advantageous for information gathering (Marsden 1988, p. 124). The implication of this finding is that heterogeneity increases exposure to less-readily accessible information, and that different types of people tap into a greater number and variety of networks, who can act as conduits of information from sources, otherwise removed from the individual knowledge seeker (Granovetter 1973). There are two reasons why heterogeneity is associated with increased diversity in knowledge networking. First, a network with a substantial amount of heterogeneity in its members increases the odds of including a member tapped into another network that circulates diverse knowledge and information. Furthermore, this individual may then serve as a conduit to this network, or in social-network terminology, can act as a structural hole, by having non-redundant relationships with diverse social groups (Burt 1992; Mark 2003). Second, the ability to sustain relationships with diverse actors may indicate an ability to appreciate knowledge that is not immediately accessible. Sustaining social and information ties with different actors is probably facilitated by a willingness to take a different perspective from

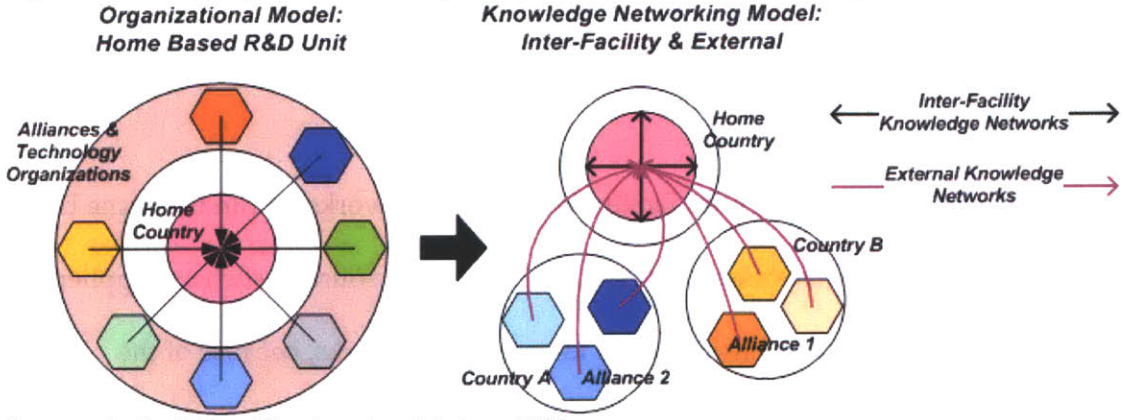
one's own and the desire to access different points of view and types of knowledge (Marsden 1987).

Combined, the above factors lead to different conclusions about the effects of personal attributes in facilitating or impeding knowledge networking. On one hand, homophilous relationships can lead to increased voluntary interactions, while heterogeneity allows individuals to tap into diverse knowledge networks and resources. The question that I pose in this study is whether personal attributes, such as gender, position, tenure, and location, and their associated cultural and lingual characteristics, affect the extent and diversity of border-crossing, local, and virtual knowledge networking of respondents in different organizational settings. The primary difference between this study and previous research on this topic, is that in this case, I examine whether personal attributes affect knowledge networking of the respondents with *any* of the knowledge resources they have at their disposal, and not with the resources that they have these characteristic in common. Second, I analyze whether individuals sharing these characteristics have markedly different knowledge networks than their comparison group. As such, the question that I pose in this study is not whether for example, women tend to communicate more with women, but whether women tend to have more similar *overall* knowledge networks with their female colleagues than their male colleagues. In addition, I also determine whether women have markedly different knowledge networks than men. As such, I do not make the assumption that just because women are different in their knowledge networking from men, that they must be similar to each other, and examine whether there are external, and internal factors that influence the knowledge networking of men and women. The findings from this study on this subject will make an important addition to the topic of organizational demographics and knowledge networking.

2.8 Mapping the Knowledge Networks to Organizational Models

Each of the organizational models I described in Section 2.3 require and utilize a variety of knowledge networks in order to tap into their knowledge resources. In this section, I present the knowledge-network maps that can best provide the means to disseminate the available knowledge in each of the above organizational models. These figures are based on the knowledge network map (Figure 2.1), which I used as a way of introducing the different types of knowledge networks under analysis in this study. I do not include virtual knowledge resources in the following maps because the extent of their utilization is more specific to the firm, than to the organizational model. In other words, each of the organizational models allow for as much or as little utilization of virtual knowledge resources, and their actual utilization is dependent on the systems and processes that are specific to the firm. Figure 2.3 shows the Home Based R&D Unit organizational model and its associated knowledge network map. This model concentrates all new technology development in the home country, and when necessary, it extends its reach outside the home country through alliances and technology organizations (Westney 1998). As such, this model relies exclusively on robust inter-facility knowledge networking, as well as some external knowledge networks with their alliance partners and technology organizations.

Figure 2.3: Mapping the Knowledge Networks of Home-Based Organizational Model

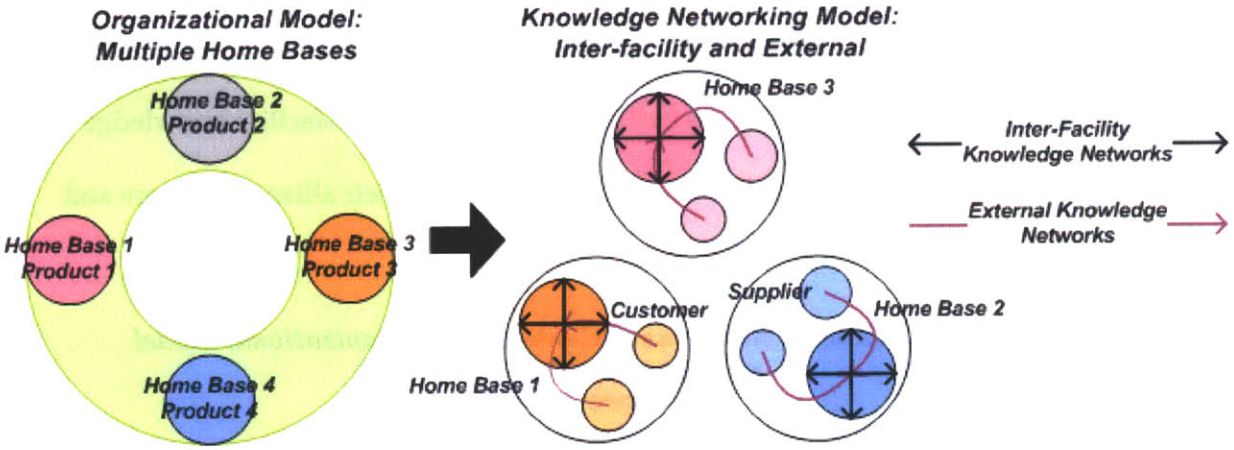


Source: *Author's Rendition based on Westney 1998.*

The external knowledge networks in this diagram are based on formal agreements and expectations between MNEs and their alliance partners. Because of the formal nature of these networks, MNEs can better manage their extent and rates of utilization, than informal external knowledge networks. Overall, this organizational model utilizes deep, but limited, knowledge networks, relying more on formal relationships, and internal knowledge networks, than on informal relations between employees and their contacts.

Figure 2.4 shows the *Multiple-Home Bases* organizational model and its supporting knowledge-network map. The main feature of this model is that within a multi-technology or multi-product MNE, the R&D function is geographically dispersed in key lead markets (Westney 1998). Although this model and the *Home-Based R&D* model are different in their characteristics, objectives, advantages, and disadvantages, they rely on the same two types of knowledge networks, albeit for different purposes.

Figure 2.4: Mapping the Knowledge Networks of Multiple Home Bases Organizational Model



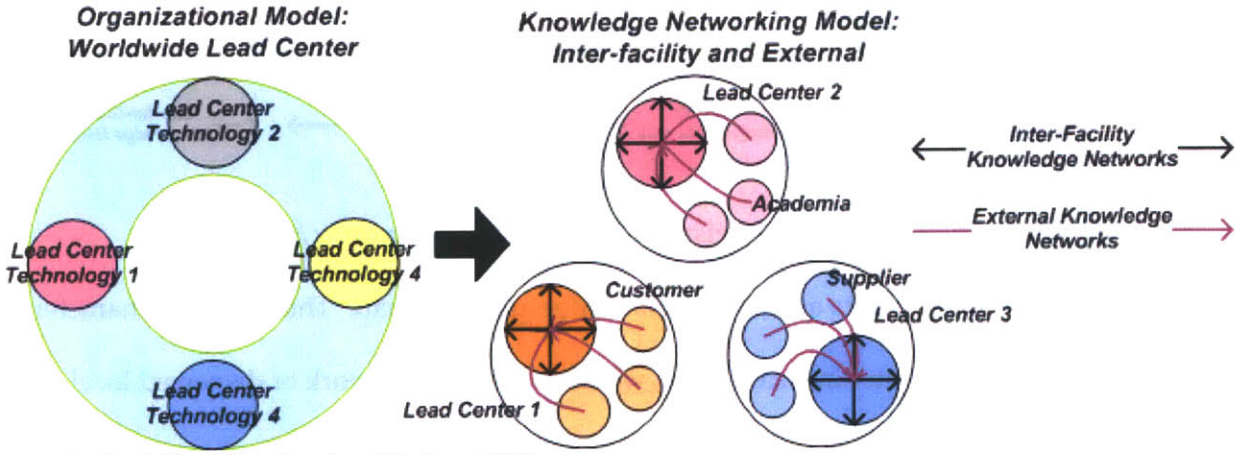
Source: *Author's Rendition based on Westney 1998.*

This model relies on extensive inter-facility knowledge networks within the home bases, as well as external knowledge networks to access local knowledge sources, such as suppliers and customers. This model lacks extensive global knowledge networks, because of the

independence of these home bases as they focus on their specific technological bases or product. Furthermore, unlike the home-based R&D organizational model, where the external networks are mandated through formal ties with established alliances, the external networks in this model can be formal or informal, and they are characterized by both formal mandated ties, and informal ad hoc personal ties.

Figure 2.5 shows the organizational model and associated knowledge-networking map for the *Worldwide-Lead Center Model*. This model is characterized by an R&D center acting as the core location for a business and technology worldwide, and is given the responsibility for managing or coordinating the activities of technology development units in one or more countries (Westney 1998). Although there are significant differences in the primary drivers and advantages of this organizational model as compared to the multiple-home bases model, they rely on similar knowledge networks. In particular, both models rely on formal and informal external knowledge networks with suppliers and customers, and extensive internal knowledge networks within the technology lead center. This model does not rely on border-crossing knowledge networks, because of the concentration of all relevant R&D expertise for a particular technology in the lead center.

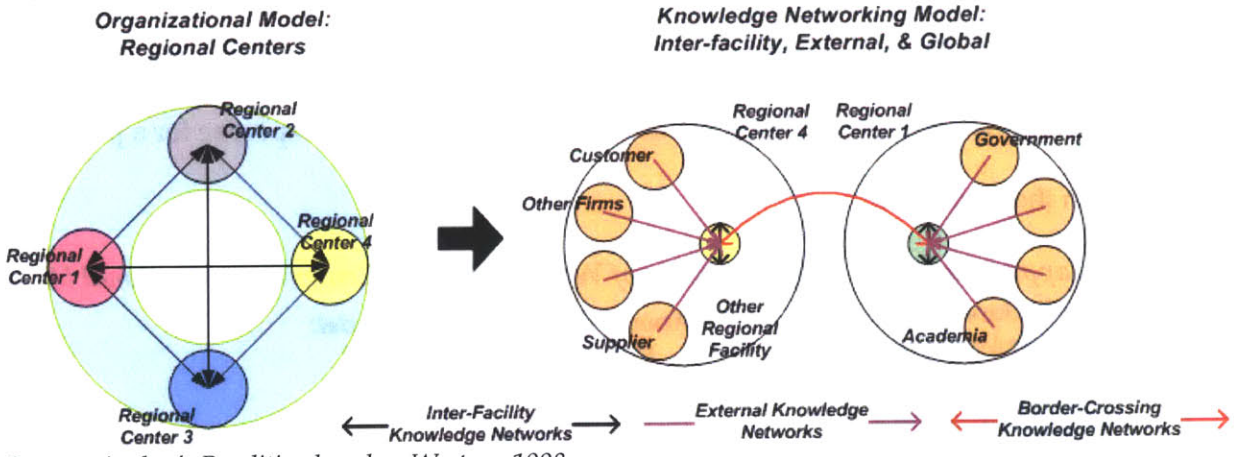
Figure 2.5: Mapping the Knowledge Networks of Worldwide Lead Center Organizational Model



Source: *Author's Rendition based on Westney 1998.*

Figure 2.6 shows the *Regional Centers* organizational model and its associated knowledge-network map. This model is characterized by a single center in each major region, with the mandate of developing technology to support the business for the countries in that region and serving as a resource for the local use of technology developed in the other regional centers (Westney 1998). From a knowledge-networking perspective, the two characteristics of this model that differentiates it from the above models are its emphasis on local use of technology, and the regional centers' mandates to support the countries within the regions. Combined, these two features result in robust local knowledge networks within each region, and limited border-crossing knowledge networks between the regional center and its affiliated country facilities, as well as between the regional facilities. As such, this model utilizes all three types of knowledge networks, although the extent of their utilization is dependent on the facility and the MNE.

Figure 2.6: Mapping the Knowledge Networks of Regional Centers Organizational Model

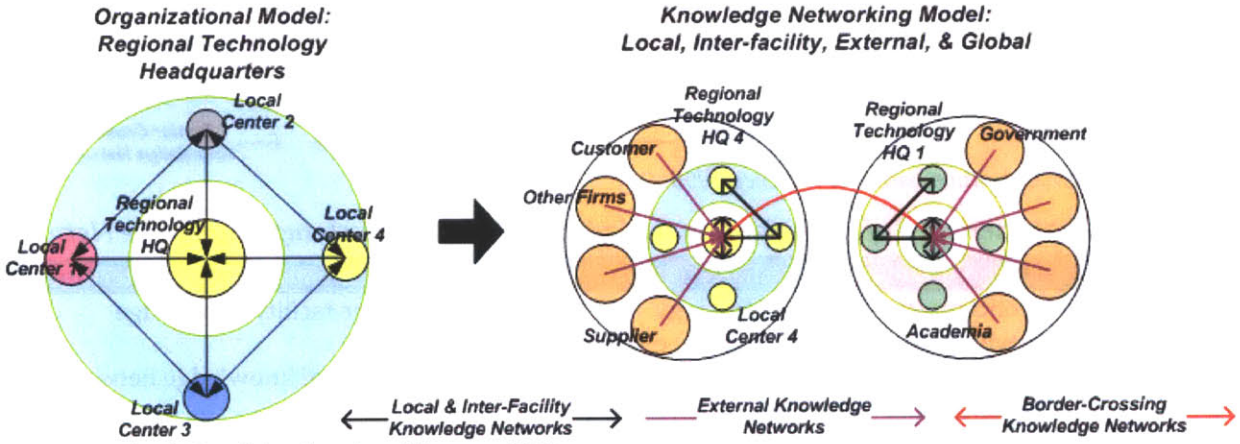


***Source**: Author's Rendition based on Westney 1998.*

Figure 2.7 shows the characteristics of the *Regional Technology Headquarters* organizational model and its associated knowledge-network map. This model is characterized by a designated lead center in each region, which manages a network of dispersed local centers within that region and coordinates activities with the other regional lead centers (Westney

1998). There is a great deal of similarity in the type and extent of knowledge networks that this model utilizes and the knowledge networks of the *Regional Centers* organizational model. Both are supposed to have robust local knowledge networks that tap into their local knowledge resources, as well border-crossing knowledge networks among the lead centers in each region and the lead center and its supporting facilities. The primary difference between the two knowledge-network maps is in the extent of border-crossing knowledge networking between the lead facility and the regional country facilities, which is extensive in this model because of the extent of the regional facilities.

Figure 2.7: Mapping the Knowledge Networks of Regional Technology Headquarters Organizational Model

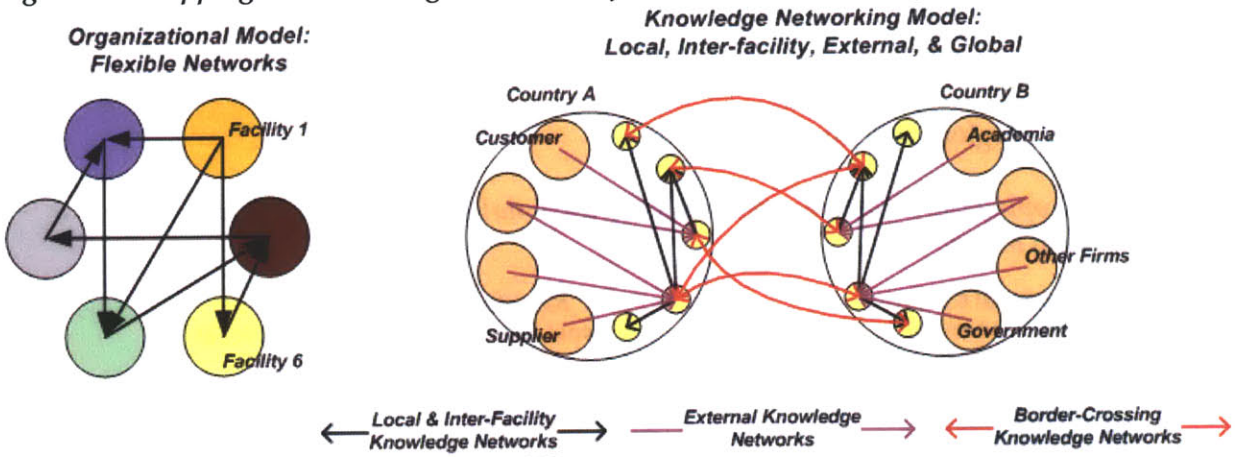


Source: *Author's Rendition based on Westney 1998.*

Finally, Figure 2.8 shows the organizational model and associated knowledge network map for the *Flexible Networks* organizational model. This model is characterized by the fact that no unit is permanently designated as the lead center with the responsibility for managing and coordinating the activities of the other units in the network (Westney 1998). Given these characteristics, the underlying knowledge networks for this model must also exhibit the same level of flexibility. Therefore, this model utilizes all available knowledge networks, including global, external, local and inter-facility knowledge resources. However, because the model

itself is fluid in nature, the extent of all of the above knowledge networking is dependent on the type of project it supports. The primary characteristic of this knowledge network is that there must be a combination of formal and informal networks that the respondents can tap into on an ad hoc basis as the needs for their utilization arise. Table 2.2 summarizes the characteristics of the above organizational models and their underlying knowledge networks that support them.

Figure 2.8: Mapping the Knowledge Networks of Flexible Networks Organizational Model



Source: Author's Rendition based on Westney 1998.

Table 2.2: Characteristics of Organizational Models and their Underlying Knowledge Networks

Model	Organizational Characteristics	Knowledge-Network Characteristics
Home-based R&D unit	Concentrates all new technology development in home country; extends its reach outside the home country through alliances and technology organizations.	1. Robust inter-facility knowledge networking. 2. Formal external knowledge networks.
Multiple-home bases	At the level of multi-technology or multi-product business units, MNEs disperse the R&D functions geographically, usually, in key lead markets.	1. Extensive inter-facility knowledge networks within the home bases. 2. External knowledge networks to access local knowledge sources, such as suppliers and customers.
World-wide lead center	Identifies a center as the core location for a business and technology worldwide, responsible for managing the activities R&D units in one or more countries.	1. Formal and informal external knowledge networks with suppliers and customers. 2. Extensive internal knowledge networks within the technology lead center.
Regional bases	Identifies a single center in each major region, with the mandate of developing technology to support the business for the countries in that region, as well as, serving as a resource for the local use of technology developed in the other regional centers.	1. Robust local knowledge networks within each region. 2. Limited border-crossing knowledge networks between the regional center and its affiliated country facilities, as well as between the regional facilities.

Model	Organizational Characteristics	Knowledge-Network Characteristics
Regional technology headquarters	Designates lead center in each region, which manages a network of dispersed local centers within that region, and coordinates activities with the other regional lead centers.	1. Robust local knowledge networks that tap into their local knowledge resources. 2. Border-crossing knowledge networks among the lead centers in each region and the lead center and its supporting facilities.
Flexible network	Designates no unit permanently as the lead center, with the responsibility for managing and coordinating the activities of the other units in the network.	1. Utilizes all available knowledge networks, including global, external, local and inter-facility knowledge resources. 2. Extent of all of the above knowledge networking is dependent on the type of project it supports.

***Source**: Author's Compilation based on Westney 1998.*

In this study, I trace the historical association of AMBE's R&D organizational model, and present the current model with its associated *targeted* knowledge networks in Chapter 3, while in Chapter 5, I present the knowledge network maps of the respondents for the three facilities. By presenting both the anticipated knowledge networks with the actual knowledge networks, I can show the areas where the extent of knowledge networking fails to meet the expectations of the management, and through the analysis of these networks (Chapters 6 and 7), I can determine the underlying factors that contribute to this discrepancy.

2.9 Conclusion

A successful knowledge-sharing effort requires a focus on more than simply the transfer of the specific knowledge. Instead, individuals need to focus their activities on structuring and implementing the arrangement in a way that bridges both existing, and potential relationship issues, and to examine the form and location of the knowledge to ensure its complete transfer. In other words, while the activities used to share knowledge, such as document exchanges, presentations, and job rotations are important, overcoming the factors that can impede, complicate, and even harm knowledge internalization are equally important in determining the ultimate results of a knowledge-sharing effort.

In this chapter, I presented the literature review relevant to this study. I divided the literature into three areas. In Part I, I discussed the drivers, trends, and organizational models associated with MNEs' efforts to globalize their R&D operations. The most relevant of these drivers is physical proximity to sources of knowledge and expertise, such as customers, suppliers, and academia, which requires the utilization of different types of knowledge networks. Although, the above resources are separated in the literature to specify the source, I consider all of these groups to be *knowledge* resources for the respondents. The results of this study contribute to the body of literature on globalization of R&D, first by providing an empirical case of the globalization activities of a large MNE in three facilities, and second, by showing whether proximity to the above sources of knowledge, actually results in tapping of these knowledge resources.

The R&D organizational models of MNEs fall into six categories, ranging from the centralized model of the *Home-Based R&D* model to the flexible and decentralized features of the *Flexible Network* model. All of these organizational models rely on a different mix of knowledge networks in order to disseminate the knowledge among the relevant respondents and resources. I presented the association between the organizational models and the networks they rely on for the dissemination of knowledge from the global, local, external, and virtual knowledge sources. I discussed the literature on border-crossing, local, and virtual knowledge networks, and pointed to the relevant characteristics that help facilitate or impede the flow of knowledge. For example, the most relevant characteristics of border-crossing knowledge networks, which are, distance and networks that span multiple countries, give rise to four impediments to knowledge networking: (1) physical distance, which research has shown to impact communication among R&D scientists in a negative manner; (2) organizational distance, which refers to the differences in the organizational and institutional environment of different

countries; (3) cultural distance, that is, the difference in the cultural, and social backgrounds of the respondents in border-crossing knowledge networks; and (4) knowledge distance, which is the extent of difference in the level of expertise of individuals in a network. Alternatively, I presented the literature on the characteristics of local knowledge networks, which facilitate the flow of knowledge. These characteristics are all related to the notion of proximity, such as functional and relational proximity, in the literature. Finally, I discussed the four functions of virtual communication tools that help individuals communicate with all types of knowledge resources. In this study, I examine the validity of the broad characterization of border-crossing, and local knowledge networks, to show whether there are circumstances where there are far more extensive border-crossing knowledge networks, despite the presence of all of the above impeding factors associated with such networks. Similarly, I analyze the characteristics of local knowledge networks, which despite all of the above facilitative attributes, may, in fact be more limited in their scope and extent, than border-crossing knowledge networks.

Additionally, I examine whether there are other factors that can affect the manner in which respondents utilize their knowledge networks. Among the most important of these in the literature on knowledge networks are personal attributes, and organizational demographics, such as gender, tenure, position, and location of the facility. Overall, the literature on the effects of these attributes on knowledge networking points to the finding that people tend to communicate with people who are similar to themselves. At the same time, there is also evidence in the literature that individuals who communicate with people from different backgrounds tend to have more expansive knowledge networks. My examination of the role of organizational demographics on the respondents' knowledge networking focuses on whether individuals sharing these characteristics tend to have *overall* different knowledge networks than their comparison group, and to determine whether they have more similar knowledge networks

with the respondents in their own group. In other words, my assumption is that difference with members of opposing groups does not necessarily translate into more similar knowledge networking among the respondents sharing these characteristics. I continue this study in the next chapter, by providing the background financial, organizational, and management characteristics of AMBE Corp. with a focus on its global R&D operations.

CHAPTER 3: THE CASE OF AMBE CORP.

3.1 Introduction [1]

As industrial corporations grow larger and more diversified, decentralized organizational procedures and incentive mechanisms tend to play an increasingly decisive role, while the role and success attributed to centralized strategic guidance and coordination tend to diminish. However, delegation of responsibility and autonomy to divisional or business-unit management has generally been traded with the establishment of elaborate top-down financial control systems (Chandler 1962). AMBE Corp. is an example of such a decentralized firm, with a diverse product portfolio divided among multiple product divisions. In this chapter, I provide the background information on AMBE's financial performance among its divisions, as well as the organizational and reporting structure of the R&D operations. I conclude the chapter with an overview of AMBE's global R&D operations.

3.2 Company Background

AMBE's products are based on over 30 core technology platforms, resulting in thousands of different products that are manufactured, managed, marketed, and distributed through multiple product divisions. During the past five years, AMBE as a whole has experienced impressive growth in both revenue and profits, despite the fact that its products' divisions have had mixed results, with some showing significant growth in profits and revenue, and others experiencing downturn in either profits, or revenue, or both. AMBE has experienced similar disparate growth among its global operations, with the Asia Pacific and China (APAC) region experiencing much more significant growth than the other regions. In fact, by 2003,

[1] The material in this chapter comes from AMBE Corp., either through personal interviews with the R&D management, or through access to AMBE documents. However, because of confidentiality reasons, I cannot identify or cite individual sources.

APAC was AMBE's most profitable region, despite the fact that it ranked third in revenue behind North America and Western Europe. The final observation regarding AMBE's financial health is the impressive increase in sales, profits, and margins for the year 2003 compared to 2002. This is noteworthy because it could signal that the management initiatives that were put in place during the previous four years are starting to show the anticipated results and pay significant dividends.

3.3 AMBE's Global R&D Organization

Each of AMBE's product divisions are large enough to constitute their own business with their own specific customer base, own general manager, marketing director, technical director, human resource director, manufacturing director, and national sales manager. AMBE is a highly decentralized company, but the organizational-design imperative is to decentralize to units that are large enough to be self-standing and, therefore, capable of funding their own R&D. While this is not a very extraordinary divisional structure, the structure has created synergistic horizontal and vertical relations, especially with respect to technological development and innovation. Although most divisional corporations keep R&D people within their own divisions, and expect exclusive loyalty to their own division, at AMBE, divisional R&D staff also has a strong attachment to the corporation as a whole. This two-way relationship is possible by AMBE's formal organizational structure, where the R&D technical operations have dual reporting relationships to both the product division and to the corporate technical vice president. Tables 3.1 and 3.2 show this relationship, as well as, the metrics for valuing their contributions to the division as well as to the corporation.

Table 3.1: R&D Employees Functional Responsibilities, AMBE Corp.

Divisions Responsibilities	CORPORATE RESPONSIBILITIES
• Support sales of imported products. • Develop new applications for existing products and technologies. • Support development and sales of locally made new/modified products. • Provide accurate communication of product requirements. • Conduct local field audits to ensure customer satisfaction. • Establish and maintain key customers and opinion leader network. • Ensure compliance with safety, environment, and toxicology regulations. • Provide analytical resource to customers. • Provide competitor analysis of products and technologies. • Generate new products locally. • Modify products for local needs. • Develop new processes and applications. • Collaborate on university and government research. • Provide service to manufacturing. • Influence local and global standards. • Access and utilize corporate resources to win locally.	• Contribute to Intellectual Property through patents. • Protect corporate intellectual property, brands and chain of supply. • Gather intelligence for local and global competitors. • Conducts competitor analysis and feeds information into divisions. • Identify industrial trends. • Partner with local university research. • Participate in new technology or product specification. • Respond to requests from other AMBE sites, US and OUS to solve problems. • Participate in global development products actively. • Gather intellectual property and corporate intelligence. • Develop Center of Excellence capabilities in selected areas. • Provide regional and global technical expertise for problem solving and technology improvements. • Support multinational and transnational customers locally and abroad.

Table 3.2: R&D Employees Functional Value-Added Metrics, AMBE Corp.

Division Value-Added Metric	CORPORATE VALUE-ADDED METRIC
• Sales which come from successful introduction of products. • All sales generated from locally modified or developed sources in which the facility defined the performance parameters. • New applications which expands the customer use or base. • Number of customers trained on use of AMBE products. • Local resolution of quality or application customer complaints.	• Number of new applications developed and communicated. • Number and quality of patents arising from local work. • Global sales from active contribution to blocking or defending strategies for global competitors. • Monetary value of new applications which contribute to global business growth. • Regional support such as training, performance measurement, analytical or problem solving or new products which results in new sales.

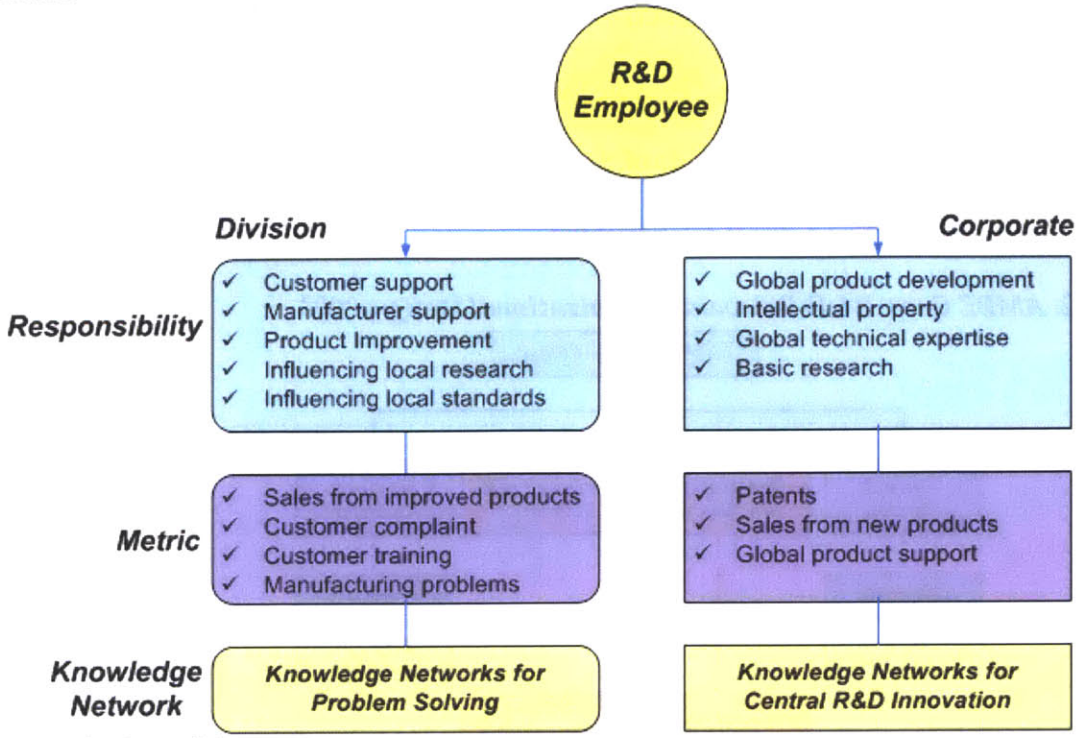
Source: *Author's Rendition.*

What is apparent from Table 3.1 is that broadly speaking, AMBE's R&D employees' functional responsibilities fall into two categories: customer and manufacturing support. This takes on many different forms, including their responsibility to keep an eye on the local market,

collaborating with local universities and government officials for improving product design and development, as well as, influencing local and global standards. Similarly, the metrics that are used to measure their contribution to the division are those that revolves around customer and manufacturing support, such as sales, level of customer training, and amount of complaint handling by customers. Alternatively, R&D employees' functional responsibilities to the *corporation* revolve more around the research aspect of their R&D roles. These responsibilities include contributing to AMBE's intellectual property and global product development, and providing global technical expertise. The metrics used to measure the employees' contributions to the Corporation, include number of patents, amount of sales generated from new product development, and regional and global product support.

For this study, the most relevant aspects of the employees' job responsibilities, and the metrics associated with them are their roles in local and global knowledge networks. For example, as part of their responsibilities to the division, the employees are expected to engage actively in local knowledge networks, including universities and government agencies. As part of their corporate responsibilities, the R&D employees are supposed to be part of the global knowledge networks, particularly AMBE-specific global R&D knowledge networks, such as, with Central R&D. In other words, the two aspects of the employees' job responsibilities correspond well with the knowledge networks under analysis in this study. Figure 3.1 shows the relationship between the R&D employees' responsibilities, metrics, and the knowledge networks under analysis in this study.

Figure 3.1: R&D Employees' Responsibilities, Metrics and Relationships to Knowledge Networks

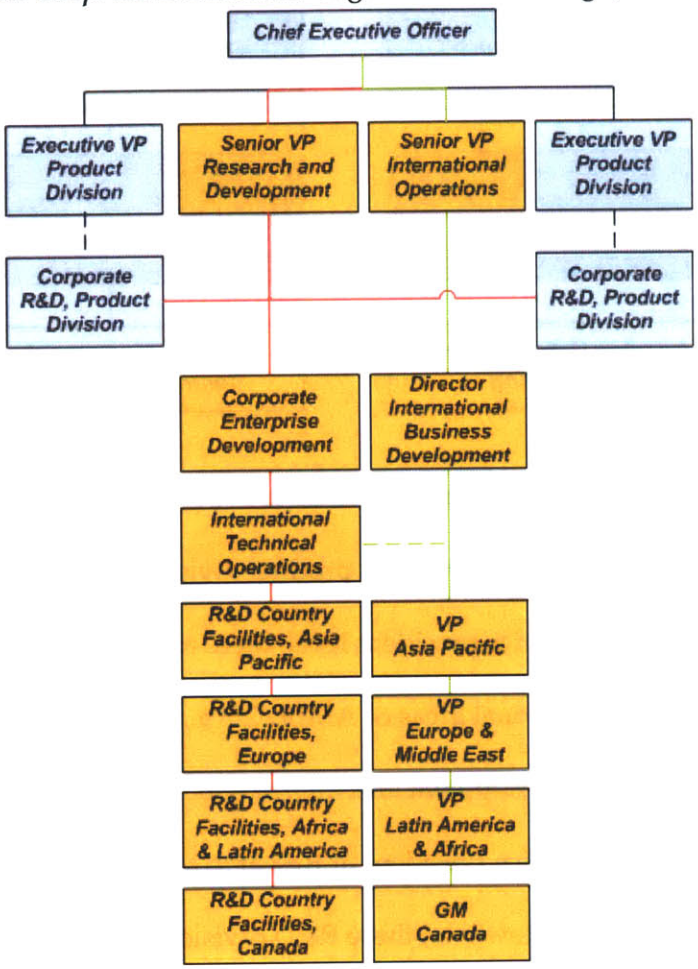


Source: *Author's Rendition.*

Figure 3.2 shows the relevant organizational structure of the international R&D operations at AMBE, where, as I stated earlier, every product division has its own R&D operations. Right below the executive vice president level, there are a number of Senior Vice Presidents who oversee the more functional areas of AMBE Corp., including finance, human resources, as well as, Research and Development and International Operations. These R&D divisions report directly to the Senior Vice President of Research and Development, who reports to the Chief Executive Officer (CEO). However, these R&D divisions also have indirect relationships with their respective product divisions. As such, the divisional R&D operations have obligations to meet the business objectives of AMBE, as well as, to the product divisions. There is however another office that specifically oversees the international R&D operations. In theory, the Office of the International Technical Operations only reports to the Senior Vice President for Research and Development, and does not have any reporting relationship with

any of the product divisions. The primary task of the Office of the International Technical Operations is to support all R&D operations, but it also supports product divisions indirectly through the product R&D divisions. Overall, AMBE's organizational matrix forces R&D operations to take into account the needs of the country, the product, and the firm as a whole, through a series of direct and direct relationships.

Figure 3.2: AMBE Corp. R&D Relevant Organizational Design, 2003



Source: *Author's Rendition.*

3.4 AMBE's Global R&D Operations

In 2003, AMBE Corp.'s total R&D expenditures were $1 billion, or nearly 7 percent of total sales. R&D is distributed at 150 laboratories in 34 countries, and conducted at three levels. The division laboratories are close to the market and work on incremental product innovation,

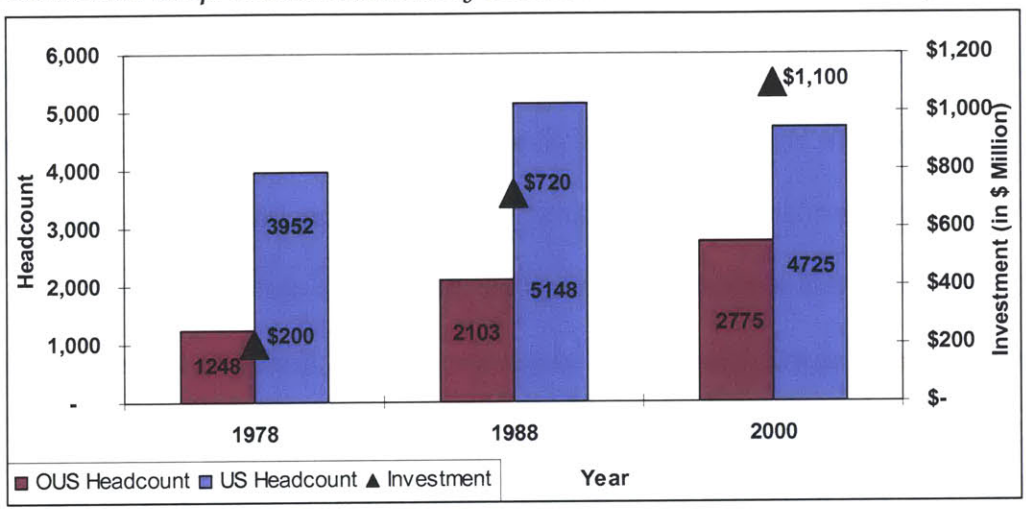
product control, and technical services that support existing product lines and technologies, and operate with a time horizon of 0-3 years. R&D engineers in sector laboratories work on technologies that reach the sector's market in 5 to 10 years, while scientists in the corporate research laboratories are creating new technologies with a future orientation that may lie 10 to 15 years ahead. Nearly every AMBE product has been *developed* in its divisional laboratories, while the basic research behind the product development is done in the corporate laboratories.

Eleven years after launching its first international operations in Brazil, Canada, England, France, Germany and Mexico, AMBE established its first Outside-the-U.S. (OUS) R&D lab in England, designated as a key center for development, a purpose it continues to serve today. By the beginning of the 1990s about one-third of all technical employees at AMBE Corp. were located at laboratories outside the United States. The primary functions of OUS laboratories are to provide technical-service support and product modification to customers, assist manufacturing operations with new product development, and, finally, to act as the 'eyes and ears' of local technological and competitive activity.

AMBE started its R&D operations about 30 years after its incorporation, and these R&D operations have gone through four distinct phases during their existence. During their early days, the primary function of the R&D operations was to support manufacturing, while technical services were used to train the sales staff and customers. This was followed by an extensive expansion of the global R&D facilities, when AMBE started full-service R&D operations in Canada, Europe, Japan, Brazil, and Australia. The OUS R&D functions expanded to include product development, and their analytical capabilities increased to complement the US R&D operations. At the same time, the corporate technical base started to expand as well. This rapid expansion of both the number of OUS facilities and the scope of their functions was followed by a slowdown in the growth of the new local businesses, which resulted in AMBE

management to regard some of the OUS facilities more as an expense than an asset, resulting in a renewed focus on US rather than OUS sales. This combination of events resulted in the scaling back of OUS R&D operations in some of the less strategic locations. Today, there are a few regional full-service R&D labs that provide local and company-wide expertise (Japan and Germany), while the emphasis has shifted toward Southeast Asia, and particularly The People's Republic of China (China) for entry and expansion of R&D facilities. I present the employment and investment trends between the US and OUS facilities of AMBE Corp. in Figure 3.3.

Figure 3.3: AMBE Corp. Global Laboratory Headcount and Investment Levels, 1978-2000



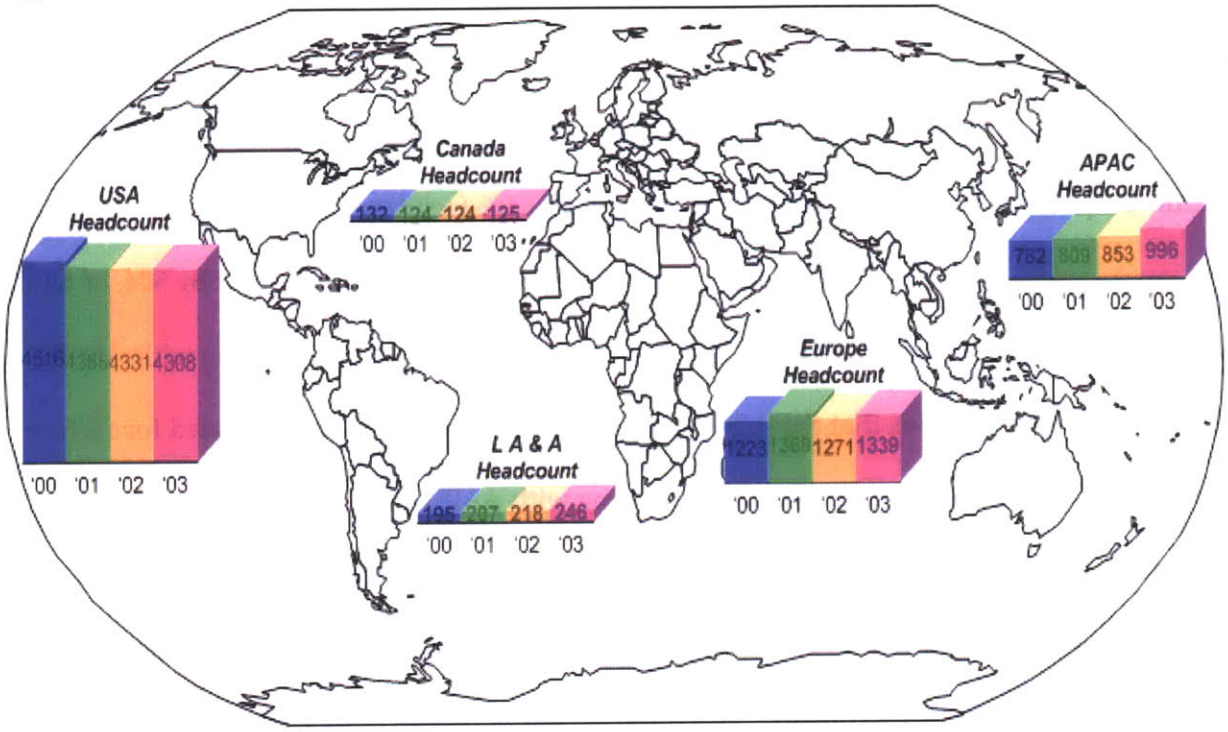
Source: *Author's Rendition.*

Figure 3.3 shows that despite the fact that the OUS R&D operations at AMBE have gone through different phases of growth and consolidation during their years of operations, overall they have expanded significantly during the past 22 years. Between 1978 and 2000, the number of OUS R&D employees more than doubled, while the headcount in the US operations increased by only 17%. At the same time, AMBE's R&D investment increased fivefold, with its per-employee investment increasing from $38,000 per employee in 1978 to over $146,000 per employee in 2000. Combined, the trends show the growing importance of OUS facilities in the

overall global operations of AMBE Corp., and the continuing expansion of AMBE's R&D investments.

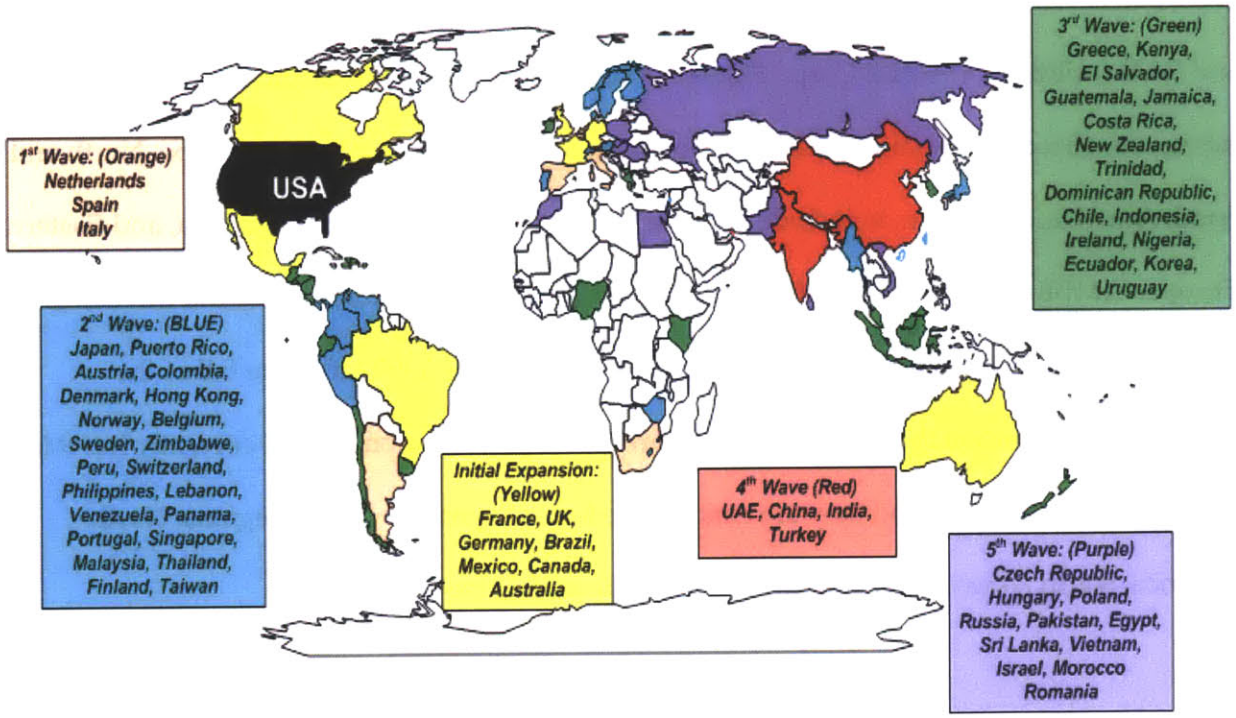
Figure 3.4 shows the details of the global headcount for AMBE's global R&D facility during the past four years. Between 2000 and 2003, the US facilities lost 208 full-time employees, while the number of full-time employees in the OUS facilities grew by 374, of which 214, or 57%, of the increase came from the APAC region. During my interviews with AMBE officials, it became obvious that the APAC region, and particularly China, is slated for further expansion for the foreseeable future. This is in line with AMBE's expectations that China's importance as a market will continue to grow, and that the expanded R&D facilities will not only support the sales and production activities in China, but also keep a close eye on the product requirements of the country. The commitment of AMBE to its global R&D operations has resulted in a network of R&D facilities across the globe. Figures 3.5 and 3.6 present the evolution of AMBE global operations as well as the current locations of all the global technical and R&D facilities for AMBE Corp. Figure 3.5 shows that AMBE has methodically internationalized its operations from its core areas of operations in Western Europe, North and South America, and Japan, to include countries in the Middle East, Southeast Asia, and Eastern Europe. AMBE took advantage of China's market liberalization efforts to expand there in 1984, and entered the Eastern European countries and Russia in the 1990s after the fall of the Communist regimes in those countries. As part of this globalization, AMBE currently has R&D facilities in 31 countries, and they are concentrated almost entirely in four regions: North America, South America, Europe, and Asia Pacific and China (APAC).

Figure 3.4: Details on AMBE Corp. Global Laboratory Headcount, by Region, 2000-2003



Source: *Author's Rendition.*

Figure 3.5: AMBE's Globalization of Overall Operations, 1951-2003



Source: *Author's Rendition.*

Figure 3.6: Location of AMBE's Global Technical and R&D Facilities, 2003

Source: *Author's Rendition.*

Although AMBE has R&D operations in all the above countries, some of the R&D facilities exist just to support customers' technical needs, as well as, manufacturing operations. They are considered part of the R&D operations because the Office of the Technical Operations, which oversees all global R&D facilities, has direct responsibility for these facilities as well. Table 3.3 shows the location of these support facilities, which are called Global Engineering and Manufacturing facilities. These division laboratories are close to the market and work on incremental product innovation, product control, and technical services that support existing product lines and technologies, and operate with a time horizon of 0-3 years. As is apparent from this figure, most of the facilities outside the core North American and European countries (France, German, United Kingdom (UK)) support only two or three products. According to information I received from the R&D managers, AMBE is very focused in creating product-country alignments, where one country's manufacturing facilities become the lead global producer of that product.

Table 3.3: Location of AMBE's Global R&D Division Facilities by Product Division, 2003

Global Engineering and Manufacturing						
Country	*Product Division 1*	*Product Division 2*	*Product Division 3*	*Product Division 4*	*Product Division 5*	*Product Division 6*
United States	☑	☑	☑	☑	☑	☑
Canada	☑	☑	☑		☑	
Germany	☑	☑	☑		☑	☑
France	☑	☑	☑	☑	☑	☑
UK	☑	☑	☑			
Belgium						☑
Spain					☑	
Netherlands	☑				☑	☑
Italy	☑		☑	☑		
Brazil	☑		☑	☑	☑	
Mexico					☑	
Argentine		☑	☑		☑	
Columbia				☑		
Japan	☑	☑	☑		☑	☑
China	☑	☑	☑		☑	
Singapore					☑	
Vietnam	☑				☑	
Taiwan	☑		☑	☑	☑	
Australia		☑	☑		☑	
South Korea		☑				
Malaysia					☑	
Thailand		☑			☑	

Source: *Author's Rendition.*

Sector laboratories are the second tier of AMBE's global R&D facilities. Table 3.4 shows the countries where there are sector R&D facilities by country and product division. R&D engineers in these laboratories work on technologies that will reach the sector's market in 5 to 10 years, which include basic research, product development, manufacturing and customer support. As is apparent from the following table, Canada, Japan, and the United States, are the only country facilities where the R&D facilities support all six product divisions. Furthermore, there are more APAC facilities that support more divisions than in other regions. To illustrate, there are 10 countries in the APAC region that have facilities that support at least one product category, and in a majority of cases, they support between three to five product divisions.

These 10 countries represent half of all countries where AMBE has sector R&D operations. This illustrates another aspect of AMBE's commitment to the APAC region, which requires a more robust R&D infrastructure to incorporate the different market and regulatory requirements into the design and developments for the products in these markets.

Table 3.4: Location of AMBE's Global R&D Division Facilities by Product Division, 2003

Global Research and Development						
Country	*Product Division 1*	*Product Division 2*	*Product Division 3*	*Product Division 4*	*Product Division 5*	*Product Division 6*
United States	☑	☑	☑	☑	☑	☑
Canada	☑	☑	☑	☑	☑	☑
Germany	☑	☑	☑		☑	☑
France					☑	☑
UK	☑	☑	☑			
Belgium						☑
Spain				☑		
Brazil	☑	☑	☑	☑	☑	
Mexico	☑	☑	☑	☑	☑	
Argentine		☑			☑	
Japan	☑	☑	☑	☑	☑	☑
China	☑	☑	☑	☑	☑	
Singapore	☑		☑		☑	
Hong Kong	☑		☑		☑	
Taiwan	☑	☑	☑	☑	☑	
Australia	☑		☑			☑
South Korea		☑	☑	☑	☑	
India	☑		☑	☑	☑	
Thailand			☑		☑	
Indonesia				☑		

Source: *Author's Rendition.*

The final set of AMBE R&D facilities is the Corporate research laboratory, which creates new technologies with a future orientation that may lie 10 to 15 years ahead. Table 3.5 shows the global location of these facilities. What becomes immediately apparent from this figure is that AMBE does not have any Corporate R&D facilities in any emerging countries. In fact, almost all these facilities are concentrated in the United States, with Germany, Japan, France, and Canada housing corporate R&D labs that support one or two product divisions. It is

important to emphasize that in countries where there is more than one class of R&D labs, the employees supporting these labs could be located within the same building and almost certainly within the same campus. As such, countries where there is more than one type of R&D facility can benefit from a richer level of internal resources than those with just one type of R&D facility. In this study, country facilities in Brazil and China support multiple products at both the division and sector levels, while the Canadian facilities support multiple products at the division and sector levels, as well as, product (3) at the corporate level.

Table 3.5: Location of AMBE's Global R&D Corporate Facilities by Product Division, 2003

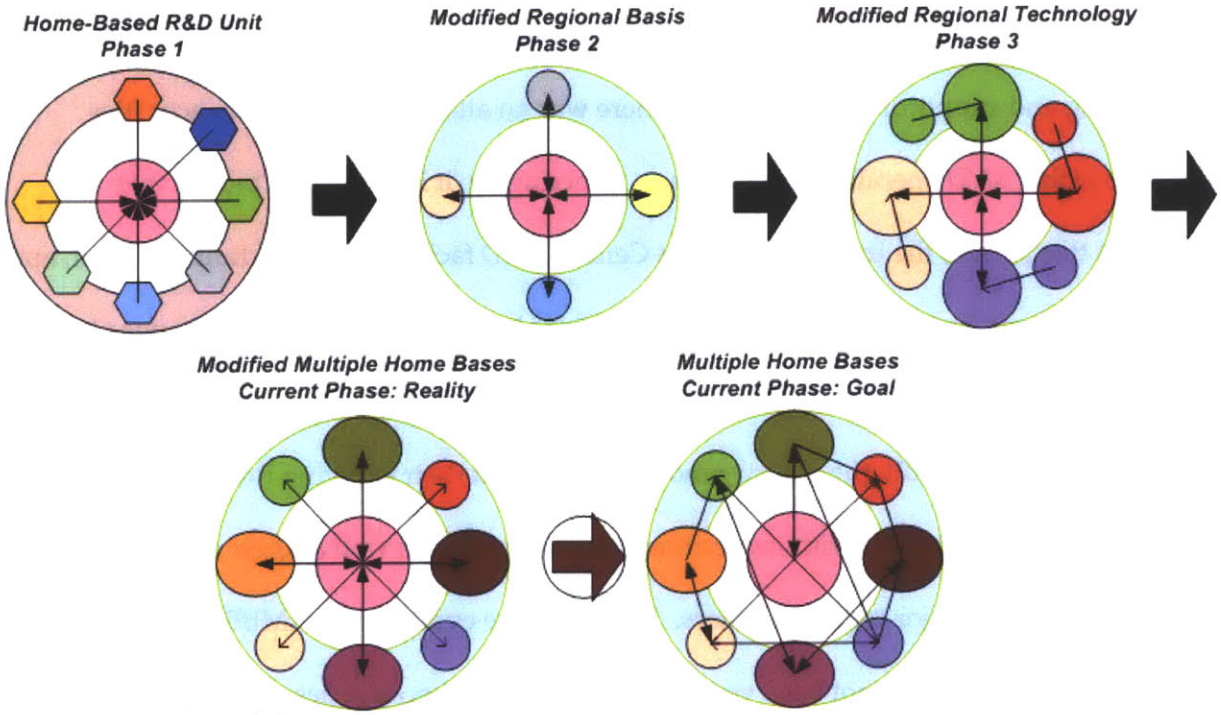
	Technology Centers						
Country	**Product Division 1**	**Product Division 2**	**Product Division 3**	**Product Division 4**	**Product Division 5**	**Product Division 6**	**Engineering**
United States	☑	☑	☑		☑	☑	☑
Canada			☑				
Germany	☑	☑	☑				
France	☑	☑					
Japan			☑			☑	

Source: *Author's Rendition.*

3.5 Evolution of AMBE's Global Organizational Models

Figure 3.7 shows the evolution of AMBE's global organizational model. AMBE started a *Home-Based R&D Unit* (Model 1), where the majority of R&D functions were performed in the home country during the first 50 years of its existence, to the *Regional Basis Model* (Model 4), with the establishment of lead centers in Canada, Brazil, UK, and Australia to support AMBEs business in those countries. To reiterate, the *Home-Based R&D Unit* concentrates all new technology development in the home country, and when necessary, it extends its reach outside the home country through alliances and technology organizations, while the *Regional Basis Model* is characterized by a single center in each major region, with the mandate of developing technology to support the business for the countries in that region and serving as a resource for the local use of technology developed in the other regional centers (Westney 1998).

Figure 3.7: Evolution of AMBE's Global Organizational Models



Source: *Author's Rendition.*

However, it is important to note that during this period, AMBE continued to rely almost exclusively on its Central R&D labs in the home country to conduct the majority of all of the basic research and development, and, as such, the importance of the home base R&D unit did not diminish with the move toward regional bases. As AMBE's globalization of its customers and production facilities grew, the regional centers began to oversee multiple smaller R&D centers within their region, and the organizational model began to resemble the *Regional Technology Headquarters Model* (5), which is characterized by a designated lead center in each region, which manages a network of dispersed local centers within that region and coordinates activities with the other regional lead centers (Westney 1998).

In a majority of cases, new R&D headquarters were established to oversee the regional centers, with the German facilities acting as the lead center in Europe, Japan in Asia and Oceania, and Argentina in South America. Finally, during the past decade, AMBE moved away

from geographical alignment of its R&D facilities, to that of product alignment of its global R&D operations. In this sense, facilities in different countries took the lead or subordinate role in developing and supporting products, and there was an attempt to coordinate activities among the global R&D operations on this basis. Once again, it is important to note that throughout this period, the importance of the Central R&D facilities did not diminish at all, and there is still a strong bias toward the *Home-Based R&D Unit* despite all the other changes in the organizational structures of AMBE Corp.

In the case of AMBE, the primary motivators behind their evolving R&D organization is their quest to align their R&D with international market needs, as well as their desire to have listening posts in the major regional centers. However, the evolution of AMBEs R&D organizational structure has not been very smooth, primarily because despite its push toward a more globally dispersed and decentralized R&D structure, AMBE has never been willing or able to disperse, and decentralize its Central facilities.

3.6 Conclusion

In this Chapter, I provided the relevant background information on AMBE Corp., including its financial condition and its organizational structure. Overall, AMBE has experienced impressive growth in both its revenue and profits, despite the fact that some of its product divisions and geographic regions have not experienced significant growth. This lackluster performance was offset by some very impressive results from other product divisions and by the revenue and profit growth in its Asia Pacific region. I showed that AMBE began globalizing its R&D operations soon after establishing its first global manufacturing operations, and has continued to expand both its total number of facilities, and the number of countries where it has R&D operations. AMBE continues to expand its global R&D operations,

increasing the number of R&D employees in the OUS facilities, even as it has been reducing the number of US R&D personnel. AMBE's global R&D organizational model has evolved throughout the years, changing from the *Home-Based R&D Unit* model to modified *Regional Centers* to *Regional Technology* and finally to the product-aligned *Multiple Home-Based* Model. Despite the evolution of its R&D organizational model, AMBE continues to rely extensively on its Central R&D facilities a great deal more for conducting its basic research and product development, than the above organizational models would require.

In Chapter 4, the methodology chapter, I present the social network methods that I employed to analyze the data, as well as the research settings and details on the surveys I used to gather the data.

CHAPTER 4: METHODOLOGY

4.1 Introduction

In this study, I use the single case of AMBE Corp. to interpret and elaborate on the objectives that I set out in Chapter 1. I chose AMBE Corp. for three reasons. First, the case meets the definition of a firm with globalized R&D facilities. In fact, as I showed in Chapter 3, AMBE Corp. has a long and varied history of globalizing its R&D operations, and the changing organizational features of AMBE's global R&D operations makes this case an especially appropriate one. Second, AMBE's stated goals for its R&D operations are one that stresses global knowledge networking among the scientists of its R&D facilities. As such, I can analyze the actual scale of their knowledge networks with the level of knowledge networking that is expected by AMBE management. Finally, the selection of the three R&D facilities within this one case, allows me to compare and analyze the knowledge networks between facilities that have different mandates, histories, and future growth expectations. I started this case study in 2001, making an original set of initial interviews with AMBE management in the fall of that year, and I signed the agreement to conduct a case of the three facilities in the summer of 2002. I conducted the web-based surveys and personal interviews during the spring, and summer, of 2003.

The structure of this chapter is as follows. In Section 4.2, I provide the details on the research setting, including the steps in the multi-level interview process, the selection criteria for including the respondents in the web-based surveys, and the details on the respondents' personal attributes. In Section 4.3, I discuss the details of the surveys and interviews, the rationale behind the questions, and how they relate to the two knowledge networks under analysis, and their supporting communication tools. I conclude this chapter by presenting the social network methods I use to analyze the data that I gathered by web-based surveys.

4.2 Study Setting

In order to conduct this study, I collected data from three R&D facilities of AMBE Corp. in Brazil, Canada, and China. I selected the facilities in these three countries for two reasons. First, the three countries have distinctly different historical growth paths and business mandates, with Brazil's business mandate and history closely mirroring the geopolitical evolution of the Brazilian government, which has resulted in periods of tremendous growth and importance, as well as episodes of limited contribution. Canadian facilities, on the other hand, have experienced steady growth, and given their proximity to the US Central facilities, they have closely followed the direction of those facilities. Finally, the Chinese facilities came into operation much later than the Brazilian or Canadian facilities, but have been growing at an incredible pace, and they are slated to expand at a much more rapid rate than the facilities in the other two countries. The second reason I selected the three countries, is because of the heterogeneity in the respondents' history, language, and culture from each other. Given that one of the factors that I examine in this study is the influence of the respondents' language and culture on the manner in which they utilize their knowledge networks and communication tools, the selection of such a diverse group of respondents allows me to use location as a proxy for respondents' language and culture.

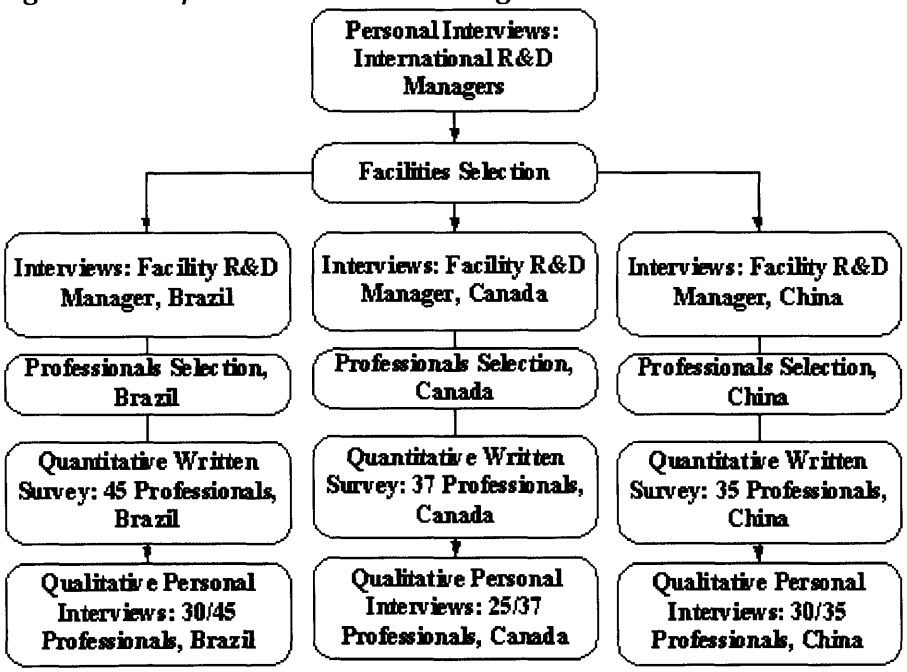
I limited the data collection to engineers, scientists, and managers from R&D and technical operations, because as I showed in Chapter 3, these are the individuals who utilize the two knowledge networks under analysis as part of their job description. I identified these individuals using formal job descriptions and line of reporting, which resulted in the selection of 45 professionals from the Brazilian facilities, 37 from the Canadian facilities, and 35 from Chinese facilities. I collected data on all 117 professionals using a multi-part questionnaire regarding (a) global and local knowledge networks for problem solving, (b) the role of personal,

electronic, and virtual communication tools, and (c) knowledge resources for central, corporate-level innovation within AMBE Corp. I followed up the written, quantitative surveys, with personal qualitative interviews of a selected group of the professionals who participated in the first round of surveys. The primary motive behind the quantitative data gathering was to understand the extent and diversity of global knowledge networks among the employees of the three facilities, as well as the effects of the respondents' personal attributes on their knowledge networks. Alternatively, the purpose of the more qualitative personal interviews, was to recognize some of the external factors behind the differences between shape and size of the knowledge and communication networks that I identified in the first part. I conducted the majority of the second-round interviews in person with the respondents in their respective facilities. However, because of the restrictions that were put in place for travel to China due to the outbreak of the Severe Acute Respiratory Syndrome (SARS), I conducted the qualitative interviews with the Chinese professionals by e-mail, telephone, or through a web survey. Out of the 35 professionals from the first round, I conducted personal interviews with 30 of the Chinese respondents. I conducted personal or telephone interviews with 30 out of 45 professionals in Brazil, and 25 out of 37 professionals in Canada. I selected the individuals for the second-round interviews based on the results of their answers to their web-based surveys. These samples included respondents with very extensive knowledge networks, those with average knowledge networks, and, finally, those with limited knowledge networks. Copies of the web-based surveys are included in Appendix A (Section 4.A). Figure 4.1 shows the sequence of interviews that I conducted throughout the data-gathering phase of this study.

As is apparent from the above figure, I conducted a series of interviews with the corporate managers of the International R&D operations. Referring back to Figure 3.2 on AMBE's organizational structures, all the managers came from the office of International

Technical Operations. The purposes of the interviews are fourfold. The first is to understand the organizational structure of AMBE's international R&D operations and how they evolved throughout the years. The second reason is to identify the challenges and concerns of the R&D management regarding the extent of knowledge networking among the global R&D facilities. This is particularly important, because my previous research into the global knowledge networking of R&D scientists showed that there is a pronounced discrepancy in the management's perception of the extent of global knowledge networks of their R&D scientists, and what my study found to be the case (Shirvani-Mahdavi 2001). As such, by interviewing AMBE's R&D managers, I could make a similar comparison of the reality of AMBE's global knowledge networks, and the management's perceptions.

Figure 4.1: Steps in the Data Gathering Process



Source: Author's Rendition.

The third reason for the interviews is to understand the managements' current and planned initiatives that could affect the manner in which R&D scientists utilize and access their knowledge resources, such as resource allocation to different communication tools, including

virtual tools and personal contact, and changes in incentive systems that could affect the way individuals share knowledge and information. The fourth and final reason for the personal interviews with the R&D managers, is to find out about their plans for future global expansion of AMBE's R&D facilities, both within their current global locations, but also into new countries. I was particularly interested in knowing about AMBE's plans for the facilities in Brazil, Canada, and China, in terms of their product affiliation, expansion plans, and possible contraction scenarios. I conducted all of my personal interviews with the R&D management in person, at AMBE headquarters, with the themes structured loosely around the above subjects. In addition to the corporate R&D management, I also conducted two telephone interviews with the facility director of each facility, mainly on the specific features of their facility and the criteria for making the appropriate selection of respondents. I present the results of these interviews in Chapters 6 and 7.

The respondent-selection process was actually more challenging than I anticipated, primarily because of the fluid nature of the respondents' responsibilities. Although the majority of employees of these facilities are supposed to have functional duties that fall into the two categories I described in Chapter 3, in reality, the respondents have one primary job responsibility and a number of secondary job responsibilities, which change based on the needs of the facility and their projects. Furthermore, because all three facilities are connected to manufacturing, sales, marketing, and customer-care operations, and there are manufacturing employees who also conduct research and development, it became evident that selecting the respondents based solely on their job titles or responsibilities could net a very diverse group of individuals.

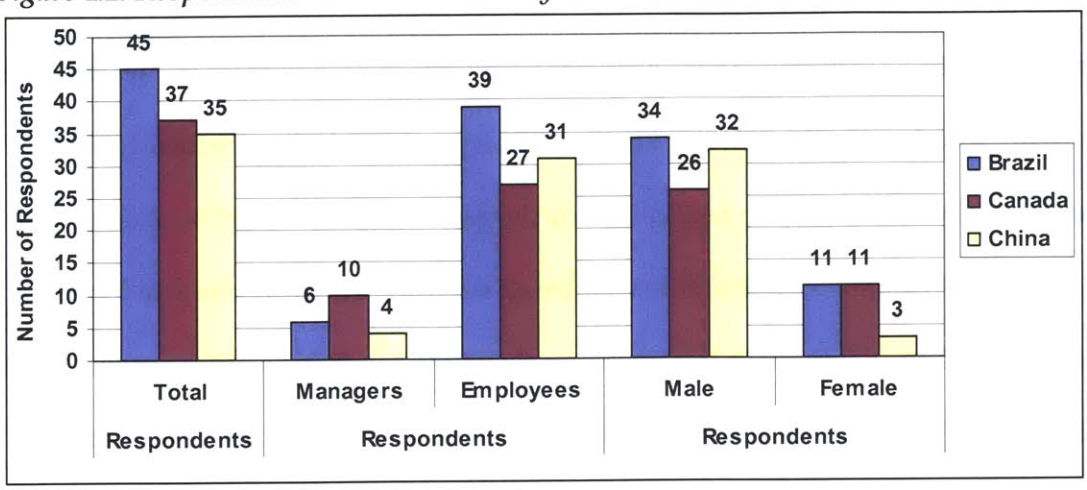
After long discussions with the directors of each of the facilities, I selected the respondents based on both their primary duties and their reporting relationship to the director

of the R&D operations at each facility. Figures 4.2-4.4 show the relevant characteristics of the respondents from the three facilities. These personal attributes, including location, are the ones that I utilize in my social-network analysis. I invited 50 respondents from each facility to participate in the study. The Brazilian facility had the largest response rate (90%) of the three facilities, where 45 individuals completed the web-based surveys. The response rate for the Canadian facility was 74%, where 37 individuals completed the surveys, and 70% for the Chinese facilities where 35 individuals completed the surveys. Combined, the 117 completed surveys represented an overall response rate of 79 percent.

Figure 4.2 shows the characteristics of the respondents who participated in the first round of surveys for the three facilities, and Table 4.1 shows how they compare to the total population of employees from the three facilities. I want to stress that the respondents were not selected randomly from the pool of all available employees in the R&D facilities, but rather everyone who was deemed eligible based on the above criteria was invited to join the study. As such, the characteristics of the final pool of respondents are based on the attributes of the individuals who chose to participate and, as such, may not be a perfect reflection of the characteristics of all eligible R&D employees (Table 4.1).

Figure 4.3 shows the amount of time the respondents have been employed at AMBE, as well as the length of their employment at their current facilities. Both the Brazilian and Canadian facilities started in 1964 and therefore have been operating for 20 years, which is a far longer time than the Chinese facilities, which only started in 1989. Thus, none of the respondents from the Chinese facilities has been, nor could they have been with the firm or the facility, for more than 15 years. In contrast, 15 of the Brazilian respondents, and 14 of the Canadian respondents have been with the *firm* for more than 15 years, and a slightly smaller number have been with their respective facility for more than 15 years (11 and 12 respondents respectively).

Figure 4.2: Respondents' Characteristics by Location



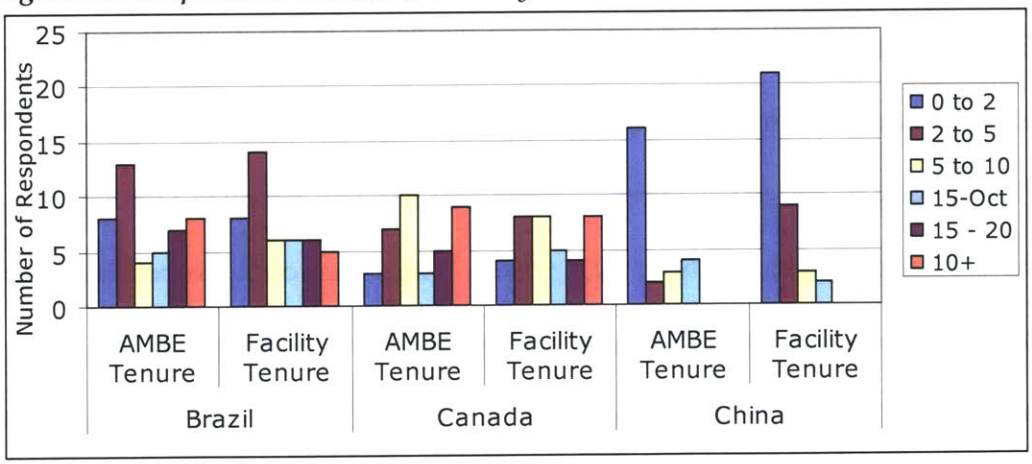
Source: *Mail-in Surveys.*

Table 4.1: Comparison of Respondents' Characteristics to the Population of R&D Employees

Location	Sub-Group	Percent Respondents	Percent Population	Percent Difference*
Brazil	Male	76%	75%	1%
	Female	24%	25%	-1%
	Managers	13%	15%	-2%
	Employees	87%	85%	2%
Canada	Male	70%	65%	5%
	Female	30%	35%	-5%
	Managers	17%	15%	2%
	Employees	83%	85%	-2%
China	Male	92%	85%	7%
	Female	8%	15%	-7%
	Managers	11%	15%	-4%
	Employees	89%	85%	4%

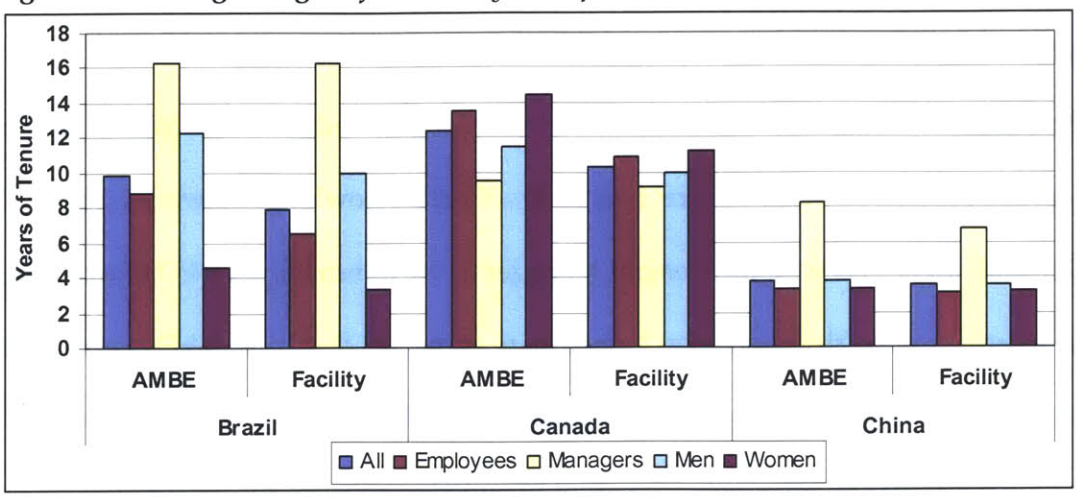
Source: *Mail-in Surveys.* * Percent Difference=Percent Respondents-Percent Population

Figure 4.3: Respondent Characteristics by Location



Source: *Author's Rendition.*

Figure 4.4: Average Length of Tenure by Group



***Source**: The Mail-in Surveys and Author's Calculations.*

The final observation is the difference in tenure levels among women between the three facilities. Women in Brazil have lower tenure levels than men, while their counterparts in Canada have a noticeably longer tenure level than men. The case in China is rather inconclusive, because the tenure levels between men and women are very similar, and also because the facilities have not been open long enough to result in noticeable differences among the different groups, and there are only three female respondents from the Chinese facilities.

4.3 Measuring the Knowledge and Communication Networks

The web-based surveys contained three questions that correspond with the two knowledge networks under analysis, and their supporting communication tools. For all three questions, I provided the respondents with a list of options from which to select, as well as additional 'blank' choices for personal, unidentified resources. Utilizing this dual approach is useful for two reasons. The identified choices exercise the respondents' memory about all the resources that they have at their disposal, and diminish the possibility the respondents under report less-frequently utilized resources. At the same time, providing the respondents with

blank lines, allows them to name their own unique resources that may not be apparent to me or other respondents.

The first question asked the respondent to identify the knowledge resources they utilize to solve day-to-day problems. From my previous study of R&D knowledge networks (Shirvani-Mahdavi 2001), and interviews with the General Manager of the International R&D Operations, as well as, the directors of the three facilities, I was aware of the fact that most R&D researchers spend the majority of their time solving problems that impede their progress in a research project, and as such this was an extremely important knowledge network for the R&D scientists. I specifically asked the respondents about their technical problems, so as not to contaminate the data with organizational, administrative, or operational problems that could also hamper their research efforts. I provided the respondents with a range of inter-facility, local, border-crossing, and virtual-knowledge resources, which correspond to the ones I described in Chapter 2, and asked them to identify how helpful they found each of the resources. In all the relevant cases, and particularly for border-crossing knowledge networks, I also asked the respondents to identify the location of the knowledge resource.

The second question revolved around the respondents' utilization of communication tools. These include, (1) personal tools, such as face-to-face meetings and conversations; (2) conventional electronic communication tools, such as telephone, e mail, instant messaging, and teleconferencing; and, (3) virtual knowledge repository and communication tools, such as AMBE-specific, government and academic databases, and general Internet resources. I included this question in the knowledge-networking survey in order to understand the level of utilization of different communication tools to access different forms of knowledge. The level of utilization of communication tools and their usefulness is becoming particularly important for large, globally dispersed, multinational firms, because there has been a major shift in

communication budgets away from face-to-face contact, and its associated travel costs, to more virtual-communication methods, such as the use of e mail and information repositories (Shirvani-Mahdavi 2001). This question and subsequent personal interviews allow me to understand the extent of these communication networks, their usefulness and shortcomings, and whether the loss in quality of knowledge exchange in face-to-face communications can be replaced by the quantity and ubiquity of virtually available knowledge. Similar to Question 1, I also asked the respondents to rate the usefulness of the tool, as well as how often they used it.

The final question corresponds with the second knowledge network under analysis, that is the network of knowledge resources the respondents utilize to find information about the latest innovative research that is conducted at AMBE's Central R&D facilities. This is different from Question 1 in two ways. First, this knowledge network is specifically about the research that is being conducted within AMBE, and, as such, the potential sources for this type of knowledge are more limited than the knowledge networks for problem solving. In fact, given the nature of corporate research, and the intellectual property rights and confidentiality issues surrounding it, it is reasonable to assume that in this case, all the knowledge resources must be confined to within AMBE itself. However, given the size of AMBE Corp. and the extent of these internal knowledge resources, the list can still be fairly extensive. Second, unlike knowledge networking for problem solving, this type of knowledge networking is not part of the researchers' daily routine. However, I also realized through my interviews with AMBE management that this form of knowledge networking is extremely important to push the innovative knowledge out of the Central Facilities and into global locations, so that it can be utilized, and transformed across AMBE. Given the more limited scope of knowledge resources that are available to respondents for these networks, the choices that I provided to the respondents consisted of AMBE-related local, global, and virtual-knowledge sources. What are

specifically absent from this list are the external-local knowledge resources, such as customers, suppliers, and government agencies. Similar to the other two questions, I provided the respondents with options to identify their own resources that were not included in my list, and I also asked them to rate the helpfulness of the knowledge resource.

Unlike the web-based surveys, the personal interviews were more informal. I chose this informal interview style for two reasons. The first was because of the diversity of the responses I received from the web-based surveys. The second, and more important reason, was because I wanted to allow the respondents to tell me their opinions of knowledge networking at AMBE, while exploring their changing nature of communication tools, and to identify the facilitators, impediments, and organizational and corporate transformations that have affected their knowledge-networking abilities. Given that AMBE is an international company based out of the United States, all respondents could speak fluent in English, and I conducted all personal interviews in English.

The personal interviews were divided into four parts. In the first part of the interviews, I asked the respondents some background information about their R&D careers, both at AMBE and prior to joining AMBE, including questions about their knowledge networks with individuals from their universities and previous firms. In the second part of the interviews, I asked the respondents to identify the facilitators and impediments to their knowledge networking, the reasons behind their choices of utilizing different knowledge resources and contacts, as well as the resources that would facilitate their utilization of knowledge networks. The third part of the questionnaire covered communication dynamism of the respondents' knowledge networks. In this part, I asked the respondents about AMBE's overall knowledge and communication resource base, how this base has evolved throughout their tenure at AMBE, and to identify the management incentives and initiatives that affect their knowledge networks.

In the final part of the questionnaire, I asked the respondents about their attitude toward communication tools, including personal, conventional, and virtual tools. In particular, I asked the respondents to describe what make different communication tools useful, and what additional resources would they need to make these tools as effective as possible. I have included a copy of the questionnaire in Appendix B in Section 4.B.

4.4 Analyzing the Knowledge and Communication Networks

After I gathered the quantitative and qualitative data from the web-based surveys and personal interviews, respectively, I conducted my analysis in three different areas. The first is the descriptive analysis of the web-based data in order to map the networks (Chapter 5). The products of this analysis are visual presentations of the two knowledge networks of each facility, and their supporting communication tools, resulting in 18 maps. Second, I use social-network analysis to uncover the underlying factors that affect the shape and extent of the above knowledge and communication networks. The factors under analysis are the respondents' personal attributes, such as position, gender, firm and facility tenure, as well as, location. I also examine the importance of all the relevant knowledge resources and communication tools, for the groups of respondents with different attributes. The two social-network tools that I use to conduct the analysis are status and equivalence analysis, which I discuss in detail in the next section.

Finally, I use the results of my personal interviews with the respondents to conduct the qualitative analysis. The personal interviews clarified and expanded on a number of factors that affect knowledge and communication networks that could not be measured and analyzed quantitatively using social network methods. These factors, such as the importance of the country's political and economic history and AMBE's management initiatives, could only be

uncovered using qualitative data gathering and interpretation, the results of which I provide in Chapters 6 and 7.

4.4.1 Social Network Methods: Survey Methodology

In designing the web-based surveys, I had to conform to strict protocols set by the Committee on the Use of Humans as Experimental Objects (COUHES), which oversees Massachusetts Institute of Technology's (MIT) social surveys. The most important of these protocols is to insure the confidentiality of the respondents. Survey research is one of the most important areas of measurement in applied social research. The broad area of survey research encompasses any measurement procedures that involve asking questions of respondents. Given the objectives of this study, I began by examining the different types of surveys that I could utilize. These are roughly divided into two broad areas: questionnaires and interviews. Next, I selected the survey method that was most appropriate for the study. The most important consideration for this study was the geographical dispersion of the respondents across multiple locations. Once I selected the survey method, I set out to construct the survey itself. Here, I examined a number of issues including: the different types of questions; decisions about question content; decisions about question wording; and decisions about response format. I discuss each of these briefly next.

1. Survey Type: Given the scope of this study, and its emphasis on quantitative and qualitative factors, I decided to conduct both a web-based survey of the respondents to determine the extent of their knowledge networks, and to analyze the importance of personal attributes on the manner they utilize their communication tools and knowledge networks, followed up by personal interviews, in order to determine the role of the qualitative factors that influence the respondents' knowledge networks.

2. Survey Method: As I stated above, given the globally-dispersed locations of the facilities under analysis in this study, I chose web-based written surveys as the most efficient, equitable, and appropriate method to gather the written data. I protected the survey sites with passwords and encryption, in order to insure that only the selected respondents participated in the surveys, and to prevent any possible security breach.

3. Choice of Questions: The three questions in the web-based surveys correspond directly to the two knowledge networks under analysis, as well as the respondents' utilization of their communication tools.

4. Questions' Content, Wording, and Response Format: The items that I included in the web-based questions were based on my interviews with AMBE's R&D managers as the most appropriate communication tools and knowledge resources the respondents have at their disposal. However, in order to make certain that I did not omit any tools or resources that are unique to the individuals, I provided blank options for respondents to provide their own selection.

4.4.2 Social Network Methods: Status Analysis

Status analysis is a social-network tool to measure popularity, and it is the tool I utilize to analyze the importance of the knowledge resources and communication tools. At the same time, status measurements can also identify whether personal attributes affect popularity of certain knowledge resources, or the size and extent of the network as a whole. At its simplest level, choice status, sociometry's early measure of popularity, is the number of actors who reach an individual (or knowledge resource in this study), *i*, divided by the number who could have done so, (Burt 1992b). Mathematically, this is presented as:

$$status = \sum_j \delta_{ji} / (N-1), j \neq i \qquad (4.1)$$

where N is the number of actors in the whole system (not just those connected to i), and δ_{ij} equals 1 if actor j can reach i, and equals 0 if j cannot reach I; otherwise δ_{ij} equals 0. As such, status varies from 0, when no one reaches i, to 1 when everyone else reaches i (Burt 1992b). The above equation provides a basic mathematical representation for the status measure; however, it is important to note that the status measure that I will be employing, Katz Status measure, is more sophisticated, in the sense that it also takes into account the exclusivity of relationships and the popularity of the tools themselves in assigning status measures.

In this study, I compare the average status measures of the different knowledge sources in the networks, as well as, their level of utilization by different groups under analysis. If, for example, the proposition holds true that individuals with longer tenure levels have larger knowledge networks, then their status measures for utilizing different knowledge resources would be greater than the respondents with shorter tenure levels. On the other hand, if it does not hold true, then there will not be a significant difference in the status scores of individuals with longer facility tenure than the population of respondents with shorter tenure. On another level, I also employ a status measure to analyze the importance of different knowledge resources and communication tools for the respondents, by calculating their average status scores.

4.4.3 Social Network Methods: Equivalence Analysis

I use the second social-network analysis tool, equivalence, to find out whether the boundaries that I draw around actors with similar attributes results in groups of individuals with similar patterns of direct and indirect, present and absent, relations with other actors, *which may or may not include strong relations with one another*. I use equivalence analysis to examine the level of similarity between the knowledge and communication networks of

different groups of individuals. According to Burt (1992b), two individuals are structurally equivalent in a network to the extent that they have identical relations with every individual in the network. Mathematically, the extent to which two individuals i and j are involved in identical relations so as to be structurally equivalent can be expressed as the Euclidean distance, d_{ij}, between their relation patterns:

$$d_{ij} = [(z_{ij} - z_{ji})^2 + \sum_q (z_{iq} - z_{jq})^2 + \sum_q (z_{qi} - z_{qj})^2]^{1/2}, q \neq i, j$$

where a distance of zero indicates completely dissimilar patterns and increasing values of d_{ij} indicate increasingly equivalent patterns. The above equation is a simple profile of relations defining an individual j's network position, arranged in a vector of Z_j of $2N$ relation variables; N variables measuring j's relations to others ($z_{j1}, z_{j2}, \ldots, z_{jN}$) and N variables measuring relations j receives from others ($z_{1j}, z_{2j}, \ldots, z_{Nj}$).

There has been a strong tradition of using equivalence analysis to identify niches within populations who share common resources (Burt and Talmud 1993; Carley 1986; Galaskiewicz and Burt 1991). In the majority of cases, researchers utilize equivalence analysis to search for common attributes of individuals based on the similarity of their knowledge relationships (e.g., Lazer 2001; Greve and Salaff 2001). For example, Greve (2001) utilized structural equivalence to partition the participants in a technical knowledge network of a project into groups of actors with similar network positions in order to identify the economic or social niches among the respondents.

In this study, I utilize the equivalence analysis in the opposite manner, namely, I partition the individuals into groups based on specific personal attributes. Next, I use equivalence analysis to examine whether these individuals have more similar knowledge networks based on the average equivalence analysis, as compared to the population of

respondents. In other words, in previous studies, researchers have partitioned the population based on equivalence scores to determine the attributes of groups with similar network relationships. However, in this study, I partition the population based on selected attributes and use the equivalence scores of these groups to determine the importance and relevance of these attributes in affecting network relationships. For this study, I choose gender, position, tenure and location (as a proxy for language and culture), because, as I discussed in Chapter 2, there is abundant research that shows that people tend to choose individuals similar to themselves for communication and knowledge networking (Marsden 1988; Newcomb 1961). The underlying premise of this approach is that if personal attributes affect knowledge networking of the respondents, then groups of individuals with the same attributes would have a greater average equivalence score than the population as a whole. For example, if position plays a role in knowledge networking and in the manner in which respondents utilize their communication tools, then, for example, managers would have higher equivalence scores than the population of all individuals.

4.5 A Note on the Social-Network Software

I used Cyram NetMiner II, which is an innovative software tool for Exploratory Network Data Analysis and Visualization. Its unique feature lies in the integration of standard social-network-analysis methodology with modern network visualization. NetMiner allows the user to explore network data visually and interactively and helps the user to detect underlying patterns and structures of the network (Cyram 2003).

4.6 Conclusion

To unravel the complex processes that underpin successful technological innovation, analysts need to explore systematically the complex patterns of personal interaction within and

across the boundaries of development teams, innovative organizations, industrial sectors, and geographical regions. A considerable amount of research indicates that innovation does not occur as a result of one single event but emerges from a bundle of ideas, information, technology, codified knowledge, and know-how, which may or may not be embodied within the product or process (Allen 1977). Thus, the strength of the network approach is that, on the one hand, it allows a detailed analysis of the dyadic links mobilized in the innovation process while, on the other hand, it provides a framework for exploring multiple sources and pluralistic patterns of communication typical in the development of technological innovation (Steward and Conway 1996).

In this chapter, I presented the three aspects of the methodology I utilized to achieve the three objectives I set out in Chapter 1. These include: (1) the means by which I gathered the required multi-level data I needed to conduct this study; (2) the measures I use to make the data relevant for the analysis; and, (3) the methods I utilize to analyze the data. In the next chapters, I present the results of the analysis, starting with a descriptive and visual representation of the networks in Chapter 5, and concluding with the results and analysis of the quantitative and qualitative data in Chapters 6 and 7 respectively.

APPENDIX 4.A.: WEB-BASED SURVEY

Title:
Name:
Location:
E-Mail:
Position:

INTRODUCTION: This survey is an integral part of a doctoral research project in which the researcher is examining the role of social networks in global R&D facilities of large multinational firms to enhance knowledge sharing and creation among their employees. In this first stage of the survey process, everyone in your facility will receive the exact same questionnaire, which is a short, five-question survey that inquires about the general nature of your social network.

CONFIDENTIALITY STATEMENT: The purpose of this statement is to assure you that the researcher will treat all of the information you provide in this survey with complete confidentiality, and that the researcher will not use it in any way, shape, or form, that could identify you, your place of employment, or the identity of your social network. This confidentiality is assured in two ways. First, all surveys are coded and kept in secure folders, available only to the researcher. No one else will have access to the surveys at any time. Second, the results of the surveys will be aggregated in a manner that will not identify any one individual, or their social networks. The aggregated results will be available to all participants of this survey upon their request. Finally, the researcher is bound by two forms of confidentiality agreements that prevents him from disclosing any information that may identify the participants of the survey, or disseminate the results in any manner that will divulge details about the facilities and their employees. The first is a confidentiality agreement between the researcher and AMBE, the second is between the researcher and Massachusetts Institute of Technology (MIT).* In this study, the researcher refers to Mr. Ali Shirvani-Mahdavi, who is a doctoral candidate at Massachusetts Institute of Technology (MIT) and is solely responsible for the content and administration of this survey.

INSTRUCTIONS: Questions 1 and 2 are about the people you seek out to help you with your technical questions, enhance your technical knowledge, or help you with whatever technical and scientific problems that may arise during the course of your daily work at your facility, and where these people are located. Please be as specific as possible when describing the location of the individuals. For example, if the individual is located at a particular facility in Japan, include both the facility's name and its location in Japan. It is important to point out that all these questions are about your contacts during the past month. Questions 3 and 4 are about the method (s) by which you communicate with the above contacts, and the frequency by which you use the indicated methods to communicate with your contacts. In all cases, please check all that apply, and if you need additional lines, or if there is an option that is not included, please include it in your answer. Finally, question 5 is expressly about the means by which you obtain information about the technical know-how and expertise that is generated in the Central R&D facilities at AMBE headquarters in St. Paul, MN, USA. Specifically, this question is about the importance of different ways by which you obtain this information. For all the above questions,

please indicate the importance of the contacts or the methods that you select. Once you have answered all the questions, please use the "Submit" button to send the form.

The "Reset this Form" button clears all the fields in the form, to allow you to start from the beginning. IMPORTANT: PLEASE REMEMBER THAT YOUR ANSWERS WILL NOT BE SAVED IF YOU EXIT THE QUESTIONNAIRE WITHOUT SUBMITTING IT FIRST. AS SUCH, PLEASE MAKE CERTAIN TO ALLOW YOURSELF ENOUGH TIME TO COMPLETE THE SURVEY ONCE YOU START IT, AND TO SUBMIT THE QUESTIONNAIRE ONCE YOU HAVE COMPLETED IT.

QUESTIONNAIRE:

Questions 1&2 - Who and Where: During the past two months, where did you get your technical and scientific information to enhance your effectiveness in doing your job? Please rank their order of importance in enhancing your effectiveness in doing your job, and use the additional lines to include options not included.

(For each question, please indicate how helpful you find the resource:
Very Helpful, Helpful, Somewhat Helpful, Not Helpful)

A. Someone in your project
B. Someone in your facility
C. Someone in other AMBE facility (Please specify)
C1.
C2.
C3.
D. Someone in academia
E. Technical or scientific journal
F. Technical or scientific website
G. Technical or scientific conference
H. Customer (s)
I. Supplier (s)
J. Someone in a government agency
K. Someone in other firms or facilities (Please specify)
K1.
K2.
K3.

Additional Lines

AL1.
AL2.
AL3.
AL4.
AL5.

Questions 3&4 - How and How Often: During the past two months, how and how often did you get your technical and scientific information? Please rank their order of importance in enhancing your effectiveness in doing your job, and use the additional lines to include options not included.

(For each question, please indicate how helpful you find the tool and how often you utilize the tool:

- Very Useful, Useful, Somewhat Useful, Not Useful
- Daily, Weekly, Monthly, Less Often)

A. Face to face
B. Telephone
C. E mail
D. Instant messaging
E. Teleconferencing
F. Web conferencing
G. Other Electronic Tools (Please specify)
G1.
G2.
H. Database query (Please specify source)
H1. AMBE
H2. Government
H3. Academia
H4. Other (please specify)
H5.
H6.
H7.

Additional Lines

AL1.
AL2.
AL3.
AL4.
AL5.

Question 5 - Contact with St. Paul: How do you obtain information about the technology and technical know-how that is developed and available at the headquarters of AMBE technical facilities, in St. Paul? Please rank their order of importance in enhancing your effectiveness in doing your job, and use the additional lines to include options not included . Please note that the scope of this question is NOT restricted to the past two months.

(For each question, please indicate how helpful you find the resource:
Very Helpful, Helpful, Somewhat Helpful, Not Helpful)

A. Someone in an R&D facility in St. Paul
B. Someone in another type of facility in St. Paul
C. Someone in your project
D. Someone in your facility
E. Someone in another AMBE facility (Please specify)
E1.
E2.
E3.
F. AMBE Database Query (Please specify the database)
F1.
F2.
F3.
G. Electronic Technical Forums
H. AMBE Technical Conferences
I. Other (Please specify name and location)
I1.
I2.
I3.

Additional Lines

AL1.
AL2.
AL3.
AL4.
AL5.

Thank you for your cooperation! If you have any questions, please contact the Researcher.

APPENDIX 4.B.: PERSONAL-INTERVIEWS QUESTIONNAIRE

Part I: Background Information:

1. How long with AMBE?
2. How long at the facility?
3. How many different positions at AMBE?
4. What did you do before working at AMBE?
5. Have you ever spent any time at another AMBE facility?
    a. If so, how do you rate the experience?
    b. If so, do you still keep in touch with the people in those facilities?
    c. Setting aside any personal reasons (such as family obligations, etc.) do you think it would be useful to work at another AMBE facility for a short period of time?
6. Where did you go to school?
7. Do you ever contact your school colleagues about problems that may come up at work? (why or why not)

Part II: Communication Facilitators and Impediments:

8. When thinking about the people you approach for help with your projects, what are the primary motivators behind your choices?
9. What are the primary reasons you do not choose other available resources, such as individuals in other facilities, electronic databases, etc.?
10. What additional resources could help you expand your communication resource base?
11. When thinking about people you have worked with on projects, do you think that they used more or less of the available resources to help with their jobs?
12. Do you feel that people with larger communication base (more contacts, more tools, more often) get things done faster and better?
    a. Why or why not?

Part III: Communication Dynamism:

13. How would you describe AMBE (as a whole) communication resource base to help you with your job? (This could be anything from putting together projects with the right mix of skills, to electronic tools and DBs, to providing with information about where to go to get the information you need)
14. How has this communication resource base been changing during your time at AMBE? (Again, this could be anything from changing spending mix for effective communication tools (e.g. less travel vs. more E tools; changing demographics, etc.)
15. How would you describe the incentive system at AMBE for people to develop and expand their communication base? (Again, this is about whether the message and the actions go hand in hand)

Part IV: Role of E tools:

16. When thinking about e tools in general, what do you think are their greatest assets in helping you with your job? (This could be anything from E mail onward, such as teleconferencing, webcasting, DBQs, Internet Based design tools)
17. When thinking about e tools in general, what do you think are their shortcomings assets in helping you with your job?
18. How relevant are E tools with helping you perform your daily tasks? (are they an afterthought, or are E tools your first choice, and only if they don't come through, do you seek more traditional methods)
19. When thinking about other people you have worked with, do you feel you use E tools more or less than they do?
20. From both technology and access perspective, how can E tools be improved upon, so that they can become more useful for you to do your job?

CHAPTER 5: MAPPING THE KNOWLEDGE AND COMMUNICATION NETWORKS

5.1 Introduction

In this chapter, I present the two knowledge-network maps, and their supporting communication tools, for each of AMBE's three facilities. To reiterate, the networks under analysis are Knowledge Networks for Problem Solving (*KNPS*), Knowledge Networks for Central R&D Innovation (*KNCRDI*), while Communication Tools for Knowledge Networking (*CTKN*) examines specifically the role of communication tools that support the above knowledge networks, and the three facilities are located in Brazil, Canada, and The People's Republic of China (China). Maps are an important component of knowledge network analysis, because visualization is an crucial aspect of both exploration and communication of knowledge-networking data. Graphical displays of knowledge networks are particularly attractive because they can present, in a compact way, the position of individual actors in a network, the level of their utilization of communication tools, and knowledge resources, as well as, what the overall network structure looks like. Brandes, Kenis, Raab, Schneider, and Wagner (1999) argue that in order to produce effective visualizations of knowledge networks, it is necessary to be conscious about two major aspects of the maps. The first is the substance that is being communicated and explored, and second, a design must map the substance to graphical presentation in an appropriate manner. The purpose of this chapter is to map the substance of the findings from the web-based surveys to an efficient and appropriate design, using the results of the social network analysis. The substance is the level of utilization of knowledge resources and communication tools by the respondents at the three facilities along the two networks, and their supporting communication tools. The design is a simple representation of the respondents as actors, and resources as events, in bipartite graphs, which I describe next. To make these maps,

I enhance the visual outputs from NetMiner's analysis of the web-based data using Visio and Pajek diagramming tools.

The structure of this chapter is as follows. In Section 5.2, I describe the utilization of bipartite graphs as a method to map knowledge networks, while in Sections 5.3-5.5, I present the nine maps of the two networks, and their supporting communication tools, from the three facilities. In addition, I provide the academic, external, and cross-location (global) gatekeeper maps of *KNPS* networks for the three facilities. I conclude the chapter by pointing to the relationship between the knowledge maps and the analysis of the knowledge networks that I present in Chapters 6 and 7.

5.2 Mapping Knowledge and Communication Networks as Bipartite Graphs

Affiliation networks are two-mode networks, consisting of a set actors and a set of events (Wasserman and Faust 1994). In this study, the actors refer to the respondents from the facilities, while the events refer to the knowledge resources or communication tools they utilize in their knowledge and communication networks. Analysts map affiliation networks through bipartite graphs, by representing both actors and events as nodes, and assigning actors to one subset of nodes and events to the other subset (Wasserman and Faust 1994).

To illustrate an affiliation network, consider the hypothetical example of six children and three events (Figure 5.1 and Table 5.1). The set of actors is denoted by $\mathcal{N}$={*Susan, Amy, Karin, Joe, Shawn, David*), and the set of events is denoted by $\mathcal{M}$={*Birthday, Parade, Game*). I present the affiliation network matrix for this example in Table 5.1. This matrix, denoted by $\mathbf{A}=\{a_{ik}\}$, shows the affiliation of the actors with the events. For example, in Table 5.1, there is a '1' at the intersection of row 1 (i**1**), *Birthday Party*, and column 1 (k**1**), *Susan*, indicating that

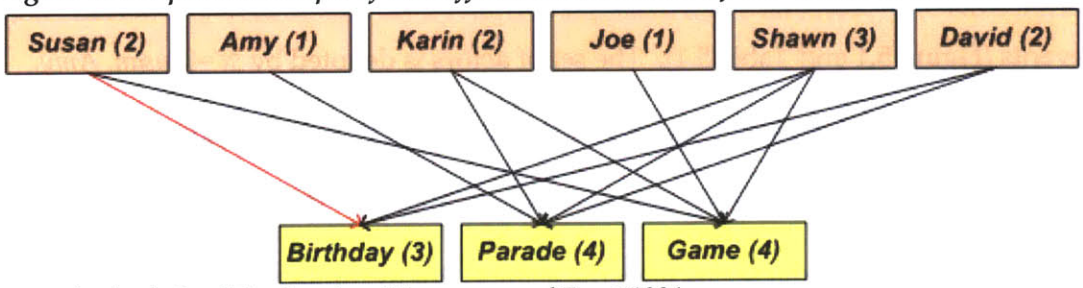
Susan attended the birthday party. Alternatively, there is a '0' at the intersection of row 2 (*i*1), *Parade*, and column 1 (*k*3), *Susan*, signifying that Susan did not go to the parade.

Figure 5.1 shows the bipartite graph of the affiliation matrix (Table 5.1). In order to translate the affiliation matrix into a bipartite graph, I draw a line between each child and their affiliated events. For example, there is a line connecting Susan to the birthday party, but there is not a line connecting Susan to the parade. In Figure 5.1, the numbers associated with the children and the events are their degree nodes. In bipartite graphs, the degree node for an actor is the number of events that the actor is affiliated with, while the degree node for an event is the number of actors that are affiliated with the event (Wasserman and Faust 1994). For example, the degree node for Susan is 2, because she attended both the birthday party and the game, while the degree node for the birthday party is 3, because Susan, Shawn, and David attended the birthday party. Overall, an advantage of presenting an affiliation network as a bipartite graph is that the indirect connections between events, between actors, and between actors and events, are more apparent in the graph than in the affiliation matrix, **A** (Table 5.1).

Table 5.1: Sociomatrix for the Bipartite Graph of the Six Children and Three Parties

	Susan (*k*1)	Amy (*k*2)	Karin (*K*3)	Joe (*k*4)	Shawn (*k*5)	David (*k*6)
Birthday (*i*1)	1	0	0	0	1	1
Parade (*i*2)	0	1	1	0	1	1
Game (*i*3)	1	0	1	1	1	0

Figure 5.1: Bipartite Graph of the Affiliation Network of Six Children and Three Events

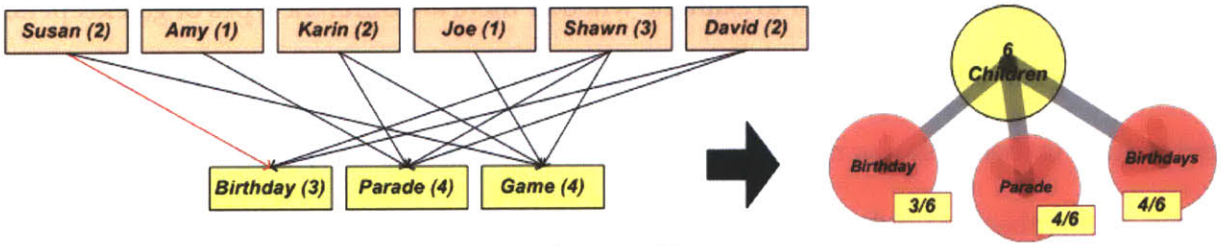


Source: *Author's Rendition based on Wasserman and Faust 1994.*

For the purposes of this study, and given the large number of respondents and their multiple affiliations with a number of knowledge resources, I combined the respondents in the

bipartite graphs, and represent their relationship with their knowledge resources as a group from each facility. The lines connecting the respondents (actors) to their resources (events) represent the percentage of the respondents from each facility that utilizes that resource, and I depict the level of utilization of each resource by the thickness of the line connecting the respondents to each of the knowledge resources. Figure 5.2 shows how the affiliation graph from Figure 5.1 would look if I used this technique to represent the affiliation matrix **A** (Table 5.1). The main difference between the two figures is that I do not identify the children individually in the consolidated graph in Figure 5.2, but present their choice of activities as a group. In reality, because I am only interested in the knowledge networking of groups of individuals based on their different attributes, I do not lose any significant content by presenting the maps in this manner (Figure 5.2). However, for the gatekeeper analysis, where the individual respondent's knowledge networking with its particular knowledge resources is important to analyze, I break down the bipartite graphs to the respondent level.

Figure 5.2: Detailed and Consolidated Versions of Bipartite Graph of the Affiliation Network of Six Children and Three Events



Source: *Author's Rendition based on Wasserman and Faust 1994.*

However, it is important to note that because I do not identify individual respondents in these maps, I cannot distinguish between the different types of roles that these individuals play. As such, it is difficult to show whether there are certain group of respondents who act as overall 'gatekeepers' to certain knowledge resources, and therefore represent a more efficient mean of bringing this external and cross-location knowledge into the facility. The purpose of the

gatekeeper maps, which break down the knowledge networking to the level of the individual respondent, alleviates this problem.

According to Allen (1977), gatekeepers are a "small number of key people to whom others frequently turned for information. Gatekeepers differ from their colleagues in the degree to which they expose themselves to sources of technological information outside their organization" (p. 145). The following features distinguish knowledge gatekeepers from their colleagues. First, they constitute a small community of individuals; second, they are the core of the knowledge network; third, their level of utilization of these external knowledge resources is greater than the population of respondents as a whole; and fourth, the linkages they develop with external actors are mostly informal (Allen 1977). However, given the extent and diversity of the external knowledge resources under analysis in this study, I separate these external knowledge resources into specialized sub-categories. There are two reasons why this is useful. The first is that Allen (1977) did not distinguish between external knowledge resources, and there is very little in the literature on knowledge networking, which has specifically examined this concept. As such, it is useful to examine whether there are different types of gatekeepers, which access specialized forms of external knowledge. The R&D management may assign individuals to these roles, or most likely, certain individuals become specialized gatekeepers, based on their background experience, and the shape and extent of their social networks. The second reason is that by understanding the underlying dynamics of the gatekeepers' knowledge networks, I can show whether the facilities' overall knowledge networks exhibit a certain amount of efficiency in accessing these external knowledge resources, which could, otherwise, be misinterpreted as 'under-utilization' of some of these sources.

In order to determine the role of the gatekeepers, I present a set of detailed maps of these respondents for knowledge networks for problem solving in Section 5.3.1. There are three

types of specialized gatekeepers I describe in this chapter. The first, external academic gatekeepers are those respondents who make use of academia, journal, or conference knowledge resources. I devised this group, because one of the main drivers that I examine in this study is whether the employees of these R&D facilities access and utilize the local academic expertise that is available to them. In particular, this is related to two of the five drivers that I described in Chapter 2: (1) stimulating innovation, and (2) ability to influence research. By examining the knowledge networking of the academic gatekeepers, I can understand whether the above drivers hold true, at least in the case of AMBE. In addition, I included journals and conferences in the 'academic' gatekeeper category, because they represent the product of academic research. Although I do not distinguish between academic and AMBE-specific conferences, the end result is that in either case, these conferences expose the respondents to external knowledge resources.

Alternatively, external non-academic gatekeepers, are respondents who utilize all the other external knowledge resources that the respondents have at their disposal, such as customers, suppliers, government agencies, and other firms and facilities. Specifically, these resources refer back to the other three drivers of globalization of R&D, which is, proximity to suppliers, customers, and sources of knowledge and expertise. All of the above resources are capable of providing the respondents with robust, non-academic knowledge, which can lead to increased innovative activity, and problem solving. However, the primary reason for including a knowledge resource in the academic or non-academic group revolves around the type of relationship the gatekeeper has with the knowledge resource. The relationship between the respondents and their non-academic external knowledge resources is based either on a market transaction (suppliers and customers), or on competition (other firms and facilities), or on market regulation (government agencies). Alternatively, the relationship with academic

resources are not, for most part, tied to market transaction, and as such can provide the gatekeepers with a much more objective knowledge.

Finally, I selected cross-location gatekeepers based on their knowledge networking with AMBE's *non-Central* global R&D facilities, where Central R&D refers to AMBE's main Corporate R&D facilities, while the global R&D facilities refer to all the remaining geographically dispersed R&D facilities. As such, these respondents do not fit Allen's definition of market gatekeepers at all. However, this is an important group of respondents, because they act as gatekeepers to all the diverse global knowledge resources that are available within AMBE. This knowledge may be the by-product of the facilities' interactions with their own external local knowledge resources, thus exposing the cross-location gatekeepers to a very rich, and diverse set of global knowledge resources. I excluded the Central R&D facilities from this list of knowledge resources for this group, because the majority of respondents in each facility already have knowledge-networking relationships with Central R&D, and as such, it is not necessary to have a specialized group that exposes the respondents to this knowledge. Furthermore, I do not conduct the gatekeeper analysis for *KNCRDI* networks, because there are no external or academic knowledge resources for the respondents to access, and the respondents' utilization of their cross-location knowledge resources is very limited. As such, all of the gatekeeper analysis in this Chapter, as well as in Chapters 6 and 7, refer only to the *KNPS* networks.

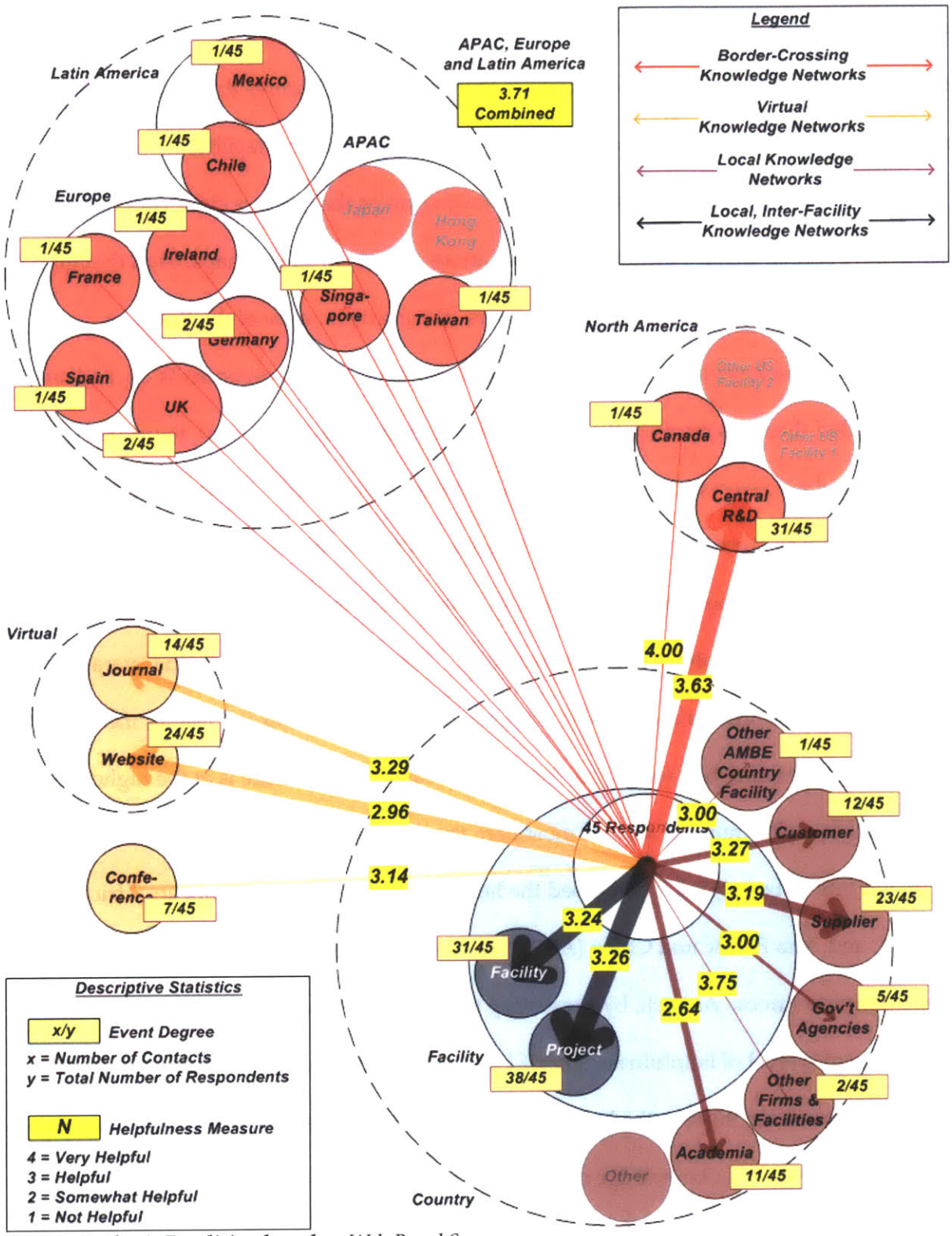
5.3 Mapping Knowledge Networks for Problem Solving (*KNPS*)

Knowledge networks for problem solving are networks of knowledge resources that respondents utilize in order to solve their technical problems. These networks can be formed on an ad-hoc basis depending on the needs of the individuals, or they could have formal structures, where individuals join or start knowledge-sharing groups whose functions include

helping them with their daily tasks. The respondents may also choose to utilize virtual knowledge repositories or electronic journals to look for solutions to their problems. Regardless of the individuals' own networks of resources, there are certain features that emerge when examining the knowledge networks of all respondents from the same facility.

There are a number of features of the following maps that require clarification. First, in order to have similar maps, I include all the resources or tools in all the maps, even though not all of the respondents utilize all of these resources. For example, none of the Brazilian respondents use the knowledge resources in Japan, but the Chinese respondents do, and, as such, I included these resources in the Brazilian *KNPS* maps as well. Second, there are two sets of numbers that are associated with each of the knowledge resources. The numbers in the bright yellow boxes represent the level of helpfulness of the resource. From the web-based surveys, I scored a very helpful resource as a '4', helpful resource as a '3', a somewhat helpful resource as a '2', and an unhelpful resource as a '1'. This helpfulness index is the average score of all respondents' scores for a particular resource. As such, this index is a *relative* measure of the respondents' valuation of each resource. In most cases, this measure is at the higher end of the helpfulness scale, implying that for most part, the respondents do not utilize the resources they do not find to be helpful. I combined the helpfulness index of the European, African, Latin American, and Asia Pacific and China (APAC) facilities, because of the low rate of utilization of these country resources. As such, by presenting this data on the aggregate level, I provide a more meaningful level of helpfulness, than if I present the data for each country. Finally, the second set of numbers, those in the beige boxes, represents degree nodes, which are the ratios of respondents who utilize a knowledge resource. Figure 5.3 shows the knowledge network map of the *KNPS* network for the Brazilian facilities.

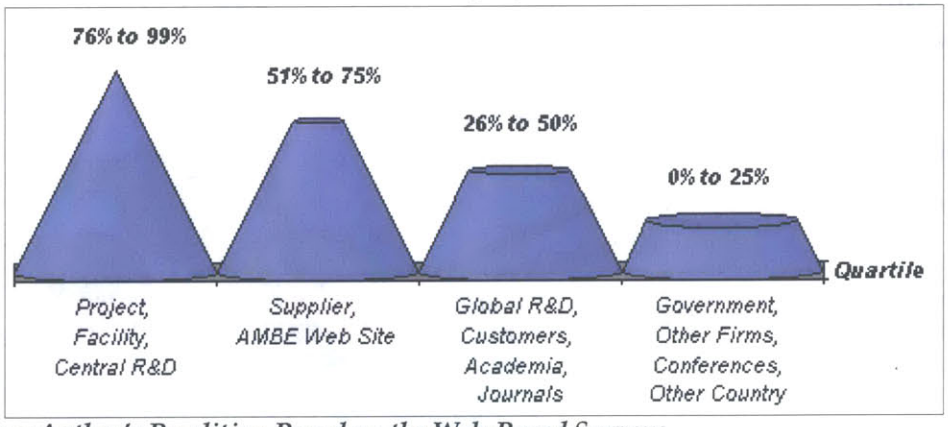
Figure 5.3: KNPS - Mapping the Brazilian Respondents Knowledge Resources



Source: Author's Rendition based on Web-Based Surveys.

If the Brazilians choose to go outside of these resources for their answers, about half of the respondents choose the AMBE website or their suppliers. The next quartile of knowledge resources are journals, customers, and academia, which are utilized by about 30 percent of the respondents, while the remaining knowledge resources, such as government, other firms, and conferences, fall in the fourth quartile of utilization, where approximately 2 to 15 percent of the respondents utilize these resources. Figure 5.4 shows this clear delineation in the manner in which the respondents utilize their available knowledge resources for problem solving. Overall, the Brazilian respondents rated the Central R&D, and global R&D facilities as most helpful, followed by facility, project and the journal. However, overall, the respondents rated almost all the resources to be helpful to very helpful, implying that the respondents utilize the resources they know can help them with their technical problems.

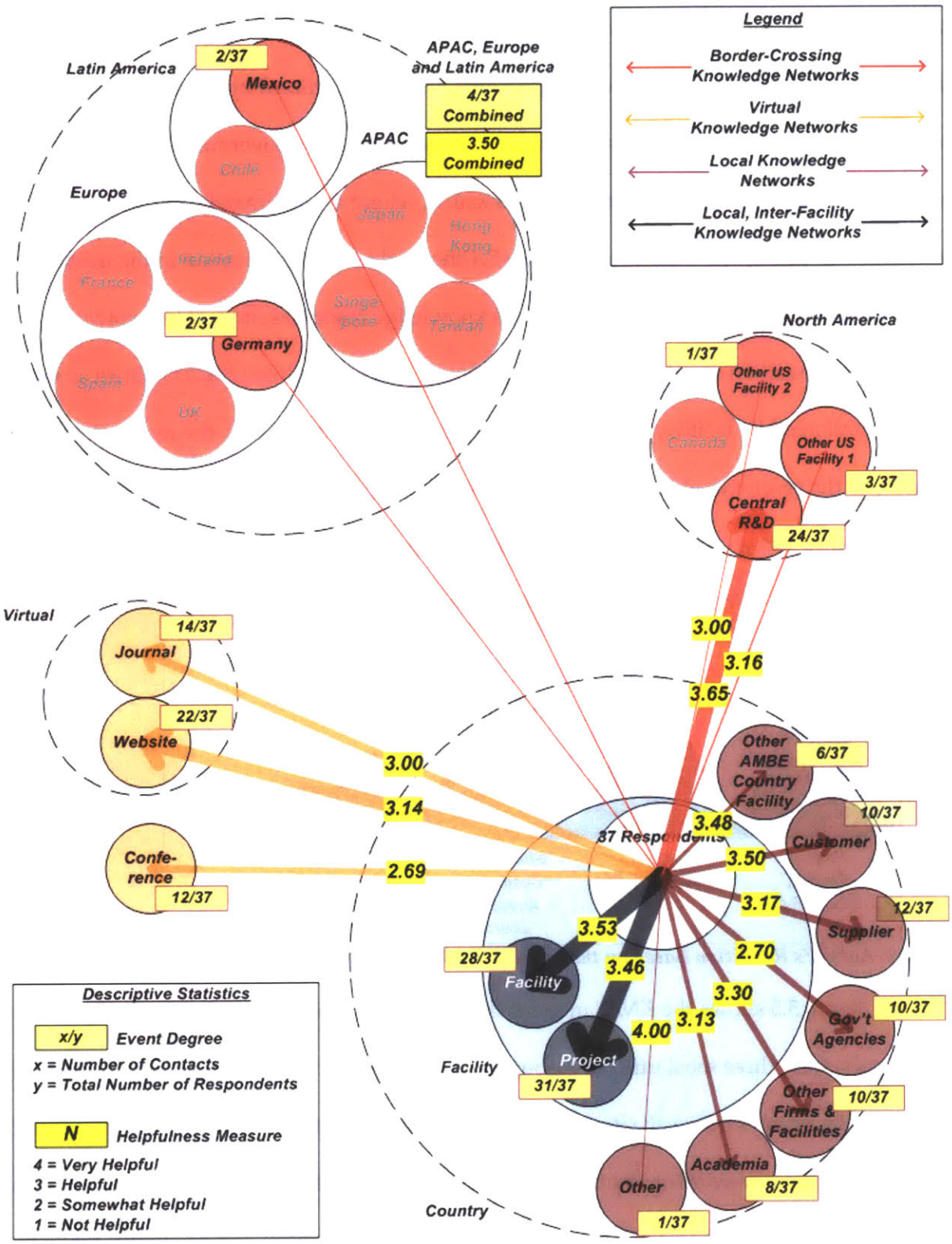
Figure 5.4: KNPS – Percent Utilization by Quartile, Brazil



Source: Author's Rendition Based on the Web-Based Surveys.

Figure 5.5 shows the *KNPS* map for the Canadian respondents. Similar to their Brazilian colleagues, their three most utilized resources are the Project, the Facility and the Central R&D respectively, with AMBE web site and journals rounding out the top five. However, with the exception of the government resources, the Canadian respondents have lower rate of utilization of their external knowledge resources, such as customers, suppliers and academia, while they utilize government resources more than their Brazilian colleagues.

Figure 5.5: KNPS - Mapping the Canadian Respondents Knowledge Resources

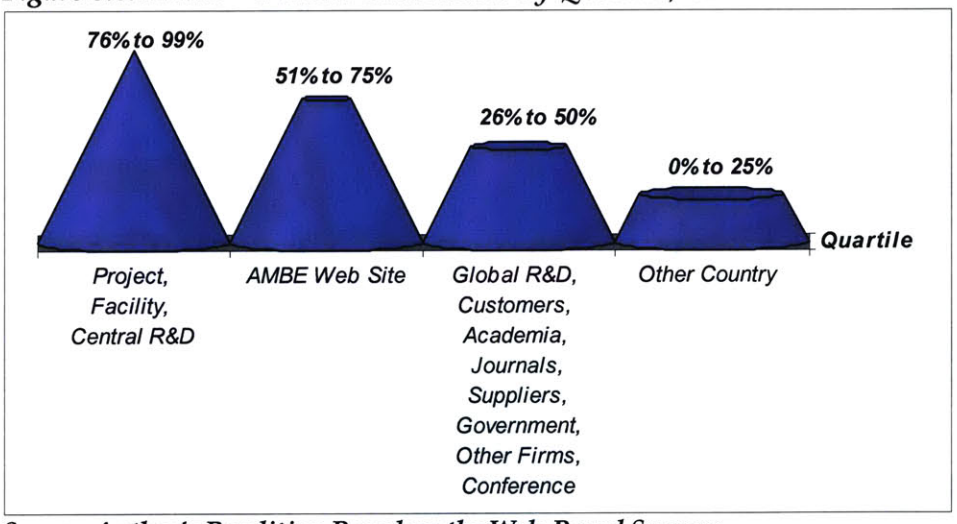


Source: Author's Rendition based on Web-Based Surveys.

Overall, the largest difference between the two groups is the extent of their global knowledge networks. While the Brazilians have knowledge-networking relationships with 11 different countries, the Canadian respondents' only global knowledge networks are with US facilities, Germany, and Mexico.

Figure 5.6 shows this delineation in the rate of utilization pf *KNPS* knowledge resources for the Canadian respondents. The Brazilian and Canadian respondents have the same knowledge resources in the top quartile, which is Project, Facility, and Central R&D, but unlike the Brazilian respondents, the majority of their knowledge resources fall in the third quartile. Overall, the Canadian respondents find their resources to be more helpful than their Brazilian colleagues, but similar to their Brazilian colleagues, the Canadian respondents rate Central R&D as their most helpful knowledge resource, followed closely by their Facility and Project.

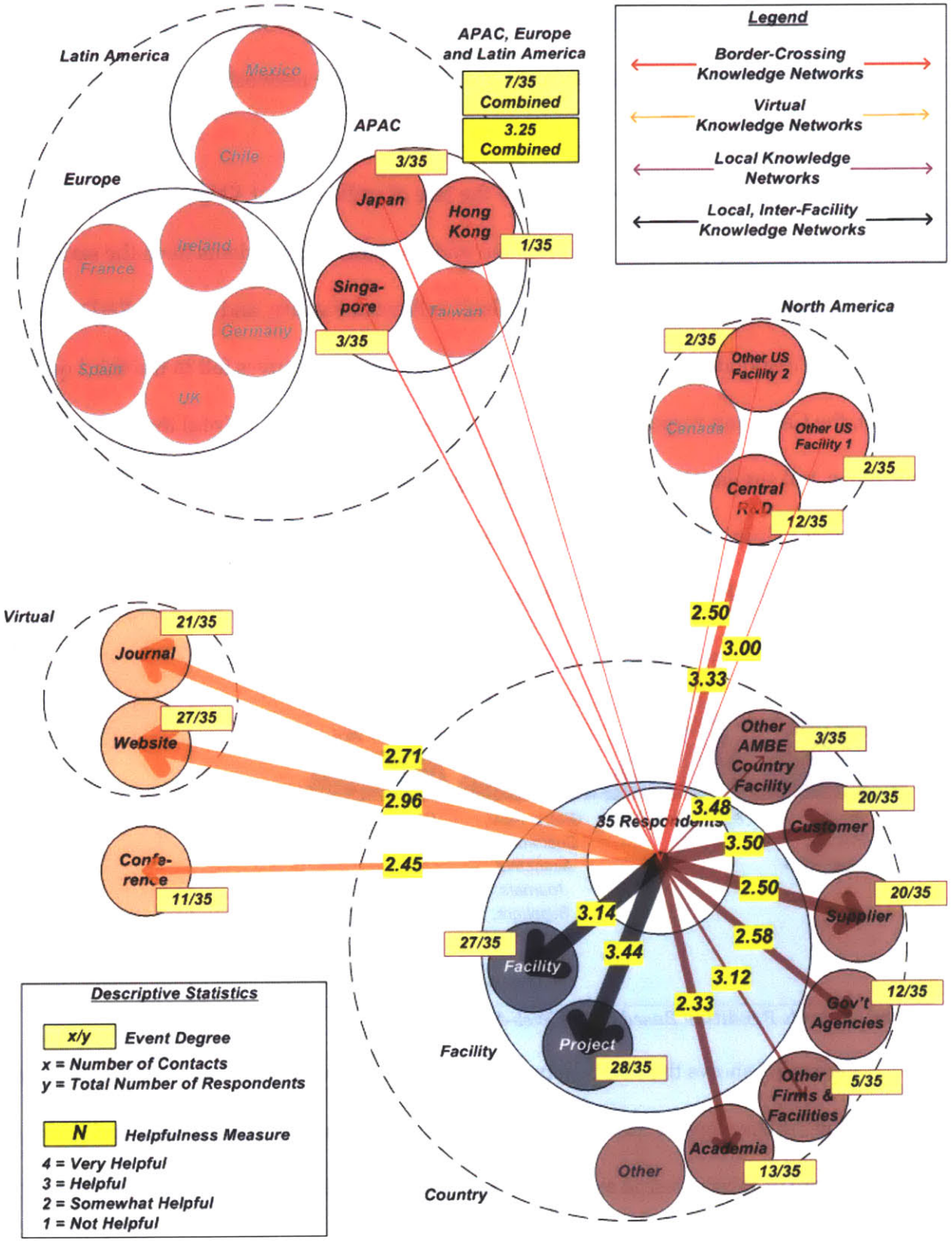
Figure 5.6: KNPS - Percent Utilization by Quartile, Canada



Source: Author's Rendition Based on the Web-Based Surveys.

Figure 5.7 shows the *KNPS* network map of the Chinese respondents. The Chinese respondents utilize Central R&D much less than their colleagues from Canada and Brazil, while utilizing more of their external and virtual knowledge resources. This is particularly true in their knowledge networking with customers and suppliers. The Chinese respondents rank all

Figure 5.7: KNPS - Mapping the Chinese Respondents Knowledge Resources



Source: Author's Rendition based on Web-Based Surveys.

of their knowledge resources as somewhat helpful to helpful, with the exception of their projects, their facility, and customers. As such, the Chinese respondents' helpfulness rating is lower than their colleagues from Brazil or Canada. Figure 5.8 shows the Chinese respondents' percent of their knowledge utilization by quartile, while Table 5.2 shows the summary results of the level of utilization of the knowledge resources for the three facilities.

Figure 5.8: KNPS – Percent Utilization by Quartile, China

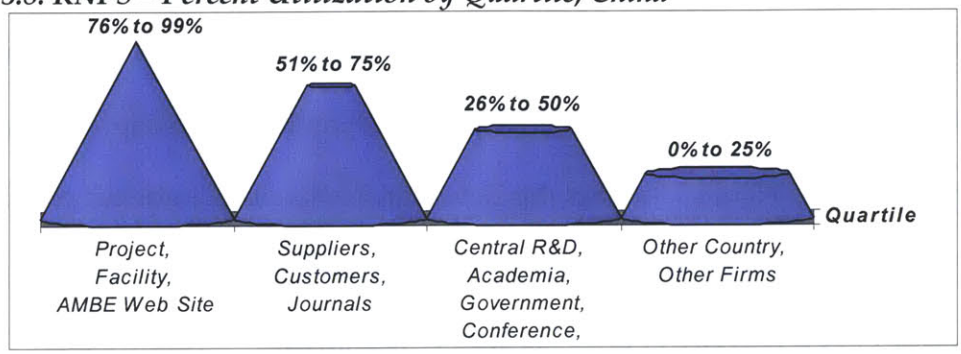


Table 5.2: Summary Results – KNPS Networks

Quartile	Brazil	Canada	China
76%-99%	Project, Facility, Central R&D	Project, Facility, Central R&D	Project, Facility, AMBE Website
51%-75%	Supplier, AMBE Website	AMBE Website	Suppliers, Customers, Journals
26%-50%	Global R&D, Academia, Journals, Customers	Suppliers, Customers, Journals, Academia, government, Conference	Central R&D, Academia, government, Conference
0%-25%	Government, Other Firms, Other Facilities, Conferences	Other Facilities	Other Facilities, Other Firms

Source: Web-Based Surveys.

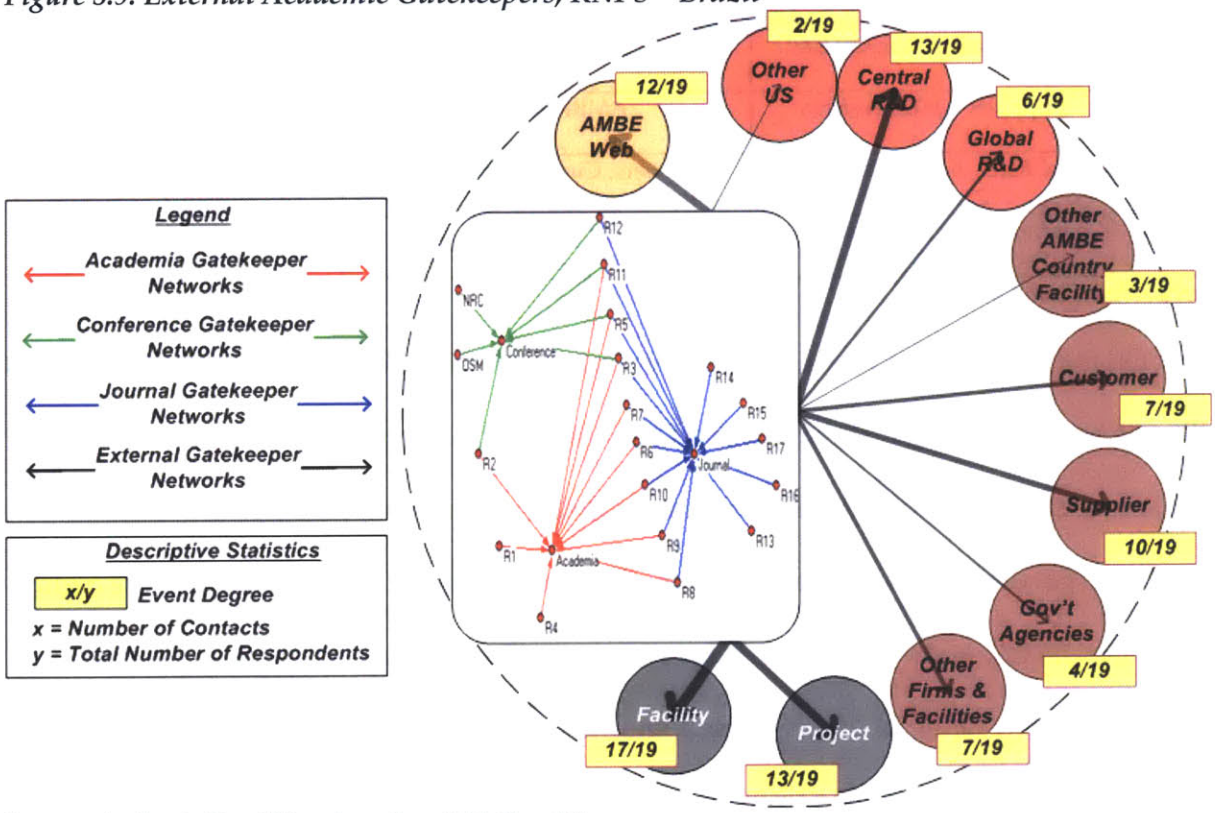
On the aggregate level, the respondents from the three facilities have markedly different *KNPS* networks. This is particularly true when comparing the respondents from the Chinese facilities to that of the Brazilian and Canadian facilities. In addition, the helpfulness measures show that in general the respondents rated the facility-wide knowledge resources more highly than the non-facility and virtual knowledge resources. The primary exception to the above observation is their rating of customers as a knowledge resource. Overall, the respondents rated the customers as the most helpful of their external local knowledge resources, which is expected, given the importance of customers' needs and opinions within AMBE's customer-

centric corporate culture. At the other end of the spectrum, the respondents rated their virtual knowledge resources lower than others, which raises important questions about the virtual tools' overall value as knowledge-networking tools.

5.3.1 Mapping the Role of Academic Gatekeepers for KNPS Networks

The purpose of these maps is to, (1) identify the gatekeepers and show their relationships with each other, and to other knowledge resources and respondents, and (2) to analyze whether these individuals have any of the characteristics of gatekeepers as defined by Allen, or whether they are simply a collection of disparate respondents who happen to access these knowledge resources. Figure 5.9 shows this detail for the Brazilian academic gatekeepers, which is comprised of 19 respondents, of which only 3 access all three knowledge resources (R3, R5, and R11), and 10 of 19 access two of three knowledge resources.

Figure 5.9: External Academic Gatekeepers, KNPS – Brazil

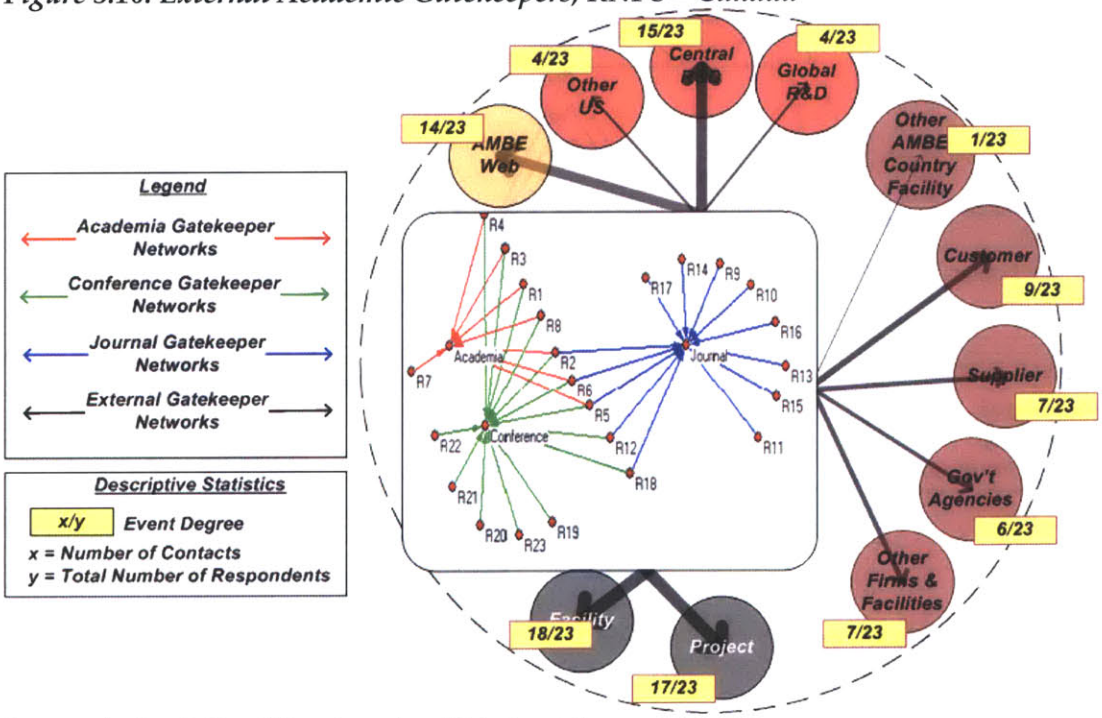


Source: Author's Rendition based on *Web-Based Surveys.*

The biggest segment of this gatekeeper group is comprised of individuals who access journals for their problem solving, followed by academic and conference resources. Figure 5.9 shows that there is a group of individuals within the Brazilian facility who act as the external academic gatekeepers, but their resource utilization does not overlap extensively across all three knowledge resources. However, there is a large overlap between the respondents who access journals and academia, implying that the real academic gatekeeper community is comprised of individuals who utilize these two resources.

Figure 5.10 shows the external academic gatekeepers for the Canadian facility, which is comprised of 23 individuals, of which only 3 respondents access all 3 knowledge resources (R3, R5, R8), while 9 of the respondents access at least two. In this regards, the Canadian gatekeepers show a lot of similarity to the Brazilian colleagues in that they are loosely structured around the three resources, but unlike the Brazilian gatekeepers, the Canadians are not structured around academia and journals, but rather around academia and conferences.

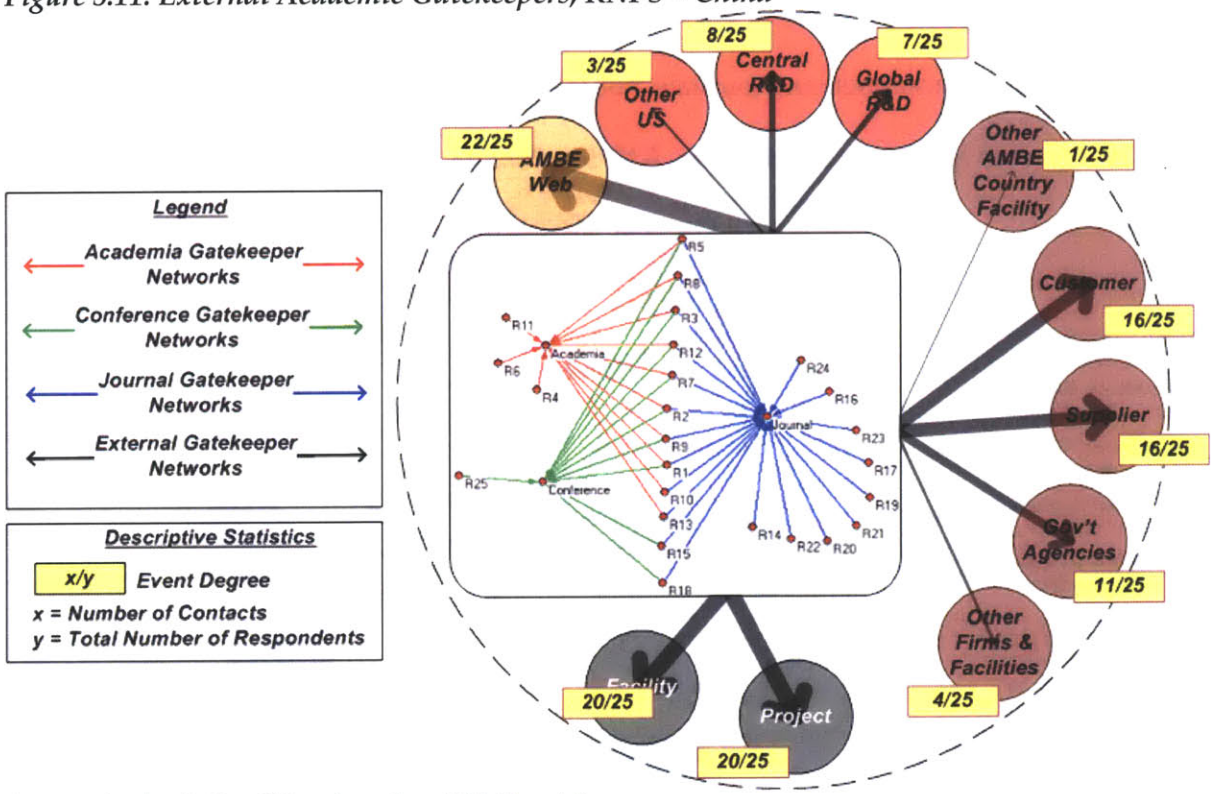
Figure 5.10: External Academic Gatekeepers, KNPS – Canada



Source: Author's Rendition based on Web-Based Surveys.

Finally, Figure 5.11 shows the academic gatekeepers for the Chinese facilities. The Chinese academic gatekeeper community is larger than either Brazil or Canada, comprising of 25 respondents, of which 8 out of 25 respondents access all 3 knowledge resources, and 12 access at least two. Unlike their Brazilian and Canadian colleagues, there is a great deal of overlap among the respondents in their utilization of the three knowledge resources. However, there is a larger group of respondents who utilize only journals within this group. In summary, it is apparent from this discussion that although all three facilities have distinct academic gatekeepers, they do not all exhibit the same features. For the Brazilian academic gatekeepers, their main areas of overlap are between academia and journals, for the Canadians, the overlap is between academia and conferences, and for the Chinese academic gatekeepers, the overlap is among all three knowledge resources.

Figure 5.11: External Academic Gatekeepers, KNPS – China

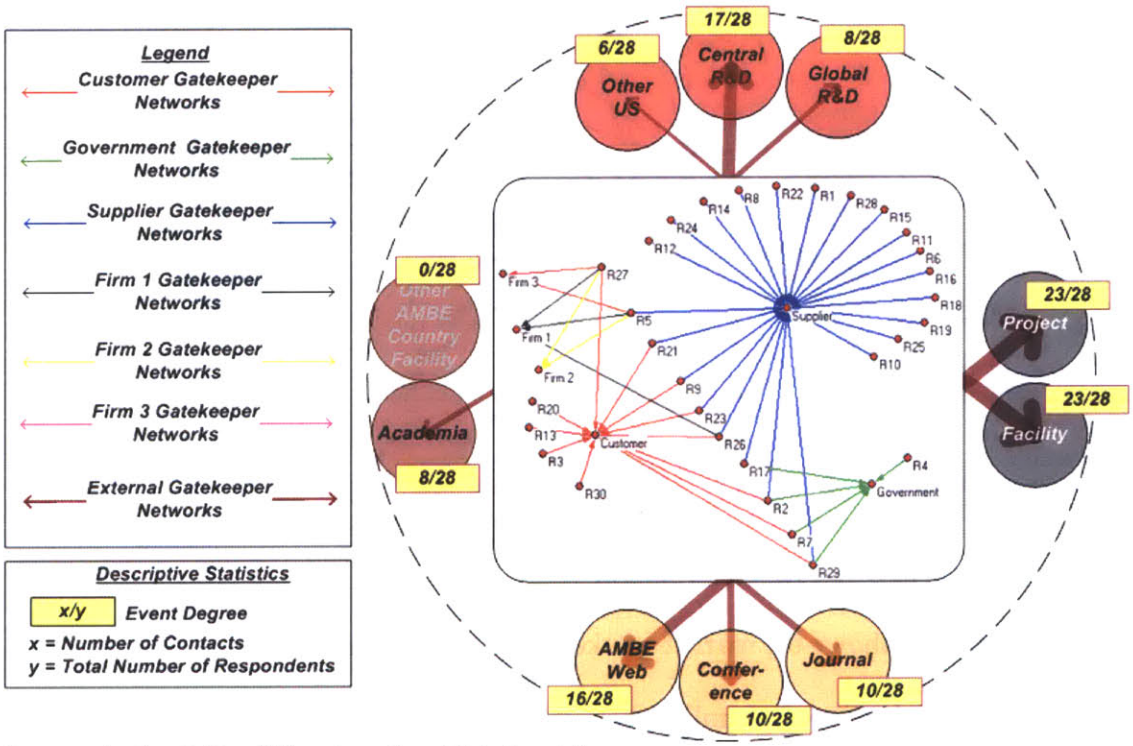


Source: Author's Rendition based on Web-Based Surveys.

5.3.2 *Mapping the Role of External, Non-Academic Gatekeepers for KNPS Networks*

External non-academic knowledge resources refer to all non-academic external knowledge resources, such as suppliers, customers, government agencies and other firms. Figure 5.12 shows the market gatekeepers for the Brazilian respondents, which is comprised of 28 respondents. In this case, the main area of overlap among the resources is between customers and suppliers, where 27 of the 28 respondents utilize either of these as a knowledge resource, and, 9 utilize both. This finding implies that within the Brazilian facilities, the external non-academic gatekeepers are those respondents who utilize both suppliers and customers, some of who may also utilize the resources with governments and other firms.

Figure 5.12: Market gatekeepers, KNPS – Brazil

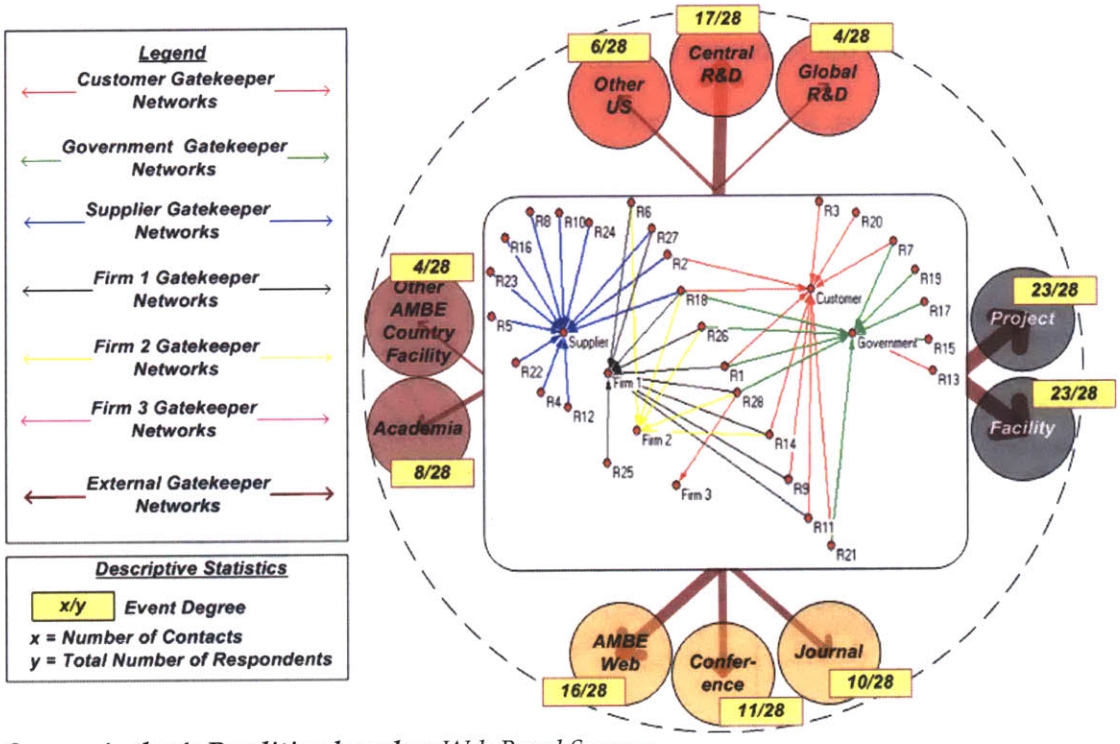


Source: Author's Rendition based on *Web-Based Surveys.*

Figure 5.13 shows the external non-academic gatekeepers for the Canadian facilities. Unlike their Brazilian colleagues, the Canadian market gatekeepers have extensive overlaps across a number of knowledge resources, although none of the respondents utilize all of these

external knowledge resources. The primary feature of this group is one of specialization. There are those respondents who specialize in government agencies and customers' knowledge networking (5 out of 28), those who focus on external firms and government agencies (5 out of 28), and a group who has knowledge networking with customers and suppliers (3 out of 28). In other words, there is not one group of external Canadian gatekeepers who access all or the majority of these knowledge resources, but there are a number of small market gatekeepers who specialize in accessing subgroups of these external knowledge resources.

Figure 5.13: Market gatekeepers, KNPS – Canada

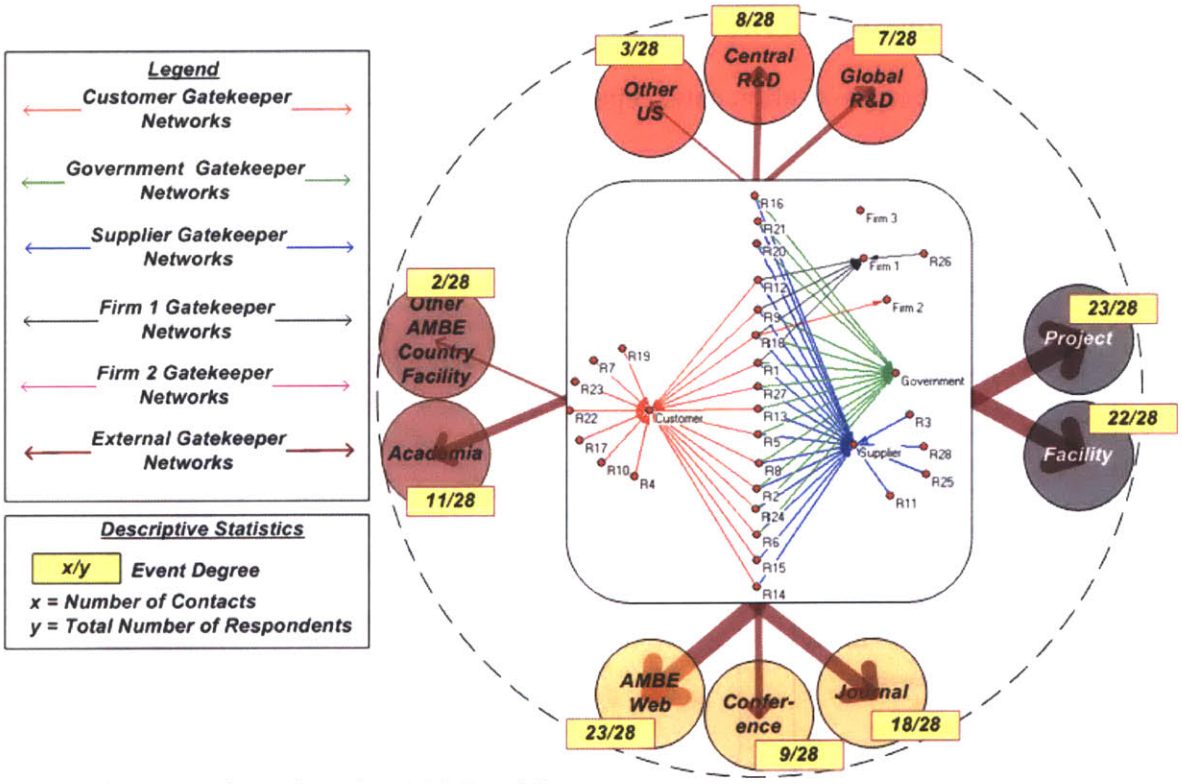


Source: Author's Rendition based on Web-Based Surveys.

Finally, Figure 5.14 shows the market gatekeepers for the Chinese facilities. Similar to the Chinese academic gatekeepers, but unlike their colleagues from the Canadian and Brazilian facilities, the Chinese market gatekeepers have an extensive amount of overlap between all of these knowledge resources. The Chinese market gatekeepers are comprised of 28 respondents, of which 2 respondents utilize all resources, 9 utilize customers, government, and supplier

knowledge resource, and 14 utilize either customers and suppliers, or suppliers and government knowledge resources. In summary, the results show that the three facilities have distinct external, non-academic gatekeepers, but they do not all exhibit the same features. For the Brazilian market gatekeepers, their main areas of overlap are between customers and suppliers, while the main feature of the Canadian market gatekeepers is one of specialization with one or more of the external resources, and for the Chinese market gatekeepers there is a robust overlap among all three knowledge resources.

Figure 5.14: Market gatekeepers, KNPS – China



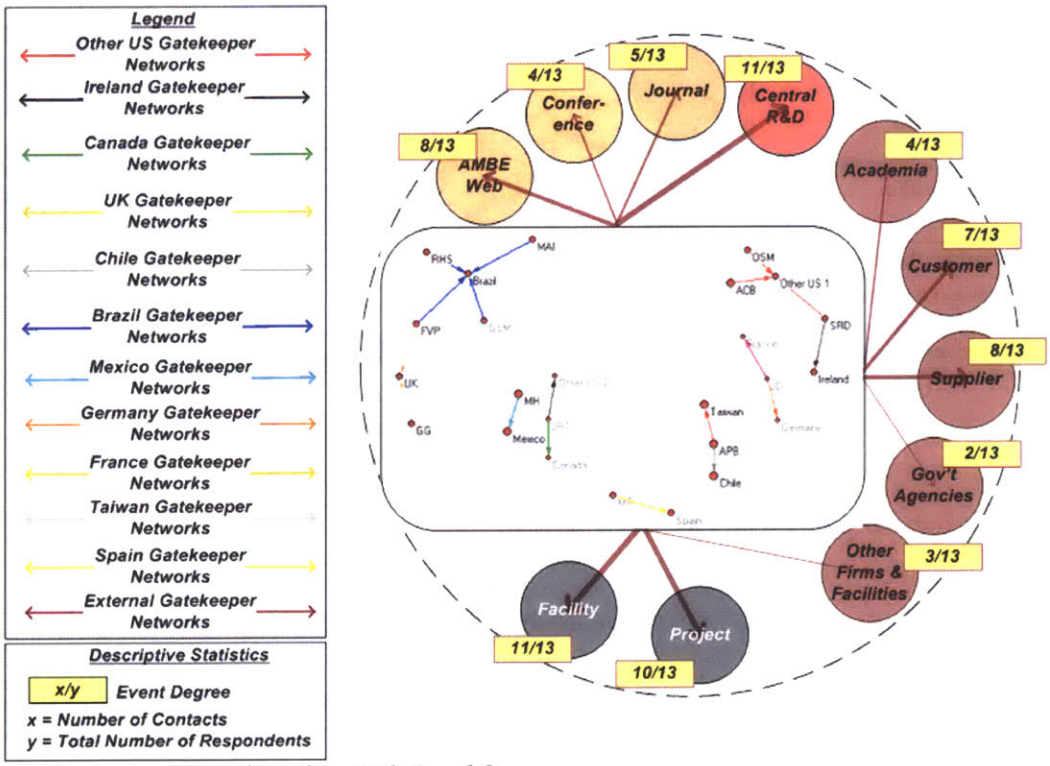
Source: Author's Rendition based on Web-Based Surveys.

5.3.3 *Mapping the Role of Cross-Location Gatekeepers for KNPS Networks*

Unlike the other gatekeepers, the role of the cross-location gatekeepers is not to access external knowledge, but rather to utilize the diverse and geographically dispersed knowledge resources that are produced at AMBE's global R&D facilities. Figure 5.15 shows the cross-

location knowledge gatekeepers for the Brazilian facilities, which is comprised of 13 respondents, accessing 11 different global R&D facilities, which results in very little overlap among the respondents and the global R&D facilities. The majority of the gatekeepers utilize only one country facility, but in cases where a respondent utilizes more than one, there are no apparent regional or product relationships between the two facilities. For example, *R1* utilizes both Taiwan and Chile, which are not aligned either geographically or by the type of products they support. The lone exception to the above observation is *R2* who has knowledge-networking relationships with Germany and France, both of which are large regional facilities, supporting multiple products. Combined, the above observations suggest that the Brazilian facilities lack coherent cross-location gatekeepers who access and utilize AMBE's globally dispersed knowledge.

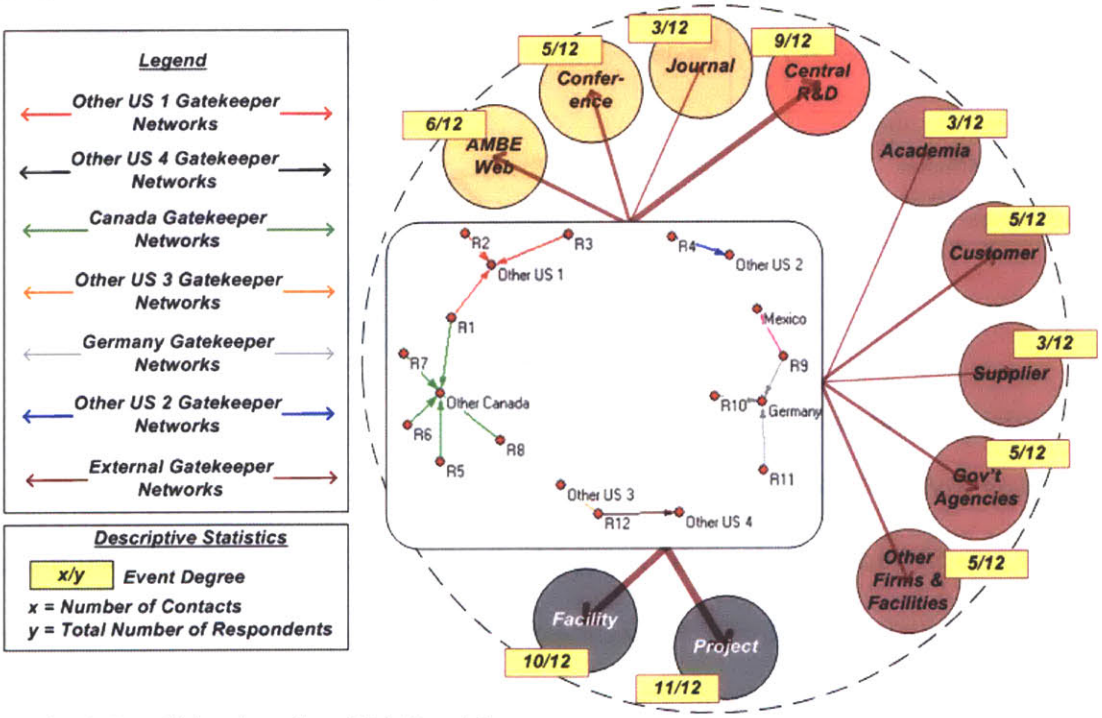
Figure 5.15: Cross-Location Gatekeepers, KNPS - Brazil



Source: Author's Rendition based on *Web-Based Surveys.*

Figure 5.16 shows the cross-location gatekeepers for the Canadian facilities, which is comprised of 12 respondents and 6 facilities, all of which are in North America, Germany, and Mexico. The network features of the Canadian cross-location gatekeepers are very similar to their Brazilian colleagues, in that there is very little overlap in the utilization of their knowledge resources. In fact, of the 12 respondents, only 3 access more than one of these global knowledge resources, making them behave less as knowledge gatekeepers, and more as individual respondents seeking knowledge in these facilities.

Figure 5.16: Cross-Location Gatekeepers, KNPS – Canada

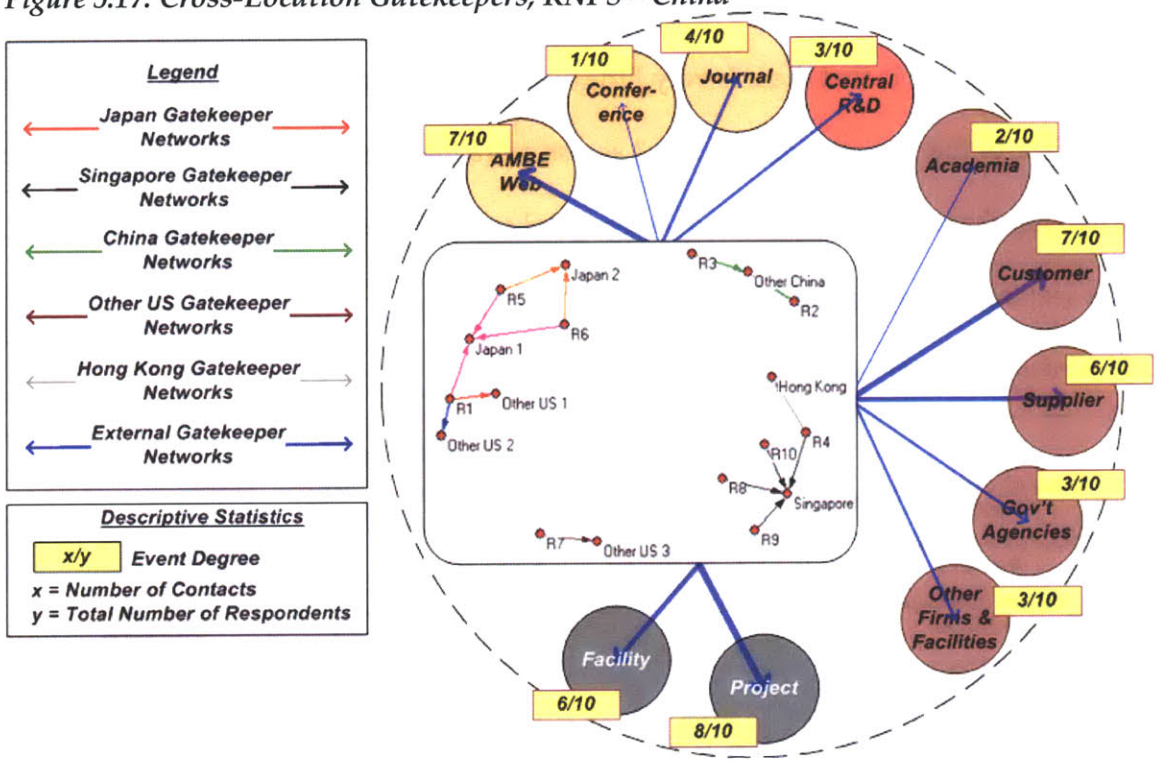


Source: Author's Rendition based on *Web-Based Surveys.*

Finally, Figure 5.17 shows the cross-location gatekeepers for the Chinese facilities, which is comprised of 10 respondents and 6 facilities. Similar to their Canadian colleagues, there is a regional quality to the knowledge networking of these gatekeepers, but unlike their Canadian colleagues, the Chinese cross-location gatekeepers exhibit more overlap in their knowledge utilization. For example, *R1* utilizes both of Japan's knowledge resources, and *R2* utilizes knowledge from both US1 and US2 facilities. In summary, the results show that none of the

facilities have cross-location gatekeepers who exhibit characteristics that are similar to their academic and external colleagues, or meet Allen's (1977) definition of knowledge gatekeepers.

Figure 5.17: Cross-Location Gatekeepers, KNPS – China

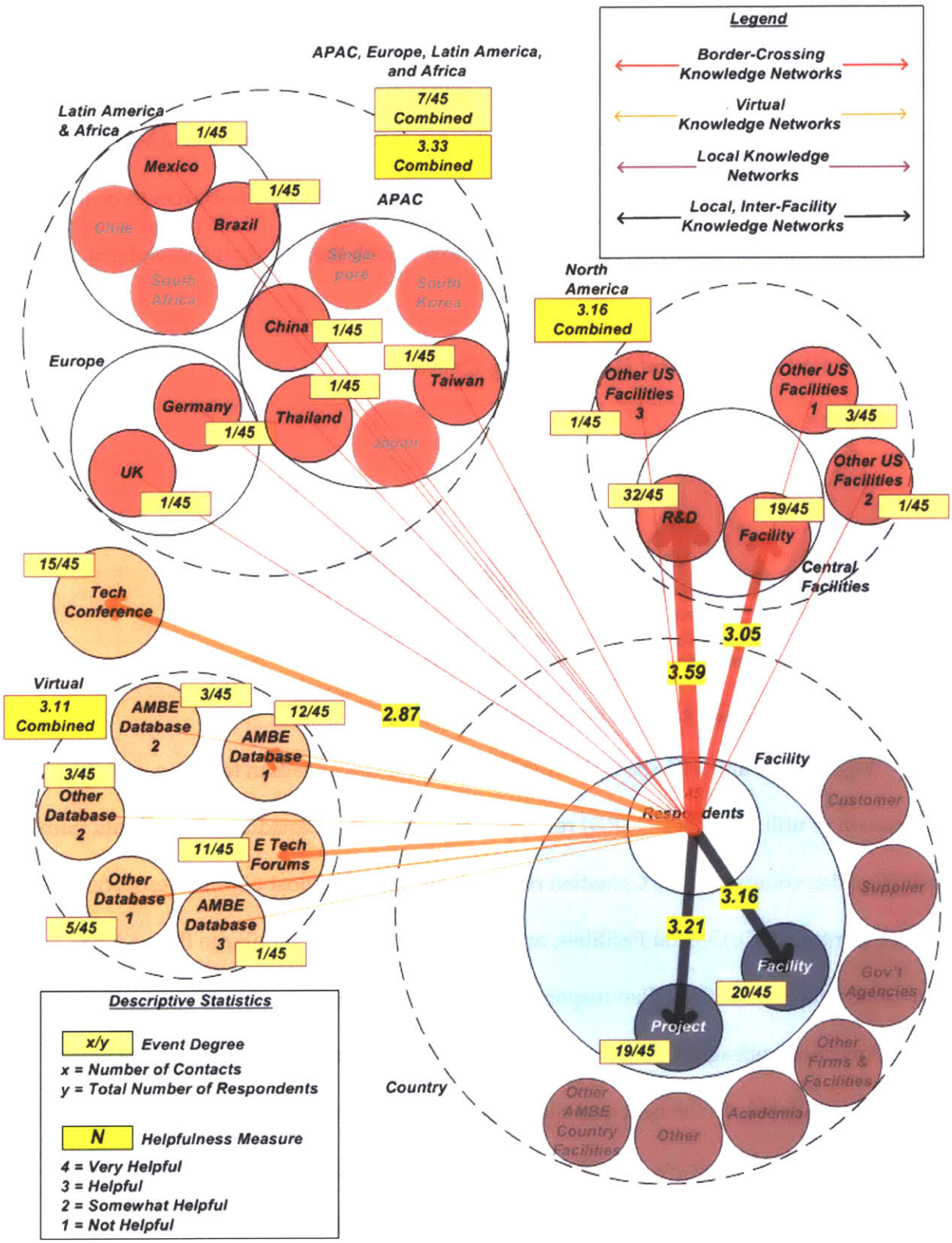


Source: Author's Rendition based on Web-Based Surveys.

5.4 Mapping *KNCRDI* Networks

Figures 5.18 and 5.19 show the *KNCRDI* network map for the Brazilian facilities, and the delineation of utilization of *KNCRDI* resources by Brazilian respondents. Respondents use *KNCRDI* knowledge resources to find out about the ongoing and latest innovatory research at AMBE's Central R&D facilities. There are three reasons why these knowledge networks are important. The first is that despite AMBE's continued globalization efforts, the majority of basic research still takes place at these facilities. The second is that they continue to be the largest of their kind within AMBE, and the ones that support the most products and divisions. The third reason is that AMBE management is eager to 'push' this knowledge out of Central R&D and into their global locations to be utilized by its dispersed researchers in their research efforts.

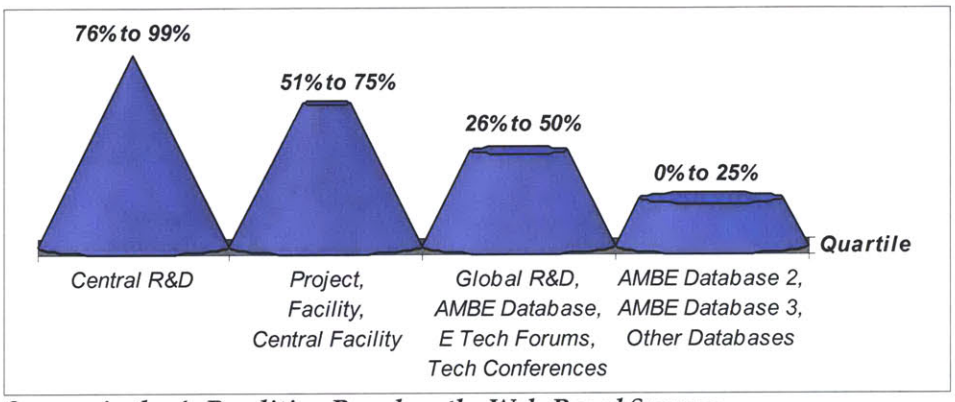
Figure 5.18: KNCRDI - Mapping the Brazilian Respondents Knowledge Resources



Source: Author's Rendition based on Web-Based Surveys.

For the Brazilian respondents, the top four *KNCRDI* resources is Central R&D, Central facilities, the respondents' own facilities, and their projects. In the next quartile, the Brazilian respondents utilize AMBE databases, technical conferences, virtual technical forums, and global R&D facilities. Finally, about 5 to 10 percent of the respondents utilize other AMBE and non-AMBE databases. The respondents rate the majority of their *KNCRDI* resources to be helpful to very helpful, with the exception of Tech conferences, which the Brazilian respondents rate as somewhat helpful to helpful.

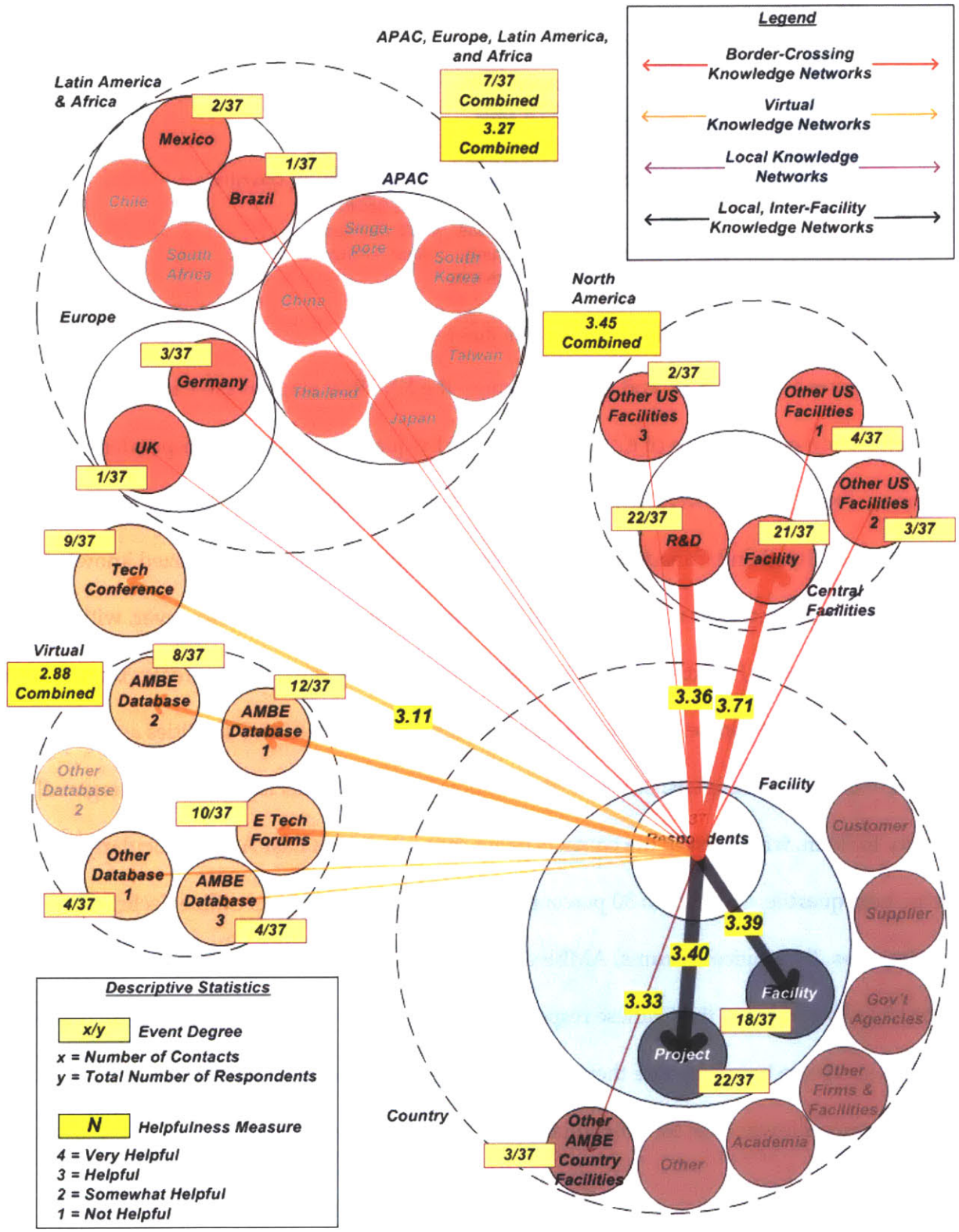
Figure 5.19: KNCRDI – Percent Utilization by Quartile, Brazil



Source: Author's Rendition Based on the Web-Based Surveys.

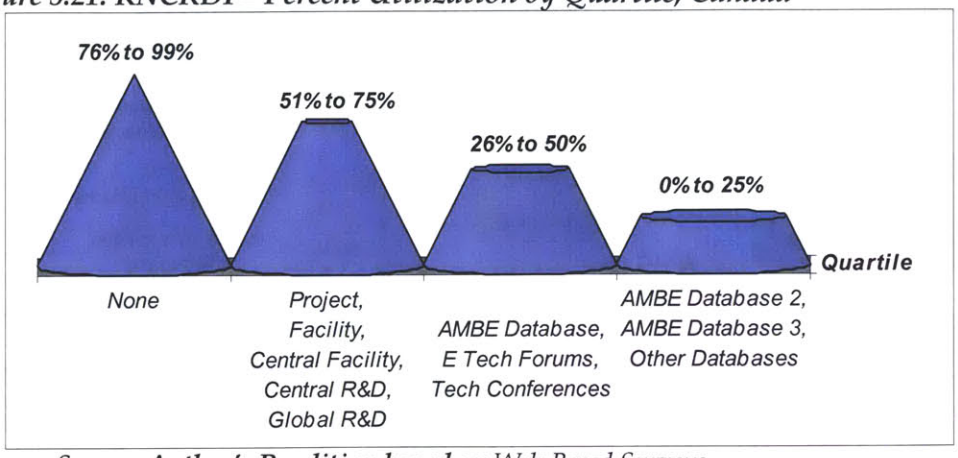
Figures 5.20 and 5.21 show the *KNCRDI* map for the Canadian facilities, and the delineation of utilization of *KNCRDI* resources by quartile for Canadian respondents. Similar to their Brazilian colleagues, the Canadian respondents' top four most popular resources are Project, Central R&D, Central Facilities, and their own facilities. Similar to their *KNPS* networks, almost all of Canadian respondents' global knowledge networking is with their North American colleagues, making their border- crossing knowledge networking more regional than global. In the next quartile, about 26 to 35 percent of the Canadian respondents utilize Technical Conferences, E Technical Forums, and AMBE databases. Finally, about 5 to 10 percent of the respondents utilize other AMBE and non-AMBE databases. The Canadian respondents generally find all their resources to be helpful or very helpful.

Figure 5.20: KNCRDI - Mapping the Canadian Respondents Knowledge Resources



Source: Author's Rendition Based on the Web-Based Surveys.

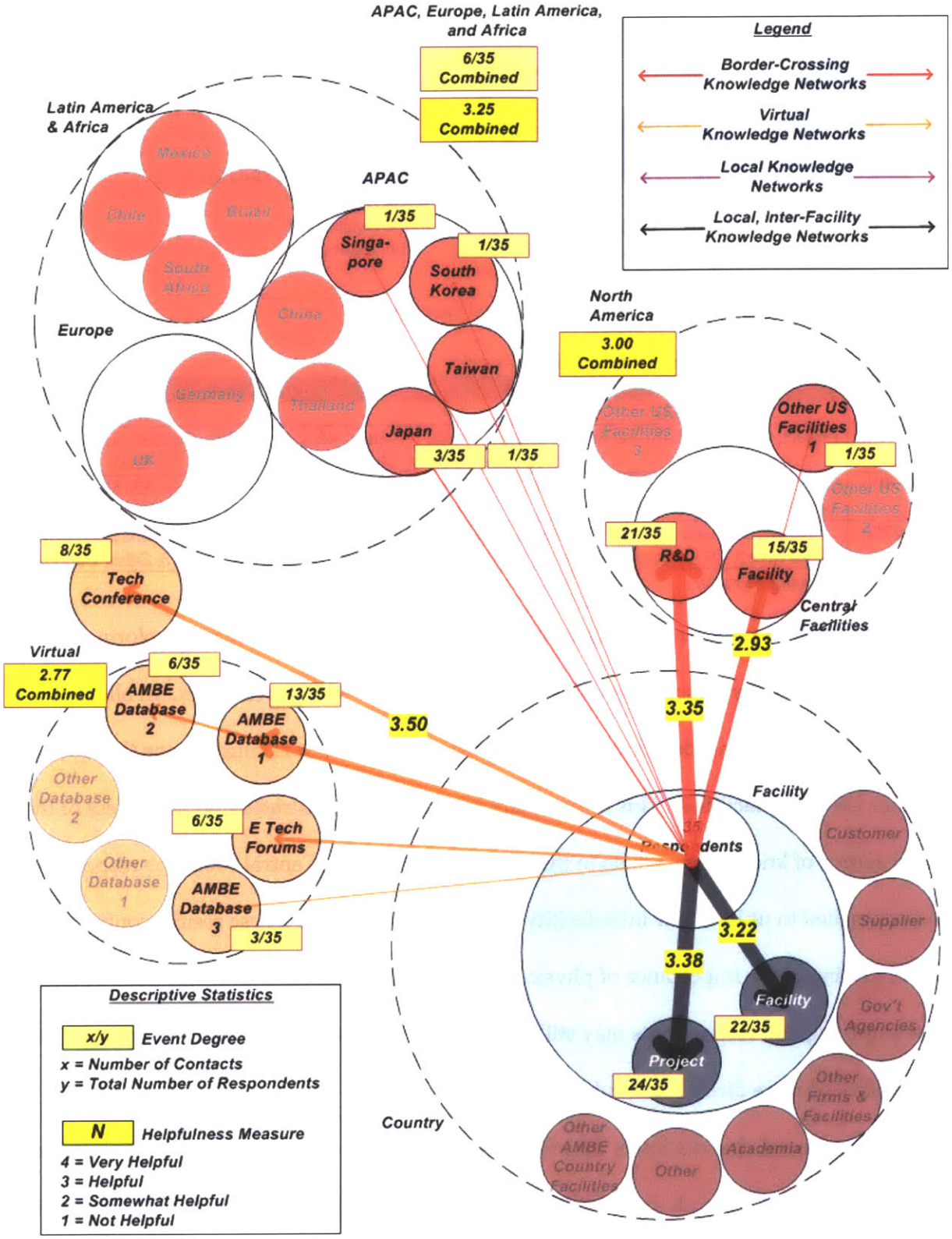
Figure 5.21: KNCRDI – Percent Utilization by Quartile, Canada



Source: Author's Rendition based on *Web-Based Surveys.*

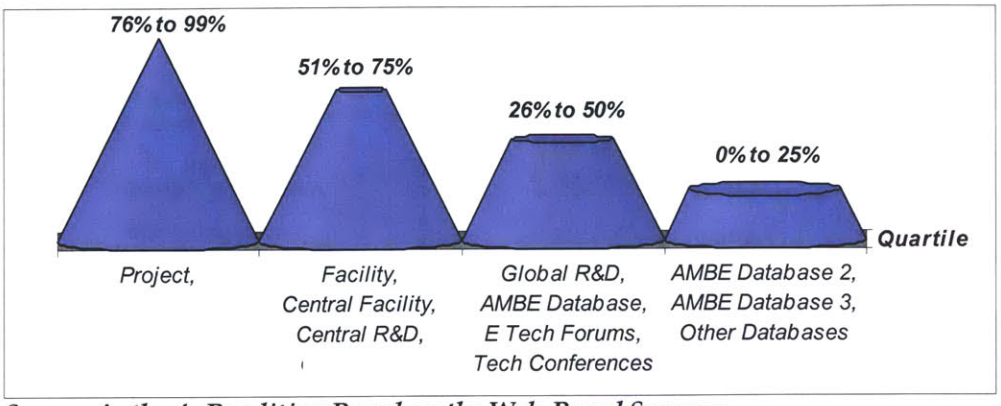
Figures 5.22 and 5.23, and Table 5.3, show the *KNCRDI* map for the Chinese facilities, the delineation of utilization of *KNCRDI* resources by quartile for Chinese respondents, and the summary findings of the *KNCRDI* network maps for the three facilities. Similar to their colleagues in Brazil and Canada, the Chinese respondents' top four most utilized knowledge resources are project, their facility, Central R&D, and Central Facilities. However, with the exception of Central Facilities, their rate of utilization of these resources is greater than the other two facilities. The Chinese respondents do not utilize their global R&D facilities as extensively as their Canadian colleagues, but their global knowledge networks have more of a regional quality to them, with most of the contacts being concentrated in East Asia, particularly, Japan. In the next quartile, about 26 to 30 percent of the Chinese respondents utilize Technical Conferences, E Technical Forums, AMBE databases, as well as, global R&D facilities. Finally, about 5 to 10 percent of the Chinese respondents utilize other AMBE and non-AMBE databases. Finally, similar to how they rate their *KNPS* networks, the Chinese respondents generally rate these resources lower than their Brazilian and Canadian colleagues.

Figure 5.22: KNCRDI - Mapping the Chinese Respondents Knowledge Resources



Source: Author's Rendition based on Web-Based Surveys.

Figure 5.23: KNCRDI – Percent Utilization by Quartile, China



Source: Author's Rendition Based on the Web-Based Surveys.

Table 5.3: Summary Results – KNCRDI Networks

Quartile	Brazil	Canada	China
76%-99%	Central R&D	-	Project
51%-75%	Project, Central Facility, Facility	Project, Facility, Central R&D, Central Facility, Global R&D	Facility, Central Facility, Central R&D
26%-50%	Global R&D, AMBE Database, E Tech Forums, Tech Conferences	AMBE Database, E Tech Forums, Tech Conferences	Global R&D, AMBE Database, E Tech Forums, Tech Conferences
0%-25%	AMBE Database 2, AMBE Database 3, Other Databases	AMBE Database 2, AMBE Database 3, Other Databases	AMBE Database 2, AMBE Database 3, Other Databases

Source: Web-Based Surveys.

There are a number of features of the above diagrams that are worth exploring in more detail. The first is the importance of local, inter-facility knowledge resources. In all three facilities, the project and the facility resources are utilized almost as much as the Central R&D or other US-based facilities. This is important because it demonstrates that regardless of the initial source of knowledge, which in this case originates from Central R&D, the respondents feel compelled to utilize their inter-facility knowledge resources. These results confirm Allen's (1977) finding of the importance of physical proximity in R&D communication, but also extends it by implying that respondents may still utilize these resources more often, regardless of the availability of more direct knowledge sources.

The second observation is the lower level of utilization of virtual knowledge resources by the respondents from all three facilities. In each case, respondents use the AMBE database more than any of the other virtual knowledge resources. However, even in the best-case

scenario, which is the Chinese respondents, only 13 out of the 35 respondents (37%) utilize the resource at all. This finding is surprising for two reasons. The first is that AMBE has invested a great deal of money and resources to make this knowledge available through their online systems. In fact, from my personal interviews with the respondents, it was obvious that the results of almost all the Central R&D research are available online. Furthermore, unlike *KNPS* networks, where the need for finding knowledge to solve problems is very immediate and necessary, *KNCRDI* networking is neither mandatory nor urgent. Respondents form these networks or access these knowledge resources, more to keep up with the research that is being conducted at the Central R&D than to solve any immediate problems. That does not imply that the information they gather cannot help them in their daily tasks, but that is not the primary motive behind forming these networks or accessing these resources. As such, one would expect that the most convenient of these knowledge resources, such as AMBE's online repositories, would be the ones of that are used most.

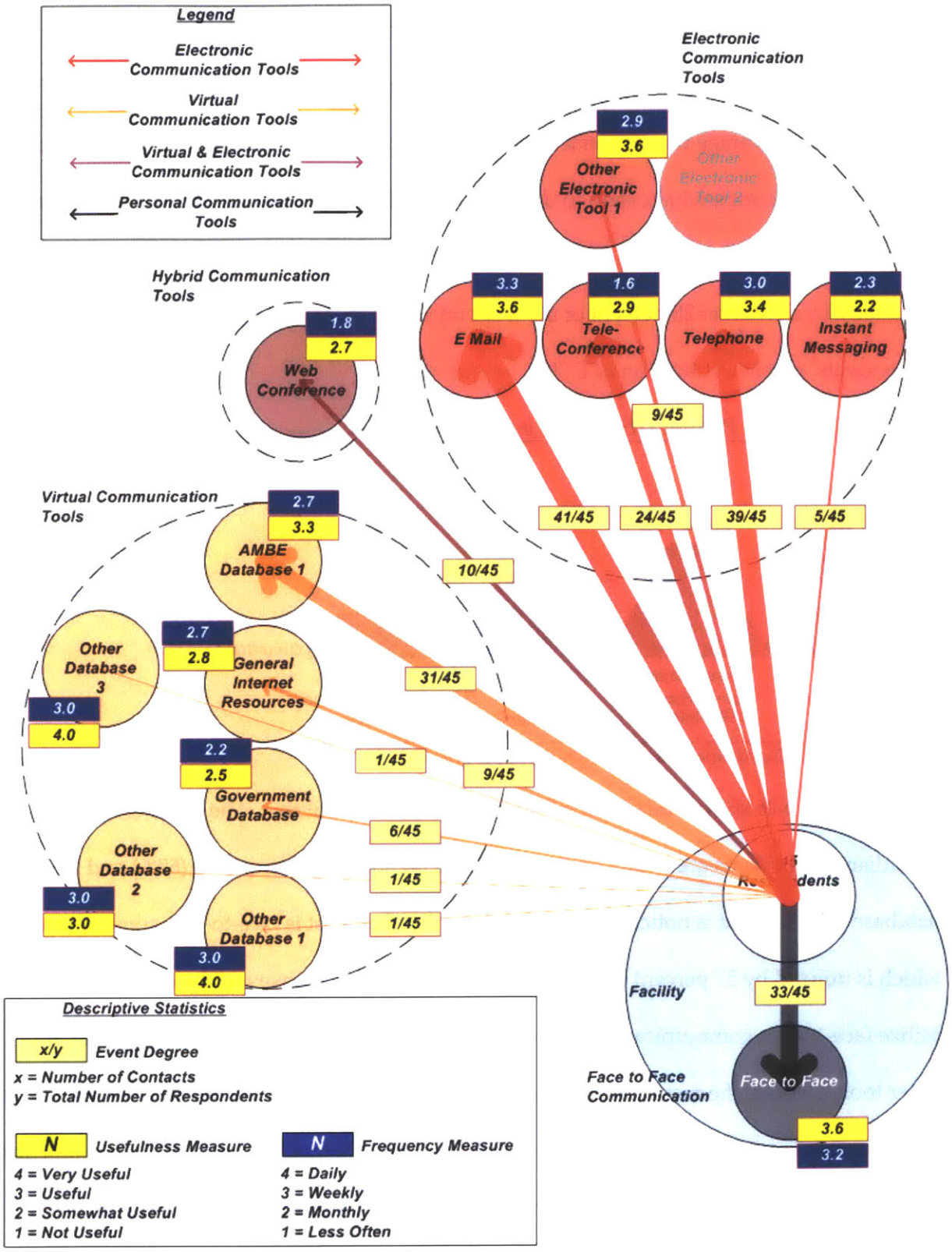
The final observation is in regards to the low utilization of Tech Conferences as a knowledge resource. AMBE takes great pride in, and devotes a lot of money and resources to initiate, promote, and sustain these Tech Conferences. Increasingly, these conferences are held online, but there are occasional live Tech Conferences at the Central R&D facilities or one of the regional centers, where relevant scientists and researchers from all R&D facilities are invited to attend. The primary purpose of these conferences is to introduce the researchers to the new and innovative research that is being conducted at AMBE, majority of which takes place at Central R&D. These are meant to be forums for presenting research findings, to exchange ideas, network with fellow researchers, and propose novel approaches to research problems. Among the respondents from the three facilities, the Brazilian respondents utilize Tech Conferences most at 33 percent, followed by the Canadian and Chinese respondents, at 24% and 23%

respectively. In other words, most respondents do not include Tech Conferences as source of finding information about Central R&D research.

5.5 Mapping Communication Tools for Knowledge Networking

CTKN networks are those conventional, face-to-face and virtual communication tools the respondents use in order to find technical and scientific information. Unlike the above knowledge networks, I asked the respondent about their usage of communication tools for accessing *any* type of scientific and technical information. The rationale behind mapping and analyzing the current network is to visualize the type of communication tools the respondents utilize to find technical and scientific information. In the following discussions, rate of utilization refers percentage of respondents who utilize a resource (thickness of the lines), while the frequency of utilization refers to how frequently they utilize these resources (blue squares). Specific to this question, I asked the respondents how frequently they utilized these communication tools. From the web-based surveys, I scored *Daily* utilization as a '4', *Weekly* utilization as a '3', *Monthly* utilization as a '2', and *Less Frequent* utilization as a '1'. The numbers in the blue boxes is the average *frequency* scores for all the respondents who utilize that tool. Figure 5.24 shows *CTKN* network map, as well as the usefulness, and frequency, indices for the respondents from the. The Brazilian respondents rely extensively on four communication tools. The most popular of these tools, e-mail, is utilized by over 90 percent of the respondents, followed by telephone (87%), face-to-face communication (73%) and AMBE database (69%). Similarly, the respondents utilize e-mail most *frequently*, followed by face-to-face, telephone, and AMBE website. Finally, the respondents find these tools to be useful to very useful, with the respondents rating face-to-face communication as most useful.

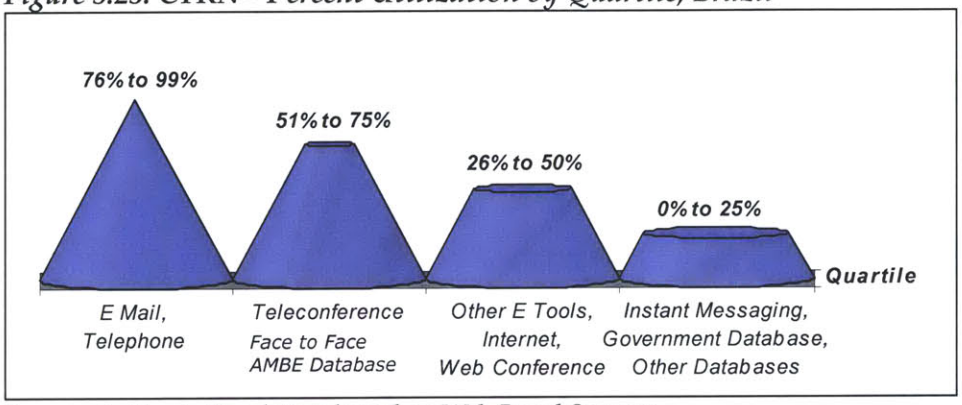
Figure 5.24: CTKN - Mapping the Brazilian Respondents Knowledge Resources



Source: Author's Rendition based on Web-Based Surveys.

Compared to these four tools, the remaining communication tools rank considerably lower in terms of their percent utilization, frequency of utilization, and usefulness. For example, the next most utilized tool is teleconferencing, which is utilized by 53 percent of the respondents, on average the respondents use teleconferencing about twice a month, and they rate the tool to be somewhat useful to useful. The final set of communication tools, such as Internet, government databases, instant messaging and web conferencing, is utilized less frequently by about 5 to 25 percent of the respondents. Figure 5.25 summarizes the Brazilian respondents' percent utilization of *CTKN*, by quartile.

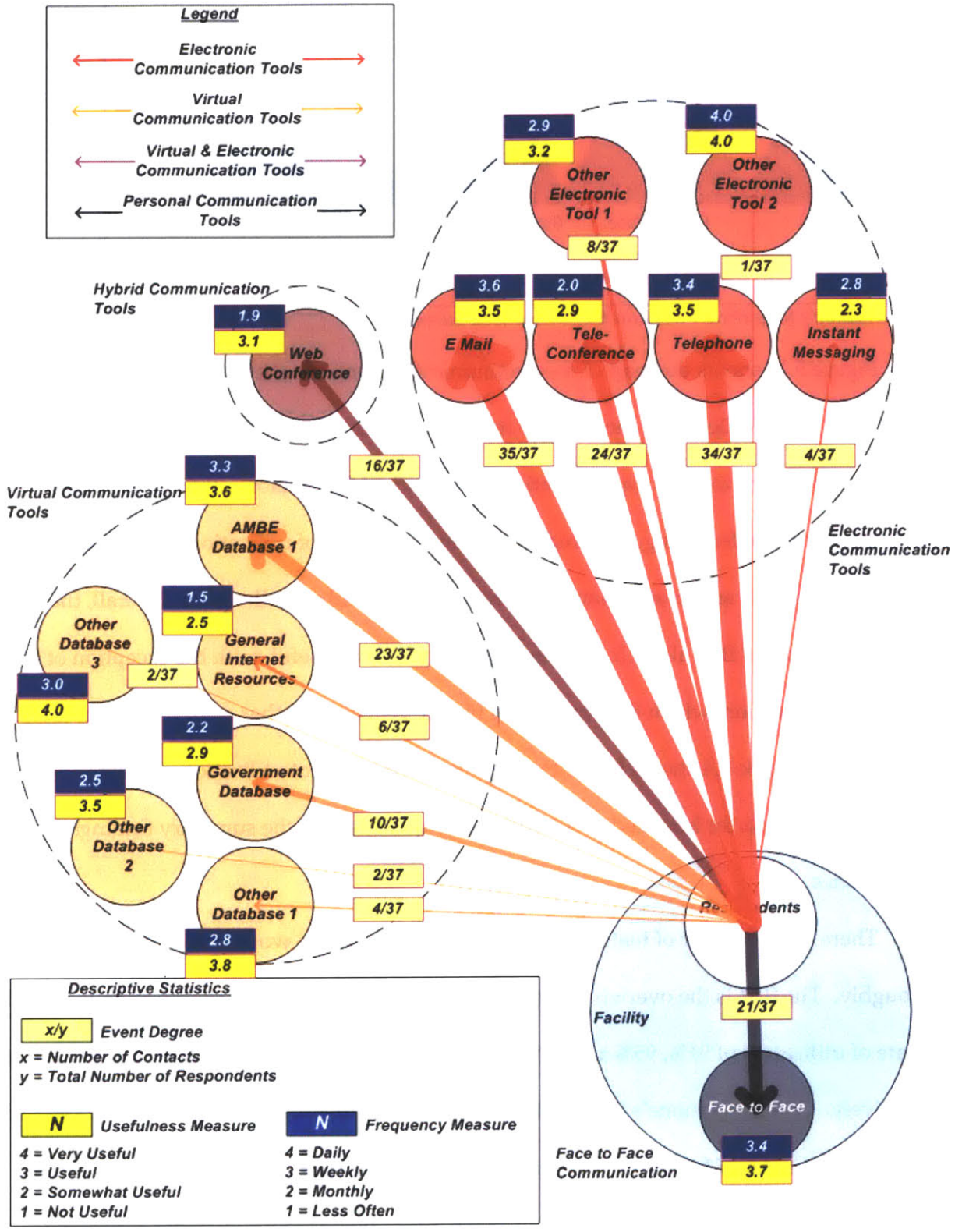
Figure 5.25: CTKN - Percent Utilization by Quartile, Brazil



***Source: Author's Rendition based on** Web-Based Surveys.*

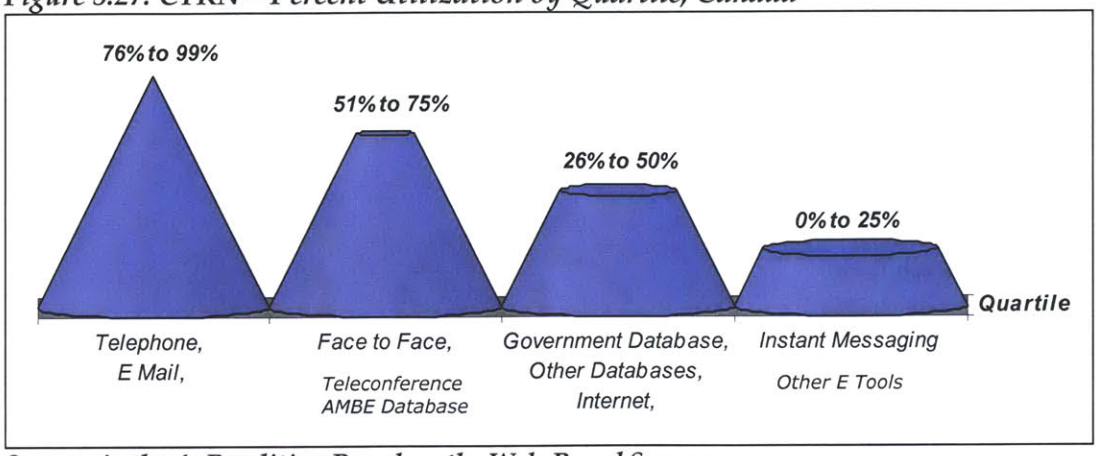
Figure 5.26 shows the *CTKN* map for the Canadian facilities. The top four tools for the Canadian respondents are e-mail (95%), telephone (92%), teleconferencing (65%) and AMBE database (62%). What is noticeably missing from the above list is face-to-face communication, which is utilized by 57 percent of the Canadian respondents. However, the respondents who utilize face-to-face communication do so more frequently, and find it more useful than any other tool. Overall, the respondents rate all these tools to be useful to very useful. Furthermore, the Canadian respondents rate their communication tools higher than their Brazilian colleagues and utilize them more frequently. Figure 5.27 shows the Canadian respondents' percent utilization of their communication tools for knowledge networking, by quartile.

Figure 5.26: CTKN - Mapping the Canadian Respondents Knowledge Resources



Source: Author's Rendition based on Web-Based Surveys.

Figure 5.27: CTKN – Percent Utilization by Quartile, Canada

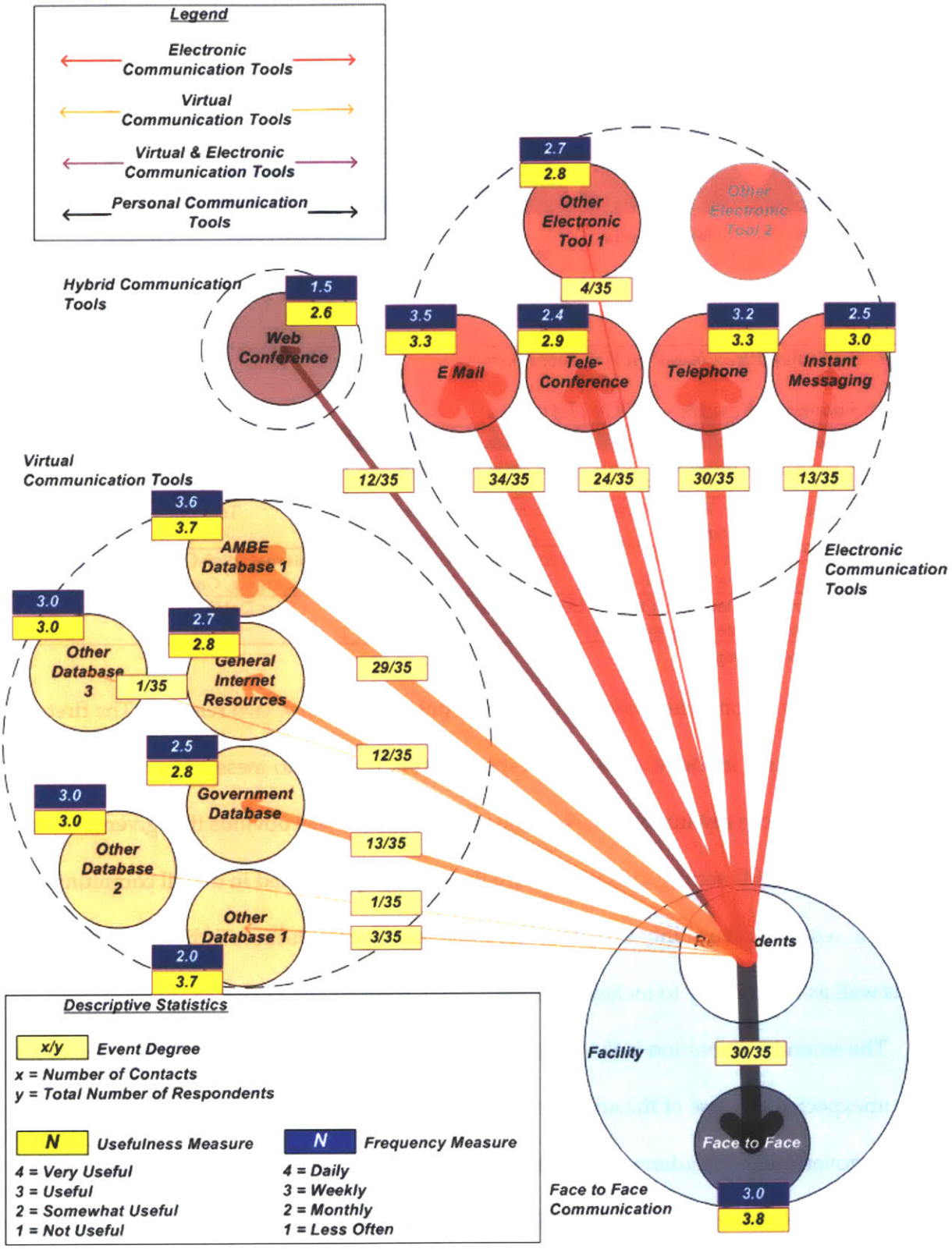


Source: Author's Rendition Based on the Web-Based Surveys.

Figure 5.28 shows the map of the communication tools for the Chinese respondents. Like their Brazilian colleagues, the Chinese respondents' top four tools are e-mail (97%), telephone (93%), face-to-face communication (86%) and AMBE database (86%). With the exception of web-conferencing, the Chinese respondents' rates of utilization of all their communication tools are greater than their Brazilian or Canadian colleagues. Overall, the Chinese respondents find all their communication tools to be useful, with the exception of face-to-face communication, which they rate much higher than all the other communication tools. Figure 5.29 and Table 5.4 shows the Chinese respondents' percent utilization of their communication tools for knowledge networking by quartile, and the summary findings for all three facilities.

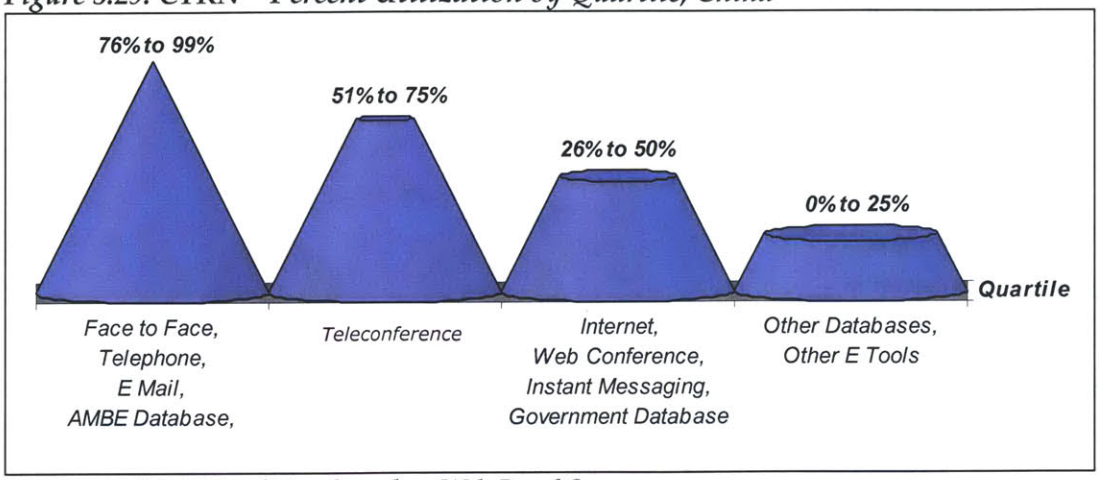
There are a number of features of the above maps that are worth exploring more thoroughly. The first is the overwhelming importance of e-mail as a communication tool, with the rate of utilization of 91%, 95% and 97% for the Brazilian, Canadian and Chinese respondents respectively. Given telephone's longer history as a de-facto conventional communication tool, and the effectiveness of face-to-face communication to convey and communicate explicit *and* tacit knowledge, makes the selection e-mail as the most popular tool somewhat surprising.

Figure 5.28: CTKN - Mapping the Chinese Respondents Knowledge Resources



Source: Author's Rendition based on Web-Based Surveys.

Figure 5.29: CTKN – Percent Utilization by Quartile, China



***Source: Author's Rendition based on** Web-Based Surveys.*

Table 5.4: Summary Results – CTKN Networks

Quartile	Brazil	Canada	China
76%-99%	E Mail, Telephone	E mail, Telephone	E Mail, Telephone, Face to Face, AMBE Database
51%-75%	Teleconference, Face to Face, AMBE Database	Face to Face, Teleconference, AMBE Database	Teleconference
26%-50%	Other E Tools, Web Conference, Internet	Government Database, Other Databases, Internet	Internet, Web Conference, Instant Messaging, Government Database
0%-25%	Government Database, Other Databases, Instant Messaging	Instant Messaging, Other E Tools	Other Databases, Other E Tools

Source: Web-Based Surveys.

E mail has become the most popular communication tool for two reasons. The first is its asynchronous nature, in that it allows the respondents to respond to messages on their own time and terms. From my interviews with the respondents, it was obvious that given the time constraints in the R&D setting, this is a feature they really appreciated in e-mail communication. The second reason, is the ability to convey the same message to multiple individuals at the same time, as well as their ability to include hyperlinks and attachments as part of the message.

The second observation is the lower level of utilization of non-AMBE virtual resources. This is unexpected because of the amount of information that is made accessible to the general public by governments, academia, consulting groups and NGOs. There are two reasons why these tools are not as important to the AMBE employees as one would anticipate, the first being

lack of time to sift through the relevant information, which is related to the more significant reason, and that is the manner in which this information is made available.

Finally, none of the respondents indicated that they used any novel or extraordinary communication tool that I had not included in my list. This is surprising because there is a constant evolution in the way existing electronic tools are utilized and in introduction of new electronic tools to organizations. For example, there is a new method of combining online video conferencing, file sharing and collaborative design work during webcasts that makes it a much more effective communication tool than webcasting or teleconferencing alone, and yet none of the respondents mentioned that as a communication tool. In addition, AMBE has introduced online design tools for R&D personnel, and not one of respondents mentioned this tool in their surveys. In short, none of the new tools that have been introduced or are being introduced on a regular basis to the R&D personnel has made a big enough impression for the respondents to include them in their surveys. The primary reason behind this lackluster attitude toward these new tools is the lag between the time they are introduced and when they become accepted and utilized in any meaningful way by the majority of respondents. The second, less important reason is that not everyone is aware of the benefits of these tools, and how they can be best utilized. Combined, the above two factors point to the need for MNEs, including AMBE, to promote, train, and educate the R&D employees on the benefits of the new design tools. As I show in Chapters 6 and 7, this is important because the respondents have a tendency to utilize the tools that they are aware of, and know to be useful.

5.6 Importance of the Descriptive Findings to *Proposition 1*

The premise behind *Proposition 1* is that in order for MNEs' globally-dispersed facilities to meet their potential as organizational bridges that span the gaps in the global knowledge

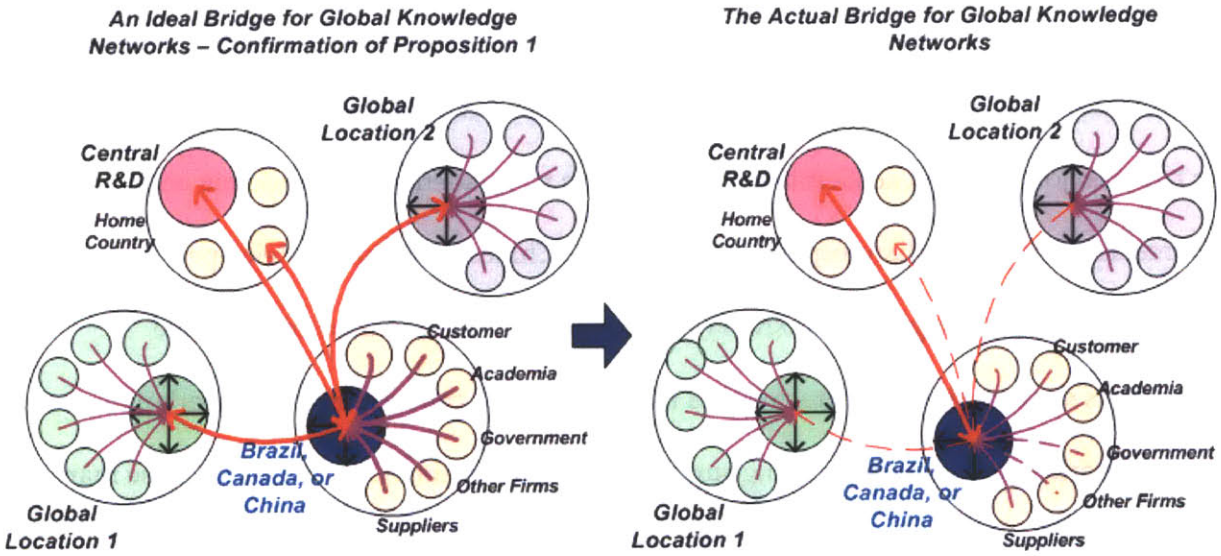
networks, they must have robust knowledge networks with both the MNEs' global knowledge resources, *and* with the host-country external knowledge resources. Of the two networks under analysis, only the findings from the *KNPS* networks are relevant to the above proposition. The reason is that, by definition, *KNCRDI* networks involve only AMBE-specific knowledge resources, and as such the respondents who utilize *KNCRDI* networks are not in any position to connect the global knowledge resources with the local knowledge resources.

Figure 5.30 shows that all three facilities function relatively well as organizational bridges that span the structural holes in these global knowledge networks. To illustrate, in all three facilities, there are specialized gatekeepers who access and utilize the external knowledge networks, and given the extensive internal knowledge networking within the facilities and projects, this knowledge is made available to the respondents within the facilities. As such, there is evidence that although the external knowledge networks are not as extensive as the inter-facility knowledge networks, the specialized gatekeepers meet the characteristics set out by Allen (1977), and as such provide this external knowledge to the respondents within these facilities.

Furthermore, in all three facilities, particularly Brazil and Canada, there are very robust knowledge networks between the majority of respondents and AMBE's Central R&D facilities. Given the importance of Central R&D to AMBE's overall innovative capacities, this is one of the most important global knowledge networks for the respondents. However, this global knowledge networking is also one-dimensional. For the majority of the respondents, Central R&D is the only global knowledge resource they utilize, despite the fact that AMBE has R&D facilities in over 30 countries. Furthermore, the cross-location gatekeeper analysis did not indicate that there are specialized gatekeepers who access these knowledge resources as a group, as is the case with the external and academic. As such, the descriptive results show that

although AMBE Corp. does not meet the requirements set out in *Proposition 1*, the three facilities do relatively well connecting the knowledge within AMBE's Central R&D with the local knowledge resources, fulfilling some of the globalization promises for the host countries, and they also access the external local knowledge networks relatively well, satisfying some of AMBE's requirements for globalizing its R&D facilities.

Figure 5.30: Validating Proposition 1



Source: Author's Rendition based on *Web-Based Surveys.*

5.7 Conclusion

The objective of this chapter is to present a visual representation of the two networks under analysis for the three facilities, and their supporting communication tools, and to show whether *Proposition 1* holds true. The maps showed the similarities and differences between the three facilities, and between the two knowledge networks. *KNPS* maps point to three key findings. First, the inter-facility and Central R&D knowledge resources are utilized more extensively than other resources across all three facilities. Second, the percent of Chinese respondents who utilize a knowledge resource is greater across most of the knowledge

resources, with the exception of Central R&D. Third, the majority of the respondents from the three facilities find most of the knowledge resources to be useful to very useful.

In order to make a distinction between under-utilization and efficient utilization of external and global knowledge resources for *KNPS* networks, I provided the external, academic, and cross-location gatekeeper maps for the three facilities. The results showed that for academic and market gatekeepers, there are coherent groups of respondents who utilize all these knowledge resources, although the extent of overlap between the knowledge resources differed among the respondents from the three facilities. For academic gatekeepers, the overlap was between journals and academia for the Brazilian respondents, and academia and conferences for the Canadian respondents, while the Chinese academic gatekeepers had noticeable overlap among all three knowledge resources. The Brazilian and Chinese respondents showed similar characteristics for their market gatekeepers. The overlap for the Brazilian market gatekeepers is among suppliers and customers, while for the Chinese market gatekeepers, the overlap is among all of the external knowledge resources. The Canadian market gatekeepers, on the other hand, exhibited features of specialization with the external knowledge resources, with sub-groups of individuals with the external gatekeeper community focusing on a combination of the different external knowledge resources. Finally, none of the cross-location gatekeepers showed the type of regional or product alignment in their global knowledge networking to be considered knowledge gatekeepers.

The maps for knowledge networks for Central R&D innovation showed that the most important knowledge resources for the majority of the respondents from the three facilities are their project, facility, Central R&D and other Central facilities, followed by AMBE databases. Similar to *KNPS* networks, the respondents did not utilize global R&D facilities to the extent of the inter-facility or the Central facility resources. Finally, the results showed that the majority of

respondents from all three facilities have a very delineated manner of using their communication tools, where overwhelming majority of respondents utilize e-mail, telephone, and face-to-face communication, but they have a much lower rate of utilization of the remaining virtual and conventional communication tools.

It is obvious from the above presentation of the data, that on the aggregate facility level, there are clear differences among the respondents in the manner in which they utilize their internal, local, virtual and border-crossing knowledge resources, and communication tools. However, there are also clear indications that on some levels, there are significant similarities between the respondents from the three facilities. Overall, although the facilities did not meet all the requirements set out in Proposition 1, they do a relatively good job of connecting the external local knowledge resources with AMBE's global knowledge resources, particularly Central R&D.

In this chapter, I concentrated on the descriptive and visual representation of the network data that I collected from the web based surveys. In the next two chapters, I extend this examination by presenting the results from the quantitative and qualitative analyses from both the personal interviews and web-based surveys. In Chapter 6, I present the results for the two knowledge networks, while in Chapter 7, I concentrate on the communication-tools network.

CHAPTER 6: QUANTITATIVE AND QUALITATIVE ANALYSIS - KNOWLEDGE-NETWORKS

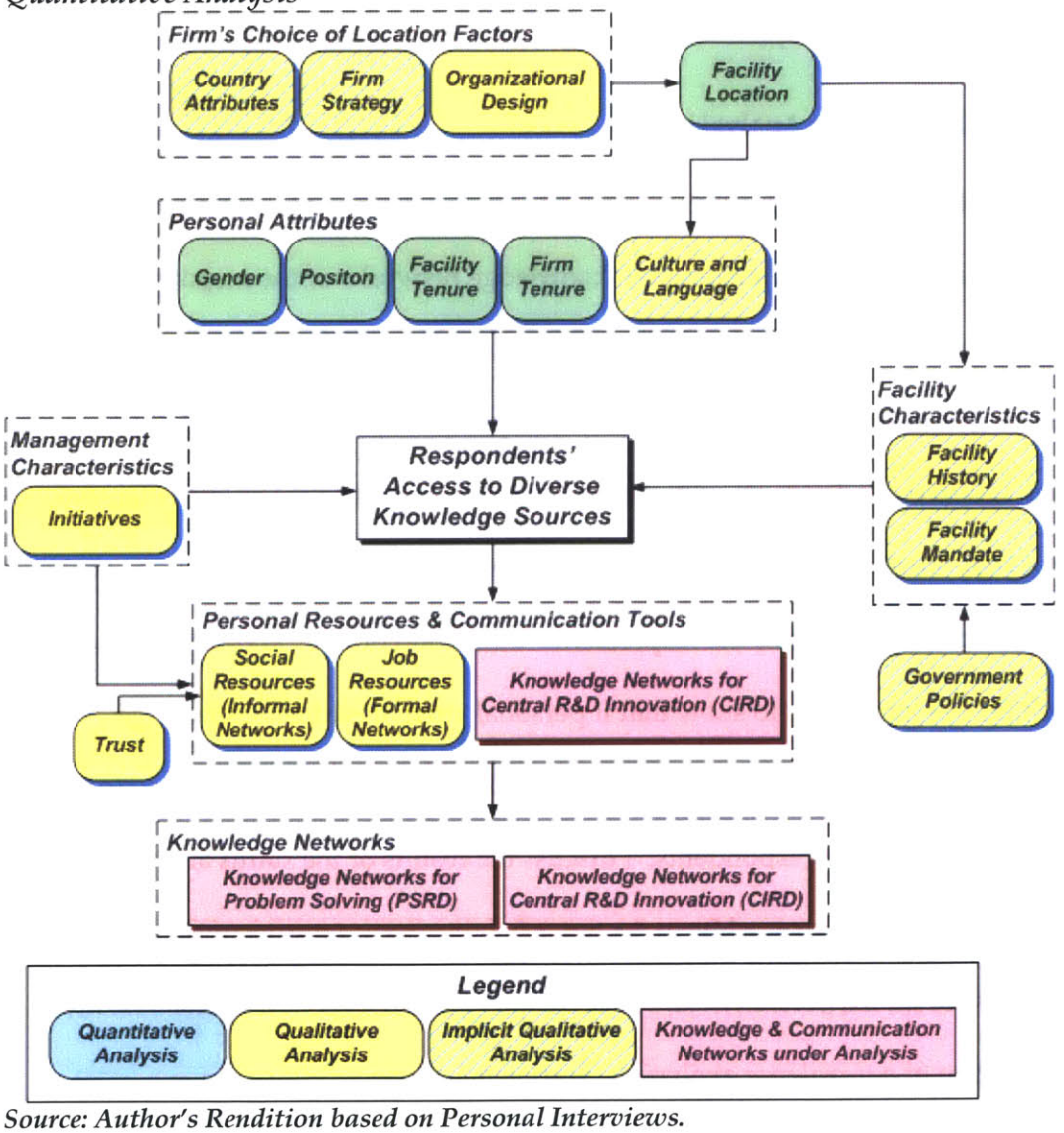
6.1 Introduction

In Chapter 5, I showed that on the aggregate level, there are distinct differences in the manner in which the respondents from the three facilities utilize their knowledge resources and communication tools. The purpose of the descriptive presentation of the network maps was to show that location plays a role in the knowledge networking activities of the respondents, and that the extent of the knowledge networking of the respondents, and the specialized knowledge gatekeepers. The purpose of this chapter and Chapter 7 is to expand the level of analysis to include the role of other personal attributes, such as position and tenure, in the shape and extent of the respondents' networks. To reiterate, the networks under analysis in this chapter are Knowledge Networks for Problem Solving (*KNPS*), Knowledge Networks for Central R&D Innovation (*KNCRDI*), and the three facilities are located in Brazil, Canada, and China. I do a similar analysis for the Communication Tools for Knowledge Networking (*CTKN*) network and provide the results in Chapter 7.

I reproduce Figure 1.1 as Figure 6.1 to reiterate the relationship among all the qualitative and quantitative factors, and their direct and indirect influence on the knowledge networks under analysis in this chapter. Broadly, the factors are divided into three categories. The first sets of factors are those personal attributes that affect the informal networks of individuals. These factors, can, in turn, have a profound effect on the individuals' access to, and information about sources of knowledge and informal knowledge networks. These personal characteristics are gender, position, facility tenure and company tenure. The second set of factors revolves around the features of the facilities where the individuals work. The relevant facility characteristic is its location. Location is an important factor because it serves as a proxy for the culture, language, history, and national characteristics of the individuals who work at the

facilities, which can influence the shape and extent of the individuals' knowledge networks. The management decision to select an international location is, in turn, influenced by the historical and evolving organizational-design imperatives of the firm, the size and growth of the facility's country domestic market, and finally its natural and intellectual resources. To distinguish between the two influencing aspects of the facilities' locations, both as a proxy for culture and language, and also in terms of its physical location, when discussing the former, I use the term, 'location', and when discussing the latter, I use the term, 'site'.

Figure 6.1: The Relationship between the Underlying Factors and the Qualitative and Quantitative Analysis



Source: Author's Rendition based on Personal Interviews.

The final set of factors is the individuals' access and utilization of their personal, social, and job-related resources, as well as their communication tools. These resources are relevant because they can facilitate the flow of knowledge among individuals, and can be particularly important in border-crossing and external knowledge networks.

The structure of this chapter is as follows. In Section 6.2, I present the results of the social network analysis on the importance of personal attributes for the two networks, and their supporting communication tools (blue boxes in Figure 6.1), while in Section 6.3, I present the qualitative analysis based on my personal interviews, emphasizing the factors represented in yellow boxes in Figure 6.1.

6.2 Quantitative Social Network Analysis

As I discussed in Chapter 4, I utilize two social network methods to determine the importance of personal attributes in shaping the knowledge networks of the respondents from the three facilities. I use the first method, status measure, on two levels: (1) to identify the most important knowledge resources for the population of respondents as a whole, and (2), to determine which groups of individuals with different attributes have more or less extensive knowledge networks. I utilize the second social network tool, equivalence measure, to analyze whether personal attributes influence the respondents' utilization of their knowledge resources. The premise behind this analysis is to show that if personal attributes affect knowledge networking, then individuals with similar attributes would have more similar knowledge networks than the population of respondents. I discuss the results of the status analysis for the knowledge resources in Sections 6.4, while in Section 6.5, I discuss the results of the status and equivalence analysis for all the personal attributes. However, I provide more details on my usage and presentation of equivalence analysis in Section 6.3.

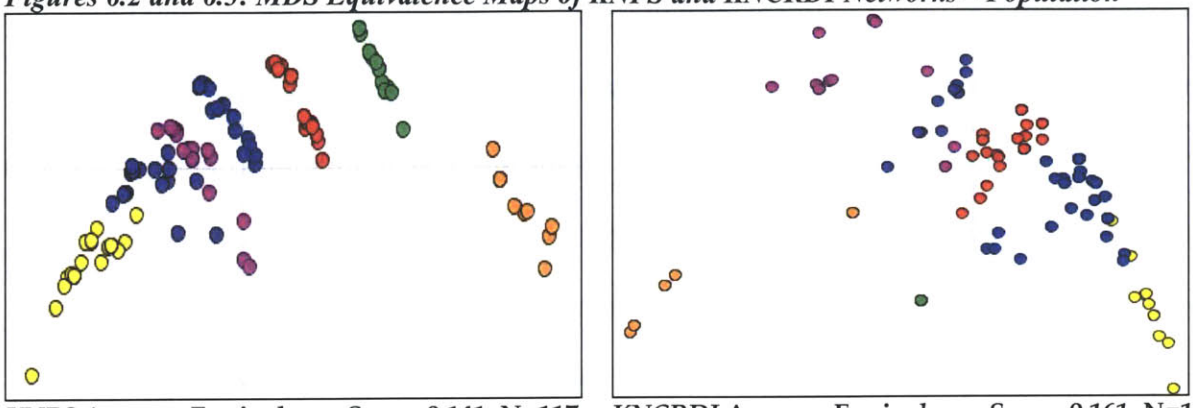
6.3 A Note on the Presentation of Equivalence Analysis

As I stated in Chapter 4, researchers use equivalence analysis to identify niches within populations who share common resources (e.g., Burt and Talmud 1993; Carley 1986; Galaskiewicz and Burt 1991). In this study, I utilize equivalence analysis to determine whether individuals sharing the same personal attributes hold similar network positions, and I use Multidimensional Scaling (MDS), to *map* the results of the equivalence analysis. According to Steyvers, "MDS describes a family of techniques for the analysis of proximity data on a set of stimuli to reveal the hidden structure underlying the data" (2002). Such maps typically consist of nodes or points representing the actors in the networks, where the level of similarity among the respondents is represented by the closeness of the actors to each other. In these maps, individuals with similar network profiles are clustered closer together, and individuals who have dissimilar networking profiles are separated from one another. The closer the nodes, the more similar the networking profiles of the two actors.

In order to examine whether personal attributes affect the respondents' knowledge network, I compare the equivalence scores and MDS maps of the groups of individuals with the same attributes, with the population of respondents as a whole. If the attribute under analysis affects the knowledge-networking patterns of the respondents, then those respondents would have more similar knowledge networking profiles, as represented by the their MDS maps and equivalence scores. In this case, an equivalence score of 1 means that the respondents have identical knowledge networking profiles, and a score of 0 indicates completely dissimilar network profiles. To illustrate, Figures 6.2 and 6.3 show the MDS equivalence maps of the population of the respondents from all three facilities for the *KNPS* and *KNCRDI* networks. In these maps, I represent the clusters of similar actors by the assigning them the same color. Generally, analysts examine these clusters in order to determine the common underlying

characteristics of the individuals within them. In this study, I compare these maps, as well as their equivalence scores, with those of groups of respondents with the same attributes, to determine the importance of that attribute in influencing the nework profiles of the respondents in that group.

Figures 6.2 and 6.3: MDS Equivalence Maps of KNPS and KNCRDI Networks – Population



***KNPS* Average Equivalence Score: 0.141, N=117** ***KNCRDI* Average Equivalence Score: 0.161, N=117**

Source: *Results of equivalence analysis based on the data from the web-based surveys.*

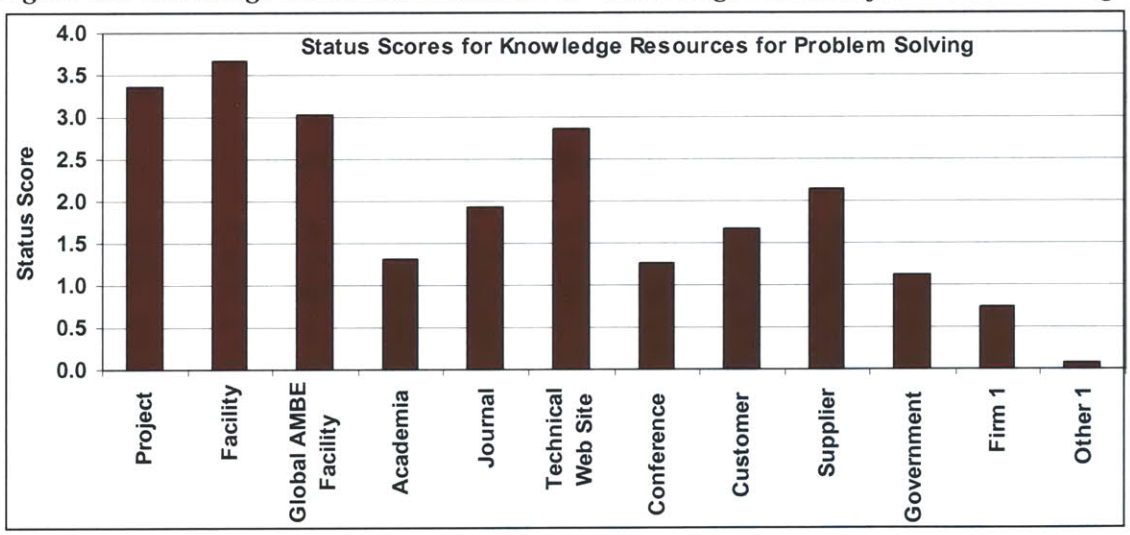
There are a number of points about these diagrams worth examining. The first is that the average equivalence scores, which I include below the maps for both networks, refer to the overall level of similarity of all the members of the network, and as such, does not take into account the level similarity between the actors within the clusters, or the level of difference between the actors, among the clusters. Nonetheless, the combination of the maps and the average scores, provide a good indication of the network profile of the respondents. Second, I examine the underlying characteristics of respondents in each of these clusters to determine whether they share any obvious attributes that could explain their similar networking profiles. The most important finding from this examination was the fact that respondents with different combination of personal attributes occupied the same clusters. For example, the nine respondents in the 'green' cluster for the *KNPS* network, consisted of respondents with different tenure levels, who worked in different countries, and held different positions. However, it is important to point out that because there are different number of respondents in each of the

groups under analysis, there may be cases where a cluster is dominated by one of these groups, such as, men in this cluster. As such, it is only through the examination of the groups of respondents as whole that one can reach the conclusion whether the personal attribute under analysis is influential in the respondents' knowledge networking. I present this analysis for all the relevant groups in Section 6.5.

6.4 Importance of Knowledge Resources

To reiterate, affiliation networks are two-mode networks and a complete analysis should give status indices for both the respondents (actors) and the knowledge resources (events) they utilize. In this section, I provide the status analysis for the respondents' knowledge resources (events) regardless of their location or personal attributes for KNPS networks (Figure 6.4).

Figure 6.4: Knowledge-Resources Status Scores – Knowledge Networks for Problem Solving



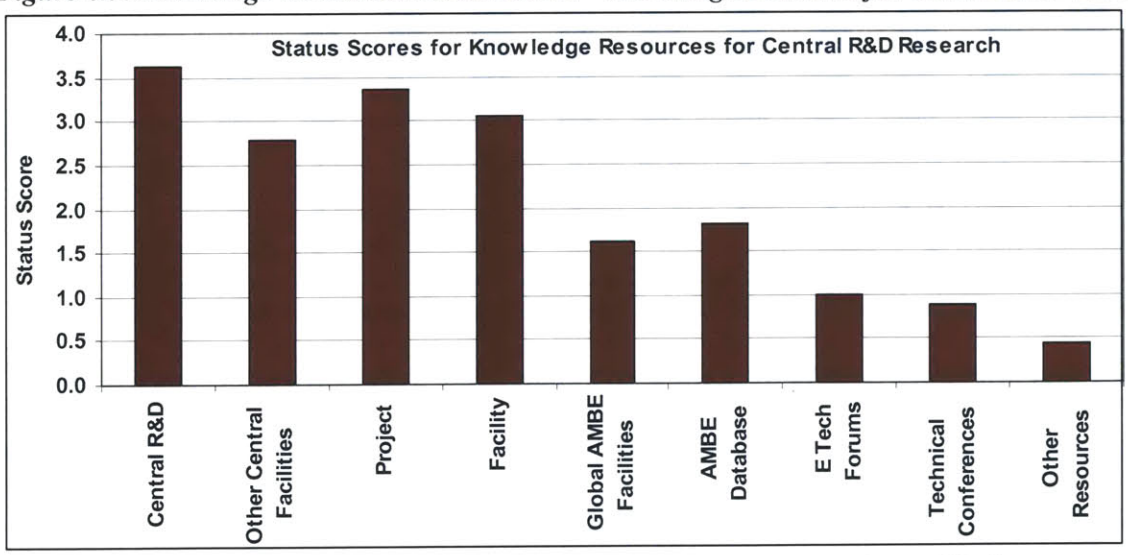
Source: The Mail-in Surveys and Author's Calculations using NetMiner II Software.

The first important finding from the above chart is the impressive importance of the technical website as a knowledge resource. Technical websites are more important than all other resources except for the facility, the project and global AMBE facilities. The second is the importance of suppliers as compared to other external knowledge resources, such as government and academia. The third observation is the surprising low status score for

conferences. In fact, of all the AMBE resources, conferences rank the lowest, scoring only higher than governments and other firms and resources. As I show later in this chapter, the main explanation for this finding is the evolving prioritization of funding for communication tools, with AMBE shifting some of the resources away from traveling to conferences and toward virtual communication tools, which may explain the low scores.

Figure 6.5 shows the importance of knowledge resources for *KNCRDI* knowledge networks. The first observation about this chart is the importance of inter-facility resources, such as respondents' project and facility. The second point about this chart is the expected importance of Central R&D and other Central facilities for knowledge networking. The results also show the overall importance AMBE databases as compared to other non-facility resources. Overall, the results from Figure 6.5 suggest that there is very little border-crossing global knowledge networking for Central R&D innovation that does not include Central or US facilities, and regardless of the where the knowledge originates from, in this case Central R&D, the importance of the respondents' projects and facilities does not diminish.

Figure 6.5: Knowledge-Resources Status Scores – Knowledge Networks for Central R&D Innovation



Source: The Mail-in Surveys and Author's Calculations using NetMiner II Software.

6.5 Influence of Personal Attributes on Knowledge Networking

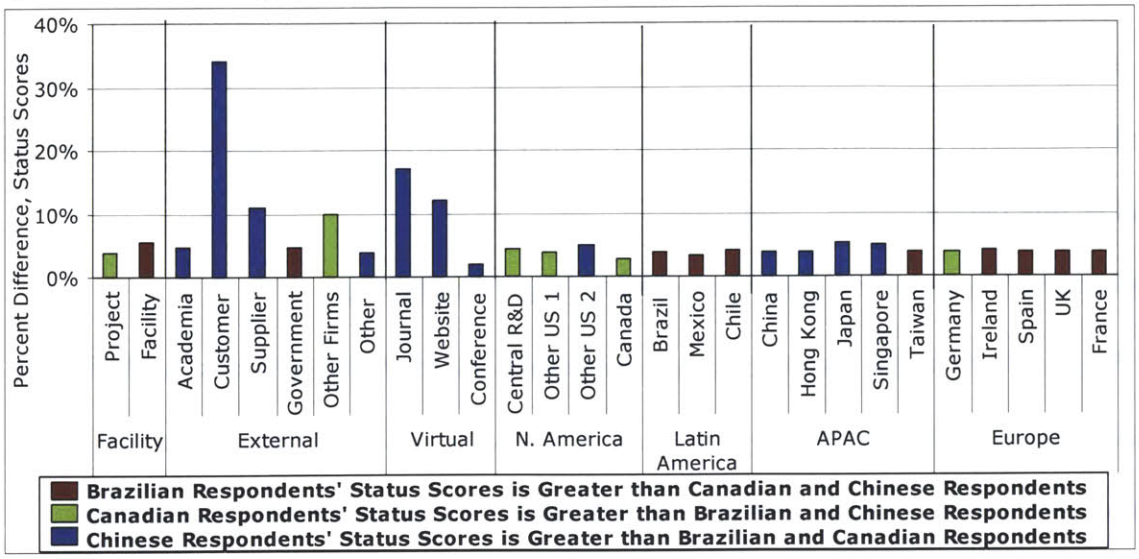
In this section, I present the status analysis of respondents in the way they utilize their knowledge resources grouped by their location (6.5.1), gender (6.5.2), position (6.5.3), as well as firm and facility tenure (6.5.4).

6.5.1 Influence of Respondents' Location on Knowledge Networking

Figure 6.6 shows the results of the status analysis for the *KNPS* network, while Figure 6.7 similar results for the *KNCRDI* network. As is apparent from these figure, there are some differences in the status scores of the respondents from the three facilities, but none of the facilities exhibit demonstrably larger status scores across multiple knowledge resources. For *KNPS* networks (Figure 6.6), Brazilian respondents have more diverse border-crossing knowledge networks, while the Chinese respondents have more extensive virtual and customer knowledge networks. In the case of *KNCRDI* networks (Figure 6.7), the Brazilian respondents exhibit greater diversity of global knowledge networking, the Canadian respondents rely more extensively on Central R&D and Central facilities, and the Chinese respondents lean toward inter-facility and virtual knowledge resources for their access to Central R&D innovation.

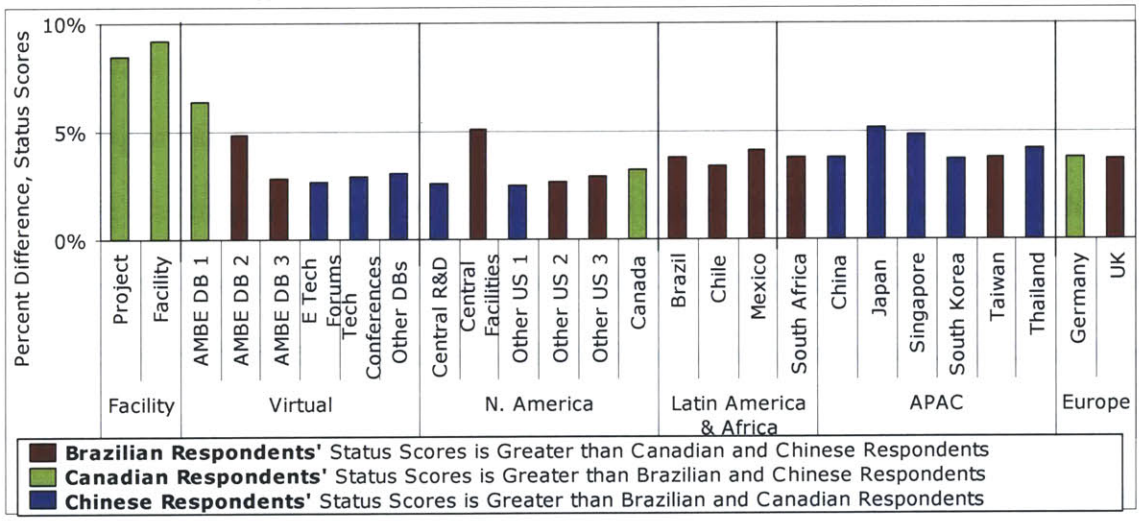
The above analysis, as well as the description of the knowledge networks from Chapter 5, shows that on the aggregate level, the respondents from the three facilities exhibit certain features that distinguish them from each other. In order to determine whether location is in fact a factor in the manner in which individuals utilize their knowledge resources, I conduct equivalence analysis using the social network method of SimRank. By using equivalence analysis, I translate the knowledge-networking patterns of the respondents in each facility into data profiles and measure equivalence by comparing these data profiles. Respondents with identical profiles or relations are equivalent and can be replaced with each other without changing the overall knowledge network.

Figure 6.6: Percent Difference in Status Scores by Respondents' Location- KNPS



Source: *Author's Rendition based on Status values from NetMiner II and Derived from Web-Based Surveys.*

Figure 6.7: Percent Difference in Status Scores by Respondents' Location- KNCRDI



Source: *Author's Rendition based on Status values from NetMiner II and Derived from Web-Based Surveys.*

As I showed above, the equivalence score for the population of respondents from all three facilities is 0.14 for *KNPS* networks and 0.16 for *KNCRDI* networks. Figures 6.A.1-6.A.3 in Appendix 6.A show the MDS equivalence maps, and Table 6.1 shows the equivalence scores, and their percent difference for the respondents in each location and the population of respondents as a whole for the *KNPS* network.

Table 6.1: Equivalence Scores for the Respondents by Location-KNPS

Group	Equivalence Score (ES)	Percent Difference*	Number of Respondents
Population	0.141	-	117
Brazil	0.152	+7.2%	45
Canada	0.128	-10.2%	37
China	0.130	-8.4%	35

* Percent Difference = ((Location ES-Population ES)/Location ES)*100

Source: *Results of equivalence analysis based on the data from the web-based surveys.*

The most important finding from these maps and table is that the respondents from Brazil have more similar knowledge networking profiles for problem solving than the population, while those in Canada and China have more different knowledge-networking profiles. Furthermore, for all three locations, the MDS maps show that there are additional clustering that takes place within these groups, implying that there are other factors that influence the *KNPS* knowledge working of these individuals that is independent of the respondent's location. These factors could be the qualitative factors that I describe later in this chapter, or they may be additional factors that I do not take into consideration in this study. However, what is important is the fact that although the respondents from the three facilities are different in their knowledge networking from respondents from other facilities, it does not mean, and the results of this analysis show, that their knowledge networking is more similar to the respondents from their own facilities.

Table 6.2 and Figures 6.A.4-6.A.6 in Appendix 6.A, show the results of the equivalence analysis for *KNCRDI* network for the three locations, as well as their MDS maps, respectively. Similar to the above findings, the results from this analysis show that the relationship between respondents' locations and the their knowledge-network profiles are mixed, with the Brazilian and Canadian respondents exhibiting less similar knowledge networking profiles, while the Chinese respondents showing more similar knowledge network profile. Furthermore, the MDS maps show that the there are fewer clusters of individuals within each facility, and overall

the respondents in each location appear to have more dissimilar networking profiles than would be anticipated if location played a major role in the manner in which the respondents utilize their *KNCRDI* knowledge resources. Combined these results suggest that location does not play a major role in the *KNCRDI* knowledge networking profiles of the respondents from the three facilities.

Table 6.2: Equivalence Scores for the Respondents by Location- KNCRDI

Group	Equivalence Score (ES)	Percent Difference*	Number of Respondents
Population	0.161	-	117
Brazil	0.153	-5.2%	45
Canada	0.151	-6.6%	37
China	0.173	+6.9%	35

* Percent Difference = ((Location ES-Population ES)/Location ES)*100

Source: *Results of equivalence analysis based on the data from the web-based surveys.*

6.5.2 Influence of Respondents' Position on Knowledge Networking

As I showed in Chapter 4, about 20 percent of all respondents identified themselves as managers. Figures 6.8 and 6.9 show the results of status analysis for the two groups for *KNPS* and *KNCRDI* networks. Unlike the status analysis for the respondents' location, the results here show that for *KNCRDI* networks, managers have more extensive knowledge networks than employees. On the other hand, for the *KNPS* networks, the results are similar to the location analysis, in that two groups have different knowledge networks, and that neither group has significantly more extensive knowledge networks than the other. This is an important finding because it shows that the importance of the respondents' positions on their knowledge networking is at least partially dependent on the purpose the knowledge network serves.

However, there are other differences worth noting. The first is that managers utilize their virtual knowledge resources for problem solving more extensively than employees, but the opposite is true for Central R&D innovation. This shows that although both groups are

comfortable using the virtual knowledge repositories, the differences in their level of utilizations must lie with the real and perceived notion of their availability, and access to relevant information. Second, for *KNPS* networks, employees have more diverse border-crossing knowledge networks than managers, while managers rely more extensively on Central R&D and Germany. As I show later in this Chapter, one of the primary reasons behind the above findings is that respondents have a tendency to communicate with individuals they have met and in general the managers at AMBE R&D facilities have had more opportunities to travel to the Central R&D facilities, resulting in a more robust knowledge-networking relationships.

Figure 6.8: Percent Difference in Status Scores by Respondents' Position – KNPS

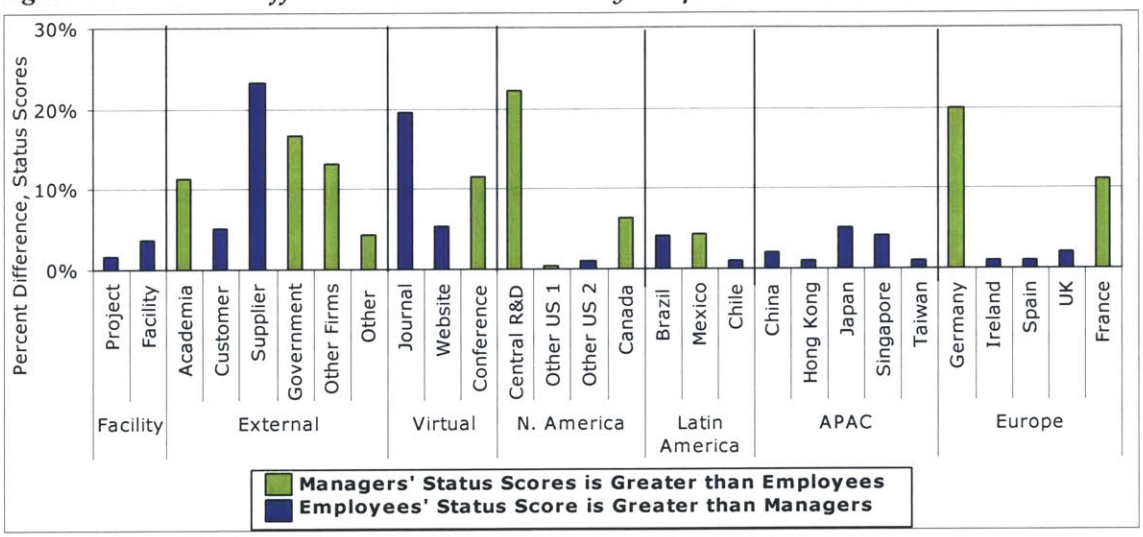
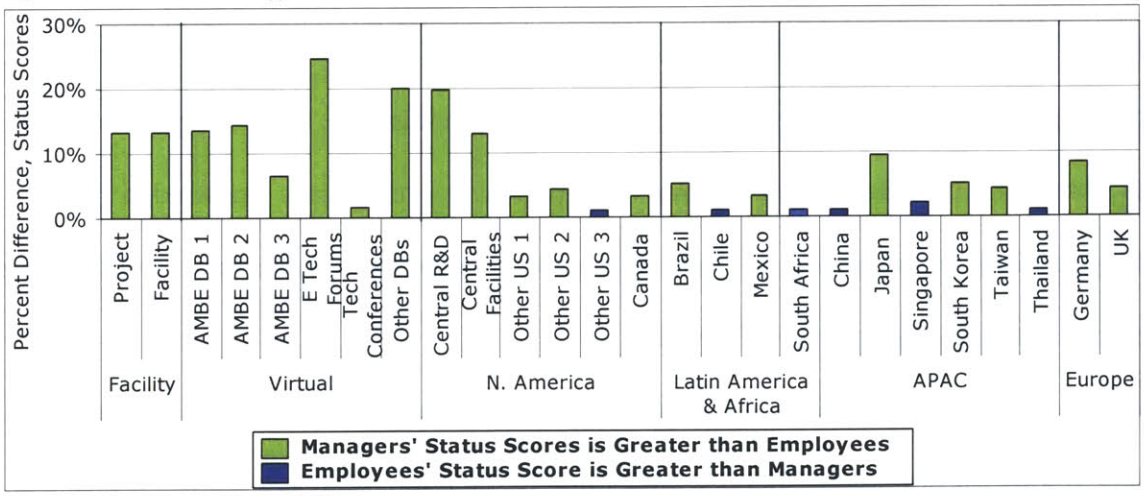


Figure 6.9: Percent Difference in Status Scores by Respondents' Position – KNCRDI



Source: *Results of Status analysis based on the data from the web-based surveys.*

Finally, employees and managers differ in their utilization of external local knowledge resources for *KNPS* networks, with employees relying on customers and suppliers more extensively than managers, and managers relying more on government, academia and other firms, than employees. Altogether, the above findings suggest that although a respondent's position does play a role in the extent of their knowledge networking, the relationship is not a very predictable one. For *KNPS* networks, employees and managers utilize different knowledge resources depending on their needs and there are no clear-cut patterns of knowledge-resource utilization that can be used to predict the shape and extent of an individual's knowledge networking based solely on their position. However, for *KNCRDI* networks, managers have distinctly more extensive networks.

As is apparent from the above analysis, for both *KNPS* and *KNCRDI* knowledge networks, employees and managers utilize either a different mix of knowledge resources (*KNPS*), or a different level of utilization of the same resources (*KNCRDI*). I utilize equivalence analysis here to find out whether these differences between managers and employees, necessarily results in knowledge-network profiles that are more similar among the respondents who hold same positions. Table 6.3, as well as Figure 6.A.7 and 6.A.8 in Appendix 6.A., show the results of the equivalence analysis for the two groups for *KNPS* networks, as well as their MSD maps. The results mirror those of location analysis, in that the relationship between the respondents' positions and their *KNPS* profiles are mixed. In this case, the managers' network profile is less similar than the population as a whole, while the employees' knowledge networking profile is more similar. In short, the equivalence analysis shows that a respondent's position does not influence their *KNPS* profile.

Furthermore, as Figures 6.A.7 and 6.A.8 show, there is a great deal of clustering that takes place among the employees that resemble those of the population as a whole. If position

played a significant role in the manner in which the respondents utilized their knowledge resources, there would be fewer clusters, and less distance between the clusters themselves. As such, it is apparent that there are additional factors that influence the employees' knowledge networks which results in the above clustering features. On the other hand, the managers' MDS map shows very little clustering, again implying that the importance of a respondents' position on their *KNPS* knowledge networking is small and inconsistent.

Table 6.3: Equivalence Scores for the Respondents by Position - KNPS

Group	Equivalence Score (ES)	Percent Difference*	Number of Respondents
Population	0.141	-	117
Managers	0.131	-7.6%	20
Employees	0.148	+4.7%	97

* Percent Difference = ((Location ES-Population ES)/Location ES)*100
Source: *Results of equivalence analysis based on the data from the web-based surveys.*

Table 6.4 and Figures 6.A.9 and 6.A.10 in Appendix 6.A, show the same analysis for *KNCRDI* networks. The results match the findings for the *KNPS* networks, showing the same mixed relationship between a respondents' position and their knowledge network profile. In this case, the network profile of the managers is more different, while the network profile of the employees is more similar. Furthermore, the MDS maps mirror the maps for *KNPS* networks, showing the same characteristic clustering for the employees, and non-clustering for the managers.

Table 6.4: Equivalence Scores for the Respondents by Position - KNCRDI

Group	Equivalence Score (ES)	Percent Difference*	Number of Respondents
Population	0.161	-	117
Managers	0.153	-5.2%	20
Employees	0.168	+4.1%	97

* Percent Difference = ((Location ES-Population ES)/Location ES)*100
Source: *Results of equivalence analysis based on the data from the web-based surveys.*

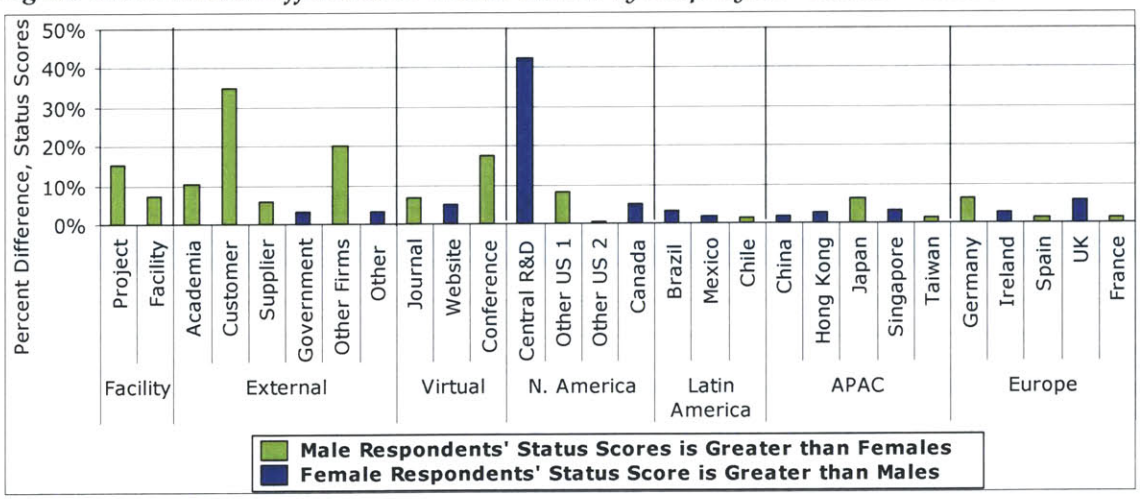
Overall, the combination of the status and equivalence analysis for the respondents with different positions points to three important findings. First, the extent that two groups utilize different knowledge resources is at least partially dependent on the knowledge network itself.

Second, despite the differences between the managers and employees in the extent and manner in which they utilize their knowledge resources, the respondents within each group do not have any more similar knowledge-networking profiles than the population of respondents as whole. This leads to the third finding, which is, given the above findings, there must be additional factors that influence the respondents knowledge networks regardless of their positions.

6.5.3 Influence of Respondents' Gender on Knowledge Networking

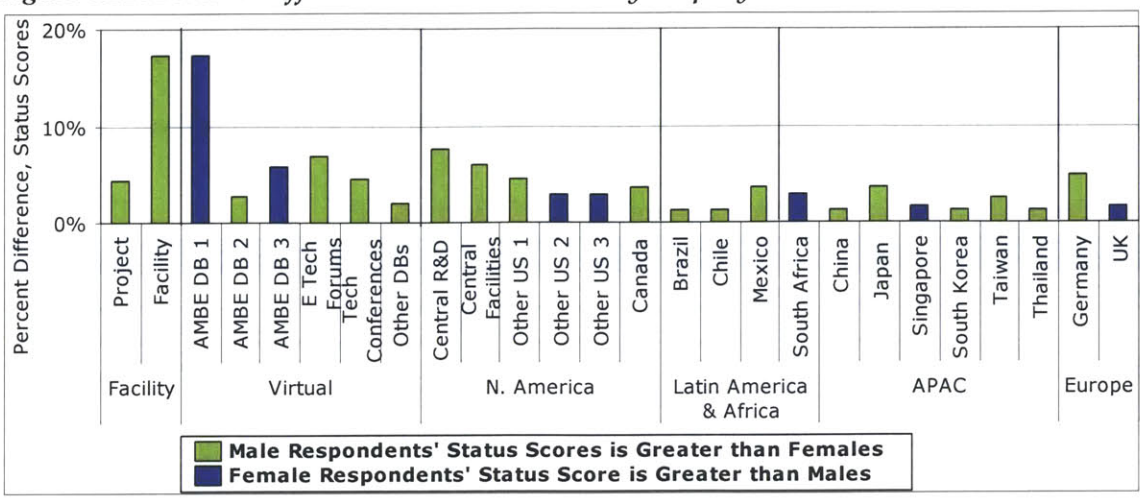
In this section, I analyze the difference in status scores of all males and females, regardless of their facility. Figures 6.10 and 6.11 show the results of this analysis for the two knowledge networks. The first and most relevant observation about the figures is that, for both *KNPS* and *KNCRDI* networks, the male respondents have slightly more extensive knowledge networks than the female respondents. The most noticeable exception for the *KNPS* networks is the fact that female respondents' status scores for Central R&D is significantly greater than the male respondents. For *KNCRDI* networks, the male respondents have slightly more extensive knowledge networks across almost all resources, with the major exception of AMBE Database 1.

Figure 6.10: Percent Difference in Status Scores by Employees' Gender – KNPS



Source: *Results of Status analysis based on the data from the web-based surveys.*

Figure 6.11: Percent Difference in Status Scores by Employees' Gender – KNCRDI



Source: *Results of Status analysis based on the data from the web-based surveys.*

These findings are very similar to the ones from the status analysis of the respondents' positions, in that, it is obvious that the influence of gender on the respondents' knowledge networking is at least partially dependent on the knowledge network itself, although this influence is smaller than that of the respondents' positions. Tables 6.5 and 6.6, as well as Figures 6.A.11-6.A.14 in Appendix 6.A, show the results of the equivalence analysis, and the MDS maps for the male and female respondents for both knowledge networks. As was the case with location and position, it is apparent that there is a mixed relationship between the influence of gender on the knowledge networking profiles for *KNPS* and *KNCRDI* networks. The results for *KNPS* networks show that the male-respondents' profiles are more different than the population, while the female respondents' knowledge-network profile are more similar. Alternatively, the results for knowledge network for *KNCRDI* networks show that male respondents have more similar knowledge networking profile, and the female respondents have less similar knowledge networking profile.

The MDS maps for the two knowledge networks mirror the MDS maps for the employee and managers from above. In this case, the MDS maps for male respondents show the same type of clustering as employees, while the MDS maps for the female respondents exhibit very

little clustering. Given the similarities in these maps, it is reasonable to reach the same conclusions, and that is, gender plays a small and inconsistent role in the manner in which the individuals utilize their knowledge resources for both the *KNPS* and *KNCRDI* networks.

Table 6.5: Similarity Measures for the Respondents by Gender– KNPS

Group	Equivalence Score (ES)	Percent Difference*	Number of Respondents
Population	0.141	-	117
Male	0.136	-3.7%	93
Female	0.149	+5.3%	24

* Percent Difference = ((Location ES-Population ES)/Location ES)*100
Source: *Results of equivalence analysis based on the data from the web-based surveys.*

Table 6.6: Similarity Measures for the Respondents by Gender – KNCRDI

Group	Equivalence Score (ES)	Percent Difference*	Number of Respondents
Population	0.161	-	117
Male	0.168	+4.2%	93
Female	0.155	-3.7%	24

* Percent Difference = ((Location ES-Population ES)/Location ES)*100
Source: *Results of equivalence analysis based on the data from the web-based surveys.*

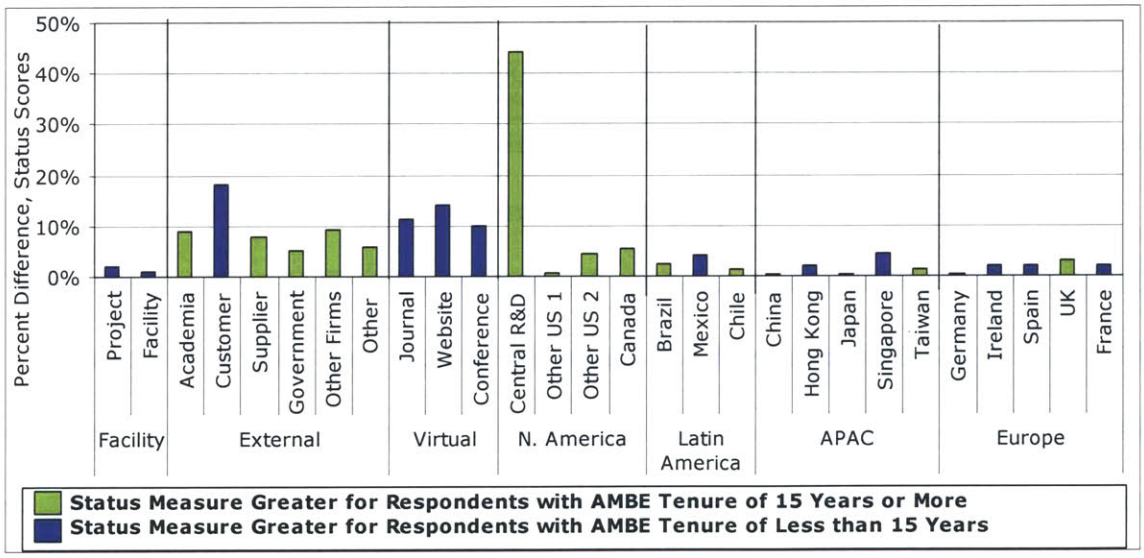
The combination of status and equivalence analysis again shows the mixed influence of gender on the respondents' knowledge networking. And similar to above findings, it is apparent that although men and women differ in their knowledge networking, this difference, does not equate to similarity among men and among women in the utilization of their knowledge resources in either network.

6.5.4 Influence of Respondents' Firm and Facility Tenure on Knowledge Networking

Of all the personal attributes under analysis in this section, the respondents' length of employment at AMBE and their particular facility may be the most influential in affecting their knowledge networks. The reasons are obvious: the longer an employee works for a firm or within a facility, the more contacts they make, the more familiar they become with all the knowledge resources, the more connections they make with external knowledge resources, and the more they travel to other global facilities, and become acquainted with AMBE's global

knowledge resources. Figures 6.12 and 6.13 show the differences in status scores for the two networks by respondents' length of firm tenure. For both the firm and facility tenure, I compare the respondents who have been with AMBE or their current facility for more than 15 years, with those with less than 15 years of tenure. The first observation regarding the following charts is that respondents with greater than 15 years of firm tenure, have greater status scores for majority of their knowledge resources than the respondents who have been with the firm for less than 15 years. The exceptions for *KNPS* networks are virtual tools and customers, and to a lesser degree, their facility and projects. The respondents with longer firm tenure have greater status scores for all other local external knowledge resources, as well as Central R&D.

Figure 6.12: Percent Difference in Status Scores by Respondents' AMBE Tenure – KNPS

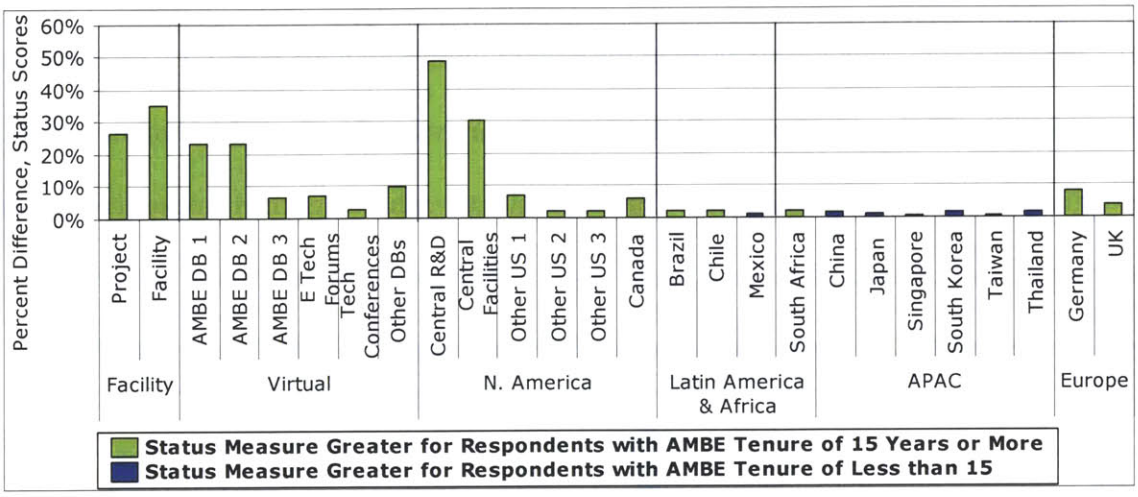


Source: *Results of Status analysis based on the data from the web-based surveys.*

However, the importance of firm tenure becomes very significant when analyzing the status results for *KNCRDI* networks. In this case, individuals who have been with the firm for more than 15 years have larger status scores for every knowledge resource except for some of the global border-crossing knowledge networks. Furthermore, the extent of the difference is much more significant than for position and gender, ranging from 5 to 50 percent. As is apparent from Figure 6.13, the respondents in this group have significantly greater status scores

for their primary knowledge resources, such as Central R&D, Central facility, respondents' facility and project, as well as AMBE databases. These results clearly show that longevity within AMBE has positive impact on the extent of knowledge networking, particularly for *KNCRDI* networks.

Figure 6.13: Percent Difference in Status Scores by Respondents' AMBE Tenure – KNCRDI

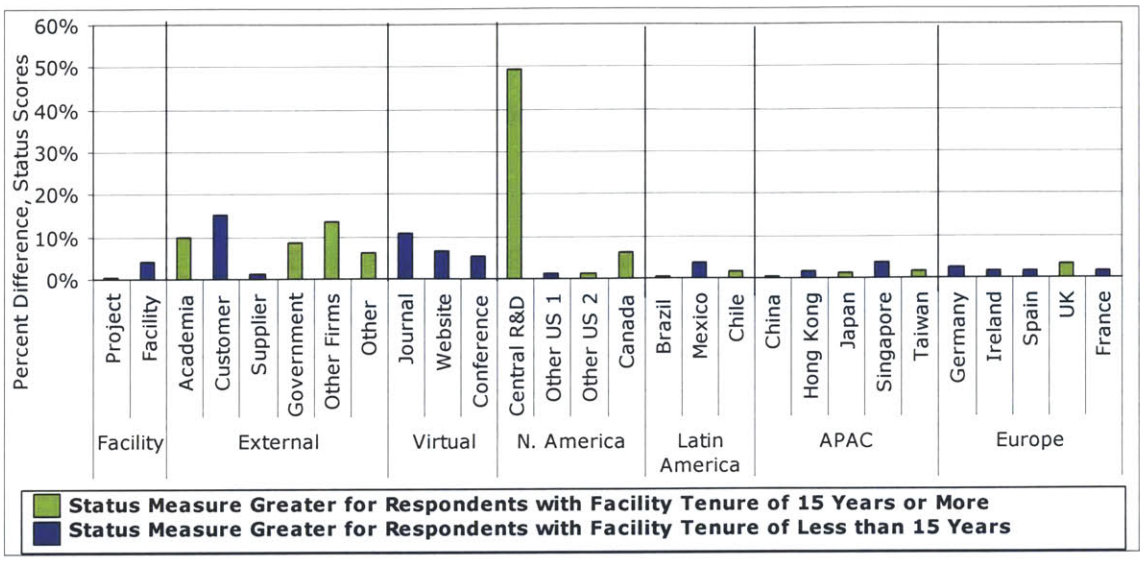


Source: *Results of Status analysis based on the data from the web-based surveys.*

The results of facility-tenure status analysis are shown in Figures 6.14 and 6.15. The results mirror the firm-tenure analysis, albeit, the differences are not as significant as that of AMBE tenure. For *KNPS* networks, the respondents who have been with their respective facilities for 15 years or more have greater status scores for all external local knowledge resources, their project and Central R&D facilities. However, except for the Central R&D, the difference between the two groups is very small. As for *KNCRDI* networks, respondents with longer facility tenure again have greater status scores for all knowledge resources than respondents with less than 15 years of facility tenure. However, the extent of the difference is less than that of AMBE tenure, but significantly more than *KNPS* networks. In short, there is more of a positive relationship between the level of firm and facility tenure for *KNCRDI*

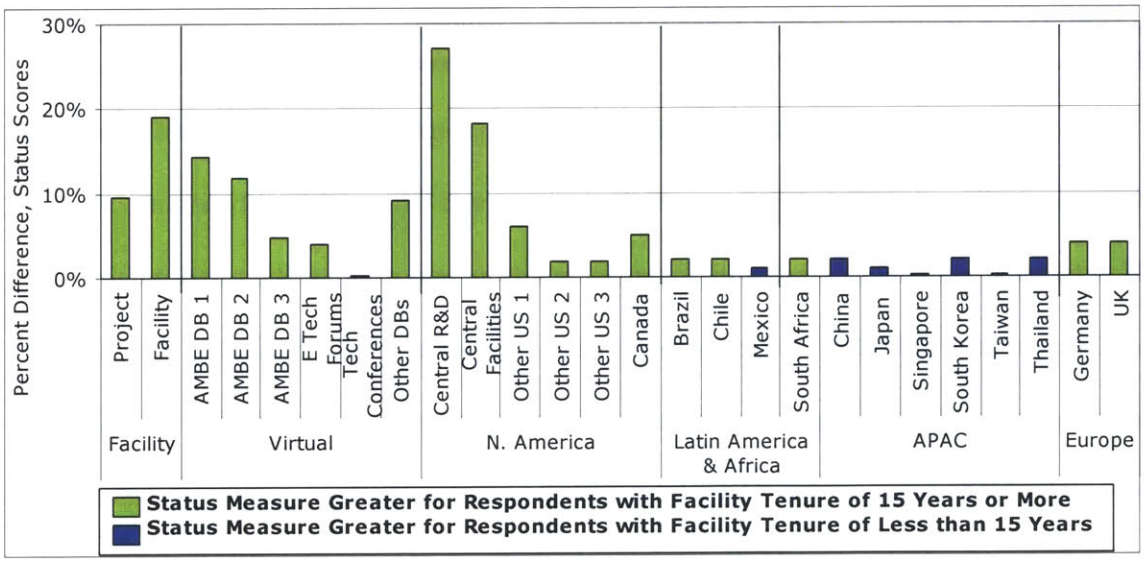
networks than for *KNPS* networks, and firm tenure plays more of a significant role than facility tenure for both networks.

Figure 6.14: Percent Difference in Status Scores by Respondents' Facility Tenure- KNPS



Source: *Results of Status analysis based on the data from the web-based surveys.*

Figure 6.15: Percent Difference in Status Scores by Respondents' Facility Tenure - KNCRDI



Source: *Results of Status analysis based on the data from the web-based surveys.*

The question then is whether this finding would be reflected in the results of the equivalence analysis. Tables 6.7and 6.8, and Figures 6.A.15-6.A.18 in Appendix 6.A., show the results of equivalence analysis, as well as the MDS maps, for firm and facility tenure for *KNPS* networks, resectively. Both groups of respondents have more similar knowledge networking

profiles for problem solving, meaning that there is a relationship between the level of firm tenure and the knowledge networking profile of the respondents. The equivalence scores translate to the fact that the clusters are slightly closer together for respondents who have been with AMBE for less than 15 years. Similarly, for the respondents who have been with AMBE for more than 15 years, the MDS maps show that the nodes are slightly closer together. However, in both cases, the differences are small.

Table 6.7: Similarity Measures for the Respondents by Firm Tenure – KNPS

Group	Equivalence Score (ES)	Percent Difference*	Number of Respondents
Population	0.141	-	117
More than 15 years	0.158	+10.8%	76
Less than 15 years	0.151	+6.6%	41

Table 6.8: Similarity Measures for the Respondents by Facility Tenure – KNPS

Group	Equivalence Score (ES)	Percent Difference*	Number of Respondents
Population	0.141	-	117
More than 15 years	0.165	+14.5%	78
Less than 15 years	0.150	+6.0%	39

* Percent Difference = ((Location ES-Population ES)/Location ES)*100

Source: *Results of equivalence analysis based on the data from the web-based surveys.*

Tables 6.9 and 6.10, and Figures 6.A.19-6.A.22 in Appendix A, show the results of equivalence analysis and their MDS maps, on the influence of firm and facility tenure for *KNCRDI* networks. As was the case with location, position, and gender, the relationship between firm tenure and *KNCRDI* equivalence scores are mixed, implying that facility tenure does not influence the knowledge networking profiles of the respondents for Central R&D innovation. The MDS maps for the KNCRDI networks point to the same conclusion as above, in the sense that for both firm and facility tenure, the individuals who have been with their firm or facility for less than 15 years, show similar clustering as the whole population, and the individuals who have been with their respective facilities, exhibit less clustering and less distance between the nodes.

Table 6.9: Similarity Measures for the Respondents by Firm Tenure - KNCRDI

Group	Equivalence Score (ES)	Percent Difference*	Number of Respondents
Population	0.161	-	117
More than 15 years	0.175	+8.0%	76
Less than 15 years	0.158	-1.9%	41

Table 6.10: Similarity Measures for the Respondents by Facility Tenure - KNCRDI

Group	Equivalence Score (ES)	Percent Difference*	Number of Respondents
Population	0.161	-	117
More than 15 years	0.169	+4.3%	78
Less than 15 years	0.155	-3.1%	39

* Percent Difference = ((Location ES-Population ES)/Location ES)*100

Source: *Results of equivalence analysis based on the data from the web-based surveys.*

6.5.5 Summary Analysis of Status and Equivalence Results

The above social network analysis of the web based data point to a number of findings. The first is that the groups of respondents with different personal attributes have different knowledge networking characteristics. This is particularly true for the *KNPS* networks, where, in almost every case, none of the groups of respondents exhibited demonstrably more extensive knowledge networks than the comparison group. However, the results are somewhat different for the *KNCRDI* networks, where the groups that I expected to have more extensive knowledge networks, that is, males, managers, and respondents with greater tenure levels, do. For example, I expected men to have larger knowledge networks, because have traditionally held positions of power, allowing them more access to more knowledge resources, and the gender status analysis of *KNCRDI* networks showed that men have more extensive knowledge networks than women. The same reasoning and associated results hold true for managers of the three facilities, as compared to the employees. Finally, both groups of respondents with longer firm and facility tenure have more extensive *KNCRDI* knowledge networks than those with shorter tenure levels. As I stated earlier, this is perfectly plausible, given that increased tenure can expose individuals to more diverse knowledge resources, which may result in larger networks.

However, the equivalence analysis and the resulting MDS maps, showed only slightly more similar knowledge networking of the respondents within any of the above groups. In fact, in some cases, the respondents in these groups exhibited more dissimilar knowledge-networking profiles than the population as a whole. Furthermore, although the MDS-equivalence maps showed pronounced clustering of the population of respondents, a closer examination of the clusters showed that the individuals in these clusters had varied personal attributes. In addition, the MDS maps of the groups of respondents showed similar multiple clustering or no clustering at all, implying that the personal attributes under analysis are not the relevant factors for explaining the formation of these clusters.

The question then is, why would the above attributes have an expansive relationship on the *KNCRDI* knowledge networks, but a mixed relationship on the *KNPS* knowledge networks. The primary reason for this difference, which emerged from my personal interviews with the respondents, is in the respondents' sense of urgency when searching for the information they need, between the two networks. There was a consensus among the respondents from the three facilities that when looking for answers to solve their technical problems, they tend to search for answers among *all* of their available knowledge resources. In other words, the need for knowledge for problem solving evens the 'playing field' in the respondents' search for answers. However, the respondents agreed that in regards to their quest for finding information about Central R&D innovation, there is little sense of urgency in their knowledge networking, and as such they can be selective about their knowledge resources, resulting in more extensive knowledge networks for individuals who may have more extensive list of contacts, because of their position in the network. As such, individuals with longer firm-tenure levels, for example, can choose all of the resources they have at their disposal, resulting in more extensive and diverse knowledge networking levels than those with shorter tenure levels.

6.6 Influence of Gatekeeper Roles for Knowledge Networks for Problem Solving

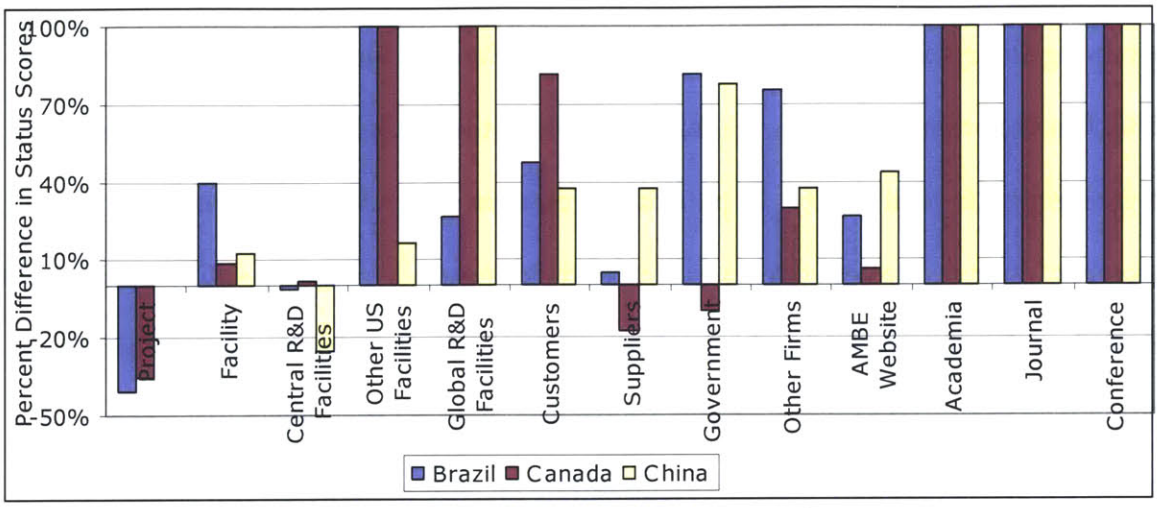
In Chapter 5, I showed that in each facility, there are groups of individuals who act as external and academic knowledge gatekeepers. Because of the importance of these individuals in accessing, interpreting, and providing this external knowledge to their colleagues within AMBE, it is important to analyze the characteristics of these gatekeepers as compared to the non-gatekeepers in each facility. In particular, I examine the difference in the extent of the gatekeepers' knowledge networking with *all* of their knowledge resources. The purpose of this analysis is to determine whether the gatekeepers' overall knowledge-resource utilization is different than non-gatekeepers, and if that is the case, how are the differences manifested in their knowledge networking profiles. I concentrate on only the external and academic gatekeepers, because as I showed in Chapter 5, the cross-location gatekeepers did not constitute a gatekeeper group, with little overlap in the manner the respondents utilized these global knowledge resources. I present the results for academic gatekeepers in Section 6.4.1 and the results for external non-academic gatekeepers in Section 6.4.2.

6.6.1 Academic Gatekeepers

To reiterate, academic gatekeepers are those respondents who utilize the knowledge resources from academia, journals and conferences. Figure 6.16 shows the results of the status analysis for the gatekeeper and non-gatekeeper populations for the three facilities, which is, the extent of their knowledge networking. As is apparent from this figure, academic gatekeepers have extensive knowledge networking with both external academic knowledge resources, but they also have broad knowledge networks across all knowledge resources. For example, the Brazilian academic gatekeepers are also the exclusive or primary knowledge brokers for all knowledge resources, with the notable exceptions of project and Central R&D. Similar results

holds true for China. In the case of Canada, the gatekeepers have exclusive or primary knowledge networks with other US and global R&D facilities, customers and other firms.

Figure 6.16: Differences in Status Scores for Academic Gatekeepers – Brazil, Canada, and China



Source: The Mail-in Surveys and Author's Calculations using NetMiner II Software.

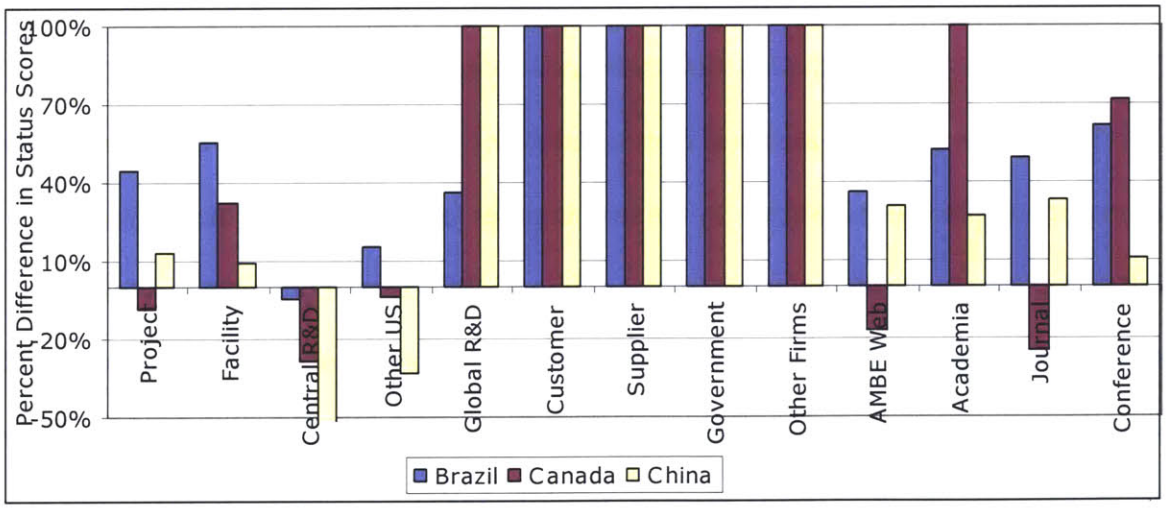
Combined, the above results point to the fact that the academic gatekeepers play a more important role of external and global knowledge networking than just being the sole gatekeepers to the academic knowledge resources. The results also point to the fact that gatekeepers may not have such clear-cut roles in accessing and utilizing specific external knowledge resources. For example, it is apparent that the academic gatekeepers in Canada also serve as global R&D gatekeepers, and its members also make up 75 percent of the respondents who are customers' gatekeepers. In summary, it may be convenient to assign the respondents to different gatekeeper groups based on their external knowledge utilization, but it may be important to realize that there is a great deal of overlap between the members of different gatekeeper groups.

6.6.2 Market gatekeepers

Market gatekeepers refer to the respondents who access the non-academic external knowledge resources, such as customers, suppliers, government agencies, and other firms and

facilities. Figure 6.17 shows the difference in status scores for the market gatekeepers for all their knowledge resources for problem solving. Similar to the academic gatekeepers, the market gatekeepers have very extensive knowledge networks across majority of the available resources, with the notable exception of their utilization of Central R&D. Between 15 to 70 percent more of the Brazilian market gatekeepers utilize their knowledge resources than the non-gatekeepers, while for the Chinese market gatekeepers those percentages range from 10 to 35 percent, and for the Canadian market gatekeepers represent all of the respondents who utilize global R&D facilities and academia. Combined, the results mirror the findings from the academic-gatekeepers analysis from above, in that the market gatekeepers' importance as knowledge brokers span across more knowledge resources than merely the ones that I designated.

Figure 6.17: Differences in Status Scores for Market gatekeepers – Brazil, Canada, and China



Source: The Mail-in Surveys and Author's Calculations using NetMiner II Software.

The combined gatekeeper analysis points to the fact that there is not a designated group of respondents whose responsibility it is to access certain external knowledge resources, but rather respondents with access to external knowledge resources generally have broader overall knowledge-resource base than non-gatekeepers. In other words, respondents who utilize

external knowledge resources usually access multiple external and global knowledge resources. As such, in addition to the above segregation of gatekeepers into different categories, there is also slight but broader separation of respondents between the groups who have more extensive internal knowledge resources and those who have more broad external knowledge resources for problem solving.

6.7 Discussion and Results of Qualitative Analysis

In the above sections, I presented the results of the quantitative analysis of the mail-in web surveys from the three facilities of AMBE Corp. Although the results showed that certain knowledge resources are more important than others, both the status and equivalence analysis dismissed the attributes under analysis as being irrelevant in explaining these differences. In this section, I use the qualitative analysis based on personal interviews, to shed more light on individual resources as well as organizational characteristics that may explain some of the differences in the way individuals utilize their knowledge resources.

The first set of factors are those that can be defined as formal structures and mechanisms that are put into place and designed by the firm in order to direct the flow the knowledge. Combined, these structures and mechanisms define AMBE's formal organizational-design features. These include the distribution of resources across facilities, including expertise and innovatory capacity, and a clear articulation of the availability and usefulness of these resources to the respondents. In other words, there are two relevant aspects of the formal features of a firm's organizational design as a facilitator or impediment to knowledge networking: (1) where are the knowledge resources located within the firm, and (2) how well do all individuals in the firm know about the existence of these sources of knowledge.

Second, the informal networks of individuals, which exist and emerge outside the formal structures that are put into place by the firm, can act as a major facilitator or impediment to knowledge networking. These informal networks come into existence for a variety of reasons, some of which are the results of the formal structures of the firm, while others are the result of social networking that takes place outside of the formal structures. What is important for this analysis is how individuals utilize these resources to access the distributed knowledge within the firm, as well as the information that is available outside of the firm, such as from academia, government, suppliers, customers, and external databases and web resources. Furthermore, as I show later in this chapter, these same resources can also hinder the flow of communication by blocking an individual's path to more useful, but lesser known resources and contacts. Based on my personal interviews, the results of this analysis are divided into five areas: AMBE's organizational R&D resource allocation and design characteristics (Section 6.7.1), respondents' personal resources, including job and social resources (Section 6.7.2), the role of trust in knowledge networks (Section 6.7.3), facility history and mandate (Section 6.7.4), and AMBE's management initiatives (Section 6.7.5).

6.7.1 Resource Allocation and Organizational Design

As I stated in Chapter 3, AMBE Corp. spends about $1 billion per year on its R&D operations. Of AMBE's 6,500 R&D scientists, approximately 2,200 are located outside of US. Of the remaining 4,400 researchers who work within the United States, approximately half are located at the Central R&D laboratories, close to AMBE's corporate headquarters. Overall then, the 6,500 AMBE researchers are divided equally in three areas: central R&D facilities, other US facilities, and outside-US facilities. Furthermore, Central R&D facilities' budget is approximately 40 percent of the total R&D budget. In short, Central R&D enjoys an extremely prominent position within the AMBE Corp.'s R&D organization. In general, the respondents

were aware of Central R&D's dominant position and felt that regardless of the technical problem they faced, there would be a resource within Central R&D that could help them find the appropriate answer, and in majority of cases they did. According to one respondent:

"...The point is not whether 'Central' R&D has all the answers...the point is that even if they don't have all the answers, that they will always know of the resources or contacts that do...The researchers at 'Central' R&D not only have very deep technical knowledge, but they also have very wide and extensive networks of scientists at all the R&D labs, and even outside of 'AMBE'...So, in essence, they are a clearinghouse for information and contacts, which makes them invaluable..."

Respondents from all three locations echoed the above observation. This sentiment was especially persistent among the Brazilian and Canadian respondents, while the Chinese respondents felt that, although Central R&D was an extremely useful resource, they did have their own shortcomings. According to one Chinese employee:

"...'AMBE' has a lot of resources which I am not very familiar with...[And] I am sure that some of them are more useful than 'Central' R&D...[But] I simply do not have the time to test every resource...[So] I went (sic) with the sure thing, and that's 'Central' R&D..."

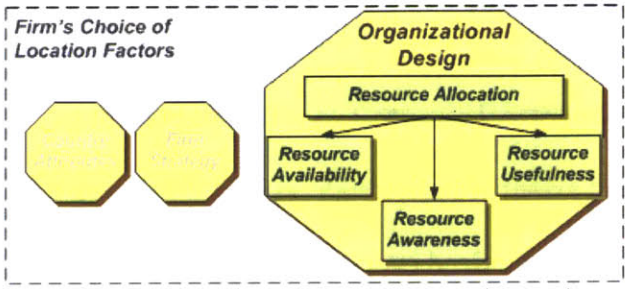
In short, the importance of Central R&D lies in its consistency of delivering solutions to respondents' problems either directly or indirectly. In actuality, the fact that respondents choose Central R&D over all other global facilities is precisely how the respondents should be behaving. The AMBE R&D organization is designed with a nearly a third of its resources concentrated in one location and it is that concentration of expertise that attracts the respondents to look for answers. As one respondent put it aptly:

"...Given the time and money constraints, it is only natural to go to the facility with the most resources and expertise...Seeking answers in R&D technical work is like water flowing...[It] seeks the path of least resistance, and at 'AMBE', that's 'Central' R&D..."

Figure 6.18 shows the details of how organizational design influences the manner in which the respondents utilize their knowledge resources at AMBE, in particular the immense popularity of the Central R&D. Figure 6.7 shows the four primary reasons that I discussed above, which are: (1) the disproportionate amount of resources that are concentrated at the

Central R&D facilities, (2) the fact that all respondents are aware of the existence of these resources, (3) and that these resources have made themselves available, and (4) proved themselves to be very useful in either solving the respondent's problem, or to point them in the right direction.

Figure 6.18: Influence of Organizational-Design Characteristics on Knowledge Networking

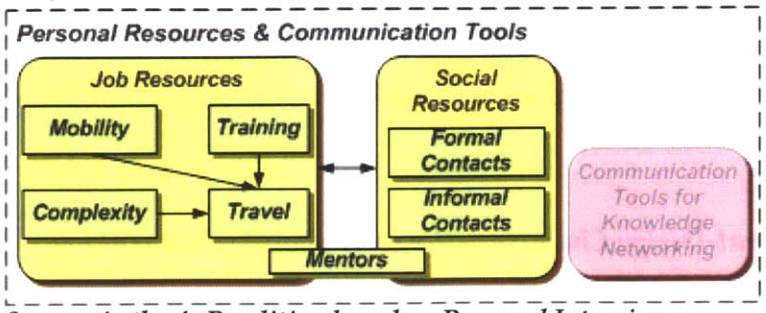


Source: *Author's Rendition based on Personal Interviews.*

6.7.2 Personal Resources

The above analysis involved the examination of the formal organizational design features of global R&D facilities of AMBE Corp., and how these features influence and determine the respondents' choice of resources they utilize for problem solving and Central R&D innovation. These organizational design features are particularly pertinent in explaining the importance that the respondents place on Central R&D facilities as a major knowledge resource. An equally important, but more complex aspect of AMBE's R&D organization is the role of informal ties and networks that respondents build throughout their tenure at AMBE and within their facilities. In the case of AMBE, the informal ties are both an extension of the formal network ties and organizational features of the corporation, as well as a byproduct of the unique personal experiences of individuals with different attributes. Combined, these resources help or hinder individual's ability to be aware of a knowledge resource, have access to it, and finally be able to utilize it in a timely and efficient manner. Figure 6.19 shows the personal and job-related resources that respondents cited most frequently during my personal interviews.

Figures 6.19: Details on Personal-Resources Characteristics and their Influence on the Respondents' Knowledge Networking



Source: Author's Rendition based on Personal Interviews.

In order to understand the significance of personal resources, it is first important to understand how they contribute to the shape and extent of individuals' informal network ties. For example, every respondent that I interviewed, and indeed every R&D employee at AMBE Corp. participates in extensive initial training at the time of their hiring and throughout their career. In fact, respondents cited AMBE Corp.'s extensive training programs as one of the key benefits of working for AMBE Corp. In the majority of cases, the respondents received this initial training at the Central R&D facilities. This was particularly true of individuals who have been with the firm for more than 5 years, regardless of their location and position. The cuts in travel budgets, as well as the increasing importance and power of virtual electronic tools during the past five years, had diminished the importance of Central R&D as the de facto training site for new employees, but even for this group, well over 70 percent had received their initial training at the Central R&D facilities. There are two very important repercussions that stems from this policy. The first is that personal exposure to Central R&D facilities introduces the individuals to the first-hand knowledge of the type of research that is conducted there, and the kind of innovation that is produced at these facilities. Almost all respondents felt that they knew a great deal more about their area of research that is being conducted at AMBE as the result of their trip to Central R&D, than they could have ever received from any other mean. According to one respondent:

"...The research can be so complex at times, that unless you can spend some time with the researcher on the process, I will never understand it, even if the researcher came on the phone and gave me the same talk, verbatim..."

The second and more important aspect of the training and the associated traveling to the Central R&D facilities is the fact that the personal connections that are made during these trips can and most often do transcend the original purpose of the trip. For example, the majority of the respondents confirmed that they continued their interactions with the individuals they met during their trips to Central R&D long after they returned to their facilities. This occurred despite the fact that the majority of individuals changed positions, assignments, projects, and occasionally product affiliation. In other words, personal contact makes a significant impression on the respondents. Furthermore, in almost every case, the contacts *at* the Central R&D facilities also act as gatekeepers and knowledge brokers to all resources within their facilities. According to one respondents:

"...I met a lot of people at [Central R&D]...And they are still very helpful...I go to [them] with questions all the time, and even if they can't help me, they know who can...So, I think going to [Central R&D] were (sic) very helpful..."

In fact, the respondents who had visited other global or national facilities all felt the same way: that regardless of the location of the facility, the personal connections transcend the original purposes of the relationship, and the contacts can and do play the role of the gatekeeper and knowledge broker for that facility. However, the key difference here is that very few individuals visited any other global facility other than the Central R&D. Invariably, the respondents who visited other global facilities listed that facility as one of their resources on the mail-in surveys. In short, respondents utilize the personal contacts they make as a knowledge resource long after the original mandate for the contact has passed, and this is true regardless of the location of the originating or visiting facility. However, Central R&D stands out because the majority of the individuals have only visited the Central R&D.

Another important component of personal resources is the role that mentors play at AMBE Corp. as a knowledge resource. At AMBE, there are two types of mentorship. The formal mentorship program is little known and practiced at some of the AMBE R&D facilities, where employees are paired up as mentor and mentee based on their research and personal interests, positions, and tenure at the facility or the firm. The second type of mentorship program is an informal system of mentor-mentee relationships that evolves between individuals as they work closely with each other. This type of mentorship is usually between a manager and an employee. What is important about the mentorship system, whether formal or informal, is the importance the respondents placed on their mentors as a first contact for problem solving or to learn about the latest innovations. This is especially true of individuals with shorter AMBE or facility tenure, and the majority of mentees cited their mentors as an extremely important resource not only for problem solving, but also all other aspects of their careers and research interests. What is important about this realization is that, according to the respondents, the formal mentorship programs can work as effectively as the organic forms, and as such can be an extremely powerful tool to direct the channels of communication.

The final two components of personal resources revolve around the respondents' job and career characteristics. In my interviews with the respondents, it became clear that the respondents who found their task to be complex utilized a more diverse set of resources. What is important here is that if the individual feels challenged in their current position, they tend to expand their resource base to find the answer to their problems. It is important to note however that the first choice of contact itself does not necessarily expand, but rather that it takes more steps to reach the solution, and in order to reach that solution, respondents tend to search out more of AMBE's resources. In other words, complexity does not diminish the importance of the first contact, it merely expands options after the first contact is made. This is perfectly intuitive,

given that complex problems would expose the shortcomings of first contacts more than simple problems.

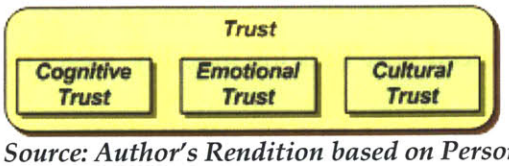
Job mobility is the last component of personal resources under analysis here. This idea is also intuitive, in that the more individuals change their positions within AMBE, the more diverse and expansive their networks and resource-utilization base becomes. It is however important to note that the majority of respondents experienced very little job mobility, either in geographical terms, or in research interests or product affiliation. In fact, almost all of the mobility was natural, upward, career progression. As such, the evidence for this association between job mobility and resource utilization is limited. Still, there is a strong relationship between geographic mobility and the manner in which respondents utilize their resources. The reasons are the same as personal contacts mentioned above. Mobility exposes the respondents to individuals in different facilities and capacities, and the relationships that are developed as the result of these contacts usually survive the original reasons for the relationship and evolve to meet the needs of both individuals in new situations.

6.7.3 The Role of Trust in Knowledge Networks

As is evident from the discussion to this point, AMBE's knowledge networks have limited but global dimensions associated with them. In fact, my conversations with the long-time employees at AMBE confirmed the fact that there has been a tremendous rise in the number of long-distance collaborations during the past 5 years with remote individuals in international facilities. These collaborative efforts are becoming more commonplace because of the increase in utilization and power of E and communication tools. What also became apparent is that these dispersed global teams rarely function as well as local project teams for a variety of reasons, some of which, such as security and access issues, I discuss in Chapter 7.

However, there is another aspect of long-distance virtual teamwork that is crucial in its efficient functioning, and that is the difference in the level of emotional and cognitive trust between members of local or dispersed teams. Figure 6.20 shows the dimensions of trust that are relevant to knowledge networking at AMBE.

Figures 6.20: Details on the Role of Trust in Knowledge Networking



Source: Author's Rendition based on Personal Interviews.

McAllister (1995) has proposed two critical dimensions of trust for knowledge networking: cognitive trust and emotional trust. Accordingly, cognitive trust refers both to judgments of competence and reliability about the other members of a team (Lewis and Wiegert 1985). Judgments of competence are based upon verifying instances of predictably professional behavior (i.e., correct task execution), while reliability refers to the congruence between words and actions (i.e., respect for deadlines). In work settings, cognitive trust is important to the extent that it allows people to count on others to provide promised contributions to a project according to agreed upon plans and schedules. Without this confidence, workers must invest additional effort in monitoring co-workers (Lewis and Wiegert 1985).

There is ample qualitative evidence from my conversations with the respondents that trust is a lingering issue whenever there is long-distance collaborative work being conducted. These underlying trust issues play a more important role if the team members have never met each other in person, or have never worked together as colleagues in a team. However, my findings also echo what other researchers have found, mainly that in authentic work situations, employees set aside their trust concerns in order to get their tasks accomplished. According to one Canadian respondent:

"...I am always more comfortable dealing with individuals I have met personally, or worked before...but, I know that we are all members of AMBE family, so I don't fret over it too much...But, I guess, it's becoming more and more virtual, so I better get used to it..."

In fact, a number of individuals mentioned specifically that they never discuss their new ideas with anyone unless it is done in person, and they are certain that their colleagues understand their concerns and expectations for confidentiality. The respondents also felt strongly about how their information is stored if they share it electronically. As such, the respondents felt that in some cases they are not worried about the person they are corresponding with, but with the individuals who may have access to their files.

The second dimension of trust, emotional trust "is the development of non-calculative and spontaneous emotional bonds and affect among two or more people" (McAllister 1995 p. 23), while emotional trust is "demonstrated through confidence and openness in sharing ideas, feelings and concerns" (p. 23). In work settings emotional trust is important to the extent that it elicits "communal relationships" (Clark, Mills and Corcoran 1989), or relationships characterized by sensitivity to personal and work-related needs of colleagues, oriented to support these needs with no demand for reciprocation. I confirmed this finding within AMBE setting, where respondents mentioned that in geographically distributed teams, level of emotional trust with co-workers is lower than in local teams. That is, local workers can see each other every day, can have meals together, can engage in unplanned discussions -- all of which contribute to a level of mutual understanding, or even friendship, that enables the formation of emotional trust. By contrast, distant workers have many fewer opportunities for the kinds of interaction that develop and maintain emotional trust.

Finally, there are the cultural differences of how individuals view ownership of knowledge. All respondents were very clear about the fact that the knowledge that is produced at AMBE belongs to AMBE. However, there was considerable difference in the way individuals

felt about personal ownership of the knowledge they have produced for AMBE. The Chinese respondents had a more communal notion of all knowledge and felt that not only does the knowledge belong to AMBE Corp., but that it also belongs to all employees of AMBE Corp. As such, the levels of protection of individual knowledge from others at AMBE are much lower than those from Canada and Brazil. On the other hand, the Brazilian and Canadian respondents felt that there are different degrees of ownership rights to knowledge that is produced by individuals at AMBE, with the understanding that all knowledge produced at AMBE belongs first and foremost to AMBE. These differences in the way individuals view their property rights to the knowledge they have created, combined with trust issues that are raised among respondents from different facilities, has serious consequences for the way individuals share their knowledge with others for problem solving or innovation. In fact, some of the respondents stated that one of the reasons that they always go through Central R&D is the simple belief that Central R&D already is the source of, or has access to all the new knowledge that is produced at AMBE, and as such, there is very little incentive on the part of Central R&D to "steal" anyone's new ideas, whether or not this is actually the case. According to one Brazilian respondent:

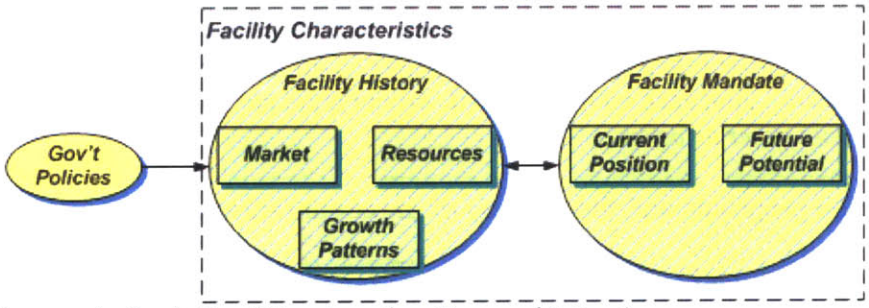
"...[Central R&D] already has access to everything that is produced here...Why would they do want to take any of my ideas..."

Combined, the above factors result in a situation that outside of specific project-related tasks and teamwork, respondents felt most comfortable with individuals they had met or worked previously, followed by their Central R&D contacts. They felt uneasy about sharing information with someone they had never met, outside of a project-related activity, and over the Internet.

6.7.4 Facility History and Mandate

As I stated earlier, one of the primary purposes that I chose the facilities in China, Canada and Brazil was to examine the effects of culture and language on the composition and extent of knowledge networks between the respondents of the three facilities. The underlying assumption was that respondents among the facilities would have knowledge networks that are more similar to the respondents in the same facility than the population as a whole. However, as I showed earlier, the difference in equivalence scores between the population as a whole and the respondents from each location was minimal as best. However, there are two other aspects of location of the facility that affects the way respondents utilize their communication tools and knowledge networks. Rather than being respondent-specific attributes from each location, these are facility-specific characteristics, specifically, the facilities' history and mandate. Figure 6.21 shows the underlying details of facility history and characteristics.

Figures 6.21: Details on Personal-Resources Characteristics and their Influence on the Respondents' Knowledge Networking



Source: Author's Rendition based on Personal Interviews.

As is apparent from Figure 6.10, there are a number of factors that impinge on a facility's history and mandate, which in turn affect the position of the facility within the overall hierarchy of AMBE's global R&D facilities, which influences the way knowledge flows into and out of the facility and its employees. The first of these factors is the history and government policies of the countries where these facilities are located. This is particularly true for Brazilian facilities,

where the Brazilian economic policy and trade liberalization have gone through tremendous changes during the period of time that AMBE has had its operations there. It is true that China has also gone through dramatic economic and policy transformations during the past twenty years, but AMBE started its Chinese operations at the same time that China began its economic-liberalization program, and as such, AMBE has been able to adjust to the ongoing changes within the Chinese marketplace as they are taking place. The liberalization and opening of the Brazilian economy during the 1990s has had a profound effect on the knowledge networks of the R&D employees of AMBE Brazil. The respondents, particularly those who have been with the firm for more than 15 years, felt that the liberalization has opened up their knowledge networks and communication resources in an extremely positive manner, and has allowed them to share information with their colleagues at other global AMBE facilities, and even more importantly, has allowed them to access knowledge resources outside of Brazil. According to one respondent who has been with AMBE for 17 years:

"...Before [1990] we had a hard time getting some of [intellectual] property we needed to get our work done...[AMBE] facilities were worried about nationalization, about leakage, about everything...Now, even though it's not completely open, it is much better...Our colleagues, especially at [Central] facilities share so much more...And even more important, we can share our knowledge with them, which was something we could never do before..."

Despite the liberalization programs and the opening of the communication and knowledge networks, the majority of the Brazilian respondents felt that the employees in other AMBE research facilities, in particular Central R&D, still did not seek out *their* knowledge sources. For many of the respondents, their research and knowledge-creation activities are simply not recognized by their colleagues in one of the facilities in the triad areas (North America, Japan or Western Europe). According to one respondent:

"...Do I wish that we received more recognition for our work from some of the other facilities, sure I do...but I know what the hierarchy is, and I know things are getting better...but we still have a

long way to go before someone from [Central] R&D comes to us to ask us to show them what we are doing here, even though we know we do good work here..."

The above observations simply confirm the findings from the status analysis, only from the other perspective. The status analysis showed that the majority of respondents choose Central R&D facilities as their primary global resource for problem solving. The irony is that the Brazilian respondents' concerns that their knowledge is not being utilized by other facilities simply underscores the fact that there are a lot of global knowledge resources, dispersed in facilities such as Brazil, that are not utilized by others, the same way Brazilian, Chinese and Canadian respondents do not utilize them.

Between the three facilities, the Brazilian respondents were most conscious of their facility's lack of contribution as a knowledge resource because of the opportunities that have opened up as the result of the liberalization policies of the Brazilian government. However, the respondents from all facilities expressed the same level of frustration as the Brazilian respondents. Some of the Canadian respondents felt that because of their proximity to the United States, that they should be considered almost an extension of the US operations. At the same time though, there was an equally nationalistic feeling about the Canadian facilities by other respondents. In fact, if there was something unique about the Canadian respondents, it was this dichotomous feeling toward their relationship with the United States operations. However, regardless of their feeling toward the United States, the majority of the respondents felt that they could contribute more to the global knowledge pool if only individuals would approach them from different facilities. Echoing the Brazilian respondents' sentiments, one Canadian respondent stated:

"*...Even the researchers who know the kind of work we do around here seem to ignore us sometime...There has to be a better way for people to know and care about our research, who work in the far-flung global facilities of [AMBE]...*"

Of the respondents from the three facilities, the Chinese respondents seemed the least puzzled and concerned by the fact that they were not approached by other facilities for problem solving. From the Chinese-respondents' answers to the second-round questionnaires, I deduce that are two reasons for this difference. The first is the fact that the Chinese facilities are much younger than the Brazilian or Canadian facilities. The lack of experience within AMBE results in lower level of expectations on the part of respondents to be able to contribute to the global knowledge pool. It is however important to note that this is a strictly subjective notion from the respondents' perspective and may not have any basis in the value of the Chinese respondents' contribution. The second reason behind the difference in the Chinese attitude toward their contribution is the importance of Japan as a regional center for the Chinese facilities. As I showed in Chapter 5, Japan plays an extremely important role in providing the Chinese respondents with the knowledge about the innovatory activities that takes place at the Central R&D facilities. This regionalization of knowledge creation and dissemination lessens the pressure or need on the part of the Chinese respondents to feel that they want to be used as a resource for problem solving.

6.7.5 Management Initiatives

As a large, knowledge intensive, multinational firm with a diverse product line and customer base, AMBE Corp. is constantly faced with a number of challenges and opportunities. Relevant to this study, these challenges and opportunities can be divided into three categories. Just like any other firm, AMBE's biggest challenge is to remain competitive and grow in a constantly changing business environment. Given AMBE's breadth of product offerings and the extent of their geographical presence, the managers at AMBE are faced with a very complex task. At the same time though, AMBE possesses a great deal of expertise and history of

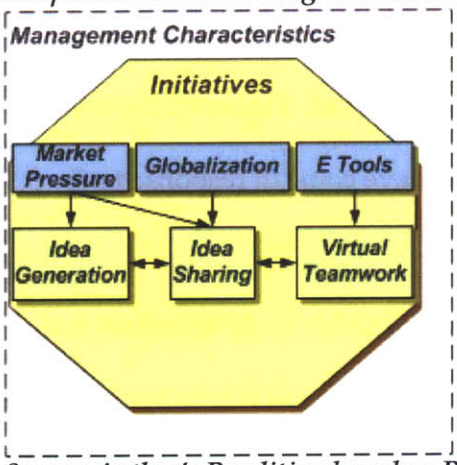
innovation along all their product lines, and are very familiar with the markets that they operate in. The lowering of trade barriers and continued liberalization policies in many of the emerging countries has opened up huge opportunities for growth, both into new countries and product lines, but also an expansion of their market share in their current locations and products. Finally, the IT and E-commerce revolution has expanded both the potential marketplace for AMBE products, as well as the potential for creating an all-inclusive knowledge network among all its employees. The realization of the above challenges and opportunities has resulted in a number of management initiatives, which regardless of their primary purposes, have had profound effects in the way ideas are generated, the manner in which they are disseminated and shared, and the communication tools that are utilized. Figure 6.22 shows the details of the characteristics of the management initiatives that have come in response to the above challenges and opportunities.

In Figure 6.22, the blue boxes represent the relevant AMBE Corp.'s opportunities and challenges that I described above, while the beige boxes represent the areas where management initiatives have focused their efforts on. There is not a one-to-one relationship between these opportunities and challenges, and the measures that are undertaken by the management. In fact, it is very difficult to specify which management initiative will have the most profound effect in each of the above areas. However, combined, the management initiatives will directly and indirectly affect the way ideas are generated, shared and how the creation and expansion of virtual team-works affects knowledge networks and the manner in which ideas are disseminated among AMBE's R&D employees.

The most relevant management initiative, dubbed here as "*IG*", looks specifically at the number of ideas that R&D employees generate during a period of time. This initiative was started within the previous two years, and is being implemented very slowly and

incrementally. In fact, "*IG*" was fully implemented in each of the three facilities only within the previous 12 months, and as such, it would be premature to judge the success or failure of the initiative given the short period of time it has been in place. However, given the emphasis that the initiative puts on accelerated idea generation, it is important to ascertain its effects on the way ideas are *shared* based on my personal interviews with the respondents. The primary goal of "*IG*" within the context of the R&D workforce is to instigate the R&D employees to produce more research ideas that can result into market-ready products in a shorter period of time.

Figures 6.22: Details on Management-Initiatives Characteristics and their Influence on the Respondents' Knowledge Networking



Source: Author's Rendition based on Personal Interviews.

The premise behind "*IG*" is that according to AMBE R&D management, historically, it takes 60,000 ideas to produce a single, viable, and commercially successful product. Because this ratio has proved to be an extremely stable historical fact, the purpose of "*IG*" is to increase the number of new product introduction by increasing the number of ideas. In other words, if the ratio cannot be improved upon, then the only way to improve on the results is by increasing the number of ideas. The "*IG*" initiative is relevant to this study because it puts a great deal of emphasis on idea generation by *individuals*. The question then is whether this emphasis on personal idea generation will impact the way individuals share these ideas through their knowledge and communication networks. The respondents themselves had mixed reviews of

"*IG*" and its effects on their knowledge networks, but there was almost a universal sentiment by the respondents that they have already noticed changes in the way people share their ideas with others. According to one Canadian respondent:

"...["IG"] is changing the way ideas are viewed by people...What ["IG"] does is that it makes ideas the new currency, and as such there is more of resistance on the part of people to just readily give it away...this is especially true when it comes to sharing ideas with people you don't know well, or only know through e mail..."

The above statement succinctly captures the potential effects of "*IG*" on knowledge networks. In an era when idea generation is one of the criteria by which one's performance is measured, it becomes a lot more important to make certain that the originators of ideas receive their due credit, and that becomes a lot more of a concern if the idea is shared with distanced (both geographical and/or personal) individuals. Given the global nature of the knowledge networks at AMBE, and their virtualization, it is apparent then that "*IG*" can severely hamper open and free exchange of ideas across global and virtual knowledge networks. Another respondent from Brazil echoed the above sentiments:

"...["IG"] is still a very new initiative, so it's hard to know how it will change things around here...[but] I can tell you that it has already made people become more aware of their ideas and how they can utilize them...Obviously, there is a good part to this, that people don't burn their ideas away...but also, some of these ideas need to be shared so the input from other people makes them better...["IG"] makes that more difficult..."

In short, the majority of respondents had mixed feelings about "IG". On one hand, they felt that as individuals they would receive more acknowledgements for their ideas, and that would be a beneficial consequence of the initiative. On the other hand, they felt that given that by definition most of R&D research is a collaborative effort, this emphasis on personal ideas would hamper those efforts.

As is apparent from Figure 6.22, there are two other broad AMBE initiatives that are relevant to this study. It is important to note that unlike the "*IG*" initiative, with its somewhat

focused agenda and its immediate effects on knowledge networks, the second and third initiatives are company-wide programs that affect knowledge networks of R&D employees by their sheer breadth. The first is AMBE's renewed efforts at further internationalizing its operations, by entering new markets, expanding in markets that they already have a presence, by taking full advantage of all the available resources at these diverse facilities, including utilizing the global knowledge base, and finally by aligning the global operations more closely together. The second is the expanded utilization of E tools to accomplish the above tasks. I will discuss E tools in detail in Chapter 7, but here I want to focus on one aspect of management initiative to expand the utilization of E tools among the R&D respondents, and that is the resultant reduction in available resources for traveling and personal contact among the respondents from different facilities.

As I stated in the previous section, the ability to travel to Central R&D had been an extremely useful exercise in making long-lasting personal contacts and providing them with a gateway to the research that is conducted at the facility and the resources that are available to them for problem solving. Although Central R&D still enjoys its place as the de facto location for training and technical conferences, the frequency of travel to Central R&D is decreasing and the trips are becoming more customer-focused. In other words, the increase investment in and utilization of E tools at AMBE has naturally resulted in decrease availability of resources for travel by the respondents among the facilities. Clearly, this trend is not unique to AMBE and will only continue to be an important part of knowledge networks among AMBE's employees. The respondents themselves felt resigned to this fact. According to one Brazilian respondent who has been with AMBE for more than 15 years,

"...There used to be a time that I would travel to [Central R&D] two, three times a year...I would go there for training, for conferences, to meet my counterparts in other projects and facilities...but

for the past few years, I only go once a year, sometime less...I understand the change and I support it, [but] I do see the shortcomings of relying only on e mail and teleconferencing..."

It is important to note that as E tools become more sophisticated, the gulf between the effectiveness of personal and virtual contacts could narrow. Unfortunately, there is a certain lag in the investments that are made by large multinationals, such as AMBE, and the power that E tools can bring to firms to take place of traveling and personal contact, which I discuss in more detail in Chapter 7.

6.8 Importance of Quantitative Analysis for *Proposition* 2

The premise behind *Proposition* 2 is that personal attributes, such as gender, position, firm and facility tenure, as well as language and culture, influence the knowledge-networking profiles of the respondents for the knowledge networks under analysis. Furthermore, *Proposition* 2 stipulates that this influence results in men, managers, and individuals with longer tenure levels to have more extensive knowledge networks. There is mixed confirmation of *Proposition* 2 from the findings of the quantitative analysis. I discuss each of these next.

The Influence of Culture and Language: The respondents from the three facilities utilize a different mix of knowledge resources, confirming the stipulation from *Proposition* 2.

The Influence of Position: The results show that position influences the two knowledge networks differently. For *KNPS* networks, the results show that employees and managers utilize a different mix of knowledge resources, refuting the premise behind *Proposition* 2 that given managers' exposure to additional knowledge sources, they would have more extensive knowledge networks than employees. However, the *KNCRDI* results also show that managers have more extensive knowledge networks than employees, confirming the assertion behind *Proposition* 2.

The Influence of Gender: The results on the influence of gender show that men have slightly more extensive knowledge networks than women for the *KNPS* networks, but significantly more extensive knowledge networks than women for the *KNCRDI* networks. Combined, the results confirm the ideas behind *Proposition 2*, although they appear to be much more relevant for the *KNCRDI* networks than *KNPS* networks.

The Influence of Firm Tenure: The results on the influence of firm tenure mirror those of position. As such, individuals with firm tenure of more than 15 years have significantly more extensive *KNCRDI* knowledge networks, but utilize a different mix of knowledge resource for *KNPS* networks, when compared to respondents with less than 15 years of tenure. As such, the results confirm the premise behind *Proposition 2* for *KNCRDI* networks, and challenge it for *KNPS* networks.

The Influence of Facility Tenure: The results on the influence of facility tenure show similar confirmation of *Proposition 2* for *KNCRDI* networks, and refutation for *KNPS* networks, as that of position and firm tenure.

Overall, the results of the quantitative analysis show that in order for *Proposition 2* to hold true, it must be modified to include the influence of knowledge network itself on the effects of personal attributes on knowledge networks. This is an important modification, because it shows that knowledge content itself affects the manner in which respondents utilize the resources, making it difficult to make broad generalizations about the influence of personal attributes on the manner in which respondents utilize their knowledge resources.

6.9 Importance of Quantitative and Qualitative Analysis for *Proposition 3*

Proposition 3 holds that there are additional factors, such as personal and facility resources, management initiatives, and trust, which can also influence the manner in which

individuals utilize their knowledge networks. Furthermore, it is because of these external factors that individuals with the same personal attributes may not have more similar knowledge-networking profiles than the population of respondents as whole, despite their differences with their comparison groups. As such, there are two parts to *Proposition 3*. For the first part, I had to confirm the proposition that respondents with same personal attributes may not have more similar knowledge networks than the population of respondents as a whole. For the second part, I had to validate the existence of additional factors that influence knowledge networks of the respondents that can explain this apparent inconsistency. I discuss each of these next.

Difference in the Knowledge-Networking Profiles of Respondents with Similar Attributes: The results of the equivalence analysis confirm the contention behind *Proposition 3*, that groups of respondents with the same personal attributes do not have noticeably more similar knowledge-networking profiles than the population of respondents as a whole. This is the case despite the fact that respondents in groups with different personal attributes have more dissimilar knowledge networking profiles. The findings confirm the stipulations behind *Proposition 3*, that there are additional factors that affect the knowledge networking of the respondents that may explain the differences in the knowledge networking of individuals with similar attributes.

The Confirmation and Importance of External Factors: The results of the qualitative analysis show that there are a number of personal and external factors that can influence the manner in which individuals utilize their knowledge resources. These factors include personal and facility resources, trust, and management initiatives, all of which affect the level of access and awareness of the individuals' diverse knowledge resources.

6.10 Conclusion

In this chapter, I presented the results of the quantitative and qualitative analysis for the two knowledge networks using the data from the web-based surveys, and personal interviews respectively. The purpose of the quantitative analysis is to examine the role of personal attributes and location on the extent and shape of their knowledge networks. The personal attributes that I chose for my analysis are position, gender, firm tenure and facility tenure. I chose the above attributes because they all have the potential to affect the extent and availability of the respondents' contacts and comfort with using different knowledge resources, which can influence their knowledge networks. The results of the status analysis showed that there are significant differences in the importance of different knowledge resources for both problem solving and Central R&D innovation. For problem solving, the most important knowledge resources are the inter-facility resources such as those in the respondents' projects and facilities, as well as Central R&D. As would be expected, the most important knowledge resources for Central R&D innovation are Central R&D and facilities and the knowledge resources within the respondents' facilities and projects. Among the external and virtual knowledge resources, the analysis showed that suppliers and AMBE-related databases are the most important knowledge resources.

I used status analysis to examine whether any of the groups of respondents with similar attributes have more extensive knowledge networks than others. The results showed that in terms of the importance of location on the knowledge networking of the individuals, that no one particular group has significantly more extensive knowledge networks than others, and the respondents in the three facilities utilize a different mix of resources. However, the results on the importance of the other personal attributes were mixed. For *KNCRDI* networks, men, managers, and respondents with tenure levels of more than 15 years, have more extensive

knowledge networks than their comparison groups. On the other hand, for *KNPS* networks, the respondents in the different groups utilize a different mix of knowledge resources, and no one group, with the possible exception of men, have more extensive knowledge networks than their comparison groups. At the same time, equivalence analysis showed that the groups are not demonstrably more similar in their knowledge networking than the population as whole. In addition, the results of the gatekeeper analysis showed that both the academic and market gatekeepers have greater status scores and utilization rates for the majority of knowledge resources for problem solving, including instances where the gatekeepers are the sole knowledge gatekeepers to additional knowledge resources that are not part of the designated resources.

In the second part of the chapter, I presented the results of the qualitative analysis that are based on my personal interviews with the respondents. The interviews clarified some of the other factors that influence the manner in which respondents access and utilize their knowledge resources for problem solving and Central R&D innovation. These factors fall into four general areas: resources allocation and AMBE's formal organizational-design characteristics, personal resources including the role of personal trust in knowledge networking, facility history and mandate, and management initiatives. All of the above factors can act as facilitators or impediments to accessing and utilizing knowledge resources, which in turn affects the knowledge networking of individuals. AMBE's resource allocation, for example, puts a great deal of resources in Central R&D, which combined with the respondents' personal resource of having made contacts there during their training, results in an overwhelming preference for Central R&D as the de facto knowledge resource outside of the respondents' facility or project. Similarly, trust can act as major impediment in border-crossing and virtual knowledge networking, and conversely can act as a facilitator in proximate and personal knowledge

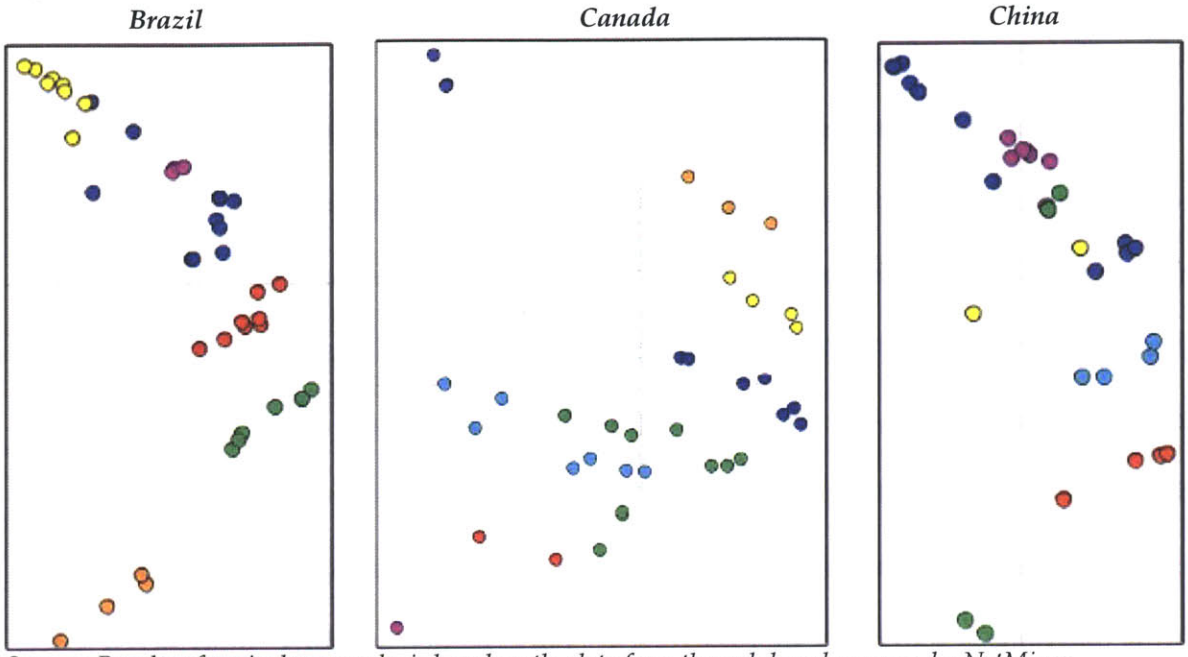
networks. In addition, I showed management initiatives in general and the role of the "*IG*" initiative in particular, with its emphasis on idea generation by individuals, has already had an effect on the way individuals share their ideas and knowledge. Finally, I discussed the role of government policy, in Brazil in particular, in the way it has opened up the communication and knowledge-networking opportunities for the Brazilian respondents. I will conclude the quantitative and qualitative analysis in Chapter 7 by presenting the results for the final network under analysis, that is, communication tools for knowledge networking.

Appendix 6.A: Equivalence Maps of Knowledge Networks

6.A.1 Mapping the Results of Equivalence Analysis

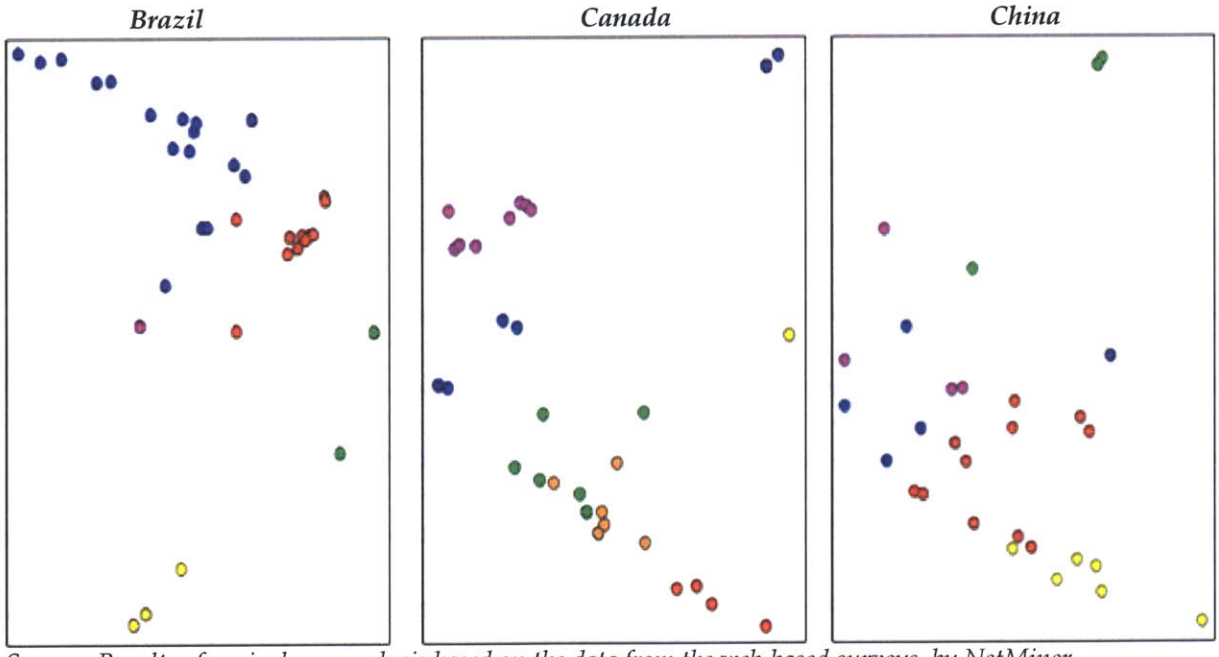
In this Appendix, I present the Multidimensional Scaling (MDS) maps of the results of the equivalence analysis that I presented in Chapter 6. According to Steyvers, MDS describes a "family of techniques for the analysis of proximity data on a set of stimuli to reveal the hidden structure underlying the data" (2002). The main assumption in MDS is that "stimuli can be described as values along a set of dimensions that places these stimuli as points in a multidimensional space and that the similarity between stimuli is inversely related to the distances of the corresponding points in the multidimensional space" (Steyvers 2002). In the following diagrams, respondents are presented as nodes (points) in a three-dimensional space, and their location in the map is based on their equivalence scores, which is in turn a measure of the similarity of their knowledge networking with the other respondents in the group. MDS equivalence maps are extremely useful in identifying clusters of individuals who have similar knowledge networking relationships with each other, and dissimilar knowledge networking relationships with individuals outside of the clusters. By analyzing the characteristics of individuals in these clusters, researchers can determine the factors that affect individuals' knowledge networks. In this case, I examine the clusters themselves to decipher whether the individuals within the clusters share the attributes that I am analyzing in this study. I have color-coded these clusters in order to better represent them, but in reality, the colors themselves do not carry any meaning. Figures 6.A.1-6.A.6 show the MDS maps of the respondents by location for the two knowledge networks, Figures 6.A.7-6.A.10 show the MDS maps of the respondents by position, Figures 6.A.11-6.A.14 show the MDS maps of the respondents by gender, and finally Figures 6.A.14-6.A.22 show the MDS maps of the respondents by firm and facility tenure for the two networks.

Figures 6.A.1, 6.A.2, 6.A.3: MDS Maps for the Respondents by Location – KNPS



Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

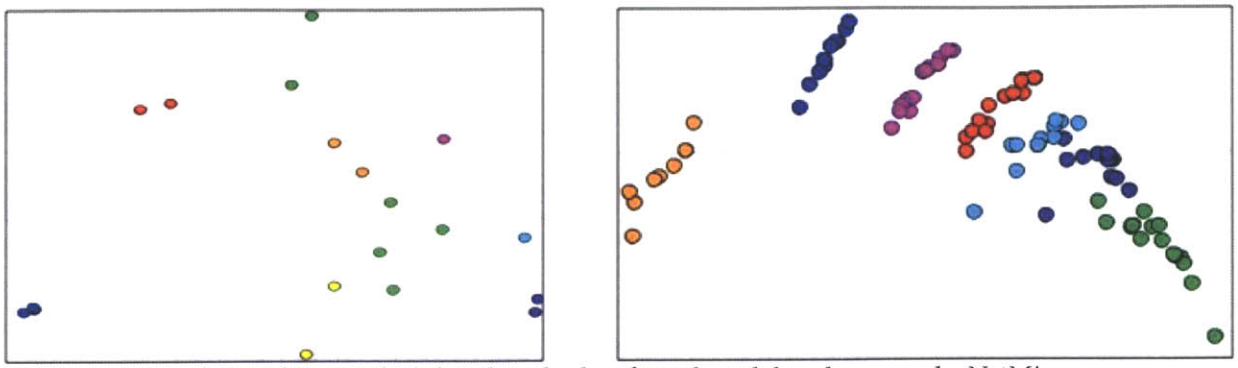
Figure 6.A.4, 6.A.5, 6.A.6: MDS Maps for the Respondents by Location – KNCRDI



Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figure 6.A.7, 6.A.8: MDS Maps for the Respondents by Position – KNPS

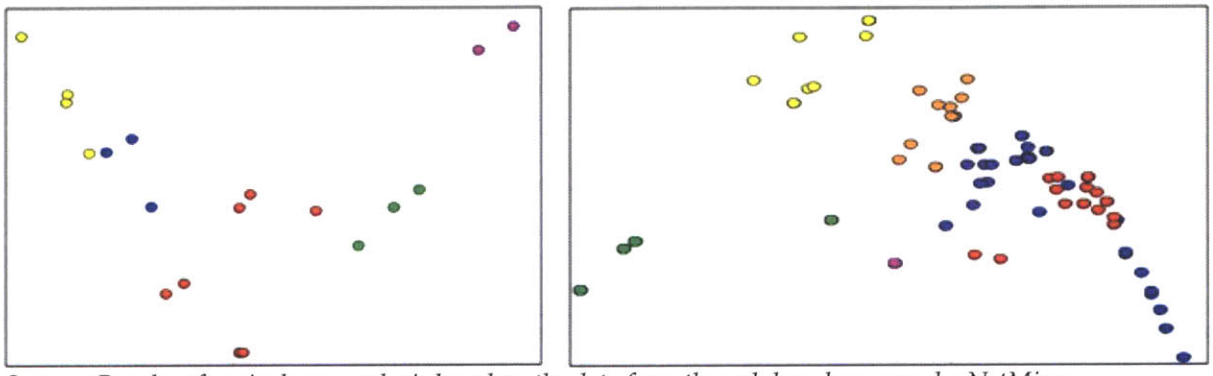
Managers *Employees*



Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figure 6.A.9, 6.A.10: MDS Maps for the Respondents by Position – KNCRDI

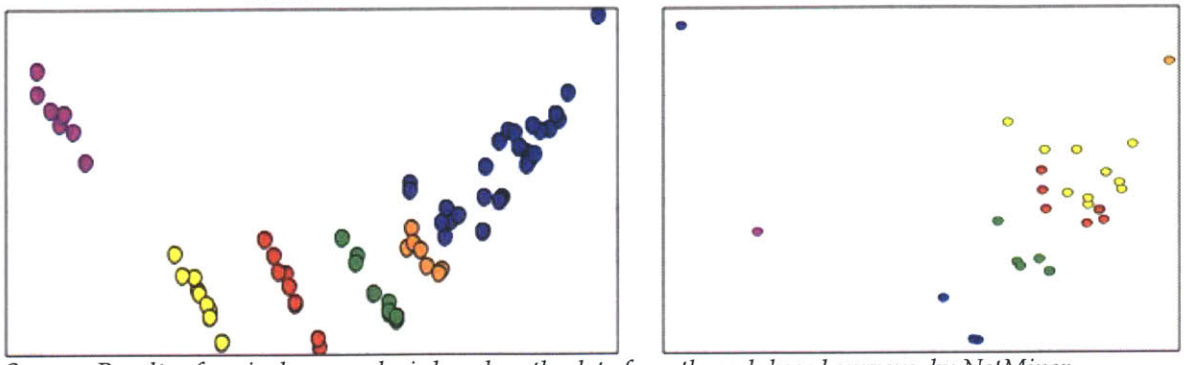
Managers *Employees*



Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figure 6.A.11, 6.A.12: MDS Maps for the Respondents by Gender – KNPS

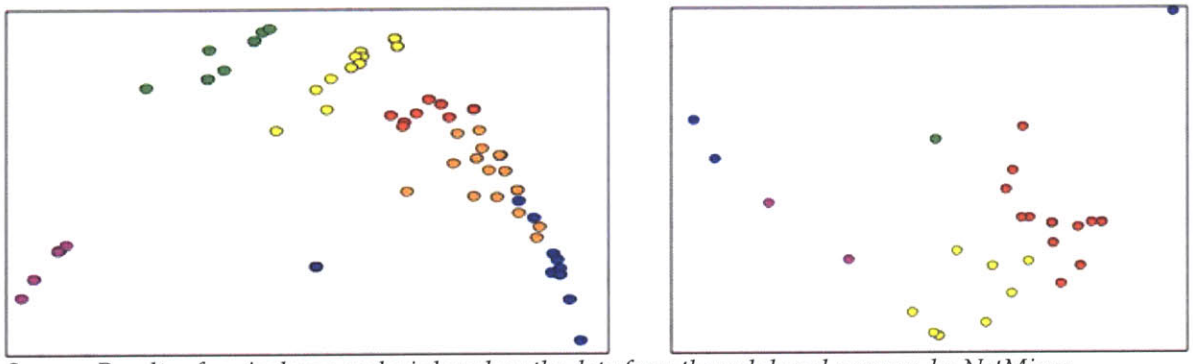
Male *Female*



Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figure 6.A.13, 6.A.14: MDS Maps for the Respondents by Gender – KNPS

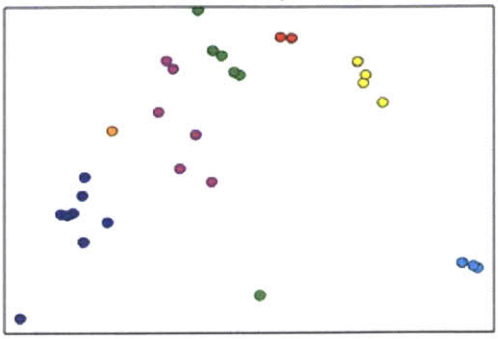
Male *Female*



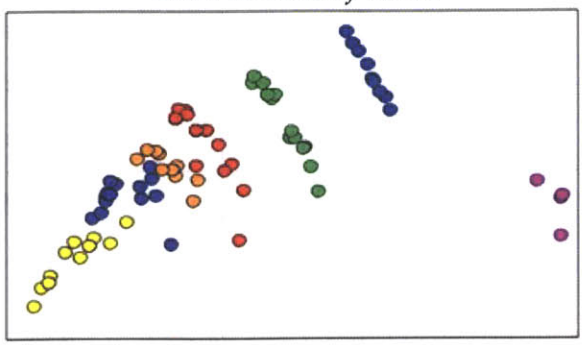
Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figure 6.A.15, 6.A.16: MDS Maps for the Respondents by Firm Tenure – KNPS

Over 15 Years of Tenure



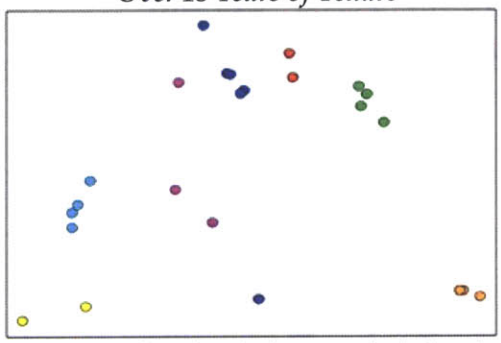
Under 15 Years of Tenure



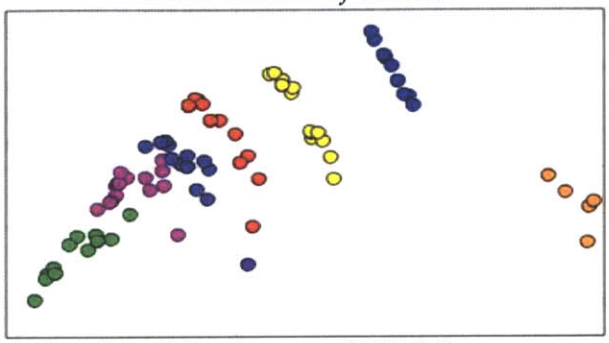
Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figure 6.A.17, 6.A.18: MDS Maps for the Respondents by Facility Tenure – KNPS

Over 15 Years of Tenure



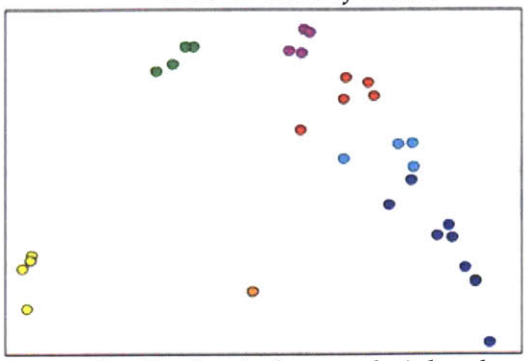
Under 15 Years of Tenure



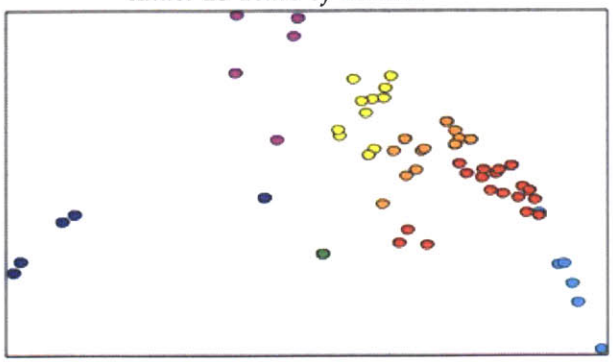
Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figure 6.A.19, 6.A.20: MDS Maps for the Respondents by Firm Tenure – KNCRDI

Over 15 Years of Tenure



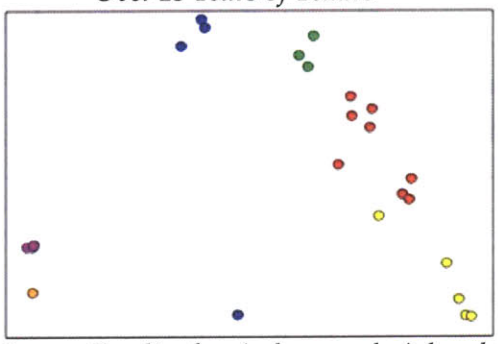
Under 15 Years of Tenure



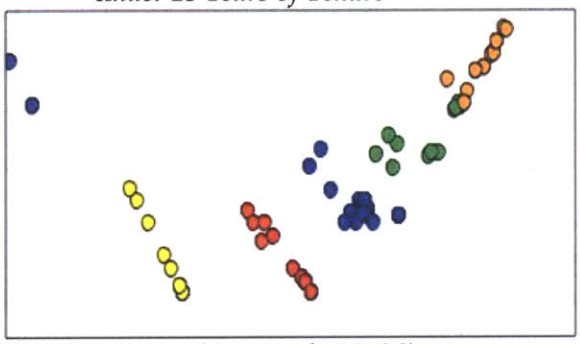
Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figure 6.A.21, 6.A.22: MDS Maps for the Respondents by Facility Tenure – KNCRDI

Over 15 Years of Tenure



Under 15 Years of Tenure



Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

CHAPTER 7: QUANTITATIVE AND QUALITATIVE ANALYSIS OF *CTKN* NETWORKS

7.1 Introduction

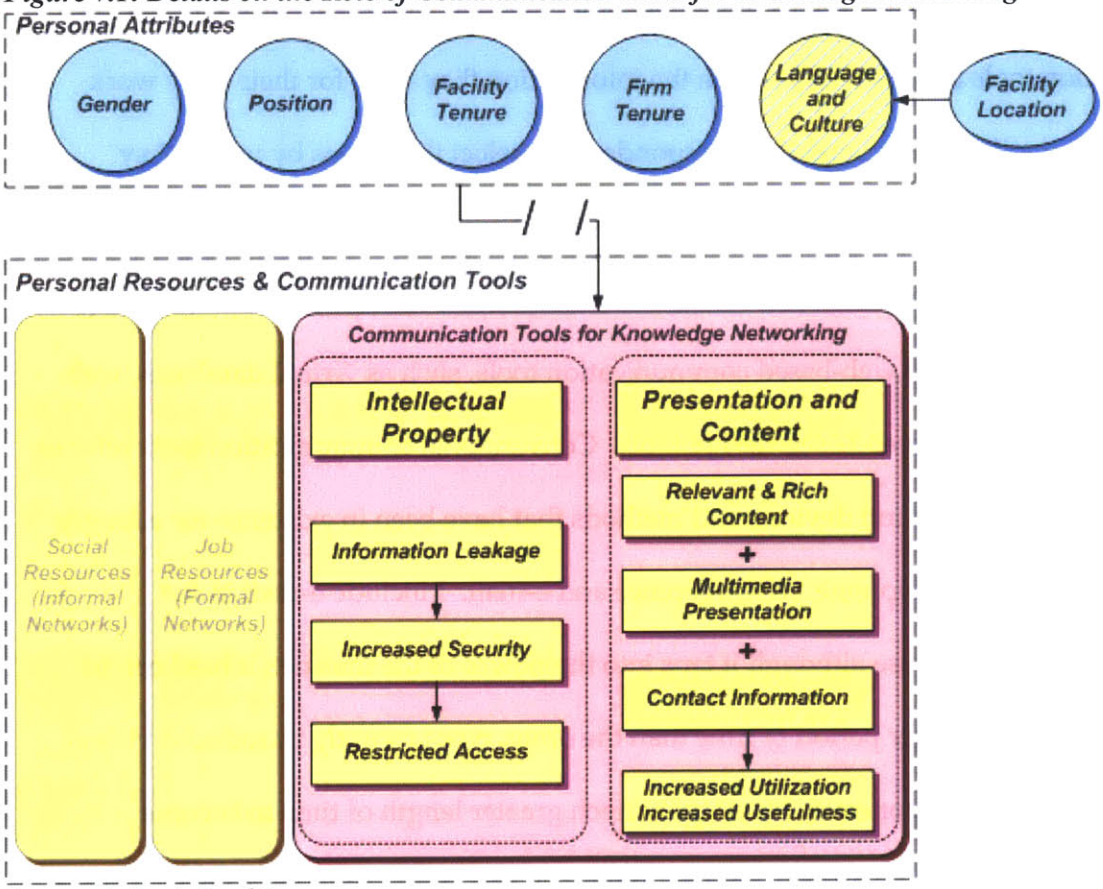
In Chapter 5, I showed that on the aggregate level, there are distinct differences in the manner in which the respondents from the three facilities utilize their knowledge resources and communication tools. The purpose of the descriptive presentation of the network maps was to show that location plays a role in the knowledge networking activities of the respondents. Alternatively, in Chapter 6, I presented the quantitative and qualitative analyses for the Knowledge Networks for Problem Solving (*KNPS*), and Knowledge Networks for Central R&D Innovation (*KNCRDI*). In this chapter I provide the quantitative and qualitative analysis for the Communication Tools for Knowledge Networking (*CTKN*) network, which examines the tools by which respondents from AMBE's Brazilian, Canadian, and Chinese facilities, utilize their communication tools to access, and obtain the information they need for their daily work activities. The mail-in survey asked the respondents to select the means by which they communicated, how often they utilized these tools and how useful they found them.

In this study, virtual tools refer to the virtual electronic tools, which take advantage of the power and ubiquity of web-based communication tools, such as virtual databases, web-based conferencing, and web-based design tools. Conventional communication tools refer to the electronic communication devices, and methods that have been in existence for a longer period of time, such as telephone, teleconference and e-mail. I include e-mail in the conventional bucket because although it taps into the power of the Internet, it has been in existence for a much longer period of time than the other, more recently introduced virtual tools, and as such the respondents have had a much greater length of time to become comfortable in utilizing it on a regular basis. Finally, in this study, personal communication

tool refers to face-to-face communication, or the type of communication that does not require any additional equipment or tools for it to take place.

Relating back to Chapter 6, communication tools are an important resource for knowledge networking because it increases the respondents' options to access and utilize their available knowledge resources. Figure 7.1 shows the two parts of the analysis that I cover in this chapter. In the first section, I use the results of the web-based surveys, and social network methods, to examine the role of personal attributes and location in the manner in which the respondents utilize their communication tools. In the second part of this chapter, I use the results of the personal interviews to present the qualitative analysis of some of the other factors that affect the rate of utilization and effectiveness of communication tools.

Figure 7.1: Details on the Role of Communication Tools for Knowledge Networking



***Source**: Author's Rendition.*

Broadly, I divide these qualitative factors to two parts. The first are those factors that fall under the heading of Security and Access, which can impede knowledge networking. The factors I analyze in this chapter revolve around the loss of intellectual property, either through theft or leakage, which result in increased security surrounding knowledge networking, and restricted access to information. The second set of factors is those that can facilitate the flow of knowledge, including the manner in which individuals and groups, create, present, and make information accessible to their colleagues.

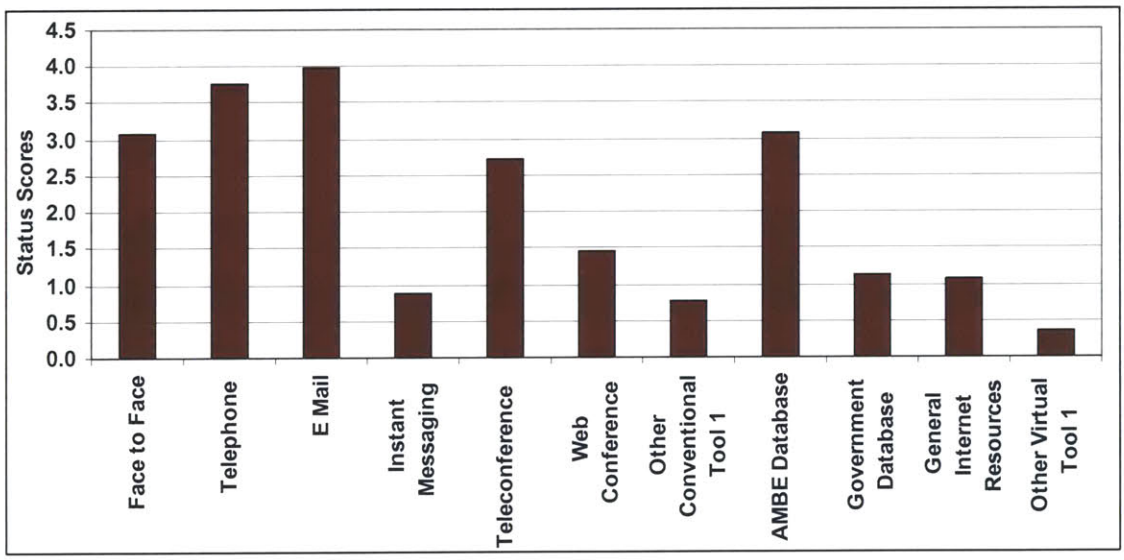
7.2 Status Analysis of Communication Tools

In this section, I provide the status analysis for the respondents' utilization of their communication tools regardless of their location or personal attributes (Figure 7.2). Although the results mirror the findings from Chapter 5, there are three points worth reiterating. First, status scores are *relative* measure of importance, and as such, the scores themselves are only relevant in comparison with other status scores. The second is the importance of conventional electronic tools in general and e-mail in particular. Of the top five communication tools, three are conventional, with e-mail and, telephone being the most and second most popular tools. This is somewhat surprising because the status analysis does not take into account usefulness or frequency of use, and only captures the respondents' level of utilization. Although the respondents identified face-to-face communication as most useful, e-mail's asynchronous characteristic, which allows individuals to postpone replying to the person they are communicating with, is extremely useful in time-constraint settings, such as an R&D facility.

The second important finding from Figure 7.1 is the importance of AMBE database as a virtual communication tool. In fact AMBE databases are almost as popular as face-to-face communication, which is surprising given the fact that in the personal interviews, the majority

of respondents stated that they preferred face-to-face communication to virtual communication tools. However, as I stated earlier, this analysis does not take into account the usefulness of the tool, and the above results are a testament to the ubiquity of AMBE databases, and the amount of resources that AMBE is devoting to them in order to make them as useful and robust as possible. Finally, the difference in web-conferencing and teleconferencing as a communication tool is one that will most certainly diminish as the power of web-conferencing increases and the costs decrease. Similar to the rise of e-mail as the de-facto conventional communication tool over telephone, web-conferencing is a resource that will eventually become the de-facto multimedia communication tool.

Figure 7.2: Communication-Tools Status Scores



Source: The Mail-in Surveys and Author's Calculations using NetMiner II Software.

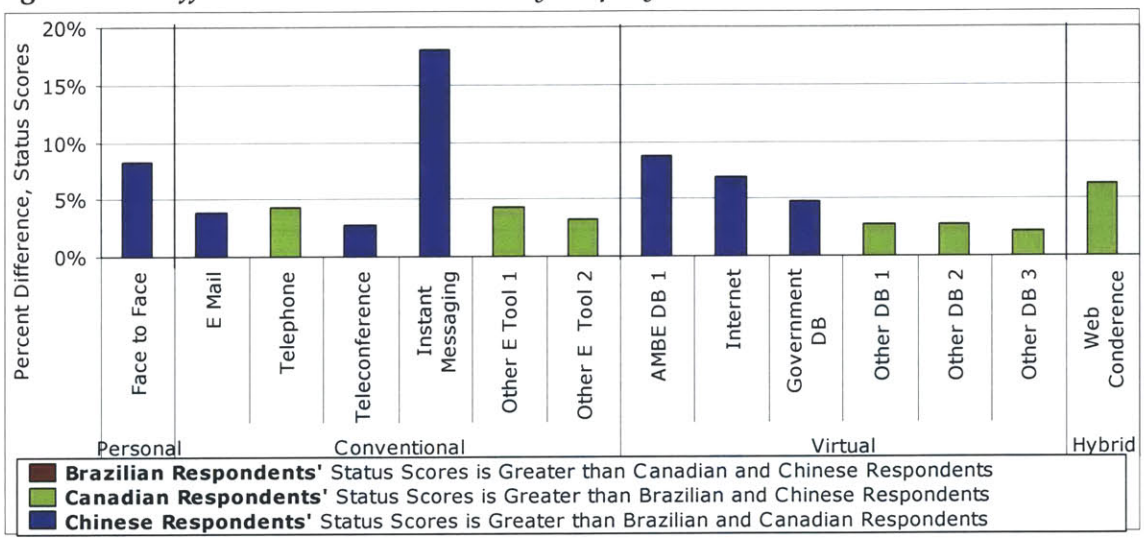
7.3 Influence of Personal Attributes on the Respondents' Communication-Tools Utilization

Figure 7.3 shows the results of status analysis of respondents from the three facilities. The first finding is that although none of the groups have greater status scores for *all* communication tools, the status scores for the Chinese-respondents' utilization of their communication tools is greater for *majority* of the tools. The Canadian respondents' also have

greater status scores for telephones, web conferencing, teleconferencing, and some of the other databases and communication tools. Alternatively, the Brazilian respondents' status scores are lower than the two other groups for all communication tools under analysis.

However, despite the greater status scores by the Chinese respondents, the variation in status scores is not that great to represent a significant difference in the manner in which individuals from the three facilities utilize their communication tools. The big exception to the above statement is the observation that of all the groups, the Chinese respondents utilize instant messaging a great deal more than the Brazilian and Canadian respondents.

Figures 7.3: Differences in Status Scores by Employees' Location and Communication Tools

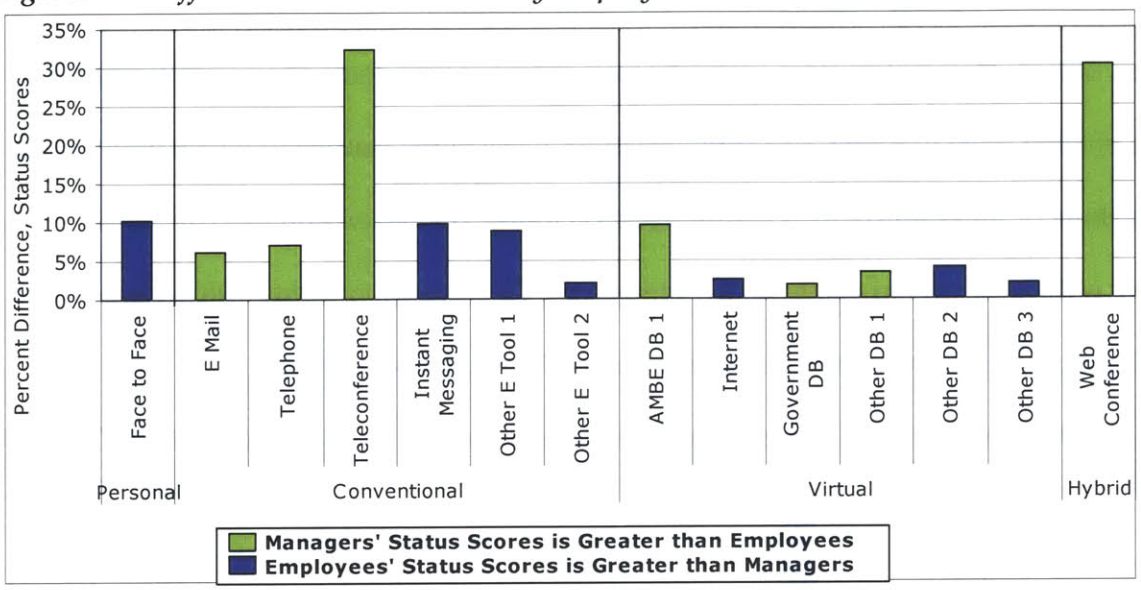


Source: *Results of Status analysis based on the data from the web-based surveys.*

Figures 7.4 and 7.5 show the status results by position and gender respectively. The first point worth examining is the predictable fact that managers utilize certain tools, such as teleconferencing and web conferencing, more than employees because of the costs associated with their utilization. In both cases, managers' status scores for utilizing these tools are significantly greater than that of the employees. The gender analysis shows a similar, but less significant difference in the utilization of these tools between men and women, where men's status scores are greater than that of women's. This relationship may exist because men

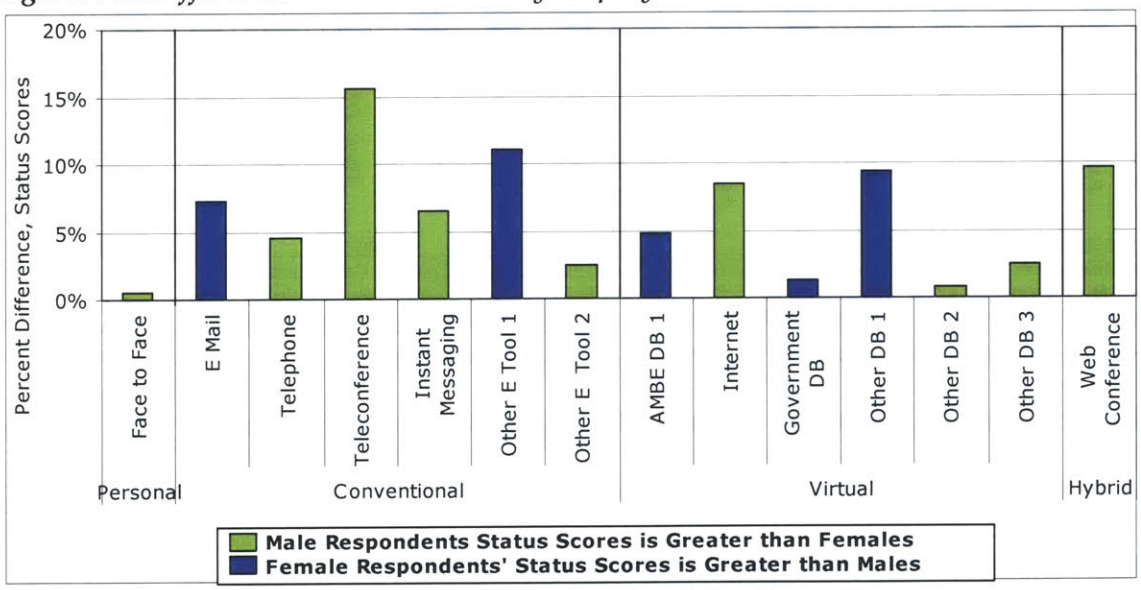
represent a larger ratio of managers, and as such, some of this difference is spilled into the gender analysis.

Figures 7.4: Differences in Status Scores by Employees' Position and Communication Tools



Source: *Results of Status analysis based on the data from the web-based surveys.*

Figures 7.5: Differences in Status Scores by Employees' Gender and Communication Tools



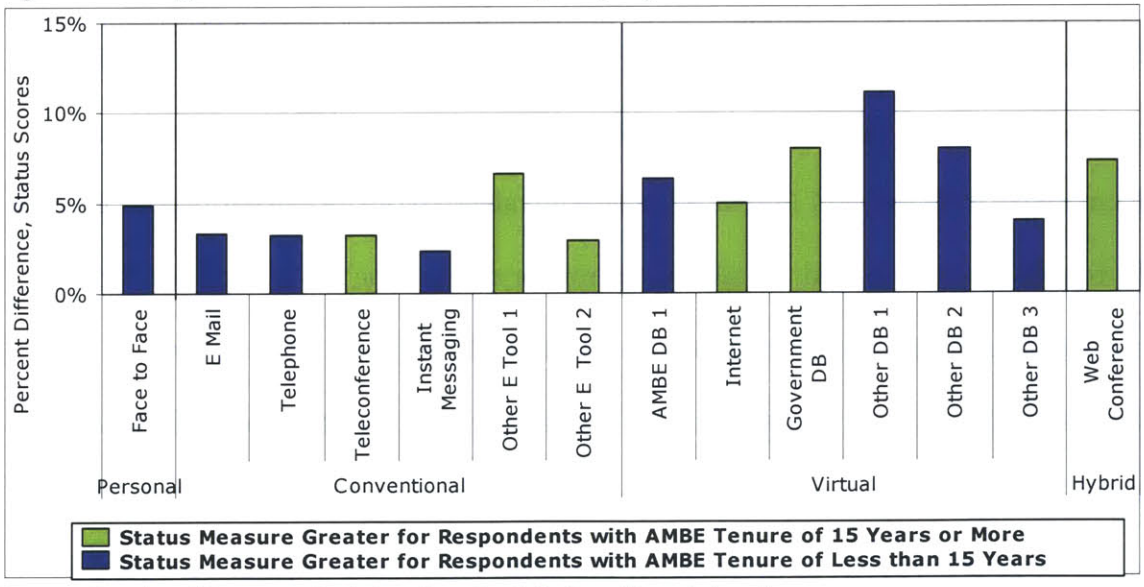
Source: *Results of Status analysis based on the data from the web-based surveys.*

The second point about the above figures is that in both cases, the difference in the status scores between the groups is small, and none of the groups stand out because of their greater status scores across multiple communication tools. Combined, the above observations suggest

that although there are differences in the manner in which groups utilize their communication tools, the differences are not that significant, and other than teleconferencing and web-conferencing by managers, none of the groups utilize their communication tools in a more significant manner than the other group.

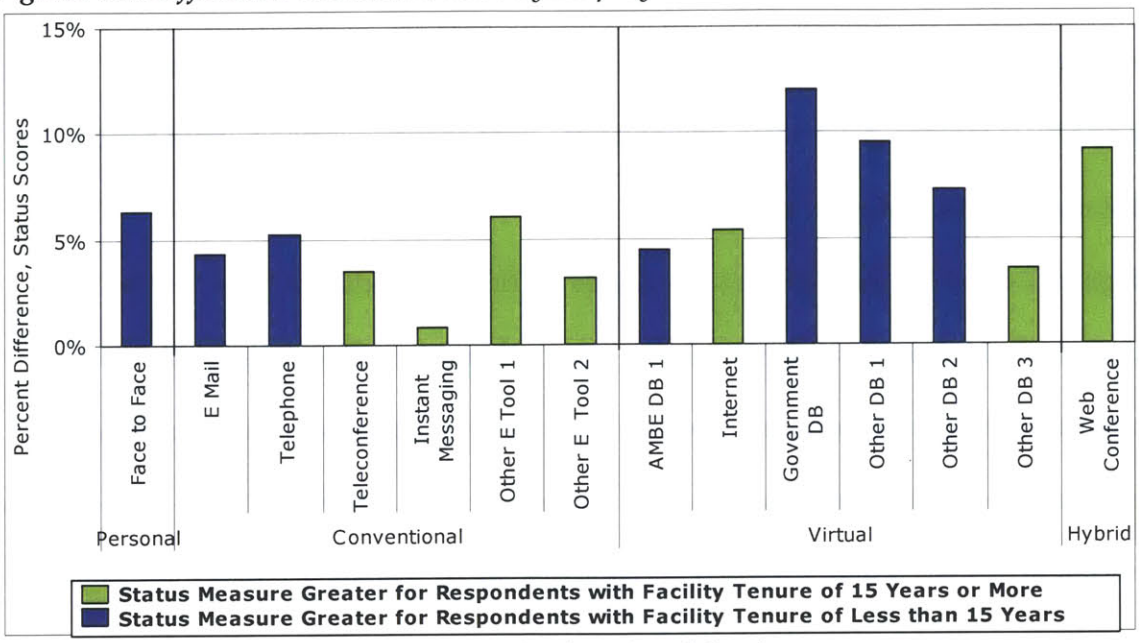
Figures 7.6 and 7.7 show the status analyses for firm and facility tenure. Unlike the knowledge-networking status analysis, where I expected tenure to play a major role in the knowledge networking of the respondents, I do not expect similar results for the utilization of communication tools. The only reason to expect any predictable differences is the same spillage in the utilization of web-conferencing and teleconferencing by managers into the utilization of these resources by individuals with greater firm and facility tenure. Having said that, the firm and facility-tenure status analysis show that the difference in communication-tools utilization is insignificant across all tools and that neither group enjoys greater status scores across multiple tools over the other group.

Figures 7.6: Differences in Status Scores by Employees' Position and Communication Tools



Source: *Results of Status analysis based on the data from the web-based surveys.*

Figures 7.7: Differences in Status Scores by Employees' Gender and Communication Tools



Source: *Results of Status analysis based on the data from the web-based surveys.*

I conduct equivalence analysis in order to determine whether personal attributes and location are a factor in the manner in which individuals use their communication tools. Table 7.1 and Figure 7.8 show the results of this analysis, as well as the Multidimensional Scaling (MDS) map of the population of respondents, while Figures 7.A.1-7.A.11 in Appendix 7.A show the MDS equivalence maps for the respondents grouped by location, position, gender, firm tenure, and facility tenure. Similar to the equivalence analysis in Chapter 6, the scores range from 0 (completely different) to 1 (identical). The equivalence score for the entire population is 0.16. The equivalence results and the MDS maps mirror those of the knowledge networks for location, position and firm tenure. In the case of location, the network profile of the respondents from Brazil are more similar to each other than the population as a whole, while those of the Canadian and Chinese respondents are more different. However, for all three facilities, the range of similarity or dissimilarity are rather small, which combined with the above observation that location can have mixed influence on the respondents' utilization of

their communication tools, means that location plays an insignificant role in the manner in which they utilize their communication tools.

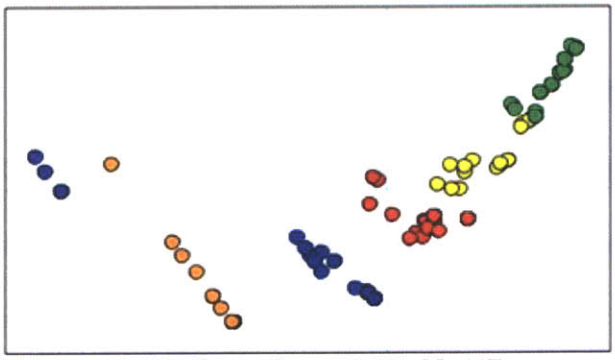
Table 7.1: Similarity Measures for the Respondents by Personal Attributes

Respondents	Equivalence Score (ES)	Percent Difference*	NUMBER OF RESPONDENTS
Population	0.161	-	117
Location			
Brazil	0.167	+3.6%	45
Canada	0.155	-3.8%	37
China	0.157	-2.5%	35
Position			
Managers	0.152	-5.9%	20
Employees	0.163	+1.2%	97
Gender			
Male	0.176	+8.5%	93
Female	0.173	+6.9%	24
Firm Tenure			
More than 15 years	0.178	+9.6%	41
Less than 15 years	0.181	+11.0%	76
Facility Tenure			
More than 15 years	0.180	+10.6%	39
Less than 15 years	0.179	+10.1%	78

* Percent Difference = ((Location ES-Population ES)/Location ES)*100

Source: *Results of equivalence analysis based on the data from the web-based surveys.*

Figures 7.8: MDS Equivalence Maps of CTKN Network – Population



***CTKN* Average Equivalence Score: 0.141, N=117**

Source: *Results of equivalence analysis based on the data from the web-based surveys.*

In addition, the MDS map for the *CTKN* networks in Figure 7.8 shows the same type of clustering that was evident in the MDS maps of the *KNPS* and *KNCRDI* knowledge networks. In order to determine whether these clusters are composed of individuals with the same attributes, I examined their underlying personal characteristics. The results mirror the findings

for the *KNPS* knowledge network, in that the clusters are composed of individuals with a variety of personal attributes, and that on this level of analysis, there appears to be no relationship between the personal attributes and the respondents utilization of their communication tools.

Similarly and for the same reasons, the influence of the respondents' position is also small. In this case, the network profile of the managers is less similar to each other, while the profile is more similar for the employees, and the range of similarity measure is again quite narrow. However, the remaining personal attributes do appear to have a greater influence on the network profile of the respondents than location and position. For each of the following personal attributes, that is, gender, firm and facility tenure, all groups under analysis have more similar network profiles with members of their own group than the population of respondents as a whole. In all three cases, the percent differences in similarity measures are actually greater than any of the other attributes for any of the networks, making the influence of these attributes for this network more significant than any of the other attributes for any of the networks.

7.4 Communication-Tools Utilization of the Knowledge Gatekeepers

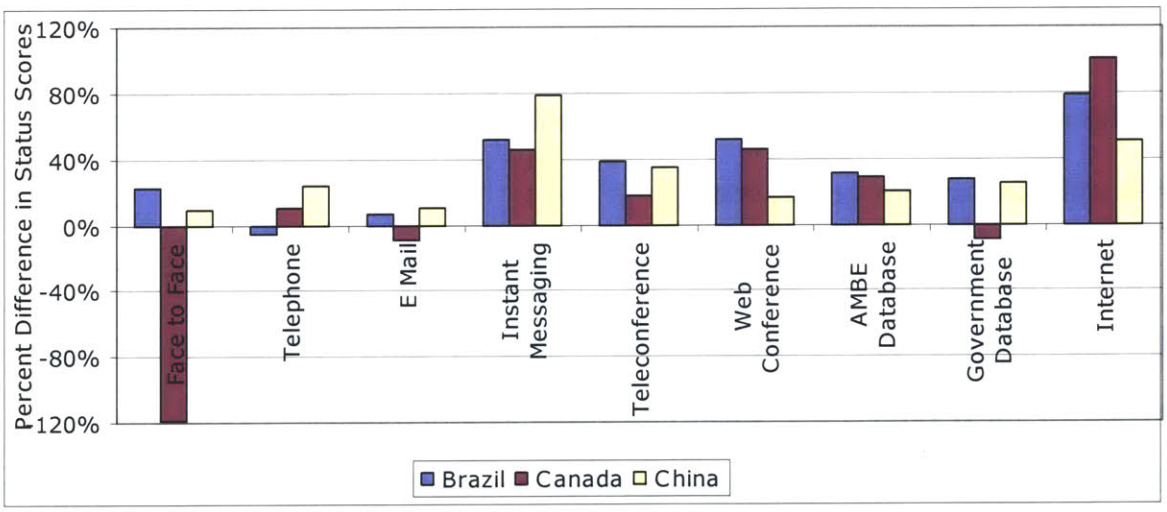
In Chapters 5 and 6, I showed the characteristics of the external, academic and global gatekeepers for the respondents of the three facilities for knowledge networks for problem solving. The results showed that there are in fact groups of respondents who access multiple external or academic knowledge resources, and these individuals have more diverse knowledge networks than the non-gatekeepers. Given the distinct differences between the knowledge gatekeepers, and their colleagues in the manner they utilize and access their knowledge resources, it is reasonable to assume that there could be distinctions in the way they utilize their communication tools as well. In this chapter, I show the results of the status analysis for the

gatekeepers and non-gatekeepers utilization of their communication tools. In Section 7.4.1, I show the results for the academic gatekeepers, while in Section 7.4.2, I concentrate on the market gatekeepers' usage of their communication tools.

7.4.1 Academic Gatekeepers

Figure 7.9 shows the results of status analysis for the academic and non-academic gatekeepers for the three facilities. The primary purpose of conducting status analysis is to show the difference in the level of utilization of different communication tools by gatekeepers and non-gatekeepers.

Figure 7.9: Differences in Status Scores for Academic Gatekeepers Utilization of Communication Tools – Brazil, Canada, and China



Source: The Mail-in Surveys and Author's Calculations using NetMiner II Software.

As is apparent from Figure 7.2, the Chinese gatekeepers have larger status scores for all the communication tools, while their Brazilian colleagues have greater status scores for all communication tools with the exception of telephone, and in this case, the difference is very small. In the case of Canadian gatekeepers, although they have greater status scores for 6 of the 9 tools, gatekeepers utilize face-to-face communication much less frequently than the non-

gatekeepers. The Canadian academic gatekeepers also utilize e-mail and government database slightly less frequently than the non-gatekeepers.

The above results show that the academic gatekeepers across all three facilities utilize their communication tools much more extensively than the non-gatekeepers. This is particularly true for the second and third tier communication tools, such as instant messaging, teleconferencing, web conferencing, AMBE database, and the Internet. Given the high rate of utilization of e-mail, telephone, and face-to-face communication by all respondents, it is not surprising the main difference between the groups would be in the areas of second and third-tier tools. The above findings show that the gatekeepers are more adept at utilizing *all* their communication tools, rather than the top four tools for the non-gatekeepers. This robust utilization of variety of tools allows the gatekeepers to take advantage of all their available knowledge resources and gives them additional flexibility in making formal and informal contacts with their knowledge resources.

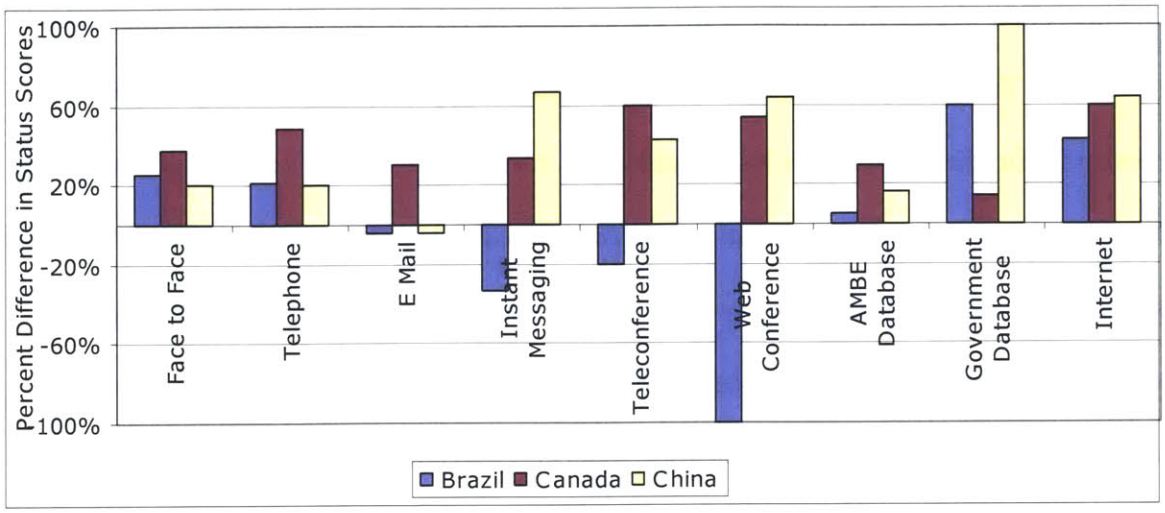
One of the questions that the above analysis does not provide an answer for, but is worth examining in future research, is whether the gatekeepers utilize all these more external knowledge resources because they utilize their communication tools more extensively, or whether they use more of their communication tools because they need all their available tools to access all their knowledge resources. Although this question cannot be answered from the above analysis, from my personal interviews with the respondents I know that it takes time and effort to establish these external knowledge networking relationships, and as such it would be reasonable to assume that the relationships are established through the help of the communication tools, and as such, it is likely that the expansion of both the knowledge networks and the utilization of communication tools occurs in step-wise fashion, with one expansion feeding into the other.

7.4.2 Market gatekeepers

Figure 7.10 shows the results of the status analysis for the market gatekeepers at the three facilities. To reiterate, market gatekeepers include suppliers, customers, government agencies and other firms and their R&D facilities. Unlike the academic knowledge resources, the majority of these knowledge resources require individual contacts, such as with a customer or a supplier, as well as the information they may have available via virtual knowledge repositories. This need for broad access to different types of knowledge requires greater utilization of all the available communication tools and this fact is reflected in the results from Figure 7.9. As is apparent from this chart, the Canadian market gatekeepers have greater status scores than non-gatekeepers for all of the communication tools under analysis, which translates to 20 to 60 percent higher utilization rates for these tools. The Chinese respondents have greater status scores for all of the communication tools with the exception of e-mail, resulting in a 20 to 100 percent greater utilization rates across these tools. In the case of e-mail, it would difficult to improve on the overall 97 percent utilization of e-mail for the Chinese respondents as a whole.

For the Brazilian market gatekeepers, the results are more mixed than their Canadian or Chinese colleagues. They have greater status scores for 5 of the 9 tools under analysis, with greater rate of utilization ranging from 5 to 60 percent. However, they also have lower status scores for 4 of the 9 tools, with the most significant difference being in their utilization of web conferencing. Overall, however, the above results show that in the majority of cases, the market gatekeepers from the three facilities utilize more of their communication tools more often than their non-gatekeeper colleagues.

Figure 7.10: Differences in Status Scores for Market gatekeepers Utilization of Communication Tools – Brazil, Canada, and China



Source: The Mail-in Surveys and Author's Calculations using NetMiner II Software.

7.5 Discussion and Results of Qualitative Analysis

In this section, I discuss the role of communication tools as both a factor in explaining some of the differences in the extent and shape of the respondents' knowledge networks, and to explore some of the reasons behind the differences in the utilization of communication tools, in particular virtual tools, that I could not explain through equivalence analysis. E tools are an important topic of discussion for two reasons. The first is their potential to revolutionize the way respondents communicate, firms produce and sell their products, and most relevant to this study, in the way knowledge producers and consumers at R&D labs utilize the tools to access the relevant knowledge and information more efficiently and productively. The second reason is the fact that firms, such as AMBE Corp., have invested an enormous amount of their resources, both monetary and in terms of betting their long-term strategy, on the promise of E tools. This investment in E tools guarantees that they will remain relevant whether or not they meet their promise or management goals. The question then is not whether E tools are effective

or not, but rather, how can they be made most effective given that they will remain part of the corporate landscape for the foreseeable future regardless of their performance.

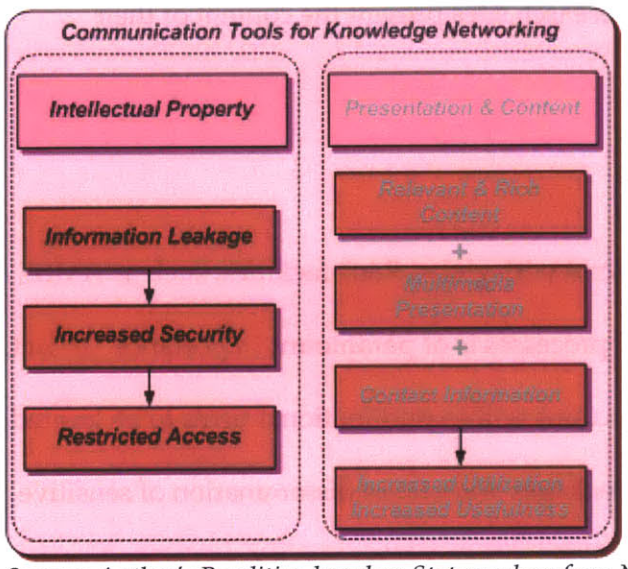
This section is divided in two parts. In Section 7.5.1, I discuss the factors that hinder the flow of knowledge among the respondents and lower the utilization of E tools by the respondents, which fall under the heading of security and access. In Section 7.5.2, I discuss the second factor that influences the manner in which different respondents utilize E tools, and that is the way different product groups and AMBE research sites present the content of their research activities.

7.5.1 Security and Access

For knowledge-intensive multinational firms with global R&D facilities, such as AMBE Corp., the security of their research findings and processes is of paramount importance. In fact, one of the reasons that R&D is one of the last functions within multinational firms to be located abroad is the concern over intellectual property leakages and secure dissemination of sensitive information across facilities. As E tools become more ubiquitous, this need for security has become a cornerstone of designing effective electronic systems. There are two broad means that firms such as AMBE have tackled the E-tool security concerns. The first is a technical solution, with increased efforts to encrypt data transmission and storage, as well as the development of sophisticated firewalls around the firms' databases and other sensitive tools. The second measure has been to restrict access to different databases and systems based on the respondents credentials, which could include the respondent's location. For example, from my conversations with respondents in the three facilities, it became apparent that the employees could not access certain databases and systems that are located at Central R&D simply because the respondents were located in Brazil. Respondents in China and Canada expressed the same

sentiments. I did not have access to the nature of information that is restricted to these facilities, nor could I confirm whether access to the same information was restricted to respondents from all three facilities. But it is apparent that by its nature, this type of broad restriction would severely hamper the free flow of knowledge and effective utilization of electronic tools. Figure 7.11 details the characteristics security and access of E tools.

Figures 7.11: Details on the Role of Security and Access in Utilizing E Tools for Knowledge Networking



***Source**: Author's Rendition based on Status values from NetMiner II and Derived from Web-Based Surveys.*

As is evident from the above figure, AMBE's primary concern over restricting access to information is to protect its Intellectual Property (IP). It is important to note that AMBE takes a number of measures to protect its intellectual property against theft and espionage, and information-system restrictions are just one of the methods. Other means of IP protection include extensive security screening of the facilities employees, segregation of disparate but complementary pieces of IP, and storing IP at the Central R&D, regardless of where it was created. However, because of its relevance to knowledge networking, in this section I focus exclusively on restricted access as a mean of securing IP. According to the respondents, restricted access is particularly frustrating for two reasons. The first is that when the

respondents are confronted with a restricted site, it represents an absolute dead-end for search for information. According to one Brazilian respondent:

"...There are times that I am looking for something for a customer, and I am on a deadline and I go through the usual channels, and when I finally find what I am looking for, I can't access the information, or if I can access it, it's only to the summary of the report...other times, I can access the information, but I can't download it, which makes it useless when it comes to actually using the information..."

It is evident from the above observation that there are different degrees of restrictions, all of which have the effect of ending a communication strand. Although the respondents understood the need for security, they could not reconcile the fact that their access was restricted primarily because of their location. Second, it was apparent from my conversation from the respondents that there was discrepancy in the respondents' knowledge of the limitations that are imposed on the facility. The majority of employees thought the managers have unlimited access to all corporate and Central R&D sites. In fact, from my conversation with the managers, it became apparent that the managers of the facilities face similar restrictions as their employees. Altogether, the restricted access negates one of the most useful features of E tools, and that is their ability to seamlessly connect disparate sources of knowledge and information across the globe.

7.5.2 Presentation and Content

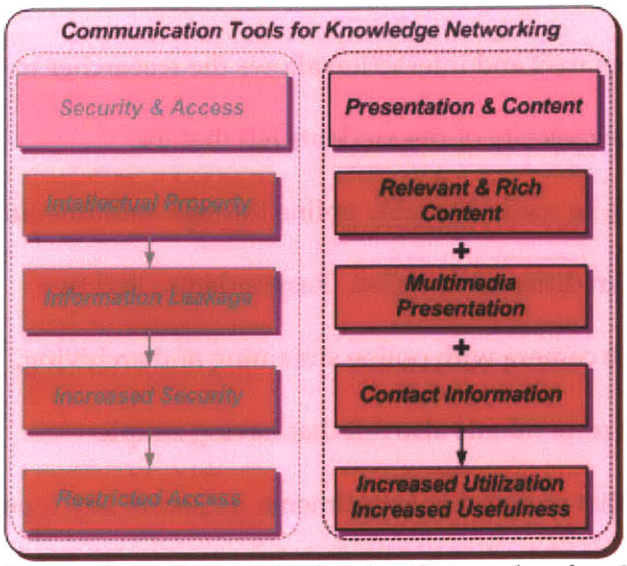
The final factor that affects the way which respondents utilize e tools for communication and knowledge networking, is the difference in the amount and manner in which research content is made available and presented to the respondents. What makes this factor relevant to this study is the fact that there is not a universal standard for content management and presentation across product groups and research facilities at AMBE Corp. Furthermore, because the respondents use a wide array of sites based on their project and research needs,

there is not a clear correlation between a respondents' primary research area or product group, and their access to more or less content and media-rich research sites. In fact, it is the ever-changing role of the researchers at these facilities that makes product-group affiliation less of a factor than the respondents' current role. At the same time, the fact that the respondents have been exposed to a variety of sites while engaged on different projects during the course of their career allows them to judge the merits of different content management and presentation methods that are utilized by different groups. Figure 7.12 details the relationship between site content, presentation and its usefulness. Based on my interviews with the respondents in the three facilities, a consensus emerged about the characteristics of useful and utilized AMBE research sites, which as is evident from Figure 7.12, fall into three categories: (1) relevant and rich content, (2) available options for multimedia presentation, and (3) the inclusion of contact information. I will discuss each of these in detail next.

1. Relevant and Rich Content: It may be a truism to state that respondents found content-rich sites more useful than others. However, what became apparent from my conversations with the respondents, content-rich did not simply mean more content and information. In fact, for the majority of respondents, one of the primary shortcomings of the majority of sites is the fact that they contain too much information, and it takes a great deal of time to get to the relevant information. The sites that respondents found most useful presented the most relevant content, that is a brief overview of research scope, methods and findings, at the beginning of the document, with links to more details from within the larger document, as well as to other relevant and available online documents. According to one Brazilian respondents:

"...The problem with most of the documents is that even if they have a useful abstract available, they don't provide links to the larger paper from within the abstract...so there is always a tradeoff between investing the time to read the whole paper or to get the information only from the abstract..."

Figures 7.12: Details on the Role of Presentation and Content in Utilizing E Tools for Knowledge Networking



Source: *Author's Rendition based on Status values from NetMiner II and Derived from Web-Based Surveys.*

At first glance, it may seem that this requirement is a rather a tedious one. However, examining this criticism within the context of time restrictions and resource availability, it is easy to understand its importance. A Canadian respondent echoes this sentiment:

"…I need to know whether a paper is worth my time or not very quickly…There are too many good papers out there, but not all of them are relevant, and there are a lot of relevant papers that I don't look at, because they don't get to the point…"

In short, increasing the amount of information and knowledge is not necessarily what the respondents are looking for in a useful system. What would make a system more useful is a combination of smarter search engines, as well as more coherent and relevant summaries with links to more in-depth internal and external resources, and the sites that provide this type of content management are the ones that are utilized more by the respondents and therefore, the respondents who utilize these resources exhibit more similar patterns of E tool utilization.

2. Multimedia Presentation: One of the reasons the respondents found personal contact and interaction so useful for their problem solving and knowledge networking was the fact that they received a hands-on demonstration of the *process* of conducting research. In so many cases, E

tools provide the respondent with the methodology and results of research projects, without the background thought processes and steps that the researcher takes in order to conduct a successful research project. However, personal contact and interaction allows the researcher to share this information with the respondents. The majority of respondents felt that the technology now existed for the same processes to be made available online through multimedia presentation of research activities and results from different facilities. Respondents cited two tools in particular that would be very useful: web camera with online streaming and archiving, as well as collaborative online design tools. The respondents also felt that having simple pictures and specifications of the research tools that are used in experiments, as part of any type of research paper would make it extremely useful to know what are the characteristics of the research tools in existence. This is particularly important for cutting-edge research, because it either introduces the respondent to a brand new tool, or to a new method of using an existing tool. Either way, it expands the respondents' knowledge base. According to one Canadian respondent:

"...Every piece of multimedia helps: pictures, web streams, specs, diagrams...even audio files...I do understand why they are not as prevalent as I feel they need to be...they are expensive, pose a security risk and they are not as sophisticated as they can be or need to be in order for them to be worth all the associated risks and costs..."

The above respondents' sentiments capture the primary reasons behind the lack of available multimedia very succinctly. It is in fact the extra investment and added security risks that prevent widespread multimedia usage.

3. Contact Information: The final factor that significantly increases the usefulness of the online resources is a simple inclusion of the essential contact information of the principle investigators at the beginning of the document. All the respondents felt having this information available, as part of a robust abstract or executive summary would make the available contact so much more

useful. From the respondents' perspectives, the only shortcoming of such possible inclusion of contact information, including telephone number and an e-mail link, would be a dramatic increase in the number of calls or e-mails that the authors of the reports might receive. Although this is a legitimate concern, there are at least two reasons to believe that the problem will not become very serious. The first is that the majority of the employees AMBE's R&D facilities are both consumers and producers of knowledge and as such are bound by the same time and resource restrictions as their colleagues. As such, knowledge consumers are both aware of this time limitations, but more importantly bound by its limitations. The second reason is that the contact information is made available as a way to improve follow-up information gathering on the part of knowledge consumers. In reality, if someone is eager and ambitious enough to contact the authors of the reports, then they will take the time to locate the individual. The inclusion of contact information is meant only to facilitate communication, and not create new and frivolous communication channels.

7.6 Conclusion

In this chapter, I presented the results of the quantitative and qualitative analysis for the final affiliation network using the data from the web-based surveys and personal interviews respectively. Similar to Chapter 6, the purpose of the quantitative analysis is to examine the role of personal attributes and locations on the extent and shape of the respondents' communication-tools networks. The results of the status analysis showed that there are significant differences in the importance of different communication tools for knowledge networking, with the most important communication tools being conventional communication tools such as e mail and telephone, as well as face to face communication, followed by AMBE databases. I also used status analysis to examine whether any of the groups of respondents

with similar attributes utilize their communication tools more extensively than others. The results showed that although there are differences in the manner in which these groups utilize their communication tools, there is no one particular group that utilizes their communication tools more extensively than others, with the possible exception of Chinese respondents. Equivalence analysis confirmed the above finding by showing that the different groups are not demonstrably more similar in their utilization of their communication tools than the population as whole, which diminishes the importance of these attributes as underlying factors that can influence the respondents' communication-tools' utilization in any significant manner. Finally, the gatekeeper status analysis confirmed that both academic and market gatekeepers utilize all their communication tools more extensively than non-gatekeepers, particularly by utilizing more of the second and third-tier communication tools.

In the second part of the chapter, I presented the results of the qualitative analysis that are based on my personal interviews with the respondents. The interviews clarified some of the other factors that influence the manner in which respondents utilize their communication tools. These factors fall into two general areas: the first is the need for security and how it affects the manner in which information is presented and made available to individuals through virtual and conventional tools, and the second is the way content is presented and distributed by different groups. All of the above factors can act as facilitators or impediments to making an effective communication tool, which can increase or decrease its level of utilization by the respondents. For example, limiting access to certain documents based on the individual's credentials, including their location, represent an absolute dead end in the search for information, which can have a profound effect on the individuals' perceptions of the usefulness and effectiveness of the communication tool. Similarly, presenting relevant content in an

efficient and media-rich manner can result in increase utilization and perceived usefulness of the communication tools.

In Chapter 8, I conclude this study by presenting the summary results from the previous chapters, how they are relevant to the central questions in this study, how they contribute to the existing body of literature on knowledge networking and globalization of R&D, as well as identifying the future research areas. Finally, I make the connection back to the original reasons why I chose this topic to investigate, and that is the role of global knowledge networks, particularly among multinational firms, to design and deliver world-class solutions to the needs of sustainable development on both the local and global setting.

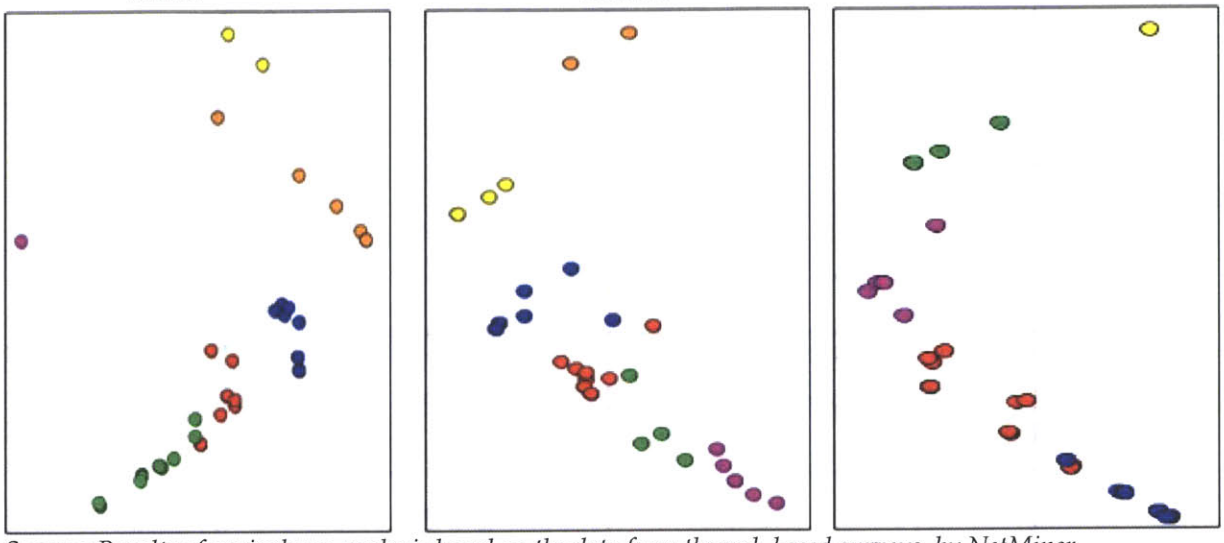
APPENDIX 7.A.: EQUIVALENCE MAPS FOR *CTKN* NETWORK

7.A.1 Mapping the Results of Equivalence Analysis

In this Appendix, I present the Multidimensional Scaling (MDS) maps of the results of the equivalence analysis that I presented in Chapter 7. Figures 7.A.1-7.A.3 show the MDS maps of the respondents by location for Communication Tool for Knowledge Networking (*CTKN*), Figures 7.A.4 and 7.A.5 show the MDS maps of the respondents by position, Figures 7.A.6 and 7.A.7 show the MDS maps of the respondents by gender, and finally Figures 7.A.8 and 7.A.9 show the MDS maps of the respondents by firm and facility tenure for the *CTKN* network.

Figures 7.A.1, 7.A.2, 7.A.3: MDS Maps for the Respondents by Location – CTKN

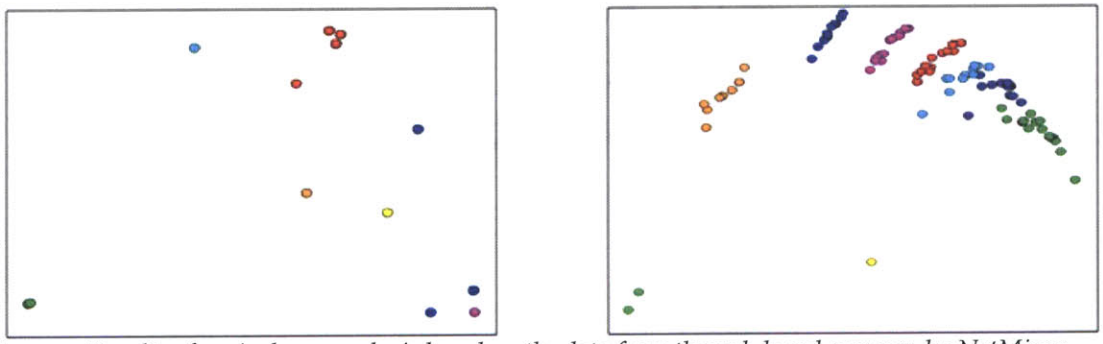
Brazil *Canada* *China*



Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figures 7.A.4, 7.A.5: MDS Maps for the Respondents by Position – CTKN

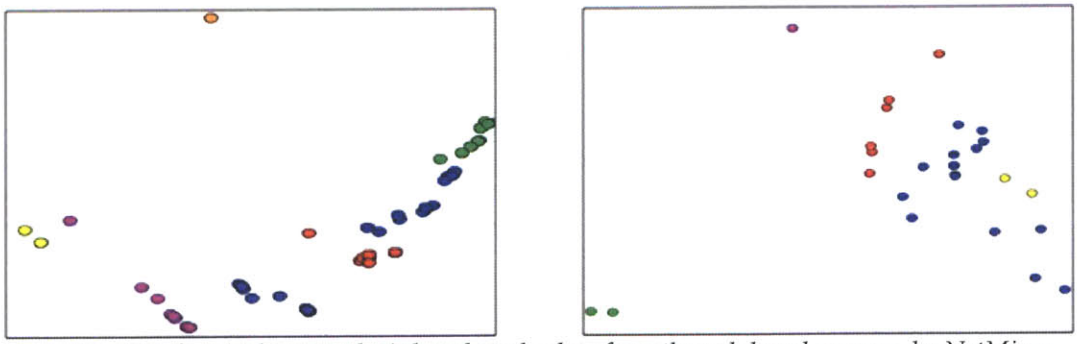
Managers *Employees*



Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figures 7.A.6, 7.A.7: MDS Maps for the Respondents by Gender – CTKN

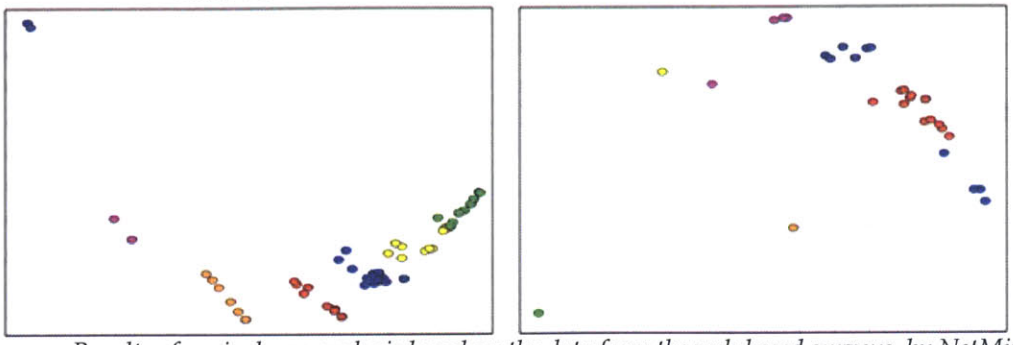
Men *Women*



Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figures 7.A.8, 7.A.9: MDS Maps for the Respondents by AMBE Tenure – CTKN

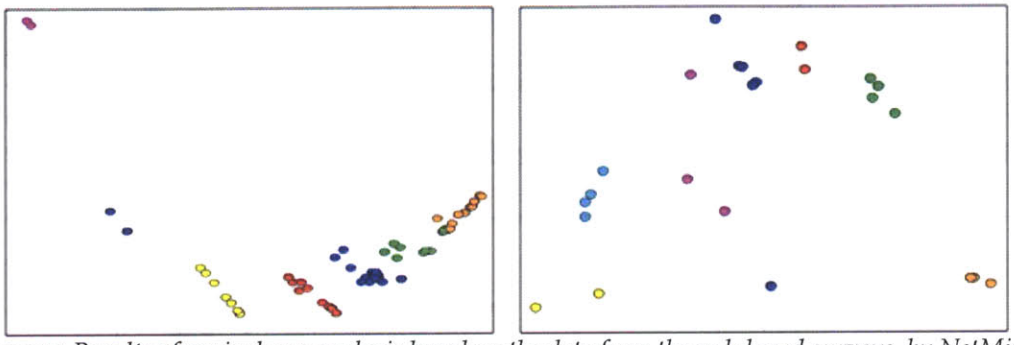
Under 15 Years *Over 15 Years*



Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

Figures 7.A.10, 7.A.11: MDS Maps for the Respondents by Facility Tenure – CTKN

Under 15 Years *Over 15 Years*



Source: *Results of equivalence analysis based on the data from the web-based surveys, by NetMiner.*

CHAPTER 8: CONCLUSION

8.1 Introduction

The impetus behind this study came from my previous research into informal social networks of R&D scientists working on environmental innovations for a large chemical company (Shirvani-Mahdavi 2001). The findings from that research showed that despite management initiatives in developing projects that were designed to tap into their global knowledge networks, the majority of project members utilized only their facility and project knowledge resources (Shirvani-Mahdavi 2001). The key questions that were left unanswered at the end of my previous project became the basis for this study. Among the most important of these questions are: (1) What are the primary reasons the respondents did not communicate with each other despite the management initiatives to facilitate knowledge networking among individuals in different facilities? (2) What are the facilitators and impediments to effective knowledge networking among R&D scientists in geographically dispersed facilities? (3) What roles do personal attributes, such as, language and culture, play in the manner in which individuals utilize their knowledge resources? (4) How do individuals use their communication tools to access different knowledge resources? And finally, (5) how can the management of MNEs manage their knowledge networks in order to better facilitate the flow of knowledge among internal, external, global, and virtual knowledge resources?

In this study, I use social network methods to describe the extent and shape of knowledge and communication networks of R&D researchers at three R&D facilities of AMBE Corp., located in Brazil, Canada, and China. I also analyze the role of personal attributes and other internal and external factors that affect the respondents' utilization of their knowledge resources. In this chapter, I conclude this study by presenting the overview of the research results, the implications of my findings for knowledge management of global R&D scientists,

the study's contribution to literature on knowledge networks and globalization of R&D, and finally the identification of future research needs.

8.2 Summary Results

In Chapter 2, I presented the relevant drivers for MNEs to globalize their R&D operations, which include proximity to suppliers, customers, sources of knowledge, ability to influence local research, and stimulating innovation. I also showed how the process of internal, local, and global knowledge networking among the R&D scientists, allows MNEs to meet the goals of globalizing their R&D. This knowledge networking brings the local knowledge of suppliers, customers, and academia, along with the global knowledge of AMBE's international R&D facilities, into the geographically dispersed AMBE facilities. The characteristics of AMBE's organizational design, with its emphasis on product-facility alignment, is designed to bring together these dispersed knowledge resources, both to enhance its product innovation capabilities, but more importantly, to provide the technical answers, and customer solutions that already exists within AMBE. In other words, if AMBE's R&D employees utilize their knowledge resources to the level that the architects of AMBE's organizational structures expect, then AMBE should achieve its desired goals from globalizing its R&D operations.

In order to analyze and understand the extent of the knowledge networks of AMBE's international operations, I conducted web-based surveys and personal interviews with the relevant employees of AMBE R&D facilities in three countries: China, Canada, and Brazil. I selected these countries because these facilities differed in their history, mandate, product affiliation, proximity to Central R&D facilities, and future growth projections. I focused my surveys on two knowledge networks, Knowledge Networks for Problem Solving (*KNPS*) and Knowledge Networks for Central R&D Innovation (*KNCRDI*), as well as the respondents'

utilization of their Communication Tools for Knowledge Networking (*CTKN*). I chose the two knowledge networks because they represent the two primary jobs of R&D employees at AMBE. The first is their responsibility to solve customers' technical problems, which includes improving the performance of existing products and services. As part of this duty, the employees are constantly confronted with new problems that require quick and efficient solutions. This duty to problem solving requires them to access the diverse knowledge sources that they have at their disposal, including those within AMBE, additional knowledge resources in their local country setting, and AMBE's virtual knowledge repositories. The second set of tasks for the R&D employees, include their responsibility to research, design, and develop innovatory products and processes that will become part of AMBE's next generation of products and services. Given AMBE's emphasis on new product development, this is an extremely important part of R&D employees' jobs. This knowledge network captures the extent of the knowledge resources the R&D employees utilize in order to access the innovatory knowledge that is developed and enhanced at AMBE's Central R&D facilities. I chose Central R&D as the focus of this network because it is at the center of AMBE's R&D efforts to develop new and innovatory products. Finally, I selected *CTKN* networks in order to understand the importance of different communication tools, in particular E Tools, in assisting the respondents utilize their knowledge resources. This is particularly important because of the amount of resources that AMBE has devoted to developing robust and efficient electronic and virtual tools that its employees could use for knowledge utilization.

I divided the results of this study into three main sections. First, I developed the descriptive maps that showed the extent and scope of the two networks, and the communication tools that support them, and I presented the results in Chapter 5. The purpose of these maps is to understand the extent of the respondents' knowledge networks, to show

whether there are any significant differences in the knowledge-networking characteristics of the respondents. I present the summary results of the descriptive analysis in Section 8.2.1. In the second part of this study, I used the results of the web-based surveys to analyze the importance of personal attributes in explaining the differences in the shape and extent of the respondents' *KNPS*, *KNCRDI*, and *CTKN* networks. The personal attributes under analysis are gender, position, the length of tenure at AMBE, the length of tenure at the respondents' current facilities, and the locations of their facilities. I present the summary results of the quantitative analysis in Section 8.2.2. In the last part of this study, I use the results of the personal interviews to examine the importance of some of the other relevant factors that influence the shape and extent of the respondents' knowledge and communication networks, and I present those results in Section 8.2.3.

8.2.1 Summary Results of Descriptive Analysis: Network Maps

I reproduce the results of the descriptive analysis from Chapter 5 as a set of consolidated tables, which show the extent of utilization of the different groups of knowledge resources for the three facilities and the two networks, and their supporting communication tools (Tables 8.1-8.3). In these tables, I indicate the extent of utilization of knowledge resources by the size of the pie, ranging from minimal utilization for the empty circles, to full utilization for the filled circles. The following tables point to four findings. The first is the importance of internal knowledge resources, such as the respondents' projects and facilities for both knowledge networks. This finding reiterates and confirms Allen's (1977) and Gertler's (1995) analyses, which illustrates the significance of distance in influencing the communication and knowledge-networking patterns of R&D personnel. The second is the low utilization of global knowledge resources by the respondents for both *KNPS* and *KNCRDI* networks. In this case, global

facilities are separated from Central R&D, because it is obvious that the level of utilization of Central R&D for knowledge networking is significantly greater than that of other facilities. Similarly, the respondents' utilization of their external local knowledge resources is lower than that of their internal resources. As I showed in Chapter 5 and 6, specialized gatekeepers are the primary respondents who conduct the bulk of knowledge networking with these resources.

Table 8.1: Knowledge Networks for Problem Solving - Summary Descriptive Results

Facility	Internal Knowledge Resources	Local Knowledge Resources	Central R&D Knowledge Resources	Global Knowledge Resources	Virtual Knowledge Resources	Most Useful Knowledge Resources
Brazil	●	◔	●	◔	◓	Central R&D
Canada	●	◔	●	○	◓	Central R&D
China	●	◓	◔	○	◑	Project

Table 8.2: Knowledge Networks for Central R&D Innovation - Summary Descriptive Results

Facility	Internal Knowledge Resources	Local Knowledge Resources	Central Knowledge Resources	Global Knowledge Resources	Virtual Knowledge Resources	Most Useful Knowledge Resources
Brazil	◑	Not Applicable	◑	◔	◑	Central R&D
Canada	●	Not Applicable	●	○	◓	Central Facility
China	●	Not Applicable	◑	○	◓	Project

Table 8.3: Communication Tools for Knowledge Networking - Summary Descriptive Results

Facility	Personal Communication Tools	Conventional Communication Tools	Virtual Communication Tools	Most Useful Communication Tools	Most Frequently Used Communication Tools
Brazil	●	●	◔	Face to Face	E Mail
Canada	◑	●	◔	Face to Face	Face to Face
China	●	●	◓	Face to Face	E Mail

Symbol	Description
●	Extensive utilization of all resources or tools
◑	Extensive utilization of most resources or tools
◓	Moderate utilization of most resources or tools, or extensive utilization of one resource or tool
◔	Moderate utilization of some knowledge resources
○	Very limited utilization of some of the knowledge resources

Source: Network Maps (Chapter 5).

Finally, for both knowledge networks, virtual knowledge repositories are the third most utilized knowledge resources, which show the significance of these resources for the manner in which respondents find solutions to their problems or Central R&D innovation. However,

despite the impressive showing of the virtual knowledge resources, the majority of the respondents did not find them as useful as their internal or Central R&D resources. Table 8.3 shows the summary descriptive results for the *CTKN* networks. This table points to two findings about the respondents' utilization of their communication tools. First, the respondents utilize conventional communication tools, such as e-mail and telephone, significantly more than any other communication tool. Second, although the utilization of virtual communication tools is varied among the respondents, the Chinese respondents in general utilize these tools more extensively than the Canadian or Brazilian respondents.

I presented the results of gatekeeper analysis for *KNPS* networks in Chapters 5, 6 and 7. In Chapter 5, I showed that the cross-location gatekeepers do not exhibit the characteristics of knowledge gatekeepers, in that there is very little overlap in the respondents' utilization of different global knowledge resources. Alternatively, the descriptive results show that academic and market gatekeepers for the three facilities demonstrate more overlaps in their utilization of different knowledge resources, resulting in a coherent group of respondents who utilize multiple knowledge resources, and as such act as knowledge gatekeepers. The Brazilian academic gatekeepers focus their networking around academia and journals, while their Canadian colleagues focus their networking around academia and conferences. Finally, for the Chinese academic gatekeepers, there is a great deal of overlap in knowledge utilization among all three knowledge resources. The network maps for the market gatekeepers showed that the Brazilian market gatekeepers' main area of focus is between customers and suppliers, while their Canadian colleagues exhibited a great deal of specialization around a combination of knowledge resources, such as, suppliers and customers, customers and government agencies, as well as, suppliers and other firms. Finally, the Chinese market gatekeepers exhibited more diverse utilization of their external knowledge resources, with a great deal of overlap across

resources. In Chapters 6 and 7, I presented the results of how the gatekeepers utilize all their remaining knowledge resources and all of their communication tools, which I reproduce here in Tables 8.4-8.7. In the following tables, the black pies indicate that the gatekeepers' utilization of their knowledge resources or communication tools are greater than that of the non gatekeepers, while the red circles indicate the opposite, and the extent of the difference is indicated by the size of the pie.

Table 8.4: Difference in Status Scores for Knowledge Networking – Academic Gatekeepers

Facility	Project	Facility	Central R&D	US Facilities	Global Facilities	Customers	Suppliers	Government	Other Firms	AMBE Web
Brazil										
Canada										
China										

Table 8.5: Difference in Status Scores for Knowledge Networking – Market gatekeepers

Facility	Project	Facility	Central R&D	US Facilities	Global Facilities	Academia	Journals	Conferences	AMBE Web
Brazil									
Canada									
China									

Table 8.6: Difference in Status Scores for Communication Tools – Academic Gatekeepers

Facility	Face to Face	Telephone	E-Mail	Instant Messaging	Tele-Conference	Web Conference	AMBE Database	Government Database	Internet
Brazil									
Canada									
China									

Table 8.7: Difference in Status Scores for Communication Tools – Market gatekeepers

Facility	Face to Face	Telephone	E-Mail	Instant Messaging	Tele-Conference	Web Conference	AMBE Database	Government Database	Internet
Brazil									
Canada									
China									

Symbol	Description	Symbol	Description
	Plus 100 percent utilization difference		Minus 100 percent utilization difference
	Plus 75-99 percent utilization difference		Minus 75-99 percent utilization difference
	Plus 50-74 percent utilization difference		Minus 50-74 percent utilization difference
	Plus 25-49 percent utilization difference		Minus 25-49 percent utilization difference
	Plus 0 to 24 percent utilization difference		Minus 0 to 24 percent utilization difference

Source: Status Analysis (Chapters 6 and 7).

The most important observation from the above tables is that the gatekeepers have greater status scores for almost all of the knowledge resources and communication tools, and in majority of cases, the difference is 50 percent or greater. The above results confirm the key role gatekeepers play in not only accessing and utilizing their primary knowledge resources, but also for having extensive knowledge networks across majority of their knowledge resources. Additionally, the gatekeepers not only utilize their primary communication tools, such as, e-mail and telephone, but also utilize their secondary and tertiary communication tools much more extensively than the non-gatekeepers.

8.2.2 Summary Results of Quantitative Analysis: Status and Equivalence Measures

In Chapters 6 and 7, I presented the results of the social network methods of status and equivalence measure. The purpose of quantitative analysis is threefold: (1) to determine the most important knowledge resources and communication tools for the population of respondents; (2) to detect the differences in the way groups of respondents utilize their knowledge resources and communication tools based on their location and personal attributes under analysis; and (3) to determine the relevant underlying personal attributes that affect the extent of the respondents' networks, based on the similarity of their networking profiles.

Figures 8.8-8.10 show the summary results of the status analysis for the *KNPS*, *KNCRDI*, and *CTKN* networks. To summarize, the results showed that for *KNCRDI* networks, managers, male respondents, and respondents with more than 15 years in firm and facility tenure have more extensive knowledge networks. However, for *KNPS* networks, none of the groups, with the exception of males, have more extensive knowledge networks across all their knowledge resources than their comparison group. For example, in the case of knowledge networking for problem solving, the Chinese respondents utilize their external and virtual knowledge

resources more than the other two groups, while the Brazilian respondents have more extensive global knowledge networks.

Table 8.8: The Importance of Personal Attributes on Respondents' Status Scores - KNPS

	Project Facility	Central R&D	Global Facilities	Academia	Journal	Customer	Supplier	Gov't	Conf.	AMBE Web
Location	○	○	○	○○○	○	◔	◕	◔	○	○	◔
Position	○	○	◒	○	◔	◔	○	◕	◔	◔	○
Gender	◔	○	●	○○	◔	○	◕	○	○	◔	○
AMBE Tenure	○	○	●	○○	○	◔	◔	○	○	◔	◔
Facility Tenure	○	○	●	○○	○	◔	◔	○	○	○	○

Table 8.9: The Importance of Personal Attributes on Respondents' Status Scores - KNCRDI

Facility	Project Facility	Central R&D	Central Facilities	Global Facilities	AMBE Database	Tech Conf.	E Tech Forums	Other Databases
Location	○	○	○	○	○○○	○	○	○	○
Position	◔	◔	◒	◔	◔○	◔	○	◒	◒
Gender	○	◔	○	○	○○	◔	○	○	○
AMBE Tenure	◒	◕	●	◕	○○	◒	○	○	○
Facility Tenure	○	◔	◒	◔	○○	◔	○	○	◔

Table 8.10: The Importance of Personal Attributes on Respondents' Status Scores - CTKN

Facility	Face to Face	Telephone	E-Mail	Instant Messaging	Tele-Conference	Web Conference	AMBE Database	Government Database	Internet
Location	○	○	○	◔	○	○	○	○	○
Position	◔	○	○	◔	◕	◕	○	○	○
Gender	○	○	○	○	◔	○	○	○	○
AMBE Tenure	○	○	○	○	○	○	○	○	○
Facility Tenure	○	○	○	○	○	○	○	◔	○

Symbol	Canada, Managers, Men, Over 15 Years of Tenure	Symbol	China, Employees, Women, Less than 15 Years of Tenure	Symbol	Brazil
●	Plus 40-100 percent	●	Plus 40-100 percent	●	Plus 40-100 percent
◕	Plus 31-40 percent	◕	Plus 31-40 percent	◕	Plus 31-40 percent
◒	Plus 21-30 percent	◒	Plus 21-30 percent	◒	Plus 21-30 percent
◔	Plus 11-20 percent	◔	Plus 11-20 percent	◔	Plus 11-20 percent
○	Plus 0 to 10 percent	○	Plus 0 to 10 percent	○	Plus 0 to 10 percent

Source: Status Analysis (Chapters 6 and 7).
Conf: Conference; **Gov't**: Government

I conducted the same analysis for *CTKN* networks, and presented the results in Chapter 7. Even more so than the status-analysis for the two knowledge networks, the results show that none of the groups utilize their communication tools more extensively than their comparison

groups, and the differences among the groups are the results of slight variations in the type of tools they utilize in each of the categories. Finally, I used equivalence analysis to determine whether the personal or location attributes, affect the knowledge or communication tool networking of the respondents. The results of equivalence analysis re-affirm the findings from status analysis by pointing out that the most relevant factors in explaining the difference in knowledge networks between the respondents are AMBE and facility tenure.

8.2.3 Summary Results of Qualitative Analysis: Personal Interviews

The findings from the quantitative analysis dismiss the importance of some of the personal and location attributes in explaining the differences between the manner in which the respondents utilize their knowledge resources or communication tools. However, the results of the qualitative analysis from personal interviews clarified the role of some of the internal and external factors in explaining both the importance of some of the tools and resources, as well as, to make clear the factors behind some of the differences in the networking characteristics of the respondents. Table 8.11 shows the summary findings of the qualitative analysis for the knowledge networks and communication-tool network respectively. I include the results of the quantitative analysis for comparison. In this table, the half-black circle indicates that the attribute or factor plays a moderately expansive role on the manner in which the individuals utilize the tool, while the filled black circles indicate a significantly expansive influence. Alternatively, the half-full red circles point to a moderately impeding influence, and full red circle indicate a significantly impeding factor on the knowledge resource or tool. Finally, an empty circles shows that the particular factor does not play a role in the manner in which respondents utilize their resources or tools.

Table 8.11: Summary of Qualitative Analysis

Personal & Location Attributes	Internal Knowledge Resources	External Knowledge Resources	Central Knowledge Resources	Global Knowledge Resources	Virtual Knowledge Resources
Location	○	○	○	◓	○
Position	○	○	○	◓	◓
Gender	○	○	◓	○	○
AMBE Tenure	○	◓	◓	○	◓
Facility Tenure	○	◓	◓	○	◓
Resource Allocation & Organizational Design					
Resource Allocation	◓	▨	●	◒	◓
Resource Availability	●	▨	●	◒	●
Resource Awareness	●	▨	●	●	◒
Resource Usefulness	●	▨	●	●	◒
Personal Resources					
Job Mobility	◓	◒	◓	◓	◓
Job Complexity	◓	◓	◓	◓	◓
Training & Travel	◓	◒	●	◒	◓
Formal Contacts	●	◓	●	◒	▨
Informal Contacts	●	◓	●	◒	▨
Mentors	●	◒	●	◒	◓
Trust					
Cognitive Trust	●	●	◓	◒	◒
Emotional Trust	●	●	◓	◒	◒
Cultural Trust	●	●	◒	◒	◒
Facility History & Mandate					
Government Policy	●	◓	◒	●	◒
Management Initiatives					
Idea Sharing	◒	▨	◒	◒	◒
Security & Access					
Information Leakage	◓	◒	◓	◒	◒
Increased Security	◓	◒	◓	◒	◒
Presentation & Content					
Relevant & Rich Content	▨	▨	▨	▨	◓
Multimedia Presentation	▨	▨	▨	▨	◓
Contact Information	▨	▨	▨	▨	◓

Symbol	Description	Symbol	Description
●	Significantly expansive influence	●	Significantly constricting influence
◓	Moderately expansive influence	◒	Moderately constricting influence
○	No discernable influence		

Source: Qualitative Analysis (Chapters 6 and 7).

There are a number of summary points worth reiterating from this table. The first is the finding that compared to other factors, personal attributes and respondents' location play a minor role in determining the shape and extent of the respondents' knowledge networks. Second, the table clearly shows that some of the qualitative factors have mixed influence on the manner in which respondents utilize their knowledge resources. For example, level of trust has a significantly expansive influence on the respondents' knowledge networking with facility knowledge resources, while at the same time, negatively influences the manner in which individuals network with their external, global, and virtual knowledge resources. Third, the majority of the qualitative factors have a positive effect on the most important knowledge resources, such as Internal and Central knowledge resources. Although I did not test the correlation between these qualitative factors, and the extent of the utilization of the knowledge resources, there is significant enough agreement among the respondents about the importance of these factors, to make their significance very robust. Finally, it is important to point out that the negative influence of the management initiative on idea sharing is based entirely on the limited amount of time that the initiative has been in place, and its long term impact on knowledge networking is not very well known.

8.2.3 The Importance of the Findings on the Propositions

The premise behind *Proposition 1* is that in order for MNEs' globally-dispersed facilities to meet their potential as organizational bridges that span the gaps in the global knowledge networks, they must have robust knowledge networks with both the MNEs' global knowledge resources, *and* with the host-country external knowledge resources. The results for *KNPS* network, which is the only relevant network in regards to this proposition, indicate that all three facilities function relatively well as organizational bridges that span the structural holes in

these global knowledge networks. For example, in all three facilities, there are specialized gatekeepers who access and utilize the external knowledge networks, and given the extensive internal knowledge networking within the facilities and projects, this knowledge is made available to the respondents within the facilities. Furthermore, in all three facilities, particularly Brazil and Canada, there are very robust knowledge networks between the majority of respondents and AMBE's Central R&D facilities. However, this global knowledge networking is also one-dimensional. Furthermore, the cross-location gatekeeper analysis did not indicate that there are specialized gatekeepers who access these knowledge resources as a group, as is the case with the external and academic. As such, the descriptive results show that although AMBE does not meet the requirements set out in *Proposition 1*, the three facilities do relatively well connecting the knowledge within AMBE's Central R&D with the local knowledge resources.

The premise behind *Proposition* 2 is that personal attributes, such as gender, position, firm and facility tenure, as well as language and culture, influence the knowledge-networking profiles of the respondents for the knowledge networks under analysis. Furthermore, *Proposition* 2 stipulates that this influence results in men, managers, and individuals with longer tenure levels to have more extensive knowledge networks. There is mixed confirmation of *Proposition* 2 from the findings of the quantitative analysis. Overall the results show that the stipulations behind *Proposition* 2 hold true for *KNCRDI* networks, but the influence of *location* is the only factor that holds true for *KNPS* networks. The results for the other personal attributes show that their influence on *KNPS* networks are mixed and that none of the groups have significantly more extensive knowledge networks than their comparison groups. Overall, the results of the quantitative analysis show that in order for *Proposition* 2 to hold true, it must be modified to include the influence of knowledge network itself on the effects of personal

attributes on knowledge networks. This is an important modification, because it shows that knowledge content itself affects the manner in which respondents utilize the resources, making it difficult to make broad generalizations about the influence of personal attributes on the manner in which respondents utilize their knowledge resources.

Finally, *Proposition 3* holds that there are additional factors, such as personal and facility resources, management initiatives, and trust, which can also influence the manner in which individuals utilize their knowledge networks. Furthermore, it is because of these external factors that individuals with the same personal attributes may not have more similar knowledge-networking profiles than the population of respondents as whole, despite their differences with their comparison groups. The results of the equivalence analysis confirm the contention behind *Proposition 3*, that groups of respondents with the same personal attributes do not have noticeably more similar knowledge-networking profiles than the population of respondents as a whole. This is the case despite the fact that respondents in groups with different personal attributes have more dissimilar knowledge networking profiles. The results of the qualitative analysis show that there are a number of personal and external factors that can influence the manner in which individuals utilize their knowledge resources, and may be able to explain the dissimilar knowledge networks among individuals with similar attributes. These factors include personal and facility resources, trust, and management initiatives, all of which affect the level of access and awareness of the individuals' diverse knowledge resources.

8.2.4 Implications and Recommendations

Based on the quantitative and qualitative analysis, the following is a broad set of recommendations that can have a positive impact on MNEs' knowledge networks, based solely on my findings from this study.

1. Importance of Organizational Design: The most important finding of this study is the observation that AMBE's organizational design of its global R&D facilities works exactly as it is expected to in regards with knowledge networking. The study shows that if the respondents choose to go outside their projects or facilities for help with problem solving or learning about new innovations, they seek and utilize the resources that they know would be plentiful (Central R&D), know from personal experience to be useful (Central R&D), have personal contact with, through attendance in training sessions or technical conferences (Central R&D), and are trustworthy (Central R&D). Given all the above reasons, the respondents choose Central R&D as their overwhelming first, second, and third choice of a global R&D facility. The key finding is that the respondents are acting in a logical manner, seeking accessible, available, and plentiful resources. The implication for MNEs is that if organizational design is working as it would be expected based on the findings from this study, then by changing the organizational design, they could expect the behavior of the respondents to change, albeit slowly.

2. Redistribution of Resources: AMBE already has robust regional R&D centers of excellence that are utilized by respondents on an occasional basis, based on their specific needs. However, the majority of respondents did not utilize these resources on a regular basis because they were uncertain that they would be helpful *every time*. One way for MNEs to alleviate this problem is by assigning certain technology platforms to these regional centers and providing them with all the available resources they could have, including reassigning some of Central R&D facilities to these regional centers.

3. Awareness of Distributed Expertise: One of key findings of this research has been that respondents utilize resources they are aware of, either through personal contact or through personal knowledge. Most of this knowledge comes through contacts that are made during their training. One method to make respondents aware of the expertise that is available in other

facilities is to distribute the training first to regional centers of excellence, and finally to national R&D labs. The implication is that once the individuals are introduced to the facilities, they, along with their contacts, can provide a pathway (in the form of a trainee and the contacts they make) through which knowledge can flow from one facility to another.

4. Border-crossing Mentorship Programs: There is near-unanimous agreement among the respondents with first-hand experience with AMBE's mentorship programs that formal and informal mentors are one of the most useful and utilized resources. The implication is that by expanding the program to include all of the global R&D facilities, MNEs can create a border-crossing mentoring program, which can act as a vehicle for formal and informal knowledge networking. In one possible model, individuals with different tenure levels are still paired up based on their career, research, and personal interests, but they are selected from facilities in different locations, preferably in different countries. There are two benefits to such programs. First, it creates yet another pathway of knowledge sharing between different facilities, while the second reason is that it may force individuals to utilize their electronic communication tools for purposes that surpass their current levels.

5. Long Distance Trust: There are a number of ways that managers may be able to enhance trust in geographically distributed teams. The first is through shared identity. Specifically, in geographically distributed work, there could be an attempt to establish super-ordinate identities that extend beyond local boundaries. However, super-ordinate identities can emerge, through the knowledge that distant workers share the same level of concern for and commitment to a common destiny. This creates a shared reference, and perhaps generates latitude for more tolerant interpretation of any future site-specific or culturally specific behaviors. The second is through improved familiarity. It is interesting to note that the findings in this study showed that it was the simple fact of visiting the other facility, which improved the

level of trust, not the frequency or duration of visits. This suggests a powerful effect for seeing counterparts at distant facilities. It may be that these visits helped breakdown the invisible co-worker syndrome in long distance collaborations. That is, the tendency for distant colleagues to be out of sight, and therefore out of mind. The third is through the role of non-work communication. Non work-related communication may serve a number of functions. The point here is that all of these trust-building activities can be accomplished through Recommendations #2 and #3. That is border-crossing mentorship programs and personal contact through training and conferences could allow for the above trust-building activities to take place.

6. Relevant, Consistent, and Concise Information: From the analysis in Chapter 7, it is apparent that the respondents receive different content and media presentation depending on the online resources they access. Overall, the online resources lack consistency in both their content matter, and in the manner in the way they present the data. For example, AMBE's current standards that emphasize rich content and media presentation can also be used as a basis for a set of new standards that may be used by all groups and websites. The following is a summary of types of standards that MNEs could use to provide rich and concise information. (1) Provide research summary with links to internal and external resources; (2) provide detailed contact information for all researchers who are involved in the project; (3) provide links to the equipment specifications that are used in the research project, if available; and (4), include rich media presentation of the material whenever possible. The media can be photographs, video and audio streams, and most importantly, interactive design tools.

8.3 Contribution to Literature and Areas of Future Research Needs

Relating back to Chapter 2, this study makes contributions to the two main literature strands that it draws from: globalization of R&D and knowledge networking.

8.3.1 Border-Crossing Knowledge Networks

I examined three types of knowledge networks in this study: border-crossing, local, and virtual knowledge networks. The findings from this research both confirm the current thinking on border-crossing networks. For example, it confirms the importance of institutional proximity to effective knowledge networking, while refuting other research results, such as the importance of knowledge distance in border-crossing knowledge networks, as well as the broad claim that physical distance can only affect knowledge networking in a negative manner. I discuss each of these next.

1. Physical Distance: Led by Allen's work on communication networks among R&D facilities (1977), there is a great deal of agreement in the literature that frequency of knowledge networking declines exponentially with distance (e.g., Gertler 1995; Hough 1972). For example, Allen found a five-percentage point likelihood of weekly communication between two engineers or scientists who are located 30 or more meters from each other (1977). However, my findings in this study show that although distance is a major factor for knowledge networking with all global facilities, the negative influence of physical distance *does not* hold true for the respondents' knowledge networking with Central R&D, confirming that distance alone cannot explain the extent of respondents' knowledge networking. Future research in this area could examine whether this finding holds true for other organizational models, or for less R&D-intensive MNEs.

2. ***Organizational Distance:*** The current thinking in the literature is that organizational distance influences knowledge networking by affecting transferability of meaning, value, and subsequently, knowledge. In this case, organizational distance refers to the degree of congruity between the organizational environments facing the two parties (e.g., Graham 1985; Kostova 1999). In this study, I provided the empirical evidence that the organizational setting, including the history, mandate, and the political situation of the country where the facility is located, play an important role in the manner in which the respondents interact with the respondents from other facilities, particularly in Brazil. However, the key questions that remain to be answered are whether the results would hold true across a spectrum of countries with different institutional settings.

3. ***Knowledge Distance:*** The existing thinking in the literature is that knowledge networking is enhanced when the knowledge gap between a source and a recipient was not so great to make the recipient unable to identify the learning (e.g., Hamel 1991; Lane and Lubatkin 1998). However, the results of this study show that the importance of knowledge distance *does not* hold true in any of the border-crossing knowledge networks, neither in terms of facilitating nor impeding knowledge networking. As such, the most significant knowledge networking is between facilities with the largest knowledge distance, that is, with Central R&D, while the opposite holds true for knowledge networking among facilities with similar levels of knowledge competencies. Future research could examine whether the idea of knowledge distance is a relative concept, which may not hold true in settings where the need to collaborate supersedes the impediments associated with knowledge distance.

4. ***Cultural Distance:*** Researchers identify several culture-related factors that can affect knowledge-networking success. For example, as social similarities of parties increase, so will their ease of communications, which allow for greater transfer success.

Furthermore, there is evidence that a strong positive relationship between recipient and source facilitates the trading of the transfer of information. The results of this study confirm the importance of cultural distance in knowledge networking, showing that the strongest knowledge networking took place within the respondents' facilities, where the cultural distance between the respondents was smallest. However, my results also show robust knowledge networking between the respondents and Central R&D facilities, which questions the validity of the above argument in all cases. Future research could examine the circumstances under which this proposition holds true, and the factors that can negate its importance.

8.3.2 Local Knowledge Networks

The following is the list of the areas where the results of this study make a contribution to the current literature on local knowledge networks, and areas of future research needs.

1. Learning Regions and Spatial Localization of Knowledge: There is a growing body of literature on learning regions, which claims that proximity between actors is an important aspect in learning. Learning regions are areas in which actors are interacting and learning, and there is a development of collective tacit knowledge that is linked to location because of functional and relational proximity (e.g., Florida 1997; Keeble and Wilkinson 1999; Gertler 1995, 2001; Zeller 2002). The results of gatekeeper analysis in this study indicated that there is some specialized knowledge networking among the respondents and their local knowledge resources. However, personal interviews with the respondents diminished the importance of these networks. Future research could provide more empirical evidence of cases where spatial localization of knowledge is limited or non-existent. This would be particularly fruitful in emerging countries, which may not have robust and significant historical knowledge networks in place.

2. ***Means of Exploiting External Sources of Knowledge:*** In order for MNEs to exploit these external knowledge resources, they need to develop conduits or mechanisms that permit the absorption and use of this local external knowledge. Knowledge can be accessed through interactions and relationships of employees with those outside the firm, by hiring former employees of competitors, from public sources such as presentations at conferences, journals, books, and patents within an industry, through their relationships with other companies, suppliers, universities and research institutions, industry associations, and customers (e.g., Almeida and Kogut 1999; Zollo, Reuer and Singh 2002; Takeishi 2001; Powell, Koput and Smith-Doerr 1996; Hanssen-Bauer and Snow 1996; Yli-Renko, Autio and Sapienza 2001; Yli-Renko, Autio and Sapienza 2001). This study provided the empirical evidence that respondents utilize all these knowledge resources, but their importance and levels of utilization is varied among the facilities. Personal interviews showed that respondents in general do not use personal relationships with former employees or classmates for work-related knowledge networking. Future research could examine the role of *external* facilitators and impediments to external knowledge networking, and the importance of policy makers in facilitating the flow of knowledge among external knowledge resources.

3. ***Importance of Collocation in knowledge networking:*** There is ample evidence in the literature on knowledge networking, which shows that communication increases by co-locating teams, and is further enhanced when groups work in non-territorial spaces. Empirical studies show that in these settings, communication barriers among R&D teams were sizably lower after co-location (Allen 1977; Van den Bulte and Moenart 1997). The results from this study confirmed this finding among the respondents from all three facilities. The most important knowledge resources for both *KNPS* and *KNCRDI* networks are the respondents' facilities and projects, even if there are more direct methods of accessing the information, as is the case with

KNCRDI networks. However, although the results do not dispute the importance of collocation, this study also shows evidence that significant knowledge networks can exist without collocation, such as with Central R&D. Future research could examine the characteristics of these networks that allow them to prosper, without the need for collocation.

8.3.3 Virtual Knowledge Networks and Communication Tools

The following are the areas where the results of this study make a contribution to the current literature on virtual knowledge networks, and use of communication tools, as well as areas for future research needs.

1. Virtual Tools' Influence on the Overall R&D Process: The current thinking in the literature is that virtual knowledge networks impact R&D primarily by altering the overall R&D process, as well as providing a critical medium for linking the development of information and new knowledge with its application (Antonelli, Guena and Steinmueller 2000; Plymale and Hartgrove 1999). The results of this study show that there is a widespread utilization of internal databases among the respondents. However, I find little evidence of virtual communication tools altering the R&D process. Most respondents feel that in its current level of sophistication and utilization, virtual communication tools are extremely useful in providing the basic information about products and processes, but it certainly has not altered the overall R&D process. Specifically, future research could examine the changes that need to take place before virtual tools fulfill their promise of transforming the R&D process. It may very well be that continued sophistication and adaptation of the new virtual tools may be enough.

2. Four General Categories of Functions for Virtual Tools: Researchers have identified four general categories of Internet functions that have potential benefits in the R&D process: (1) as communication tools; (2) as connection tools; (3) as transfer tools; and (4), as access tools

(Antonelli, Guena and Steinmueller 2000; Plymale and Hartgrove 1999). The results of this study showed that the most important function of virtual tools is as communication tools, such as e-mail. The second most important function is to access databases in order to transfer and download files. Overall, the results confirmed the four functions of virtual tools in R&D settings. As part of a future research, it would be useful to know how the importance of these functions evolves, and what new functions will become more relevant. Future research could not only define these new functions, but provide the empirical evidence as to their worth in actual R&D settings.

8.3.4 Gatekeeper Analysis

Below are the results of this study on the role of gatekeepers in knowledge networks, their contribution to the current literature and the areas of future research needs.

1. The Role of Gatekeepers: The current thinking on the functions of gatekeepers is that they, (1) search outside information, (2) translate the knowledge for internal use, and (3) communicate it internally with the members of the organization (e.g., Allen and Cohen 1969; Allen 1977; Katz and Tushman 1981; Tushman and Katz 1980). Although the findings in this study showed that the gatekeepers in the three facilities perform the following functions, it also extends the current thinking by showing that there can be more than one type of gatekeepers, and as such these individuals do not have to be adept at translating all forms of external knowledge, but rather they can specialize in specific areas. This specialization allows the individuals to develop more robust formal and informal networks with these external knowledge resources, which allows them to tap into both the explicit and implicit knowledge. However, as the sources of external knowledge become more diverse in globalized R&D settings, it would be useful to conduct a longitudinal study that examines how gatekeeper roles

come into existence, how they evolve, how they flourish in new global locations, and whether MNEs can develop 'professional' gatekeepers who can play the role in different locations.

2. Gatekeepers utilization of Communication Tools: There have been a number of studies on the role of gatekeepers who manage and organize outside information through the use of communication tools (e.g., Roy-Norelid 2004; Hinds and Bailey 2003), but there is very little in the literature on gatekeepers that examines how the utilization of their communication tools differs from non-gatekeepers. The results of this research showed that all gatekeepers under analysis utilized a more extensive set of communication tools than non-gatekeepers. This was particularly true of their utilization of second and third tier tools, such as web-conferencing, government databases, general Internet resources, and instant messaging. The key question that could be explored in the future is whether the additional utilization of communication tools is as the result of more extended knowledge networks, or whether the extended knowledge networks are possible because of the enhanced utilization of communication tools.

8.3.5 Factors Affecting Knowledge Networks and Utilization of Communication Tools

The following are my findings on the factors that influence the manner in which individuals utilize their knowledge resources, the extent of their knowledge networks, and their utilization of communication tools. This is an area where this study has made significant contribution to the current literature on knowledge networking.

1. Personal Attributes and Location: The most relevant literature is on the relationship between an organization's demographic composition and the manner in which it influences communication, because people tend to communicate with those who are similar to themselves (Kanter 1977; Pfeffer 1983; Simmel 1950). Zenger and Lawrence (1989) examined the relationship between age and tenure and communication frequency and showed that tenure

exerts an important influence on the technical communication frequency for individuals outside project groups.

The results of this study show that personal attributes influence the individuals' knowledge networks, but the extent of this influence is dependant on the knowledge network. For example, male respondents and managers, have more extensive *KNCRDI* networks than female respondents and employees, respectively. However, there is a positive relationship between the extent of knowledge networking, and the firm and facility tenure of individuals. As such, individuals who have been with their firms or facilities for longer periods of time utilize more of their available knowledge resources, and both and facility tenure are a factor in knowledge networking. Finally, the findings show that there is no relationship between the location of the R&D facility where the individuals works and the extent of the individual's knowledge networking levels, or the types of knowledge resources the individuals utilizes. By extension, given the differences in language and culture between the individuals from the three facilities, and the homogeneity of culture and language among the individuals within the three facilities, the findings show little correlation between the extent of knowledge networking of individuals and their background culture and language.

The findings from this study point to robust future research questions. Among them: Do gender or position play a role in knowledge networking for other types of knowledge networks than problem solving or innovation discovery, or in a different setting than R&D? Do facility and firm tenure continue to be positively associated with the level of knowledge networking for other types of knowledge networks or in different settings other than R&D? Are there other location attributes that can be important in affecting the extent of knowledge networking, such as the size of the R&D facility, the number of years in operations, the number of product affiliation, its location within the country, its proximity to headquarters? There

could also to be more research that examines the relationship between language and culture and its affects on knowledge networking more directly.

2. ***Resource Allocation***: The current thinking in the literature is that the level of resource allocation among organizations, contributes to the motivation and ability to exchange and transfer knowledge that enhances the growth of intellectual capital. In addition, social capital provides benefits of relevance, timeliness and trustworthiness of the information and knowledge shared and used in a network (Nahapiet and Ghoshal 1998; Sandefur and Laumann 1998; Coleman 1988, Tsai and Ghoshal 1998). The findings from this study show that in this case, the most significant factor in determining the importance of an internal knowledge resource for both *KNPS* and *KNCRDI* networks is the amount of resources that are devoted to Central R&D. This form of organizational design results in a concentration of talent and experience, which enhances Central R&D's internal social capital, that has proven itself to be extremely useful in the past, and continues to be utilized to the present. The fact that managers have a great deal of influence over the knowledge flow and knowledge networking of their employees through their resource allocation allows for a great deal of planning and management initiatives that can direct the employees' knowledge networks. Future research could look specifically at modeling the relationship between resource allocation, organizational design, and knowledge networking.

3. ***Personal Resources and Individuals Social Capital:*** The existing thinking in the literature is that greater levels of social interaction, and access between an individual and its key contacts increase the knowledge the individual acquires through that relationship. This is accomplished through intensifying role interactions, by enhancing the individual's ability to recognize and evaluate pertinent knowledge and by increasing its incentives to exchange and process information (Ring and Van de Ven 1992; Cohen and Levinthal 1990; Lane and Lubatkin 1998;

Dyer and Singh 1998). In this study I show that additional personal resources that are derived from such job-related activities as mobility, complexity, training, and mentorship, exposes individuals to additional formal and informal contacts that can serve as future direct or intermediary knowledge resources. Future research areas could look at all available job-related resources, and to develop the framework that examines the relationship between these resources, and the level of knowledge networking between individuals.

5. Trust: In Chapter 2, I discussed two critical dimensions of trust for knowledge networking: emotional trust and cognitive trust. Emotional trust is the development of non-calculative and spontaneous emotional bonds and affect among two or more people, while Cognitive trust refers both to judgments of competence and reliability about the other members of a team (McAllister 1995; Clark, Mills and Corcoran 1989; Lewis and Wiegert 1985). The results of study confirm the importance of cognitive and emotional trust in knowledge networks. Trust helps facilitate the extended amount of knowledge networking between individuals and their colleagues in their project, facility and Central R&D, and impedes the flow of knowledge between individuals, and their global and external knowledge resources. Trust is also an issue in virtual knowledge networking because of the opacity of where the information is going or where the information is coming from. As the extent and diversity of knowledge resources grow in globalized R&D settings, and as MNEs tap into local, external, virtual and global knowledge networks, lack of trust among the different nodes in the knowledge networks could prove to be one of the most difficult bottlenecks in the knowledge networks for MNEs' management to solve. Future research could conduct additional case studies of successful 'trust management' among MNEs and to identify the characteristics and initiatives associated with it.

6. Facility History and Mandate: Currently, there is very little in the literature on how the history of a facility as it is shaped by government policy affects knowledge networking. The

results of this study show that in the case of Brazil, the facility's history and mandate are greatly influenced by government policy, which also influenced the manner in which the respondents utilize and access global knowledge resources. Future research could identify additional cases where there has been a strong relationship between government policy and the evolution of the mandate and growth of an R&D facility.

8.3.6 Globalization of R&D

In Chapter 2, I identified the five relevant drivers behind MNEs' efforts to globalize their R&D operations, which are, proximity to markets, proximity to suppliers, proximity to sources of knowledge and talent, stimulating innovation, and, ability to influence research. The following are the areas where the results of this study make a contribution to the current literature on globalization of R&D, as well as areas for future research needs.

1. Proximity to Markets: According to researchers, proximity to customers provides individuals with direct, unfiltered insight into customers' needs, which in turn allow them to be more responsive to those needs in designing and developing their products for that particular market (Granstrand, Håkanson, and Sjörlander 1992). The results of this study show that among the external knowledge resources, customers are one of the most utilized ones. The respondents also found their knowledge networking with customers to be useful or very useful for problem solving. In short, the results of this finding confirm the current thinking in the literature of globalization of R&D. However, future research could examine the extent of knowledge networking with customers in different settings, for different knowledge networks, and temporally, in order to understand how these networks evolve over time.

2. Proximity to Suppliers: The present opinion in the literature is that proximity to suppliers allow the suppliers and the MNEs to engage in joint R&D ventures, in order to minimize risks,

but more importantly to satisfy diverse final-customer demand (Granstrand, Håkanson and Sjörlander 1992). This study's findings show that similar to their knowledge networking with customers, the respondents also have strong knowledge networking relationship with their suppliers. Future research could also examine these networks across time, in different settings, and for different purposes.

3. Proximity to Sources of Knowledge and Talent: Currently, analysts believe that in order for MNEs to gain access to the output of concentrated sources of technology, they have to be physically close to them, and participate in the local network of technology production (Granstrand, Håkanson and Sjörlander 1992). However, my findings show very limited knowledge networking between the respondents, and other firms or R&D facilities. However, each facility does have a group of gatekeepers who have knowledge networking relationships with academia. Future researchers could examine how the needs for knowledge networking with other firms can be reconciled with security concerns, and how MNEs' can tap into the knowledge networks of academic communities without having to hire the students from these institutions, and how they can foster and take advantage of these networks once they do hire these individuals.

4. Stimulating Innovation: The current thinking in the literature is that the blending of different educational systems, market environments, and customs generate new innovations (Granstrand, Håkanson and Sjörlander 1992). The findings from this study find little evidence of this type of blending. The external knowledge networking was done through gatekeepers, and from both the mail-in surveys and personal interviews, it was apparent that there was little or no contact between the majority of respondents, and the international R&D community that was present in all these regions. There is a distinct discrepancy between this study's findings and the current thinking in the literature on this topic. Future research could examine the

conditions under which these R&D operations engage in the type of networking that can stimulate innovation, and what steps need to be taken in order to insure the type of blending that is currently described in the literature. Table 8.12 shows the summary of the above discussion.

Table 8.12: Summary of Research Findings and Contribution to Literature

Area	Factor	Research Finding	Contribution to Literature
Border-Crossing Networks	Physical Distance	Major factor in knowledge networking, but does not hold true for Central R&D.	Confirms and extends.
	Organizational Distance	Empirical verification through the case of the Brazilian facility.	Confirms and extends.
	Knowledge Distance	Its importance *does not* hold true in any of the border-crossing knowledge networks.	Challenges.
	Cultural Distance	The strongest knowledge networking took place within the facilities.	Confirms.
Local Networks	Learning Regions	Existence of some local knowledge networking through gatekeepers.	Weak confirmation.
	Exploiting Local Knowledge	Low importance and utilization of local knowledge resources through gatekeepers.	Weak confirmation.
	Importance of Collocation	The most important knowledge networks are with the facilities and projects.	Confirms and extends.
Virtual Networks	Virtual Tools' Impact on R&D	Little evidence of virtual communication tools altering the R&D process.	Challenges.
	4 Functions of Virtual Tools	The respondents utilize the four functions of virtual tools in R&D settings.	Confirms.
Gatekeeper analysis	The role of Gatekeepers	Gatekeepers can have specialized external knowledge networking.	Contributes.
	utilization of E Tools	Gatekeepers utilized a more extensive set of communication tools than non-gatekeeper.	Contributes.
Knowledge Networks Facilitators and Impediments	Attributes & Location	The most important personal attributes are firm and facility tenure	Contributes.
	Resource Allocation	The findings showed the importance of organizational design and resource allocation.	Contributes.
	Personal and Social Resources	The importance of job mobility, job complexity, training, and mentorship.	Contributes.
	Trust	The results show the importance of trust in all knowledge networks under analysis.	Confirms.
	Facility History and Mandate	Brazil showed their importance through government policy in knowledge networking.	Contributes.

Area	Factor	Research Finding	Contribution to Literature
Globalization of R&D	Proximity to customers	The findings show that customers are among the most utilized external knowledge sources.	Confirms and extends.
	Proximity to Suppliers	The findings show that suppliers are also among the most utilized knowledge sources	Confirms and extends.
	Proximity to Expertise	Little evidence of extensive knowledge networking with sources of expertise.	Challenges.
	Stimulating Innovation	Little evidence of blending that results in the ability to stimulate innovation.	Challenges.

Source: Literature Review; Qualitative and Quantitative Analyses (Chapters 2, 5, 6, and 7).

8.4 Addendum: Knowledge Networks, Globalization of R&D and Sustainable Development

As I stated earlier in this chapter, the impetus and the underlying questions for this study came from my findings in the communication and social networks of R&D employees of a large chemical MNE (Shirvani-Mahdavi 2001). Although I changed the focus of this study, future research on knowledge networking for environmental innovation, can bring together a number of research strands that could make significant contribution to both the literature on sustainable development, and knowledge networks. There are a number of reasons why studying knowledge networks for sustainable development will be fruitful to management of international firms, environmental researchers, and policy makers.

The first reason is that leading companies, such as AMBE, recognize that while only a small portion of their R&D is made exclusively for environmental reasons, the majority of their R&D investments include an environmental component. Firms invest in research and technology to improve the resource efficiency of their products and manufacturing processes because it is cost effective to do so. R&D investments are made for many reasons, among them cost reduction, market access, and product improvement, of which environmental consideration is only one. However, it is also true that environmental considerations are being elevated during the R&D planning process because they have linked these concerns to the primary business objectives.

In addition, if markets exist, companies undertake even radical change to satisfy them. All the companies, including AMBE, monitor their customers' willingness to pay for environmental attributes. AMBE tracks global trends in resource scarcity, environmental regulations, voluntary product standards, and customer environmental priorities and needs, so they can respond rapidly to emerging markets. AMBE is also changing their relationship with suppliers and customers. Organizational and services innovation, such as tighter links between manufacturers, their suppliers, and their customers, may spur additional technology innovations to lessen environmental effects at lower cost or increase technology diffusion. Furthermore, AMBE shares information with suppliers and customers regarding environmental regulations, resource scarcity, product standards, and customer environmental priorities in order to develop new products and services with improved environmental features. In the past, these links were important for AMBE for expanding the use of recycled materials and product remanufacture as well as for creating alternative, more environmentally benign chemicals. In other cases, however, AMBE requires suppliers to avoid certain chemicals and to develop processes to manage environmental issues.

Future research into knowledge networks for sustainable development and environmental innovation must take the results of this study as a starting point to examine whether knowledge complexity, such as those involving Environmentally-friendly Design (EfD), affects knowledge networks and what factors can help facilitate the flow of knowledge among globally dispersed scientists. In addition, future research must examine whether private personal concerns of R&D scientists can influence their research agenda, even if they are not completely supported by the firm. In other words, in R&D settings where personal initiative is rewarded, as is the case with AMBE, would a scientist's own environmental concerns spill over into the type of research they conduct, and if so, how can these initiatives be placed on the

facility's R&D agenda. In the end, global and local knowledge networking among R&D scientists is important for sustainable development because they bring together local and global solutions in an innovatory setting of powerful actors in the quest for the development of environmentally friendly technologies.

8.5 Conclusion

My study identifies the relationship between knowledge networking and three sets of factors that can act as facilitators or impediments for effective internal, external and border-crossing knowledge networks. The first set of these factors, personal attributes, prove to play a minor role in the manner in which individuals utilize their knowledge resources. The main exception to the above finding is the role of firm and facility tenure. I also found the second factor, the facility's location, which I used as a proxy for the respondent's language and culture, to be inconsequential in the respondents' knowledge networking. The last set of factors, mostly internal to the facility or the firm, proved to be more important to the knowledge networking of the respondents and the manner in which they utilize their communication tools. Although the findings from this research provide the empirical evidence for the current theories in the literature on knowledge networks and globalization of R&D, it also negates some of the current assumptions. There is a great deal of additional research that can be conducted to confirm these findings in different settings, across different time periods, and different knowledge networks, particularly those that involve complex knowledge, such as sustainable development.

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