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Alliance Networks

An Investigation among Iranian SMEs in the Nanotech Industry

Fatemeh Salehi

Luleå University of Technology

Master Thesis, Continuation Courses
Marketing and e-commerce
Department of Business Administration and Social Sciences
Division of Industrial marketing and e-commerce

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Alliance Networks: An Investigation among Iranian SMEs in the Nanotech Industry

Supervisors:
Dr. Mehdi Sepehri
Prof. Albert Caruana

Examiners:
Dr. Amir Albadvi
Dr. Parastoo Mohammadi
Dr. Naser Salmasi

Prepared by:
Fatemeh Salehi

Tarbiat Modares University Faculty of Engineering
Department of Industrial Engineering

Lulea University of Technology
Division of Industrial Marketing and E-Commerce

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Abstract

In order to thrive, SMEs are claimed to need networks comprising a variety of relationships. High-tech firms that seek to reduce costs, respond speedily to market demands and build competitive advantages around their core competencies cannot execute strategies without drawing on the skills and resources of other organizations. A comprehensive insight of the surrounding network of SMEs is vital for managers, policymakers, and business marketers to achieve growth and profitability.

The purpose of this study is to investigate alliance network of Iranian SMEs active in Nanotech industry. The thesis aims to provide a thorough understanding of actor firms and their relationships in the network, recognize prominent actors, and identify entrepreneurial opportunities around them.

Extensive review of prior researches allowed us to obtain the suitable approach for investigating and analyzing the network. Semi-structured interviews with twenty four Iranian Nanotech SME managers are conducted to unveil their alliances with other companies, organizations and research centers. The interview framework is designed based on possible cooperation areas of high-tech firms, extracted from literature, and is refined regarding high-tech business experts' opinions and pilot interviews.

After collecting the data, social network analysis techniques are used to identify prominent players in the network. As well as the analysis of the entire network of Iranian Nanotech SMEs relations, networks of specific cooperation types are presented that enable the investigation of the network from different perspectives. Entrepreneurial opportunities surrounding prominent actors were unveiled via applying structural hole analysis on the network.

The results show salient actors along with opportunities facing them in the network of Iranian Nanotech SMEs. Furthermore, dense and sparse alliance networks of SMEs present the areas they have more strengths or weaknesses. Moreover, the distinguishing characteristics of the networks are described in managerially helpful ways in order to increase the strategic value of the alliances.

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Chapter One

Introduction

1 Introduction

Marketing, in essence, is about the management of the external relations of the firm and the marrying of this with internal operations (Wilkinson and Young, 2002). It is not enough for marketers just to try to understand and work with their customers. Instead they must understand what happens in the wider network that surrounds them and both constraints their operations and provides opportunities for growth (Ford et al., 2002).

This study is based on the idea that if we want to understand the behavior of a business company then we have to look at its relationships with other companies. Rather than being a free agent able to develop and implement their strategy alone, each is dependent on others in order to act and each has to react to or accommodate the aims and strategies of others. In other words, the basic assumption of network thinking is that, "no business is an island" (Ford et al., 2002, Hakansson and Snehota, 1990).

The growing technological intensity of companies' offerings and the rising costs of technological development have led companies to specialize in fewer of the skills needed to satisfy the requirements of their end-customers. This has increased the interdependencies among actor firms and has caused greater interest in networks by business people (Ford et al., 2002). In order to succeed, SMEs are claimed to need

networks comprising a variety of relationships. These networks compound of diverse actors including suppliers, subcontractors, customers and lead users, as well as competitors, universities, R&D partners, distributors, business service providers, and investment partners (Möller et al., 2007).

Having a deep understanding of the surrounding network of SMEs, recognizing salient players in the network, and identifying entrepreneurial opportunities will help managers in setting proper market strategies, and partnerships development to achieve growth and profitability. This research investigates the alliance network of SMEs active in Nanotech industry in Iran to provide policy makers, SME managers, and business-to-business marketers with an insightful analysis of the network they are situated in.

This introductory chapter of the thesis begins by defining alliance network and stressing its importance in business operations. Then, the research background is described, followed by an explanation of our target industry in this study. The subsequent section includes problem definition which guides the reader to the research questions. Finally, structure of the thesis is presented.

1.1 Alliance Network Definition

In its most abstract form a network is a structure where a number of nodes are related to each other by specific threads. Håkansson and Ford (2002) mentioned that a complex business market can be seen as a network where the nodes are business units – manufacturing and service companies and the relationships between them are the threads. Both the threads and the nodes in the business context have their own particular content. Both are ‘‘heavy’’ with resources, knowledge and understanding in many different forms. This heaviness is the result of complex interactions, adaptations and investments within and between the companies over time. It is not a world of individual and isolated transactions between companies. Instead, each node or business unit, with its unique technical and human resources is bound together with many others in a variety of different ways through its relationships.

In this research, we consider a network as a set of actors together with a set of linkages between the actors. The actor may be an organization, firm, university, research center, or laboratory. The linkage embraces a diversity of collaborative forms like joint Research and Development activities, financial cooperation, supplier-buyer partnerships, joint production activities, distribution coalitions, managerial cooperation, marketing alliances, outsourcing agreements, and joint ventures. These relationships have been referred to as 'partnerships', 'networks', or 'strategic alliances', but they all describe how the role of a tightly integrated hierarchy is supplanted by 'loosely coupled' networks of organizational actors (Lin and Zhang, 2005). In this study, we use the term network to encompass various forms of collaboration and emphasize the action of connecting.

1.2 Alliance Network Importance

A firm is embedded in a network of ongoing business and non-business relationships, which both enable and constrain its performance (Ritter et al., 2004). Networks are important to marketers, strategists and entrepreneurs (Pitt et al., 2006b). Marketers, for example, are interested in the social networks of which customers become part, for they may determine how rapidly innovations spread through a market. In business-to-business markets, marketers would wish to pay attention to the networks in which customer firms act as nodes, and also to the informal networks that exist within buying centers, in order to determine relative influence and the nature of roles (Pitt et al., 2006a).

Strategists often study organizational networks in order to determine the existence or otherwise of strategic alliances, or to ascertain where power lies in a seemingly unstructured set of contacts. Students of entrepreneurship and marketers alike have noted that in many cases entrepreneurial innovation comes not only from the development of new offerings or the identification of new markets, but from the assembly of diverse units into a new entrepreneurial form (Pitt et al., 2006a).

Alliances are becoming increasingly important as vehicles for improving economic performance and creating competitive advantages (Dyer et al., 2008). Networking is important for all small firms but it is particularly important for small high-tech or new technology-based firms. The reasons for this appear to relate to two features of such

firms, namely the high level of uncertainty in both technology and market, and the interdependency of technology development in other firms. These firms do not use management in the normal sense. They have to establish a network and create a networking behavior, generating the meaning of management in their network. They do not start by having specified roles, and this makes the networking as action very important. Networking is a type of organizing, in which new small high tech firms develop projects. It is impossible to understand these firms without their networks (Moensted, 2007).

Thus, no one interaction, whether it is a sale, purchase, advice, delivery or payment can be understood without reference to the relationship of which it is a part. Similarly, no one relationship can be understood without reference to the wider network. Each company gains benefits and incurs costs from the network in which it is embedded and from the investments and actions of all of the companies involved (Håkansson and Ford, 2002).

1.3 Alliance Network Background

While the study of relationships and networks in business has a long history, their role and importance in value creation and delivery is the subject of increasing attention in the marketing and business literature (Ritter et al., 2004). Examples of this are the development of concepts of collaborative advantage; the role and importance of cooperative strategies and alliances; cooperation and competitive advantage (Wilkinson and Young, 2002); the development of the Industrial Marketing and Purchasing (IMP) Group[1] and the markets-as-networks tradition; the rise of relationship marketing in marketing management theory (Möller and Halinen, 1999); focus on the network properties of markets and economies (Achrol and Kotler, 1999); and advances in logistics and supply chain management (Ritter et al., 2004).

The tasks of managing in relationships and networks have been discussed in various ways in the literature, using a number of different concepts. Ritter et al. (2004) have structured

[1]The IMP (Industrial Marketing and Purchasing) Group was formed in 1967 by researchers from five European countries. The group has since carried out a large number of studies into business relationships and the wider networks in which they operate.

these contributions to several levels of relationship and network management. These are depicted in Figure 1-1, where each dot represents an individual actor, which could be a person, business unit, firm, or other type of organization.

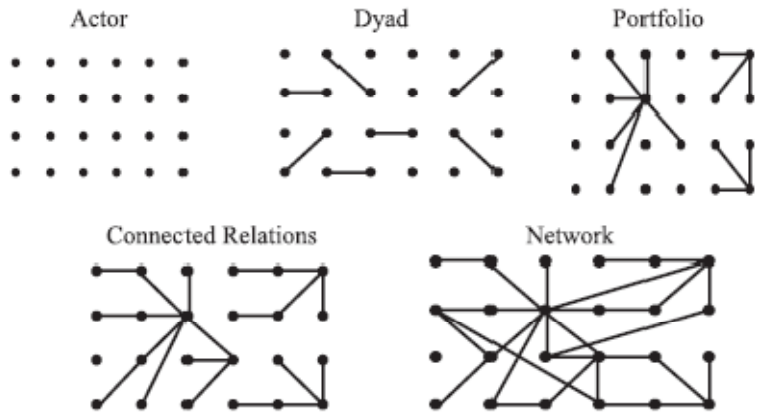


Figure 1-1. Levels of relationship and network management (Ritter et al., 2004)

The first level is the individual actor viewed in isolation, which is similar to most resource-based theories of firms. But as Ford et al. (2002) have pointed out, a firm is not an island but is connected to other firms and organizations in important ways that require management attention. The second level is that of the individual dyad. This has been the focus of much research attention in the study of buyer–seller relationships in business markets and distribution systems. But relationships, like firms, are not isolated from each other but are interconnected forming networks (Wilkinson and Young, 2002).

One form of connection between relationships centers on an individual actor or firm, which is simultaneously involved in a number of relationships. These constitute an actor or firm's relationship portfolio and the set of tasks involved in managing such a set of relationships. The fourth level of management is that of connected relationships in which the actor is not directly involved, such as the indirect connections between a firm and its customer's customers or supplier's suppliers. Here, the role of relationships as bridges or conduits to other relationships becomes important, giving rise to various types of indirect network functions of relationships. The strength of weak ties as important potential bridges to different types of actors and knowledge becomes relevant (Ritter et al., 2004).

The final level of management is that of the network itself. Here, the concepts of network or macro-position and network identity become relevant. These arise as a result of the interactions taking place among actors in the network, from the various micro-positions of actors, including interaction between and within firms and other types of organizations (government actors), and business and non-business interactions (Ritter et al., 2004). The present study focuses on the fifth level of network management because it aims to provide a thorough understanding of the surrounding network of Nanotech SMEs in Iran.

1.4 Research Area

Nanotechnology presents opportunities to create new and better products. A nanometer is one billionth of a meter (10^{-9} m) – about one hundred thousand times smaller than the diameter of a human hair, a thousand times smaller than a red blood cell, or about half the size of the diameter of DNA. Nanotechnology is defined as research and technology development at the atomic, molecular, or macromolecular levels using a length scale of approximately one to one hundred nanometers in any dimension; the creation and use of structures, devices and systems that have novel properties and functions because of their small size; and the ability to control or manipulate matter on an atomic scale (U.S. Environmental Protection Agency, 2007).

Governments and private entities are pouring billions of dollars into Nanotechnology research and development each year. Nanotechnology will revolutionize society's manufacturing processes and will have nearly boundless applications (Lin, 2007).

In recent years, Iran's policymakers have emphasized the development of science and technology, and particularly the development of high-tech industry (Ghazinoory and Heydari, 2008). Since early 2001 Islamic Republic of Iran has begun its activities to develop Nanoscience and technology. The twenty year vision of the country has emphasis on developing and promoting Nanotechnology nationally. In August 2003, the Iranian National Nanotechnology Initiative Council (INIC) was established to achieve this goal. Its 10 year strategy plan has started from 2005 and aims to gain access to the proper position among the 15 advanced nations in Nanotechnology in 2015 (Iran Nanotechnology Initiative Council, 2006).

According to the statistics by international databases such as Web of Science (ISI) Iran has gone up from 52nd in 2001 to 25th in 2007 in the ranking for paper publication in Nanotechnology-related fields by an increase from 17 to 465 papers, representing about 0.8 percent of all papers worldwide (Maghrebi and Kazemi, 2008).

Iranian government supports Nanotechnology-related businesses by providing service like financing, giving business information, managerial, technological, and marketing consultations, holding general and professional training courses, facilitating international cooperation of the firms, etc. These services are offered to Nanotech SMEs by Iran Nanotechnology Business Network (INBN) that was established by INIC in 2007 and aims to strengthen Nanotech companies in the country.

1.5 Problem Definition and Research Questions

It is vital for policymakers, strategists, SME managers, and business-to-business marketers to be acutely aware of their surrounding environment to make sound decisions. Gaining a comprehensive insight of the surrounding network is much more important for firms competing in high-technology markets where much-hyped hyper competition has become a reality. Whether they want to be or not, indeed, whether they are aware of it or not, these firms will find themselves to be part of local and global networks (Pitt et al., 2006b). To be beneficiary of opportunities and manage challenges of an industry, it is essential to understand the network of involved players and their relationships deeply.

This research aims to investigate the network of SMEs active in Nanotech industry in Iran to answer the following research questions:

1. What is the current state of alliance networks facing SMEs active in nanotechnology arena in Iran?
2. Who are the most prominent actors in these networks?
3. What are the entrepreneurial opportunities surrounding these actors?

1.6 Structure of Thesis

The rest of this report is structured as follows. Chapter two provides a review on alliance networks' literature, discusses benefits and risks of getting involved in strategic alliances, and also explains IMP group approach toward business networks. Furthermore, social network theory and the theory of structural holes and previous alliance network studies that used these theories are overviewed in the next chapter.

Chapter three describes the methodology we used to investigate alliance network of Nanotech SMEs in Iran. It includes the research design and the method used for collecting and preparing data on SMEs and their relationships. Then the methodology for applying social network analysis techniques on the gathered data, specifically prominence analysis method, is discussed. Following that, the method of discovering structural holes in a network is explained.

The results obtained from applying the analysis on the network are presented in chapter four. It illustrates the network pictures from different perspectives along with a thorough description of number and nature of alliances. Results of prominence analysis are discussed in detail and salient actors in each network are identified. Then, the results of structural hole analysis are mentioned and possible entrepreneurial opportunities surrounding prominent actors are pointed out.

Chapter five concludes by providing answers to the research questions and some managerial implications. It also presents limitations of the current study and directions for future research.

Chapter Two

Literature Review

2 Literature Review

This chapter reviews pros and cons of getting involved in strategic alliances, and also explains IMP group approach toward alliance networks. Furthermore, social network theory and the theory of structural holes and previous studies that have used these theories to investigate alliance networks are overviewed in this chapter.

2.1 Benefits of Strategic Alliances

A firm's relationships are one of the most valuable resources that a company possesses. They provide direct benefits in terms of the many valued functions they perform and the resources they help create and provide access to, including knowledge and markets. They also provide indirect benefits because they grant access to other relations, organizations, resources, and competencies. A firm's ability to develop and manage successfully its relationships with other firms may be viewed as a core competence, which varies among firms and which is an important source of competitive advantage (Ritter et al., 2004).

Gilmore et al. (2006) also address access to information, resources, markets and technologies as motives for engaging in inter-organizational ties and cooperation and issue their importance in a competitive circumstance.

Other advantages of network participation are considered to include learning, trust, norms, equity and context. Research on 'learning' explores whether firms that have experience working with other organizations are more likely to form new network ties and become dominant players in networks. The importance of 'trust' in building inter-organizational networks is also acknowledged, and the difficulties of measuring trust and its effect on inter-firm co-operation. Research into 'norms' and monitoring showed that even if actors trust one another, problems may arise when they collaborate. 'Equity' relates to where collaborations are more likely if partners have similar status and power, and 'context' relates to the broader cultural, historical and institutional context of inter-organizational networks (Gilmore et al., 2006).

There are other reasons for the increase of alliances, in spite of their difficulties. The globalization of competition requires a strong presence in the three major markets, the Americas, the Asia-pacific region, and Europe. This demands very high investments in marketing and distribution. Another aspect increasing the cost of operation is the advancing technological complexity. Most industries are becoming more knowledge intensive. Pressures on resources and capabilities have led companies to seek strategic alliances with such competitors with whom they have joint interests in some markets and/or product fields, and such goals and competence profiles which are mutually compatible. Therefore, no firm can afford to be a self-contained "island" anymore; learning through relationships is crucial for the battle over the future (Möller and Halinen, 1999).

The issue is much more beneficial and critical for smaller firms, as is stated in the literature. Small firms are not strong enough in their own resources and have to organize to get an influence on project development by generating projects in networks (Moensted, 2007). By configuring effective alliance networks at founding, startups access social, technical, and commercial competitive resources that normally require years of operating experience to accumulate, buffering themselves from hazards typically faced by new firms and sowing seeds of future opportunities to develop their alliance networks (Baum et al., 2000).

In sum, according to Pittaway et al. (2004), Lipparini and Sobero (1994), Biemans (1992, 162) cited by (Möller et al., 2007), (Lin and Zhang, 2005), and (Dicksona et al., 2006), the actors provide the SMEs with a variety of benefits including:

- Sharing the economic risk of an innovation development
- Realizing cost-efficiency in operation
- Achieving reduced time-to-market
- Pooling complementary skills
- Offering access to financial resources
- Enabling access to new markets, technologies and knowledge
- Increasing flexibility, speeding up organizational learning
- Affecting the structure of competition, sustaining competitive advantages

The capability to form and manage partnerships is relevant in all industries but particularly in high-tech industries. High-tech industries are characterized by rapid technological change that has a major effect on the management of innovation, not only within companies but also within partnerships (Hagedoorn, 1993; Powell, 1998). The more companies develop partnering capabilities, the more these are expected to be useful in quickly responding to promising new technological opportunities through various partnerships (Hagedoorn et al., 2006).

2.2 Risks of Strategic Alliances

Although considerable debate exists regarding the risks and benefits of building relationships with other organizations for commercial purposes, few would disagree that forming and managing external relationships is an important strategy for small business development (Street and Cameron, 2007). However, effectively doing so appears to be a difficult issue, given that an estimated 60% of partnerships fail (Ritter et al., 2004).

Baum et al. (2000) discuss that strategic alliances are inherently incomplete contracts in which the property rights associated with alliance output and profits may not be well defined. As a result, collaborators risk opportunistic exploitation by their partners, including leaking proprietary knowledge to partners or otherwise losing control of

important assets. Opportunistic behavior, from an RBV (Resource-based View) perspective, is seen as behavior that while designed to maximize the resources derived from an alliance by a participant to the alliance is not necessarily in the best interest of the alliance (Dicksona et al., 2006). Although appropriate use of governance structures might ameliorate these concerns, intra-alliance rivalry retains the potential to severely disrupt an alliance and to harm a participating firm (Baum et al., 2000).

Empirical findings of Gils and Zwart (2004) indicate that Several entrepreneurs do not cooperate because they fear transferring their know-how and losing their competitive advantage (Gils and Zwart, 2004). Another risk comes from the issue that inter-firm partnerships are by definition linked to more than one company where shared responsibilities increase potential managerial complexity (Hagedoorn et al., 2006).

(Brass et al., 2004) have done a review research on the antecedents and consequences of inter-organizational networks.

Considering all the benefits and risks of making alliances, each company should have an insightful knowledge of its surrounding environment in order to mitigate the risks and benefit from the opportunities in the network it faces. IMP group approach helps us to examine alliance networks which provide both opportunities and restrictions for any company.

2.3 IMP Group Approach

Ford et al., (2002) developed a way of analyzing the content of a single relationship within a network:

Activity Links

A relationship can systematically link the inter-dependent activities performed in a supplier and a customer. This can include basic service or production activities. It can also include the activities that facilitate or control a production process. It can also include logistics or design (Ford et al., 2002).

Resource Ties

A relationship can also tie together resources in both of the companies. These resources may be the products, service capabilities or facilities that are built together through the relationship. The tie can be physical, such as when a pipeline connects the two companies but more commonly it is the knowledge resources of the two companies that are adapted to each other (Ford et al., 2002).

Actor Bonds

Business relationships always have a social content. People in the two companies get to know each other through interaction and this is important in the growth of trust, which is necessary for the relationship to develop. Sentiments, attitudes, norms and values are affected by the evolution of the relationship and the two companies become part of the same social system. These social dimensions add up to the bonds existing between the two companies. These bonds are a central part of the identity of a company and of its ability to work with others (Ford et al., 2002).

2.3.1 Connected Relationships

A relationship is developed through interaction between two companies. Yet in this interaction the two companies cannot just think about developing this relationship by itself, but must also relate it to the other relationships they have. Managing and developing a relationship is not an isolated activity, but just one piece in a larger puzzle that IMP group call a network. A marketing manager responsible for developing a single relationship must consequently look at in this larger context and how it affects a larger *activity pattern*, *resource constellation*, and *web of actors* (Ford et al., 2002).

Activity Pattern

The activities that the supplier and customer perform in relation to each other must synchronize the two company's operations, but all their other relationships provide restrictions and opportunities for this process. Production, logistics, administration, design can all be moved, redesigned or connected to each other in different ways and

different relationships, on both the supplier's and the customer's side. The overall outcome of this activity pattern is determined by interaction between all of the companies involved. This determines the efficiency of the network as a whole and the well-being of each company (Ford et al., 2002).

Resource Constellation

The resources involved in a relationship are also parts of a larger whole. The offering of a single company will depend on its own resources and those of other companies. The ties between these different resources are important as they affect the characteristics of each of them. Through interaction, the different resources are systematically related to each other, embedded in each other's operations and developed in order to cope with each other's characteristics and requirements. In this way the two companies "co-evolve" (Ford et al., 2002).

Web of Actors

The companies in a network do not just consist of a set of resources that perform activities. They are purposefully directed by many individual actors. These individuals form a social structure and have views of each other in relation to the total network and they act on those views. The individuals bring the network to life. As in all social structures there are elements of friendship, closeness, distance, antagonism, prejudice, and so on. The individuals may belong to professional associations, they may change their employment between companies in the same network. Their companies may be connected through ownership or there may be strong cultural or operational links between them. These individuals try systematically to influence each other as their companies co-evolve. This process of individual influence is both an effect of the co-evolving relationships between companies in the network, but also an important influence on it (Ford et al., 2002).

2.3.2 Positions in a Network

A network is a special organizational form that relates companies to each other in a particular structure based on their relationships with others. Each company in a network has a unique position in relation to all the others. A company's network position is defined by the characteristics of the company's relationships and the benefits and obligations that arise from them (Ford et al., 2002).

A company's network position determines the opportunities and restrictions that it faces. A realistic understanding of these is an essential preliminary to developing and changing that network position. Analyzing network position, deciding and achieving change, are the essence of business marketing strategy (Ford et al., 2002).

IMP Group approach of analyzing relationships in a network along with other related literature were used to design the framework for semi-structured interviews with managers which will be discussed in chapter three. Next part provides a review of social network theory (SNT) and theory of structural holes (TSH) that are used in this study.

2.4 Social Network Theory

While the study of social networks had its origins in sociology (Granovetter, 1973; cited by (Pitt et al., 2006b)), it has also become important to both academics and practitioners in business disciplines such as marketing, international business, strategy and entrepreneurship (Pitt et al., 2006b).

SNT argues that decision making is not done independently but in consideration of the relationship an object has with other objects in the network. This combination of objects and relationships allows complex social networks to be modeled and provides a strong theoretical and mathematical basis for testing hypotheses about social relationships and their influences (Pitt et al., 2006b).

Next section defines social network and its fundamental concepts.

2.4.1 Fundamental Concepts in Network Theory

There are several key concepts at the heart of network analysis that are fundamental to the discussion of social networks. This section provides definitions of some of these key concepts needed for this study.

Actor. Social network analysis is concerned with understanding the linkages among social entities and the implications of these linkages. The social entities are referred to as *actors*. Actors are discrete individual, corporate, or collective social units. Examples of actors are people in a group, departments within a corporation, public service agencies in a city, or nation-states in the world system (Wasserman and Faust, 1994).

Relational Tie. Actors are linked to one another by social *ties*. The range and type of ties can be quite extensive. The defining feature of a tie is that it establishes a linkage between a pair of actors. Some of the more common examples of ties employed in network analysis are: evaluation of one person by another (for example expressed friendship, liking, or respect), transfers of material resources (for example business transactions, lending or borrowing things), etc (Wasserman and Faust, 1994).

Group. To a large extent, the power of network analysis lies in the ability to model the relationships among systems of actors. A system consists of ties among members of some (more or less bounded) group. A *group* is the collection of all actors on which ties are to be measured (Wasserman and Faust, 1994).

Relation. The collection of ties of a specific kind among members of a group is called a *relation*. For example, the set of friendships among pairs of children in a class room, or the set of formal diplomatic ties maintained by pairs of nations in the world, are ties that define relations. For any group of actors, several different relations might be measured (Wasserman and Faust, 1994).

Social Network. Having defined actor, group, and relation we can now give a more explicit definition of social network. A *social network* consists of a finite set or sets of actors and the relation or relations defined on them. The presence of relational

information is a critical and defining feature of a social network (Wasserman and Faust, 1994).

2.4.2 Modes of Network

The most common type of network is a *one-mode* network, since all actors come from one set. A network data set containing two sets of actors is referred to as a *two-mode* network, to reflect the fact that there are two sets of actors. A two-mode network data set contains measurements on which actors from one of the sets have ties to actors in the other set (Wasserman and Faust, 1994). Higher-modes social networks are also discussed in social network literature.

2.4.3 Direction of Networks

Directional ties in a network have an origin and a destination, for example person A regards person B as a close friend, which does not necessarily mean that person B regards person A as a close friend as well. Non-directional ties have no direction, for example, if person A lives near person B, it automatically implies that person B lives near person A (Pitt et al., 2006a).

2.4.4 Centrality and Power

All sociologists would agree that power is a fundamental property of social structures. There is much less agreement about what power is, and how we can describe and analyze its causes and consequences (Hanneman and Riddle, 2005). This part we will look at some of the main approaches that social network analysis has developed to study power, and the closely related concept of centrality.

The Several Faces of Power

Degree

Actors who have more ties to other actors may be in advantaged positions. Because they have many ties, they may have alternative ways to satisfy needs, and hence are less dependent on other individuals. Because they have many ties, they may have access to,

and be able to call on more of the resources of the network as a whole. Because they have many ties, they are often third parties and deal makers in exchanges among others, and are able to benefit from this brokerage. So, a very simple, but often very effective measure of an actor's centrality and power potential is their degree (Hanneman and Riddle, 2005).

In undirected data, actors differ from one another only in how many connections they have. With directed data, however, it can be important to distinguish centrality based on in-degree from centrality based on out-degree. If an actor receives many ties, they are often said to be *prominent*, or to have high *prestige*. That is, many other actors seek to direct ties to them, and this may indicate their importance. Actors who have unusually high out-degree are actors who are able to exchange with many others, or make many others aware of their views. Actors who display high out-degree centrality are often said to be *influential* actors (Hanneman and Riddle, 2005).

Closeness

Degree centrality measures might be criticized because they only take into account the immediate ties that an actor has, rather than indirect ties to all others. One actor might be tied to a large number of others, but those others might be rather disconnected from the network as a whole. In a case like this, the actor could be quite central, but only in a local neighborhood (Hanneman and Riddle, 2005).

Closeness centrality approaches emphasize the distance of an actor to all others in the network (Hanneman and Riddle, 2005). Closeness measures how close an actor is to all the other actors in the network. An actor is central if it can quickly interact with all others. The measure finds actors with the shortest communication paths to the others (Pitt et al., 2006a).

Betweenness

Betweenness centrality views an actor as being in a favored position to the extent that the actor falls on the paths between other pairs of actors in the network. That is, the more

people depend on me to make connections with other people, the more power I have (Hanneman and Riddle, 2005).

This measure is important because ‘a point of relatively low degree [centrality] may play an important ‘intermediary’ role and so be very central to the network. The betweenness of a point measures the extent to which an agent can play the ‘broker’ or ‘gatekeeper’ with a potential for control over others’ (Scott, 1991; cited by (Pitt et al., 2006a)).

Eigenvector

The eigenvector approach is an effort to find the most central actors (i.e. those with the smallest farness from others) in terms of the "global" or "overall" structure of the network, and to pay less attention to patterns that are more "local" (Hanneman and Riddle, 2005). Actors with high eigenvector centralities are those which are connected to many other actors which are, in turn, connected to many others (and so on). The perceptive may realize that this implies that the largest values will be obtained by actors in high-density substructures (Butts, 2007).

A company with strategic network capabilities is expected to be able to position itself in such a way that it can draw information and learn from a variety of partnerships. In terms of social network theory this implies that a company with well-developed specific network capabilities acts as a strategic player that has maneuvered itself in a central position in between other companies. A company with such a central position in an inter-firm network is understood to have information about both the positioning of other companies in the network and their information flows, which enables it to use its central position to successfully choose future partners (Freeman, 1977; Knoke and Kuklinski, 1982; Wasserman and Faust, 1994; cited by (Hagedoorn et al., 2006)). Furthermore, a central network position shapes a company’s reputation as a skilled and knowledgeable partner that makes it an attractive partner for other companies in the network (Brass, Butterfield and Skaggs, 1998; Powell, Kogut and Smith-Doerr, 1996; cited by (Hagedoorn et al., 2006)).

As mentioned in this section, SNT explains the mechanisms and structures that individuals use to accumulate power in social settings, leading to the related construct of social capital (Scott, 1991; Wasserman and Faust, 1994; cited by (Pitt et al., 2006a)). Contingent to SNT is the theory of structural holes which aims to explain 'how competition works when players have established relations with others' (Burt, 1992). Next part provides a review of TSH and related concepts.

2.5 Theory of Structural Holes

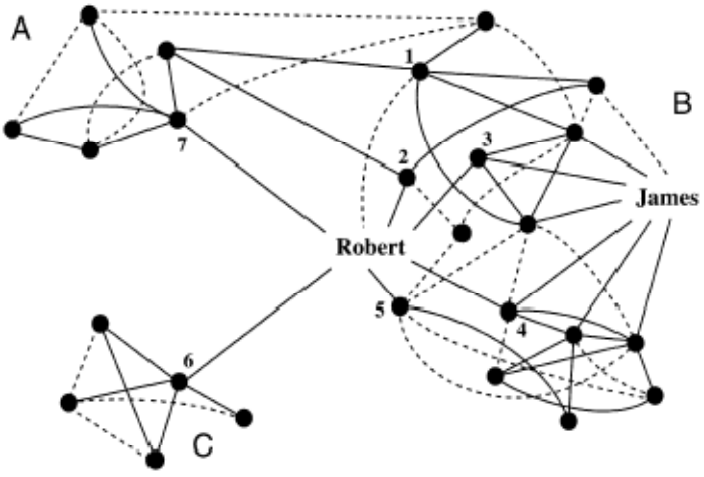
According to Burt (1992), much of competitive behavior and its results can be understood in terms of player access to "holes" in the social structure of competitive arena. The holes in social structure, or, more simply, structural holes, are disconnections or non-equivalencies between players in the arena. Structural holes are entrepreneurship opportunities for information access, timing, referrals, and control. Burt (1992) explains how players with networks rich in structural holes – players with networks that provide high structural autonomy – enjoy high rates of return on their investments. These players know about, take part in, and exercise control over more rewarding opportunities. Competitive advantage is a matter of access to holes (Burt, 1992).

2.5.1 Social Capital

A player brings at least three kinds of capital to the competitive arena. First, the player has financial capital. Second, the player has human capital. Third, the player has social capital: relationships with other players. The social capital of people aggregates into the social capital of organizations. Property and human assets define the firm's production capabilities. Relations within and beyond the firm are social capital (Burt, 1992).

Social capital is different from financial and human capital. First, it is a thing owned jointly by the parties to a relationship. No one player has exclusive ownership rights to social capital. Second, social capital concerns rate of return in the market production equation. Through relations with colleagues, friends, and clients come the opportunities to transform financial and human capital into profit (Burt, 1992).

The social capital metaphor is that certain people have an advantage because they are better connected to other people. Think of society as a market in which individuals and groups exchange ideas, goods, support, etc. Over time, certain people meet more frequently. Certain people have sought one another out. Certain people have completed exchanges with one another. There is at any moment a network, as illustrated in Figure 2-1, in which individuals are variably connected to one another as a function of prior contact, exchange, and attendant emotions. Figure 2-1 is a generic sociogram and density table description of a network. People are denoted by circles. Relationships are denoted by lines. Solid (dashed) lines connect pairs of people who have a strong (weak) relationship. Cell (A and B) of the density table is the average strength of relationship between people in groups A and B (Burt, 2002).



Density Table of Relations Within and Between Groups

.65			Group A (5 people and 8 ties; 5 strong, 3 weak)
.05	.25		Group B (17 people and 41 ties; 27 strong, 14 weak)
.00	.01	.65	Group C (5 people and 8 ties; 5 strong, 3 weak)

Figure 2-1. (A–C) Social capital and bridges across structural holes (Burt, 2002)

Selecting the best exchange, however, requires that each person has information on available goods, sellers, buyers, and prices. Information can be expected to spread across

the people in a market, but it will circulate within groups before it circulates between groups (Burt, 2002).

For example, the sociogram in Figure 2-1 shows three groups (A, B and C), and the density table at the bottom of the figure shows the generic pattern of in-group relations stronger than relations between groups in that diagonal elements of the table are higher than off-diagonals (each cell of a density table is the average of relations between individuals in the row and individuals in the column). The result is that people are not simultaneously aware of opportunities in all groups. Even if information is of high quality, and eventually reaches everyone, the fact that diffusion occurs over an interval of time means that individuals informed early or more broadly have an advantage (Burt, 2002).

2.5.2 Bridges across Structural Holes

The weaker connections between groups in Figure 2-1 are holes in the social structure of the market. These holes in social structure – or more simply, structural holes – create a competitive advantage for an individual whose relationships span the holes. The structural hole between two groups does not mean that people in the groups are unaware of one another. It only means that the people are focused on their own activities such that they do not attend to the activities of people in the other group. Holes are buffers, like an insulator in an electric circuit. People on either side of a structural hole circulate in different flows of information. Structural holes are, thus, an opportunity to broker the flow of information between people, and control the projects that bring together people from opposite sides of the hole (Burt, 2002).

Robert and James in Figure 2-1 have the same volume of connections, six strong ties and one weak tie, but Robert has something more. James is connected to people within group B, and through them to friends of friends all within group B. James can be expected to be well informed about cluster B activities. Robert is also tied through friends of friends to everyone within group B, but in addition, his strong relationship with contact 7 is a conduit for information on group A, and his strong relationship with 6 is a conduit for information on group C. His relationship with 7 is for Robert a network bridge in that the

relationship is his only direct connection with group A. His relationship with contact 6 meets the graph-theoretic definition of a network bridge. Break that relationship and there is no connection between groups B and C. More generally, Robert is a broker in the network (Burt, 2002).

2.5.3 Structural Holes and Control Benefits

Once structural holes are identified an important question is how these benefits can be used to capitalize on the opportunities in the network. Structural holes not only provide information benefits, they also give actors a certain amount of control in negotiating their relationships with other actors. The concept of *tertius gaudens* ['the third who benefits'] (Simmel, 1923; cited by (Pitt et al., 2006a)), describes the person who benefits from the disunion of two others. For example, when two people want to buy the same product, a third (the seller) can play their bids against one another to get a higher price. Structural holes are the setting in which the tertius gaudens operates. An entrepreneur stepping into a structural hole at the right time will have the power and the control to negotiate the relationship between the two actors divided by the hole, often by playing their requirements against one another (Pitt et al., 2006a).

2.6 Previous Alliance Network Studies

Networks of strategic alliances have been studied in many industries, for instance the studies of (Powell et al., 2005) on the biotech industry, (Baum et al., 2003) on bank syndicates, (Riccaboni and Pammolli, 2002) on the life sciences and ICT industry, (Ahuja, 2000) on the international chemicals industry. There were business network studies that used SNA (Rank et al., 2006, Gay and Dousset, 2005, Schilling and Phelps, 2007), and some researchers added TSH to their examination of alliance networks (Hagedoorn et al., 2006, Zaheer and Bell, 2005, McCarthy et al., 2007, Pitt et al., 2006b, Pitt et al., 2006a).

Here we focus on Pitt et al. (2006b) investigation of alliance networks. In their article they examined the networks facing SMEs in the biotechnology industries in Sweden and Australia. They compared the structures of networks in business-to-business markets in

two countries, and show how these associations can improve participants' effectiveness, and ultimately, their social capital and financial returns in global markets.

They used one-mode business networks on the Internet made up of a set of actors with directional ties. Websites of Biotech SMEs were considered as nodes and hyperlinks as ties between the nodes. Using social network analysis salient actors in the network were identified. Then structural hole analysis was used to identify possible entrepreneurial opportunities in the network.

Based on their research, Swedish firms find themselves linked strongly to American government departments, and Australian players are significantly connected to major Indian firms. They mentioned that social network analysis enables international managers to become aware of these links in order to explore the opportunities they may present, and perhaps to minimize the possible threats they may imply. The Structural Hole Analysis identified several possible entrepreneurial opportunities for global firms and suppliers of biotech products in the network.

Reviewing previous alliance network studies allowed us to obtain the suitable approach for investigating and analyzing the alliance network of Nanotech SMEs in Iran. Next chapter describes the methodology applied in this study which is mostly based on the research done by Pitt et al. (2006).

Chapter Three

Research Methodology

3 Research Methodology

In this chapter the research methods that are used to answer the research questions are presented. The chapter starts with a description of the research design and explains the method used for collecting and preparing data on SMEs and their relationships. Then the methodology for applying social network analysis techniques on the gathered data, specifically prominence analysis method, is discussed. Following that, the method of discovering structural holes in a network is explained. Finally, the way we used to visualize network data in this study is mentioned.

3.1 Research Design

The research design constitutes the blueprint for the collection, measurement, and analysis of data (Cooper and Schindler, 2003). It specifies the procedures necessary to obtain the information needed to structure and/or solve the research problem. Research designs are of two broad types: exploratory and conclusive. As is shown in figure 3-1

conclusive designs may be further categorized as either cross-sectional or longitudinal (Malhotra and Peterson, 2006). Figure 3-1 also highlights the type of research design pursued in this study.

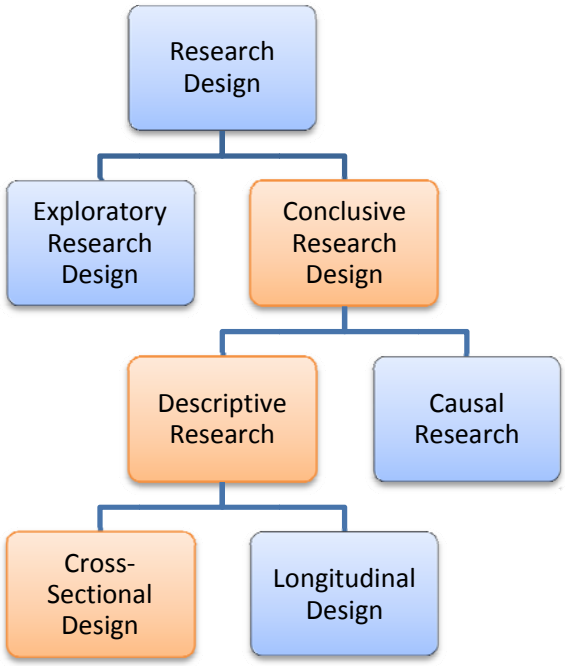


Figure 3-1. A Classification of market research designs (Malhotra and Peterson, 2006)

Exploratory research is a type of research design that has as its primary objective the provision of insights into and comprehension of the problem situation confronting the researcher. Conclusive research is research designed to assist the decision maker in determining, evaluating, and selecting the best course of action for a given situation. Conclusive research can be used to verify the insights gained from exploratory research (Malhotra and Peterson, 2006).

Descriptive research is a type of conclusive research that has as its major objective the description of something – usually market characteristics or functions (Malhotra and Peterson, 2006). This type of research is concerned with finding out *who*, *what*, *where*, *when*, or *how much* (Cooper and Schindler, 2003). Like descriptive research, causal research requires a planned and structured design. But major objective of a causal

research is to obtain evidence regarding cause-and-effect relationships (Malhotra and Peterson, 2006).

This thesis aims to investigate the network facing SMEs active in Nanotech industry in Iran and find out who the most prominent actors are and what entrepreneurial opportunities exist in this network. Therefore it is considered a descriptive kind of research.

3.1.1 Research Time Dimension

Cross-sectional studies are carried out once and represent a snapshot of one point in time. Longitudinal studies are repeated over an extended period (Cooper and Schindler, 2003). This research involves the one-time collection of information so pursues a cross-sectional design. The cross-sectional design is the most frequently used descriptive design in marketing research (Malhotra and Peterson, 2006).

3.2 Data Collection Method

In order to collect data on business network of Iranian Nanotech SMEs, we need to recognize actors of the network and unveil the links connecting them.

3.2.1 Identifying Actors

SMEs active in Nanotech industry in Iran were identified using information provided by Iran Nanotechnology Initiative Council (INIC), which is a governmental organization under the auspices of Technology Cooperation Office of Presidency of Iran. INIC has a database of companies working in Nanotech industry in Iran. Currently, there are twenty four Iranian Nanotech firms that all of them are investigated in this study.

3.2.2 Identifying Relationships

Regarding IMP group approach, it is possible to investigate the content of relationships in a network by interviews and by inspection of offerings, facilities and routines and in this way build a picture of the activity links, resource ties and actor bonds that they contain (Ford et al., 2002). In this research semi-structured interviews (of two hours) were

conducted with managers of all twenty four Iranian Nanotech firms to unveil their alliances with other companies, organizations and research centers.

Semi-structured Interview

A semi-structured interview is a method of research used in the social sciences. While a structured interview has a formalized, limited set of questions, a semi-structured interview is flexible, allowing new questions to be brought up during the interview as a result of what the interviewee says. The interviewer in a semi-structured interview generally has a framework of themes to be explored (Lindlof and Taylor, 2002).

To guide the interview to gain the desirable data on relationships of NF[2]s, an interview framework was designed based on possible cooperation areas of high-tech firms. These cooperation fields were extracted from literature and interview questions were designed on their basis. Then two high-tech business experts were asked for their opinions to refine the questions and make them appropriate for the Iranian context. In addition, three pilot interviews were done in order to achieve an acceptable precision in asking questions. Interview questions are shown in appendix A.

Table 3-1 shows cooperation fields of the interview framework and their references.

Table 3-1. Cooperation Types

No.	Cooperation area	References
1	Joint R&D Activity (New product design, Gaining new knowledge and technology, Patent analysis, etc.)	(Ford et al., 2002, Veludo et al., 2004, Möller et al., 2007) & Expert Opinion
2	Investment/financial resources	(Neves, 2007)
3	Supplying raw materials	(Ford et al., 2002, Neves, 2007, Möller et al., 2007)
4	Joint Production Activity (Producing new or complementary product or service, developing production lines, etc.)	(Ford et al., 2002)
5	Cooperation with Industrial customers	(Ford et al., 2002, Möller et al., 2007)

[2] Nanotech Firm

No.	Cooperation area	References
6	Distribution network (Iran or foreign branches or sales representatives)	(Ford et al., 2002, Möller et al., 2007)
7	Marketing	(Ford et al., 2002, Möller et al., 2007)
8	Logistics	(Ford et al., 2002)
9	Managerial Cooperation (Joint strategy setting, joint planning and problem solving, Consulting, etc.)	(Veludo et al., 2004, Möller et al., 2007)
10	Product standardization	Expert Opinion
11	Other relationships	

Interviews enabled the gathering of data on each NFs partners, types of their relationships (Table 3-1), and the strength of each relationship.

Each Cooperation tie could be strong or weak. By strong tie we mean long-term cooperative relationship between NFs and other actors. Weak ties indicate on short-term relationships with others or those relationships that less time or energy is invested. Weak ties are worthy since they may result in strong alliances in future.

3.3 Data Preparation Process

3.3.1 Coding

After conducting semi-structured interviews, the data on cooperation ties of NFs needed to be prepared in a suitable format for analysis. Each actor (i.e. NFs, universities, organizations, research center, etc) was assigned a code number. Names and code numbers of all actors in the network are shown in tables 7-1 and 7-2 in appendix B.

Different types of cooperation are also assigned a number to allow analysis of networks of specific relations (which will be discussed in chapter four).

3.3.2 Constructing Network Matrix

The analytic software used in this study (R software[3], SNA package) gets the network 'adjacency matrix' as input for analysis. Therefore the way the matrix was constructed is described here.

The adjacency matrix represents who is next to, or adjacent to, whom in the network (Hanneman and Riddle, 2005). There are as many rows and columns as there are actors in the data set. The elements of the matrix represent the strength of ties between the actors. For our matrix, values of '1','0.5', and '0' are considered for 'strong ties', 'weak ties', and 'no ties' respectively.

3.4 Data Analysis Method

As mentioned in previous chapter, SNT provides a strong theoretical and mathematical basis for testing hypotheses about social relationships and their influences. This study uses social network analysis techniques to identify the most prominent actors in Iran Nanotech business network. Then, using structural hole analysis, the entrepreneurial opportunities surrounding these actors are unveiled.

This part starts with explanation of methods for calculating actor prominence measures which are used for prominence analysis. Then the method of discovering structural holes in a network is discussed.

3.4.1 Actor Prominence Measures

Prominence analysis is done using five measures that their definitions were discussed in chapter two. Here we mention the method for calculating each measure.

Degree

Degree centrality measures the proportion of actors that are adjacent to a particular actor (Wasserman and Faust, 1994). In directed networks we can distinguish between in-degree

[3] A Programming Environment for Data Analysis and Graphics, Version 2.7.1 (2008-06-23)

and out-degree. *Out-degree* computes the number of links sent to another actor, while *in-degree* refers to the number of links received by each actor.

Closeness

In order to calculate closeness of an actor we need to define path and distance. A *path* in a network is a sequence of links in which no actor in between the first and last actors occurs more than once. In an undirected network, the distance between two actors is simply the number of links or steps in the shortest path that connects the actors. A shortest path is also called a *geodesic*. In a directed network, the geodesic from one actor to another is different from the geodesic in the reverse direction, so the distances may be different. The *distance* from actor u to actor v is the length of the geodesic from u to v (Nooy et al., 2005).

With the concept of distance, we can define closeness centrality. The closeness centrality of an actor is based on the total distance between one actor and all other actors, where larger distances yield lower closeness centrality scores. The closer an actor is to all other actors, the easier information may reach it, the higher its centrality. The closeness of an actor v in network G is defined as

$$Closeness(v) = \frac{Number\ of\ other\ actors}{Sum\ of\ all\ distances\ between\ v\ and\ all\ others}$$
$$= \frac{|V(G)| - 1}{\sum_{i\ in\ V(G)} d(v,i)\,, i \neq v}$$

where $d(i,j)$ is the distance between i and j.

Closeness is ill-defined on disconnected networks, unless distances between disconnected actors are taken to be infinite. In this case, $Closeness(v) = 0$ for any v lacking a path to any actor, and hence all closeness scores will be 0 for networks having multiple weak components (Freeman, 1979).

Betweenness

The betweenness centrality of an actor is the proportion of all geodesics between pairs of other actors that include this actor. The betweenness of an actor v is given by

$$Betweenness(v) = \sum \frac{g_{ivj}}{g_{ij}} \quad i \neq j, i \neq v, j \neq v$$

where g_{ijk} is the number of geodesics from i to k through j (Freeman, 1979).

Eigenvector

Eigenvector centrality (implemented in SNA via evcent) is simply the absolute value of the principal eigenvector of A (where A is the network adjacency matrix). This can be interpreted variously as a measure of "coreness" (or membership in the largest dense cluster), "recursive" or "reflected" degree (i.e., v is central to the extent to which it has many ties to other central nodes), or of the ability of v to reach other actors through a multiplicity of short walks (Butts, 2008).

To identify the most prominent actors in the network, we compute five prominence measures (i.e. in-degree, out-degree, closeness, betweenness, and eigenvector) for each actor in the network. These values will be normalized via dividing them by their maximum value. Then the average (mean) values of five prominence measures are obtained for each actor. Three actors having higher mean values are recognized as prominent actors in the network. The reason behind, is that prominence by definition incorporates the full extent of centrality measures, not just a high score on one of the measures.

3.4.2 Method of Discovering Structural Holes

Actors identified to be prominent in the network are further analyzed to unveil entrepreneurial opportunities around them. This is done by means of a code, written in R software, based on Burt's (1992) formula of structural holes.

The analysis includes several measures, the most important of which are:

- p_{ij}, the proportion of i's network time and energy invested in each relationship (Burt, 1992);
- c_{ij}, the constraint of absent primary holes. An actor's (i) entrepreneurial opportunities are constrained to the extent that another of his contacts (q), with whom he has a strong relationship, invested heavily and therefore also has a strong relationship with actor j. c_{ij} must therefore be low for structural holes (entrepreneurial holes) to exist (Burt, 1992);
- O_i, the lack of holes around the actor itself (Burt, 1992).

Burt's formulas for calculating above measures are defined as

$$p_{ij} = \frac{A_{ij} + A_{ji}}{\sum_{q \in V \setminus i}(A_{iq} + A_{qi})}$$

$$c_{ij} = \left(p_{ij} + \sum_{q \in V \setminus i,j} p_{iq} p_{qj} \right)^2 O_j$$

for a graph of order N, where A is the graph adjacency matrix (Burt, 1992).

O_j, oligopoly, is a measure of the organization of players within the cluster around contact j such that it would be difficult to replace j, or threaten him with being replaced, by some other in the cluster. There are several ways of measuring O_j. The measure varies from a minimum of zero to an upper limit of one. Picking one measure for O depends on available data and cluster boundaries in a study population. The most direct measure would be to have network data on players and relations within the cluster around contact j. To the extent that j is a central player connected with everyone else in the cluster, there are few structural holes to develop between him and the people with whom you could replace him ($O_j = 1$) (Burt, 1992).

Structural holes occur around a specific actor when he has a large O_i (no or few structural holes around the actor himself); and there is a large p_{ij} and a small c_{ij} at the other end of a relationship with another actor (large amount of time and energy invested in the relationship, small constraint on the actor's entrepreneurial opportunities). These conditions give rise to what Burt (1992) calls the hole signature of an actor. Visual representation of the difference between p_{ij} and c_{ij}, as is shown in section 4.3 chapter four, provides an easy way to identify the structural holes around a specific actor (Pitt et al., 2006b).

3.5 Data Visualization Method

Network analysis uses one kind of graphic display that consists of points (or nodes) to represent actors and lines (or edges) to represent ties. When sociologists borrowed this way of graphing things from the mathematicians, they re-named their graphics "sociograms". Mathematicians know the kind of graphic displays by the names of "directed graphs" "signed graphs" or simply "graphs" (Hanneman and Riddle, 2005).

For our purpose we used *gplot* function, the standard network visualization tool within the SNA library of R software, to illustrate sociograms. This function generates a layout using Fruchterman and Reingold's force-directed placement algorithm (Fruchterman and Reingold, 1991) in order to draw networks.

Chapter Four

Data Analysis and Results

4 Data Analysis and Results

The results obtained from applying the analysis on the network are presented in this chapter. It illustrates the network pictures from different perspectives along with a thorough description of number and nature of alliances. Results of prominence analysis are discussed in detail and salient actors in each network are identified. Then, the results of structural hole analysis are mentioned and possible entrepreneurial opportunities surrounding prominent actors are pointed out.

4.1 Iran Nanotech SME Network

The sociogram containing all actors and their relationships is depicted in figure 4-1. There are 614 actors and 785 links.

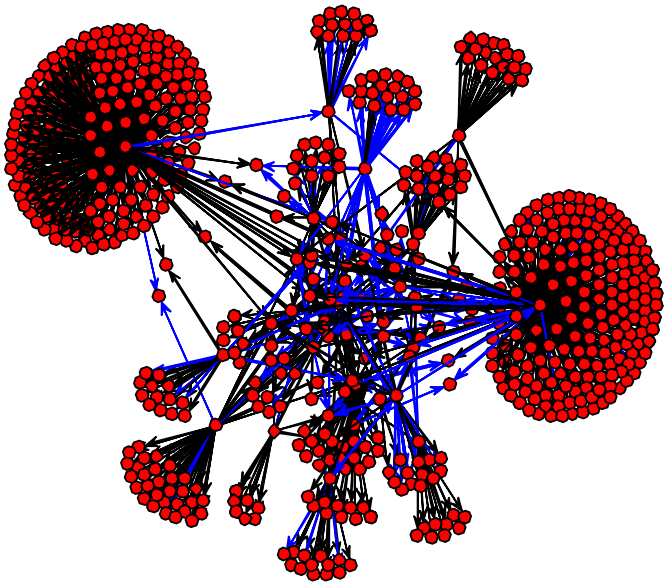


Figure 4-1. Iranian Nanotech SME Network – All Ties

In figure 4-1 actors are presented with red circles. Black arrows show strong ties between actors and blue ones represent weak ties. The direction of each tie shows that source NF has established cooperation tie with destination node. Type and number of source NFs are shown in figure 4-2. Destination node might be a company, a university or research center or other organizations. Number of all actors in the network is listed in table 4-1. Each actor has a code number and name that are shown in appendix B.

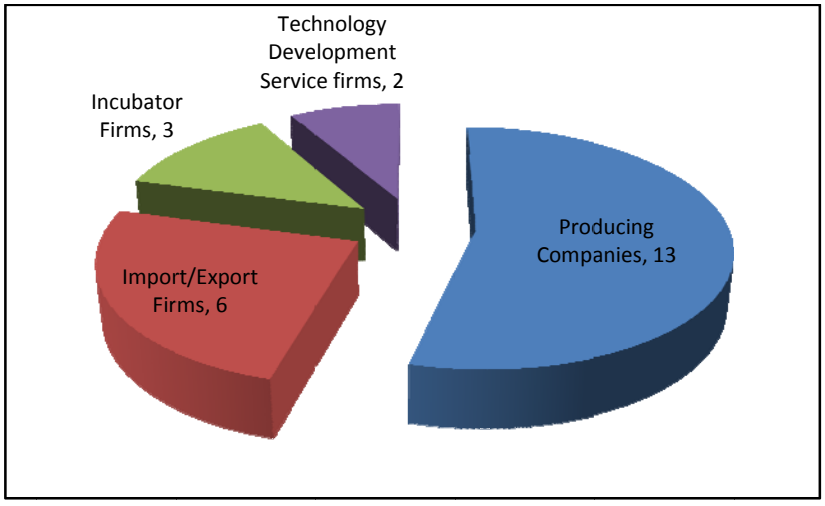


Figure 4-2. Type and number of Nanotech SMEs

Table 4-1. Type and number of all actors in the network of Nanotech SMEs

Category	Number	Code
Nanotech Company	**24**	**1XX**
• Producing Companies	13	
• Tech Development Service firms	2	
• Import/export Companies	6	
• Incubator firms	3	
University & Research Center	**43**	**2XX**
• Iranian Universities	18	
• Iranian Research Centers	15	
• Iranian Laboratories	4	
• Foreign Universities	2	
• Foreign Research Centers	4	
Other Companies or Organizations	**547**	**3XX, 3XXX**
• Iranian private companies	63	
• Iranian branches of NFs	393	
• Foreign branches of NFs	13	
• Iranian governmental organizations	34	
• Foreign companies	44	
Countries	**41**	**4XX**
All Nodes	**614**	

It is difficult to draw meaningful conclusions just by looking at the network. Therefore social network analysis techniques are used to discover which of these nodes are most prominent in the network.

4.2 Prominence Analysis Results

Five centrality measures were computed, namely in-degree centrality, out-degree centrality, closeness, betweenness, and eigenvector. Table 4-2 shows a summary of the results. For each centrality measure, six nodes that have higher values are presented. The numbers under *Node* column in the table refer to the actor's code number and *Value* column shows the calculated centrality measure for that node.

Table 4-2. Prominence measures – Nanotech SME network

In-degree		Out-degree		Closeness		Betweenness		Eigenvector	
Node	*Value*	*Node*	*Value*	*Node*	*Value*	*Node*	*Value*	*Node*	*Value*
313	19.5	104	215.5	313	0.5093	102	125335.08	102	0.5622
223	9.0	102	204.0	102	0.4511	104	116769.53	104	0.4059
201	7.5	108	39.0	104	0.4393	313	50885.60	313	0.1102
205	7.0	113	30.5	209	0.4272	108	20164.31	113	0.0923
209	6.5	107	22.5	223	0.4223	124	16691.85	223	0.0854
212	6.0	115	19.0	220	0.3979	121	14266.15	209	0.0754

Table 4-2 shows that node 313 (INIC) has a high in-degree centrality. This means that most NFs have cooperation ties with INIC. Two other nodes that receive more links are 223 (Tarbiat Modares University) and 201 (University of Tehran - Nano Science & Technology Research Center).

If we consider out-degree centralities, nodes 104 (Kaveh Float Glass Co.) and 102 (Nano Nasb Pars Co.) have higher number of links sent to other actors with a substantial difference with node 108 and other nodes in this column. This is due to the large number of ties they have with other actors and their wide branch network which will be discussed later in this chapter. Figure 4-3 shows the Nanotech SME network with emphasis on nodes' out-degree centrality. Size of each node in the sociogram is a function of its out-degree measure. There are twenty four nodes bigger than others which are twenty four SMEs investigated for this study.

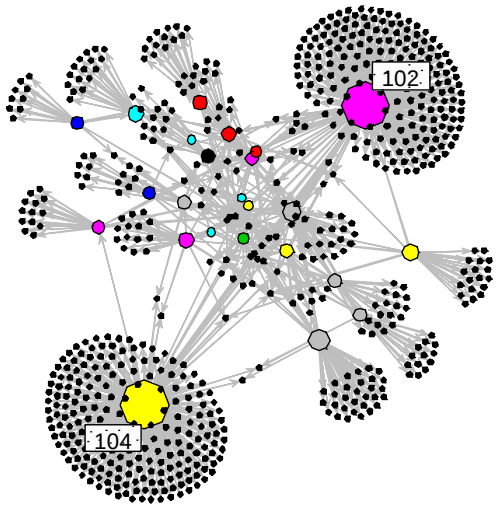


Figure 4-3. SME network with node size based on out-degree

In table 4-2, Node 313 (INIC) has a higher closeness centrality measure that means INIC can quickly interact will all other actors in the network since it has the shortest communication paths to others. Betweenness identifies 102 and 104 as actors that are between many actors in their linkages with each other. These two nodes have also higher eigenvector centralities. It means they are connected to many other actors which are, in turn, connected to many others (and so on).

After normalizing all prominence measures and calculating the mean for each node in the sociogram, three most prominent actors in SME network are unveiled. Table 4-3 shows prominent actors with their reference number, name, and average value of normalized prominence measures.

Table 4-3. Prominent actors in SME network

Prominent Nodes	Node Name	Normalized Mean
102	Nano Nasb Pars Co.	0.80
104	Kaveh Float Glass Co.	0.70
313	Iran Nanotechnology Initiative Council	0.52

The network examined above contains relationships of all kind among actors. For a detailed investigation, sociograms of specific link types are discussed below.

4.2.1 R&D Network

One of the important networks obtained is the network showing cooperation of NFs with universities, laboratories, and research centers on their joint research and development activities (Figure 4-4). There are twenty NFs that have strong or weak R&D ties with other actors. Totally there are 107 actors and 145 relationships in this sociogram.

NFs do not have R&D alliances with each other, mostly they have cooperation with universities and research centers in Iran. This way they are connected to each other indirectly. Some NFs have R&D collaborations with universities or research centers in other countries, therefore disconnected from others. For example node 114 (Nano Sina Co.) has R&D alliance with node 3573 (Fraunhofer Institute) in Germany.

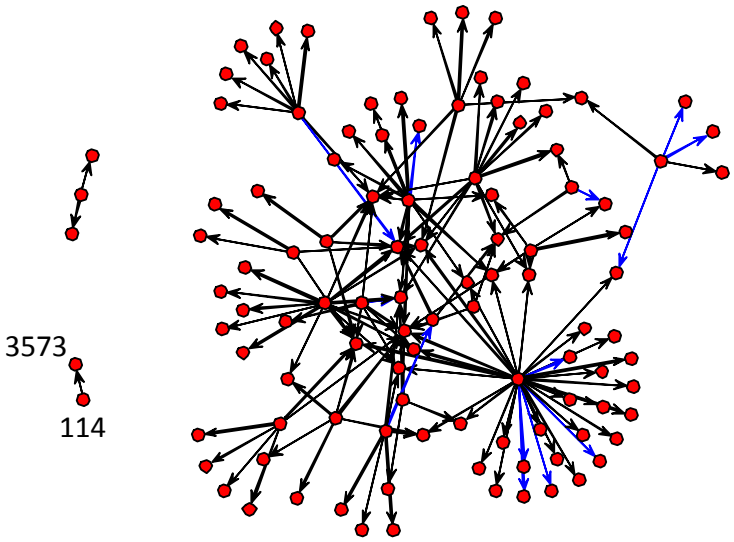


Figure 4-4. R&D network

Table 4-4 shows prominence measures calculated for R&D network. We discuss each one in detail.

Table 4-4. Prominence measures – R&D Network

In-degree		Out-degree		Betweenness		Eigenvector	
Node	*Value*	*Node*	*Value*	*Node*	*Value*	*Node*	*Value*
223	9.0	102	30.5	102	2500.61	102	0.5466
201	7.0	113	14.0	223	784.34	113	0.2545
205	7.0	104	12.5	209	781.57	223	0.2344
209	6.5	108	12.0	104	739.87	209	0.2054
212	5.5	106	7.5	108	710.19	201	0.1978
202	5.0	111	6.5	113	687.38	104	0.1811

Observing in-degree centrality scores reveals that node 223 (Tarbiat Modares University) is referred to by most NFs. After that, nodes 201 (University of Tehran – Nano Science & Technology Research Center) and 205 (Oil Industry Research Center) are two actors that have more R&D collaborations with NFs. Figure 4-5 shows R&D network with emphasis on in-degree centralities (nodes with higher in-degree centralities are shown bigger).

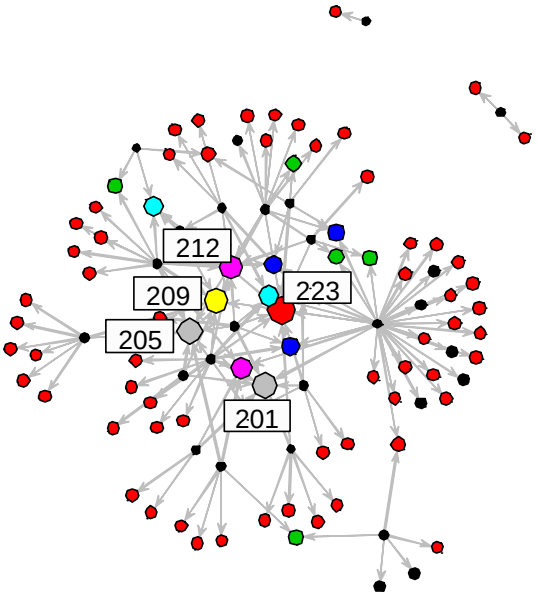


Figure 4-5. R&D network with node size based on in-degree

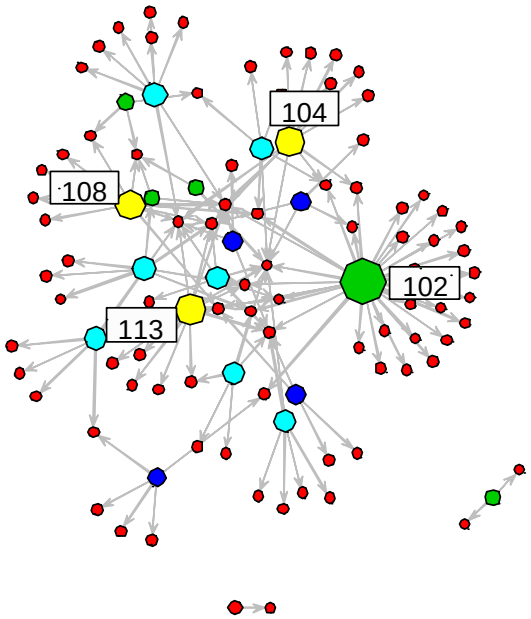


Figure 4-6. R&D network with node size based on out-degree

Actors who display high out-degree centrality are often said to be influential actors (Hanneman and Riddle, 2005). With regard to this, node 102 (Nano Nasb Pars Co.) seems most influential actor in R&D network, since it has cooperation ties with many

others. Other actors with more R&D out-ties are 113 (Narmin Shimi Co.), 104 (Kaveh Float Glass Co.), and 108 (Iramont Co.) that have similar scores on this criteria.

As mentioned in chapter three, closeness is not measured on disconnected graphs like R&D network. The betweenness values of nodes 102, 223, and 209 show that they can play the 'broker' or 'gatekeeper' with a potential for control over others. Using eigenvectors to find the most central actors (i.e. those with the smallest farness from others) in terms of the global or overall structure of the network, 102, 113, and 223 are in a positional advantage.

Normalizing prominence measures and identifying actors with higher average values gives us prominent actors in R&D network which are shown in table 4-5.

Table 4-5. Prominent actors in R&D network

Prominent Nodes	Node Name	Normalized Mean
102	Nano Nasb Pars Co.	0.6
223	Tarbiat Modares University	0.3485
209	Sharif University of Technology - Institute for Nanoscience & Nanotechnology	0.2821

4.2.2 Financial Cooperation

Most NFs rely on their own financial resources. Some of them have used monetary assistance of INIC which are shown in figure 4-7. Two NFs, namely 114 and 106 are joint ventures of INIC and other institutes.

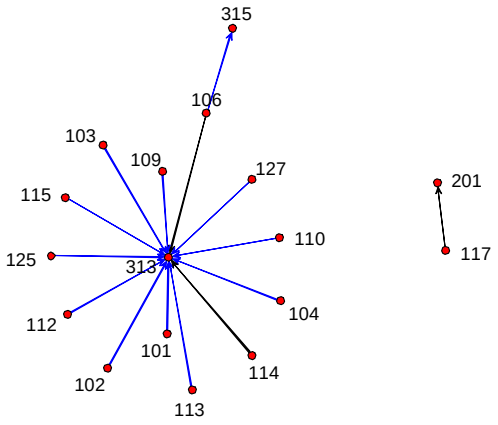


Figure 4-7. Financial cooperation

4.2.3 Suppliers Network

Each NF manager was asked about their source of raw materials and equipments. Figure 4-8 demonstrates relationships among NFs and their suppliers.

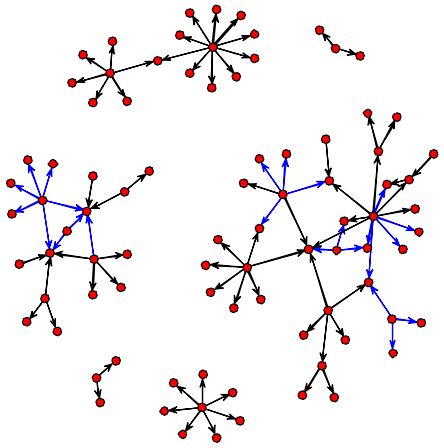


Figure 4-8. NFs and their suppliers network

Table 4-6. Prominence measures – NFs and suppliers network

In-degree		Out-degree		Betweenness		Eigenvector	
Node	*Value*	*Node*	*Value*	*Node*	*Value*	*Node*	*Value*
407	4.5	120	10.0	127	343.53	127	0.57133
378	4.0	127	8.5	407	200.53	407	0.34631
601	3.5	108	7.0	108	165.00	411	0.21856
411	2.5	123	7.0	115	162.00	111	0.21594
102	2.0	104	6.0	111	138.03	102	0.21516
350	2.0	115	5.0	410	136.50	410	0.21188

As is shown in Table 4-6, NFs tend to buy their raw materials from China (node 407). But each NF imports its needed material independently. Apart from importing, Merck Co. (node 378) and brokers in Tehran Bazaar (node 601) are the two main suppliers of raw materials in this network. Germany (node 411) is mostly the source of instruments or equipments other actors need. Figure 4-9 shows main suppliers in the network.

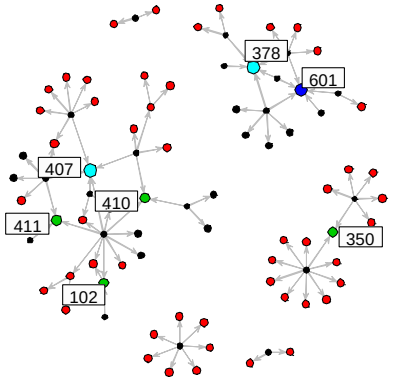


Figure 4-9. NFs and suppliers network with node size based on in-degree

Nodes with more out-ties, namely 120 (BSM Ltd.) and 127 (Nanoshop Virtual Store), have access to more resources. When we investigate these nodes it is revealed that node 120 is an importer of high-tech laboratory instruments. It has a wide range of source countries but no NF buys its equipment from that (i.e. in-degree centrality=0). Node 127 is an online shop that sells Nanotech related products. Two of its suppliers are nodes 102 and 103. It also sells some Nanotech products from countries like Germany, Austria, China, and Taiwan. These actors have good brokerage positions in the network in order to supply others with raw materials and equipments.

4.2.4 Production Cooperation

Actors that have joint production activities with others are depicted in figure 4-10. Eleven NFs have cooperative production with other actors in the network.

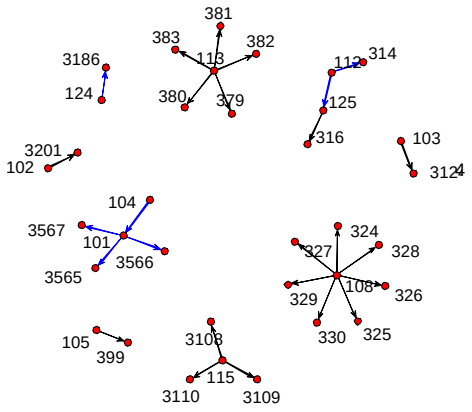


Figure 4-10. Joint production activities network

Table 4-7. Prominence measures – Joint production activities network

Out-degree		Betweenness		Eigenvector	
Node	*Value*	*Node*	*Value*	*Node*	*Value*
108	7	108	21	108	0.7071
113	5	113	10	325	0.2672
115	3	101	6	329	0.2672
101	1.5	115	3	327	0.2672
102	1	112	2	330	0.2672
103	1	125	2	324	0.2672

In-degree centrality values for most nodes in this network are the same (equal one) which means no outstanding actor exists that most NFs have established production coalitions with. Out-degree and betweenness values for nodes 108 (Iramont Co.) and 113 (Narmin Shimi Co.) are higher than the other nodes which means these two have more production partners.

4.2.5 Alliances with Industrial Customers

At the time of interview, NF managers where asked about coalitions with their industrial customers. The resulting network is illustrated in figure 4-11. Three NFs namely node 106 (Bonyan Nano Fanavaran Pars Co.), node 113 (Narmin Shimi Co.), and node 125 (Nano Pars Spadana Co.) have established alliances with their industrial customers. This is due to the nature of their products. They produce industrial goods and are actually situated in the value chain of their industrial customers. Most other NFs are producers of finished goods, thus having no cooperation with big industrial groups.

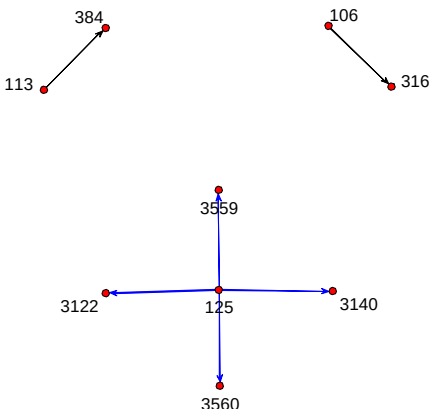


Figure 4-11. NFs and their industrial customers network

Table 4-8. Prominence measures – NFs and customers network

In-degree		Out-degree		Betweenness		Eigenvector	
Node	*Value*	*Node*	*Value*	*Node*	*Value*	*Node*	*Value*
316	1	125	2	125	6	125	0.7071
384	1	106	1	-	-	3122	0.3535
3122	0.5	113	1	-	-	3140	0.3535
3140	0.5	-	-	-	-	3559	0.3535
3559	0.5	-	-	-	-	3560	0.3535
3560	0.5	-	-	-	-	125	0.7071

4.2.6 Distribution Network

Some NFs have branches in different cities of Iran and also in some other countries to sell their products in different geographic regions. Figure 4-12 shows the sociogram of NFs and their distribution network.

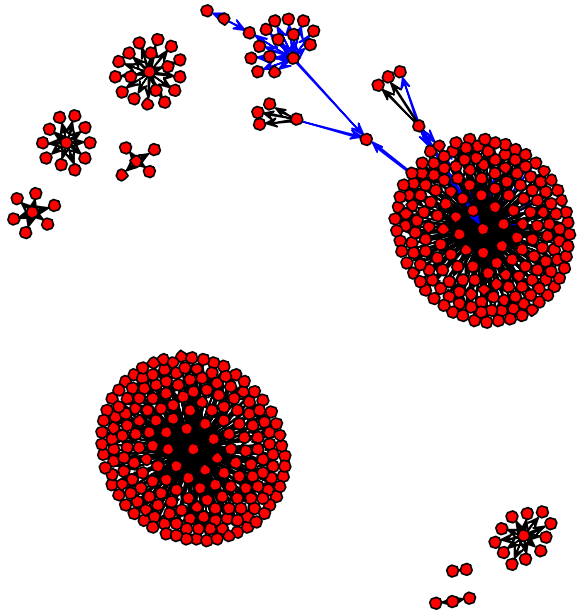


Figure 4-12. Distribution Network of NFs

Table 4-9. Prominence measures – Distribution network

In-degree		Out-degree		Betweenness		Eigenvector	
Node	*Value*	*Node*	*Value*	*Node*	*Value*	*Node*	*Value*
401	1.5	104	189	102	19854.5	104	0.7071
-	-	102	169	104	17766.0	-	-
-	-	107	17	401	3848.0	-	-
-	-	108	11	124	3077.0	-	-
-	-	103	10	121	597.5	-	-
-	-	124	8	112	597.0	-	-

As is depicted in figure 4-13 and regarding table 4-9, only node 401 (UAE – Dubai) has an in-degree centrality of 1.5. It means three NFs (nodes 102, 124, and 112) have a sales representative in Dubai.

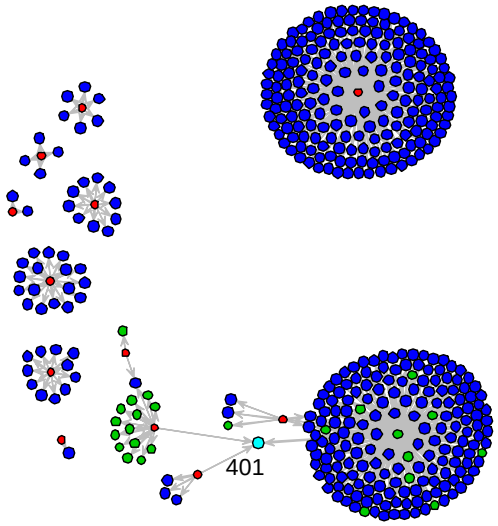


Figure 4-13. Distribution Network with node size based on in-degree

Concerning out-degree centralities node 104 (Kaveh Float Glass Co.) with 189 Iranian and foreign branches and node 102 (Nano Nasb Pars Co.) with 169 Iranian and foreign branches have wider and more powerful distribution networks. Consequently these two companies are the most influential actors in the distribution network. After these two, node 107 (Chitotech Co.) with 17 branches, node 108 (Iramont Co.) with 11 branches and node 103 (Pishgaman Nano Aria Co.) with 10 branches have wider geographical distribution.

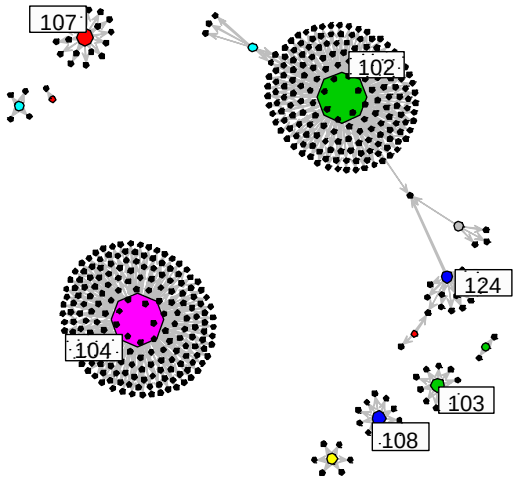


Figure 4-14. Distribution network with nodes size based on out-degree

4.2.7 Marketing Alliances

Marketing is an increasingly demanding function in industrial high-technology companies due to the expanding complexity and uncertainty faced by the management (Möller and Rajala, 1999). NFs that have marketing cooperation with other firms are represented in figure 4-15. Inspecting these actors and their relationships reveals that some relationships are established with advertising agencies to increase products publicity. Almost no NF has a rigorous marketing plan to sell its high-tech product in the market. This problem has been addressed by NF managers at the time of conducting interviews.

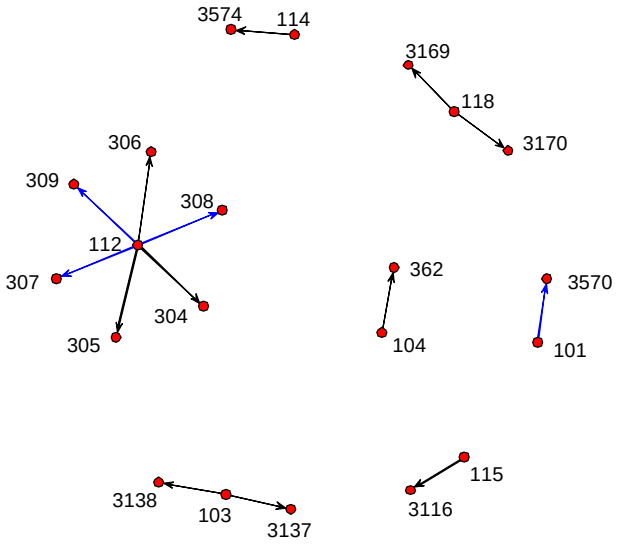


Figure 4-15. NFs' marketing alliances

4.2.8 Managerial Cooperation

Figure 4-16 shows that four NF managers benefit from joint strategy setting, cooperative planning and problem solving. Other NFs do not have partners assisting them in management issues.

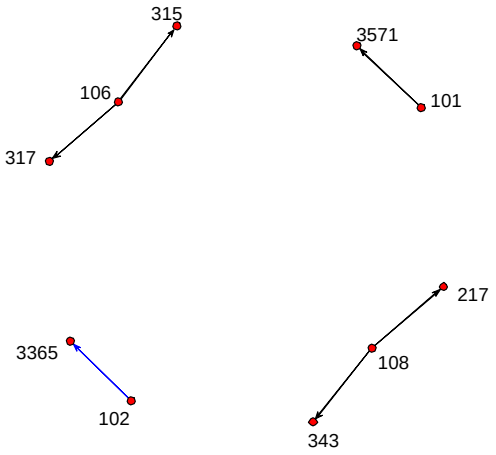


Figure 4-16. NFs managerial cooperation

4.2.9 Cooperation on Standardization

Some NFs have cooperation with standard institutes to obtain required certificates and standards for their products. Actors involved and their relationships are shown in figure 4-17.

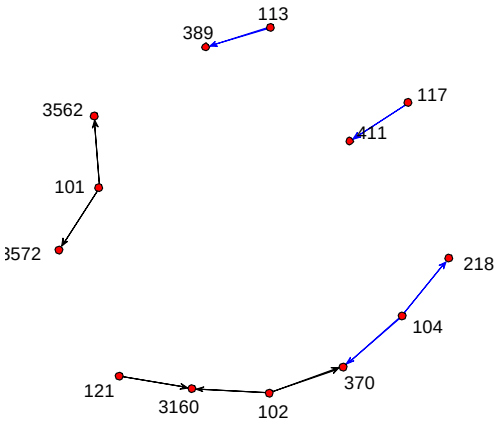


Figure 4-17. Cooperation for Standards

4.2.10 Foreign Ties

An important network for marketers, strategists and, policy makers is the network of NFs' foreign relations. Figure 4-18 illustrates the sociogram of the NFs that have ties with overseas companies, organizations, or research centers. All Iranian and foreign actors are shown by red circles. Black arrows represent strong relations between Iranian

NFs and their foreign partners. Blue arrows show weak such links. Red arrows are drawn to show nationality of each foreign actor.

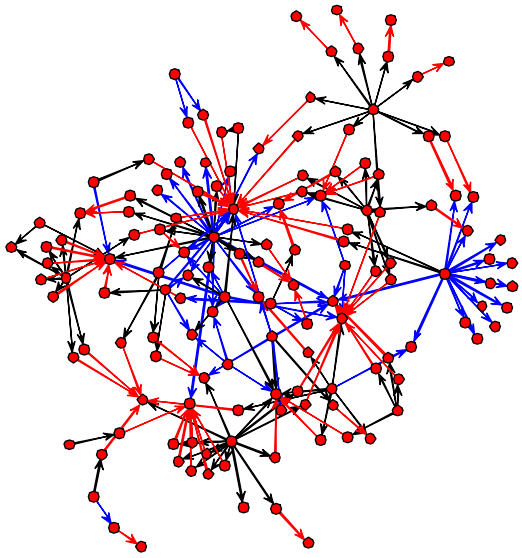


Figure 4-18. Network of Foreign Ties

Table 4-10. Prominence measures – Network of Foreign Ties

In-degree		Out-degree		Closeness		Betweenness		Eigenvector	
Node	*Value*	*Node*	*Value*	*Node*	*Value*	*Node*	*Value*	*Node*	*Value*
411	19.6	102	17.5	411	0.3829	102	5199.437	102	0.5199
403	11.4	108	15.0	102	0.3787	401	2843.980	411	0.3703
410	10.4	104	10.0	401	0.3423	411	2605.415	127	0.2246
405	10.1	120	10.0	127	0.3373	124	2123.384	403	0.1845
407	8.1	123	10.0	111	0.3317	111	1437.366	401	0.1490
408	7.0	124	9.5	403	0.3202	127	1346.110	248	0.14816

Prominence measures shown in table 4-10 let us discover key nodes in the network. In-degree centrality, closeness, and eigenvector values reveal that node 411 (Germany) is an important actor in the network. Iranian NFs interact with Germany on issues like purchasing raw materials, machinery and equipment, and in some cases they have R&D alliances. This is important in a sense that if commercial relations with Germany become restricted, as a result of some factors like sanction, about 19 Iranian-German partnerships will be lost.

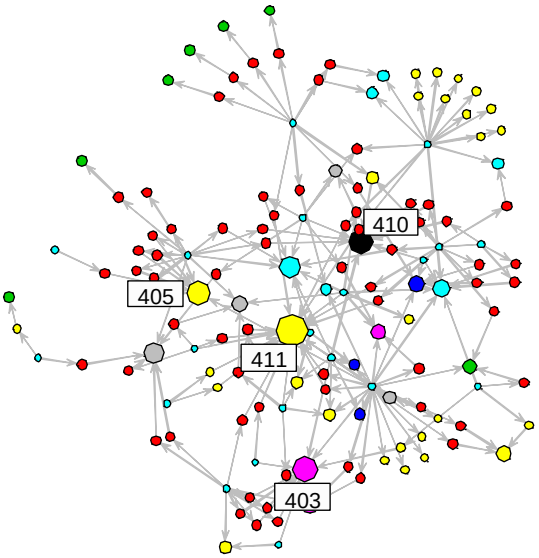


Figure 4-19. Network of Foreign Ties with node size based on in-degree

Nodes with more out-ties are 102 (Nano Nasb Pars Co.) and 108 (Iramont Co.) which means they have more collaborations with other countries. Nodes with higher out-degree values are represented in figure 4-20.

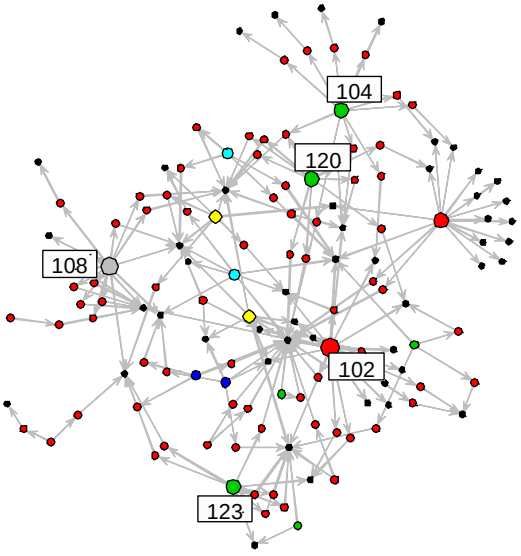


Figure 4-20. Network of Foriegn Ties with node size based on out-degree

Prominence by definition incorporates the full extent of centrality measures, not just a high score on one of the measures. Hence, centrality measures are normalized and their mean for each node is calculated. Table 4-11 lists three actors with higher mean values.

Table 4-11. Prominent actors – Network of foreign ties

Prominent Nodes	Node Name	Normalized Mean
102	Nano Nasb Pars Co.	0.7978
411	Germany	0.6426
403	Russia	0.4045

4.2.11 Relations without Distribution Network

Another useful sociogram for analysis is the sociogram of all relations among actors excluding distribution network of NFs. The reason behind is that two NFs (i.e. nodes 102 and 104) have a large number of sales representatives compared to other nodes and this might cause us to interpret it as a bipolar network. Regarding each company's information and discussing the issue with experts at INIC business network revealed that this interpretation may not be very true. These two companies who seem dominant in the network have big parent companies and introduce the parent company's distribution network as their own. As the manager of INIC business network mentioned, although the distribution networks of parent companies have the potential to sell these companies' products, about thirty percent of them are already doing so.

Therefore, in order to investigate the network from another perspective and not to pass details unnoticed, we conduct our analysis on the sociogram of all relations without considering actors and links related to all NFs distribution networks. The resulting network picture is shown in figure 4-21.

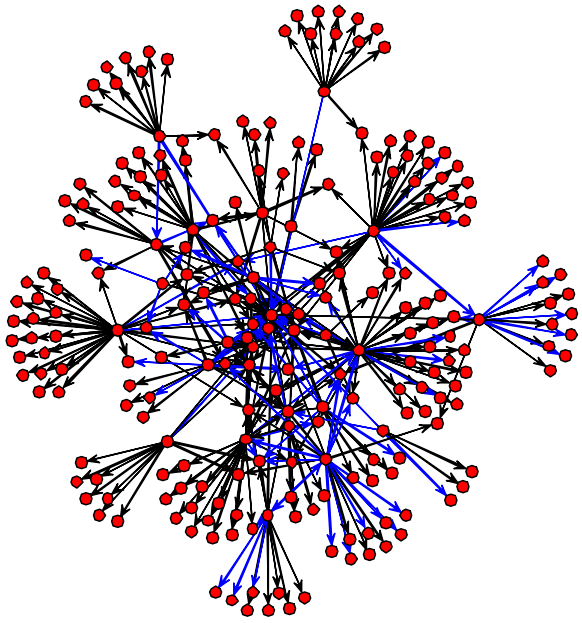


Figure 4-21. Relations without distribution network

Since just actors who were sale representatives were removed, in-degree centrality values did not change compared to the sociogram of all relations discussed at the beginning of this chapter. Out-degree values in table 4-12 show that node 102 (Nano Nasb Pars Co.) is linked to more diverse actors and after that nodes 108 (Iramont Co.), 104 (Kaveh Float Glass Co.), and 113 (Narimin Shimi Co.) have established more and nearly the same number of alliances with others.

Nodes 313 and 102 are closer to all the other actors in the network. They are also between many actors in their linkages. If we consider more global patterns in the network, not just local ones, nodes 102, 313, and 113 will be identified regarding eigenvector measure.

Table 4-12. Prominence measures – Relations without distribution network

In-degree		Out-degree		Closeness		Betweenness		Eigenvector	
Node	*Value*	*Node*	*Value*	*Node*	*Value*	*Node*	*Value*	*Node*	*Value*
313	19.5	102	36.0	313	0.5280	313	12227.54	102	0.3993
223	9.0	108	28.0	102	0.4224	102	6878.91	313	0.3315
201	7.5	104	26.5	113	0.4109	104	5511.76	113	0.3281
205	7.0	113	26.5	125	0.4064	125	4598.43	125	0.2238
209	6.5	115	17.5	104	0.3869	108	4499.29	104	0.1788
212	6.0	125	14.5	127	0.3824	113	3808.17	223	0.1752

Normalized centrality measures and their means reveal three most prominent nodes (Table 4-13).

Table 4-13. Prominent actors – Relations without distribution network

Prominent Nodes	Node Name	Normalized Mean
313	Iran Nanotechnology Initiative Council (INIC)	0.7660
102	Nano Nasb Pars Co.	0.7032
113	Narmin Shimi Co.	0.5448

If we compare the result of prominence analysis of the network of all relations (table 4-3) with the network without distribution network analyzed here, we'll see that INIC and Nano Nasb Pars Co. are identified prominent in both analyses. Another important actor namely Narmin Shimi Co. is recognized here. After them nodes 104 (Kaveh Float Glass Co.), 108 (Iramont Co.), and 125 (Nano Pars Spadana Co.) have nearly the same level of importance among NFs in the network.

4.3 Structural Hole Analysis Results

The next step involves the results of Structural Hole Analysis that looks at the three most prominent actors in the network and seeks to discover patterns and entrepreneurial opportunities that might not be evident from a simple visual inspection of the map of the network. The function developed in R software based on Burt's (1992) formula (explained in previous chapter) is used to perform Structural Hole Analysis for prominent actors in each network.

4.3.1 Network of All Relations

As discussed in the methodology chapter, structural holes occur around a specific actor when he has a large O_i (no or few structural holes around the actor himself); and there is a large p_{ij} and a small c_{ij} at the other end of a relationship with another actor (large amount of time and energy invested in the relationship, small constraint on the actor's entrepreneurial opportunities). These conditions give rise to what Burt (1992) calls the hole signature of an actor. Table 4-14 shows the values for p_{ij} and c_{ij} for INIC (node 313) in the Iranian Nanotech SME network.

Table 4-14. Structural Hole Analysis for INIC in SME network

Nanotech Firm	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
101	0.051	0.004	0.0475
102	0.051	0.004	0.0475
103	0.051	0.003	0.0479
104	0.051	0.003	0.0481
105	0.051	0.003	0.0482
106	0.051	0.003	0.0483
109	0.051	0.003	0.0484
110	0.051	0.003	0.0484
112	0.051	0.003	0.0485
113	0.051	0.003	0.0485
114	0.051	0.003	0.0485
115	0.051	0.003	0.0486
117	0.051	0.003	0.0487
125	0.051	0.003	0.0487
127	0.051	0.003	0.0487
107	0.026	0.001	0.0249
108	0.026	0.001	0.025
111	0.026	0.001	0.025
118	0.026	0.001	0.025
119	0.026	0.001	0.025
120	0.026	0.001	0.025
121	0.026	0.001	0.025
123	0.026	0.001	0.025
124	0.026	0.001	0.025

Visual representation of the difference between p_{ij} and c_{ij} provides an easy way to identify the structural holes around a specific actor. The hole signature for INIC in the SME network is shown in Figure 4-22.

The upper line in figure 4-22 describes the proportion, p_{ij}, of the player's network time and energy invested in each relationship. The lower line describes the extent to which each investment constrains the player's entrepreneurial opportunities, c_{ij}. Two lines are close to each other when there are few structural holes for negotiating a relationship. Contacts are listed in the horizontal axis in descending order of investment, then constraint. From left to right, relations are listed in order of their significance for the player's entrepreneurial opportunities.

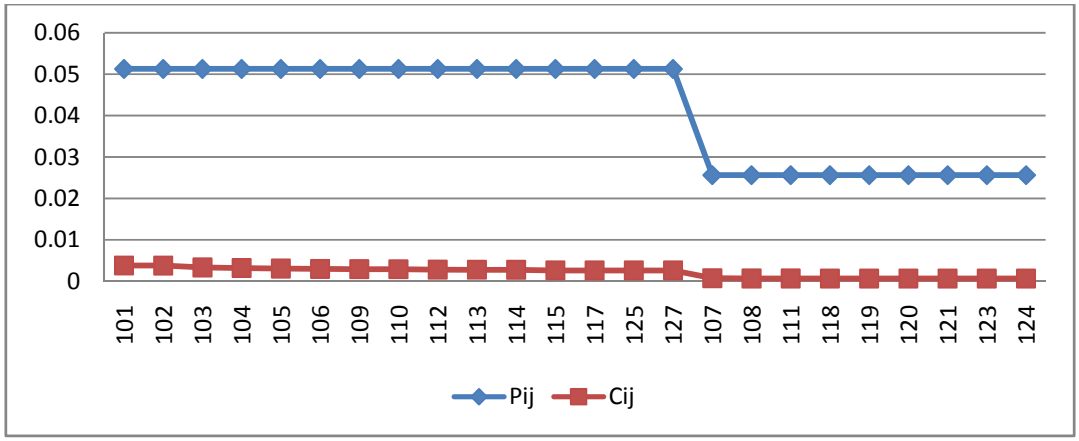


Figure 4-22. . Hole Signature for INIC in SME network

The jagged edges of a hole signature identify sites where the player has the most and the least opportunity for entrepreneurial behavior. Three kinds of relations are distinguished: opportunity, constraint, and sleeper (Burt, 1992). Each kind of relation and their occurrence in figure 4-22 are described here.

A large band in the hole signature indicates an opportunity relationship. Such a band occurs when a relationship represents a large proportion of the player's network time and energy (high blue line at the top of the hole signature), and there are numerous structural holes around the contact reached with the relationship (low red line at the bottom of the signature). There are the relationships in which the player has the greatest room to negotiate, and so control (Burt, 1992). As is shown in figure 4-22, these relationships exist between INIC and the nodes listed in table 4-15.

Table 4-15. Actors with opportunity relationships for INIC in SME network

Node Number	Node Name
101	Nano Pac Persia Co.
102	Nano Nasb Pars Co.
103	Pishgaman Nano Aria Co.
104	Kaveh Float Glass Co.
105	Noavaran Catalyst Co.
106	Bonyan Nano Fanavaran Pars Co.
109	Nano System Pars Co.
110	Poosheshhaye Nano Sakhtar Co.
112	Baspar Nano Bon Co.

Node Number	Node Name
113	Narmin Shimi Co.
114	Nano Sina Co.
115	Panatech Co.
117	Modiriat Behbood Niroo (Jazika) Co.
125	Nano Pars Spadana Co.
127	Nanoshop Virtual Store

A high, narrow band in the hole signature indicates a constraint relationship. Such a band occurs when a relationship represents a large proportion of player time and energy, but few structural holes surround the contact reached with the relationship (blue line at the top and red line at the bottom of the signature are both high). This is the relationship in which the player is most out of control (Burt, 1992). Figure 4-22 does not show relationships of this kind. It means INIC is not at a disadvantage under its relationships with the contacts listed in figure 4-22.

There are opportunities to protect, constraints to do something about, and then everything else. The third is a residual category of relations given little attention in the player's current activities. The relationship represents little time and energy, so there is little to protect and little to gain by alleviating constraint. The relationship is ignored. Yet it could be significant if the relationship is developed further (Burt, 1992). These relationships occur in figure 4-22 between INIC and contacts listed in table 4-16.

Table 4-16. Actors with sleeper relationships for INIC in SME network

Node Number	Node Name
107	Chitotech Co.
108	Iramont Co.
111	Poosheshhaye Nano Sakhtar Co.
118	Tamam Mavad Mohandesi Co.
119	Tedsei Co.
120	Fanavari Behnoorsazan Mahyad Co.
121	Farjen Pooyesh Co.
123	Fanavan Araz Tajhiz Co.
124	Nano StarTech Co.

The three categories of relationships refer to a player's network at a moment in time. The third category contains relations ignored for current purposes, not necessarily neglected for life. They are on hold, sleepers ready to wake (Burt, 1992).

Structural hole analysis was applied to two other prominent actors in the Iranian Nanotech SME network, namely nodes 102 and 104, and resulted values for p_{ij} and c_{ij} are shown in tables 7-3 and 7-4 of appendix C. The results indicate that these actors are rich in structural holes because they are connected to many actors that are mutually unconnected. According to Burt (1992), ego networks rich in structural holes imply access to many distinct information flows.

Considering tables 7-3 and 7-4 in appendix C, values for p_{ij} are small (i.e. 0.004) in the results of SHA for both node 102 and node 104, however, there aren't many constraints in negotiating to get a favorable return on investment (Max(c_{ij}) = 0.0001). It means small amount of time and energy is invested in relationships of low constraints. Despite the fact that these relationships have little to protect and little to gain, it should be noted that they have potential value to be developed further.

4.3.2 R&D Network

As examined in section 4.2.1, three most prominent actors of R&D network are nodes 102, 223, and 209. This part explains the results of applying SHA on these actors in the network of R&D partnerships using illustrative hole signatures. Values for p_{ij} and c_{ij} for these nodes are presented in tables 7-5, 7-6, and 7-7 and in appendix C.

The hole signature for Nano Nasb Pars Co. (node 102) is shown in figure 4-24. The results indicate that node 102 has equal strength relations with contacts 201 to 3200 listed in figure 4-23 and the relations are not constrained. The distribution of opportunity and constraint across node 102's R&D relationships with mentioned contacts is the same. The small amounts of c_{ij} mean that there are numerous structural holes around the contacts reached with relationships of node 102. The actors listed in figure 4-23 could be more valuable to node 102 if it develops the relationships with them further and invests more time and energy in them in future.

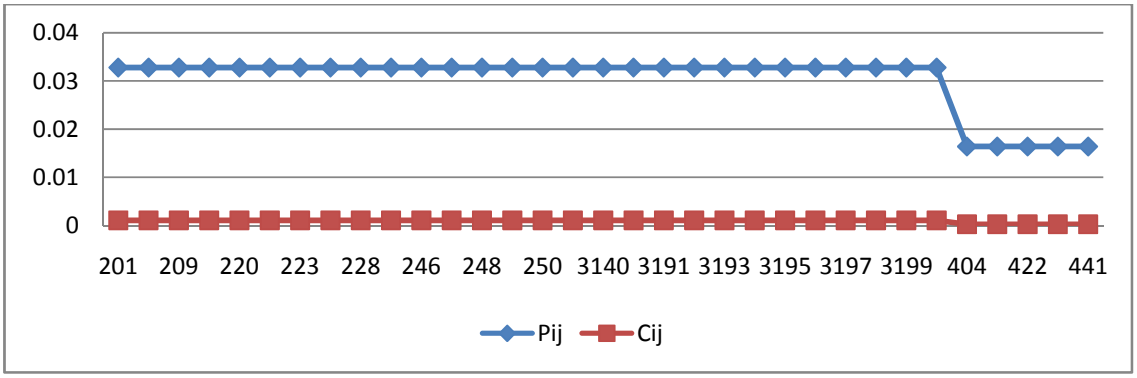


Figure 4-23. Hole Signature for node 102 in R&D network

Other prominent actors in R&D network, Tarbiat Modares University (node 223) and Sharif University of Technology (node 209), are analyzed to find structural holes surrounding them. Hole signature for node 223 (Figure 4-24) reveals a similar distribution of opportunity and constraint across all contacts it reaches with its relationships. There are large bands in the hole signature that indicate opportunity relationships in which the player has the greatest room to negotiate, and so control. The current condition favors node 223 so it can be expected to protect the relation's form and interpretation against forces outside the network.

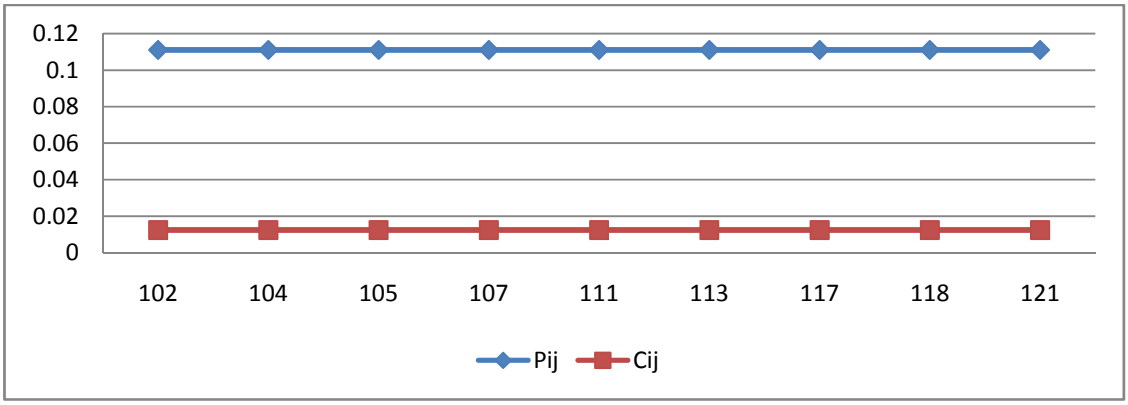


Figure 4-24. Hole Signature for node 223 in R&D network

The same argument applies to what hole signature of node 209 shows (Figure 4-25). There are six opportunity relationships surrounding node 209 in the current network of R&D relationships.

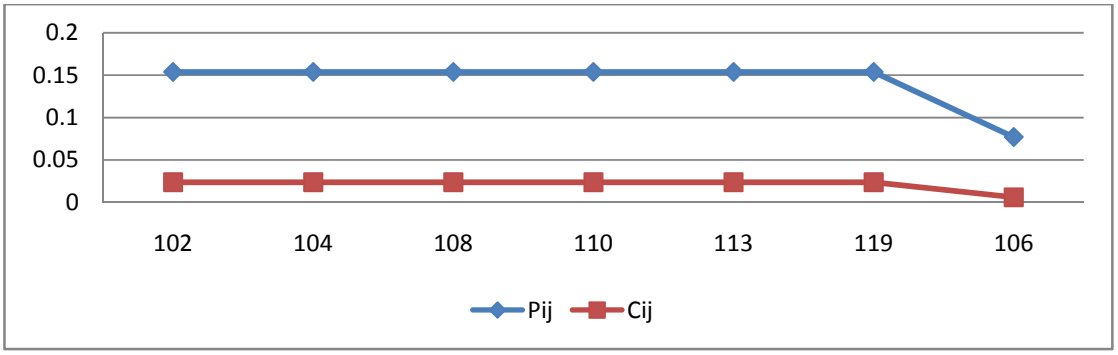


Figure 4-25. Hole Signature for node 209 in R&D network

Chapter Five

Conclusion

5 Conclusion

This last chapter, discusses the contents and issues of the thesis and answers the research questions stated in chapter one and draws conclusions from the analysis in chapter four. Furthermore, implications for management, limitations of the research and directions for further research are provided.

5.1 Findings

The purpose of this study was to investigate alliance network of Iranian SMEs active in Nanotech industry. The investigation aims at tackling three main issues

- current state of business networks facing NFs in Iran (RQ1),
- prominent actors in these networks (RQ2), and
- entrepreneurial opportunities surrounding these actors (RQ3).

Extensive review of prior researches allowed us to obtain the suitable approach for investigating and analyzing the above mentioned issues. The approach used to address each question and the resulted answers are as follows.

5.1.1 Current State of Alliance Networks

In order to understand the current state of alliance networks facing NFs we had to recognize NFs and their relationships. A list of the firms which are currently active in Nanotech industry in Iran was provided by Iran Nanotechnology Initiative Council. There are twenty four active SMEs in Iran and all of them were investigated in this study. Among them are manufacturing companies, import/export companies, incubator firms and technology development service firms.

Alliances among firms were found through conducting semi-structured interviews with managers of Nanotech SMEs. An interview framework about possible cooperation areas of high-tech firms was extracted from related literature and high-tech business experts' opinions. The framework was used to guide the interview to gain the desirable data on relationships of NFs.

The gathered data on actors and their relationships enabled the construction of sociograms of the network. Sociograms are proper tools for representing actors and relationships in a network. In chapter four, sociogram of all relations and also sociograms of different cooperation types were depicted and actors involved and their relationships were discussed in detail. Having information on various cooperation ties among NFs, we represented current state of the network from different aspects. Table 7-8 in appendix D provides detailed information on who is connected to whom in the network of Iranian Nanotech SMEs.

When the network of all relations is split into networks of specific link types, it gives us the ability not only to obtain a detailed understanding of current state of these networks but also to compare their states with each other. Considering number of actors involved in each separated network, it is clear that most NFs have established research and development ties with universities, research centers or other organizations. Thus, in the R&D network more actors and ties are involved. On the contrary, networks of financial cooperation, alliances with industrial customers, marketing alliances, managerial cooperation, and standardization have few actors and ties. This could be because firms in the high-tech sector have more focus on the creation and accumulation of knowledge-

based competencies in order to yield long-term survival. Therefore, they create tight and loose relations with other actors on research and development issues.

Totally, there are 614 actors and 785 ties in the network of all relations of NFs. The ratio of the current number of ties in the network to the maximal number of ties is defined as network density. Considering network density, there is a sparse network of alliances among Nanotech SMEs in Iran. It can be inferred that there are many opportunities in this network which could be exploited in the future by establishing further alliances.

An important aspect in investigating current state of a network is recognizing the developmental stage of NFs in organizational life cycle. Most NFs in this study are in growth stage of their life cycle. Consequently, the results should be interpreted considering the fact that Nanotech is an emerging industry and SMEs active in this field are young and in initial stages of their life cycle.

5.1.2 Prominent Actors

To find prominent actors in the network we used five prominence measures used in social network analysis, namely in-degree, out-degree, closeness, betweenness, and eigenvector. Actors with higher scores on all measures were identified as prominent in each network.

Considering all NFs and all kinds of relationships among them, two NFs, namely Nano Nasb Pars Co. and Kaveh Float Glass Co., and INIC are recognized as most prominent actors. Nano Nasb Pars Co. is also identified prominent in R&D network. Two universities which give NFs more services regarding R&D activities are Tarbiat Modares University and Sharif University of Technology. In the network of financial cooperation there is INIC which provides NFs with some monetary supports.

In the network of suppliers, Chinese companies, Merck Co., and brokers of Tehran Bazaar are main actors that supply raw materials for NFs. Iramont Co. and Narmin Shimi Co. are two NFs that have more production partners in the network of joint production activities. Alliances of NFs with their industrial customers are very few, limited to those who produce industrial goods. These NFs include Nano Pars Spadana Co., Narmin Shimi

Co., and Bonyan Nano Fanavaran Pars Co. that have established close partnerships with their industrial customers. They are situated in the value chain of other industrial groups. Other NFs are producers of finished goods so having no relationships with industrial groups as their customers.

Two NFs that were identified prominent in the network of all relations, i.e. Nano Nasb Pars Co. and Kaveh Float Glass Co., have wider distribution networks compared to other NFs, 169 and 189 branches respectively. Except these two, eight other firms have sales and distribution representatives but the number is much less (their number of branches varies from 1 to 17).

Marketing is taken for granted in most NFs and as the sociograms revealed, these firms show few tendencies to form marketing alliances with other companies. Thus, no prominent actor exists in the network of marketing alliances. About four firms out of twenty four studied NFs have cooperation with other companies on managerial issues like strategy setting, planning, and problem solving. The same argument is true for collaboration on standardization. Six firms have relationships with other institutes or firms to work on standardization of products based on Nanotechnology.

Considering the network of relationships with actors in other countries reveals that foreign ties of NFs have been formed mostly with Germany. Iranian NFs interact with Germany on issues like purchasing raw materials, machinery and equipment, and in some cases they have R&D alliances. Among NFs, Nano Nasb Pars Co. and Iramont Co. have more ties to foreign countries. Totally, prominent actors in the network of foreign ties are Nano Nasb Pars Co., Germany, and Russia.

As mentioned earlier two NFs have wider distribution networks compared to other nodes and this might cause us to think of the whole network as a bipolar one, having two dominant players and some other small firms. This is not a right interpretation due to the fact that these two NFs introduce distribution network of their parent companies as their own. Thus, in order to have more realistic interpretation, another prominence analysis was conducted on the network of all relations excluding distribution networks. The

resulting network reveals more or less similar patterns for the relationships of all NFs. Prominent nodes in this network are INIC, Nano Nasb Pars Co., and Narmin Shimi Co..

5.1.3 Entrepreneurial Opportunities

In order to identify entrepreneurial opportunities in the network, we applied structural hole analysis to the network of Iranian Nanotech SMEs. In addition to the three most prominent actors of the network of all relations, salient actors of R&D network were analyzed to unveil entrepreneurial opportunities surrounding them. The analysis revealed that actors identified as prominent in our network are rich in structural holes. The reason behind is that they are connected to many actors that are mutually unconnected therefore they have access to many distinct information flows.

The structural hole analysis identified several possible entrepreneurial opportunities for firms active in the Nanotech industry. These opportunity relationships can now be investigated to see whether or not it is practical to find a *tertius* strategy. As with centrality measures these opportunity relationships can develop the social capital of the network, and the previously hidden network then becomes strategic for the organizations in question (Pitt et al., 2006b). In this case, for example, one of the interesting opportunities exists between INIC and the firms named in table 4-15.

A typical tertius gaudens strategy in this case would involve a third party organization that puts itself between INIC and manufacturing firms listed in table 4-15 and negotiates the relationship between them. An entrepreneurial opportunity for the third party organization may be to serve as an intermediary between INIC and this set of companies to control the flow of information and knowledge among them.

Results of structural hole analysis for Nano Nasb Pars Co. and Kaveh Float Glass Co., two other prominent nodes in the network, showed that small amount of time and energy is invested in relationships of low constraints. These relationships have potential to be strengthened by the involved actors or by a third party organization.

Hole signatures of prominent actors in the R&D network also revealed that these actors are surrounded by many opportunity relationships in which they have the greatest room to negotiate, and so control. Structural holes around Tarbiat Modares University and Sharif University of Technology in the R&D network are opportunities to broker the flow of information between these two universities and Nanotech firms, and control the projects that bring together NFs from opposite sides of the hole.

5.2 Discussions and Managerial Implications

This part discusses what we found from investigating the network from different aspects and provides some implications for management.

5.2.1 Influential Speedy Actors in the Network

Prominence measures not only allow marketers to identify the actors that will have the most influence on the network, it also shows which actors need to be targeted to disseminate information in the network in the fastest way possible. This observation finds a strong tie-in with and is supported by diffusion of innovation theories (Rogers, 1995; Valente, 1995; cited by (Pitt et al., 2006b)). Valente (1995) as cited by (Pitt et al., 2006b) notes "For networks, structural centrality is associated with more rapid diffusion for advantageous innovations and slower diffusion for more risky/uncertain innovations". Centrality is therefore not only an important measure to decide which actors are the most influential in a network; it also directly affects the speed with which new information is disseminated.

Indeed, research in a number of fields has demonstrated the importance of identifying central network links as opinion leaders in the diffusion of innovations, from an SNA perspective (Deroian, 2002; Gibbons, 2004; cited by (Pitt et al., 2006b)). In the network of all relations, examined in chapter four, Kaveh Float Glass Co., Nano Nasb Pars Co., and INIC were identified prominent in the network. Regarding the above discussion, if policy makers or business marketers intend to introduce information (e.g. a standard, an innovation, a promotional activity, etc.) in the Iran Nanotech network, these influential

and speedy actors will have the most potential to be used to boost innovation across whole regions.

Considering the analysis conducted on network of relations without distribution network, other influential actors are Narmin Shimi Co., Iramont Co., and Nano Pars Spadana Co.. One possible interpretation would be that these are good points for disseminating the information through the network and because they are key actors, the network will be weakened by removing them.

5.2.2 Nanotech an Emerging Industry

As there is no actor with high values on both in-degree and out-degree centrality measures among firms, we may infer that there is no major player in this industry which is both an important source (high in-degree) and also collaborates with many others or refers to many others (high out-degree). It means no major firm exists in the current network being both a recipient and a transmitter of information. This may be justified by considering the nature of this industry in Iran. Nanotech industry is an emerging industry (Miyazaki and Islam, 2007) and most SMEs active in Nanotech field are in growth stage of their life cycle.

5.2.3 Highly Connected Actors

Differences among actors in how connected they are can be extremely consequential for understanding their attributes and behavior. More connections often mean that actors are exposed to more and more diverse information. Highly connected actors may be more influential, and may be more influenced by others (Hanneman and Riddle, 2005). One NF, namely node 102, has lots of out-ties in network of all relations, network of relations without distribution network, R&D network, and also network of foreign ties. Totally it has established 215 weak and strong relationships with others. This amount of ties for a SME of 6 year-old may not seem advantageous.

Dittrich et al. (2007) have shown that it is not the number of alliances which matters but the nature of the alliance network which is most important. In fact, management attention and integration costs may grow exponentially beyond a certain level of alliances

(Duysters and De Man, 2003; cited by (Dittrich et al., 2007)). In other words, a firm can start to suffer from information overload and diseconomies of scale once it is involved in too many alliances at the same time (Dittrich et al., 2007). Hence, it is worth noting that although alliance networks create opportunities for companies, firms should not focus on expanding the number of alliances as a goal in itself.

Therefore, companies have to be efficient and avoid wasting too much effort on cooperating with as many partners as possible. This would create a lot of experience, but the scanning of many potential partners and the creation and maintenance of a large number of partnerships is a time-consuming and expensive activity that takes up a lot of managerial resources that could be used for alternative purposes. Instead, companies are advised to be efficient in their networking strategy and to avoid experimenting with a large number of partnerships with companies that are not well connected in the overall network (Hagedoorn et al., 2006).

5.2.4 R&D Ties and Alliances with Industrial Customers

High-tech industries are characterized by their ever-shortening technology development cycles and short product life cycles, which form a constant pressure on companies to respond quickly to changing market needs and to new technological opportunities. Timely access to new technologies and state-of-the-art scientific knowledge that is developed outside the boundaries of the firm is crucial to competitive success in these industries. As a result of a number of factors – globalization of markets, the increasing complexity of technologies and the increasing costs of R&D – even the largest firms are no longer able to individually monitor all the technological and scientific developments that are important for their core markets. Cooperation with a variety of partners enables companies to simultaneously detect several scientific and technological developments, as well as respond quickly to the most promising new opportunities (Hagedoorn et al., 2006).

Having interactions and cooperation with universities and research centers is necessary for high-tech SMEs but it is not sufficient. They need to valorize their research findings through cooperation with big industrial groups to enable exploitation of the knowledge

industrially and commercially. Catherine et al. (2001) have shown that biotech SMEs in France have close relations with universities and public research laboratories, and valorize their research through contracts or licenses to big groups. SME ties with universities facilitate R&D transfers. They make venture capital companies aware of the qualities of a firm's research, and facilitate the scientific management of the firm (Audretsch and Feldman, 1996 cited by (Catherine et al., 2001)). R&D partnerships with large groups are a source not only of income for SMEs but also of credibility vis-à-vis financiers and other partners. They also enhance the firm's learning dynamics (Senker and Sharp, 1997 cited by (Catherine et al., 2001)).

Considering the situation of Nanotech firms in Iran, our network of joint R&D activities show Iranian NFs have established many R&D ties with universities, research centers, and organizations. As mentioned in section 5.1.1, comparison of R&D network with other networks in this study reveals that most NF partnerships are formed around R&D activities. Albeit the type of R&D ties between NFs and universities, research centers, or laboratories are more of the type of receiving services than conducting joint research and development projects.

From our network of cooperation with industrial customers, it is noticeable that Iranian NFs have very few ties with big industrial groups to valorize results of their R&D activities. Apart from a few firms that are producers of industrial goods, others are involved in producing finished goods. Those industrial goods producers have relationships with large industrial companies and are actually situated in the value chain of those companies. But other NFs are directly producing end-products, thus having no cooperation with big industrial groups.

Taking two networks of R&D and cooperation with industrial customers into consideration, we can infer that NFs' ties with universities and research centers seems strong but these ties are mostly of the type of getting services from those centers not of the type of conducting joint research and development projects. On the other hand, ties with industrial groups have not been formed. Thus both relationships with research centers and industrial customers need to be strengthened. This fact should be noticed by

both NF managers to invest more on building such relationships and government to support them in creating such cooperation opportunities.

5.2.5 Financial Cooperation

The network of financial cooperation reveals that except some financial assistance from INIC, most NFs are established by their own internal monetary resources. At the time of interview, NF managers stated that relying on their internal resources is a result of not having proper financing conditions in banks or financial institutes for supporting high-tech SMEs. This might be a reason, but another reason could be the lack of ability of these firms in preparing bankable reports for financers or not providing thorough information about their tangible and intangible assets to get credits form banks or financial institutes.

5.2.6 Raw Material Suppliers

Chinese companies, Merck Co., and brokers of Tehran Bazaar are actors that supply raw materials for NFs. Each NF purchases its needed material independently. One possible strategy for NFs is to do their procurement collectively. This could be accomplished through central actors in the network.

5.2.7 Distribution Network

As mentioned in chapter four, two nodes namely 102 and 104 have access to a wider distribution network compared to other SMEs. This causes us to think of these two distribution networks as potential channels to distribute and sell other SMEs' products too. Bringing this suggestion to the manager of INIC business network, we concluded that this could be a practical strategy using distribution network of node 102 (Nano Nasb Pars Co.). Node 102 is a producer of Nanotech-based products and its sales representatives can add other Nanotech-based product to their product basket. This type of cooperation has potential to create value for both node 102 and the SME that wants to use 102's distribution network.

The same strategy seems not applicable to the case of node 104. This is due to the different type of its distribution network. Node 104 (Kaveh Float Glass Co.) is part of a big industrial group (Kaveh Glass Industrial Group) that manufactures a range of glass related products and their sales representatives just sell these kinds of products. So, regarding product type of other SMEs, using 104's distribution network might not be appropriate.

5.2.8 Marketing

Marketing alliance network analyzed in chapter four shows that forming marketing alliances has not been considered adequately by NF managers. High-tech companies tend to have more of an engineering orientation than a marketing orientation, and thus top management tends to be more skeptical about the value of marketing (O'Sullivan and Abela, 2007). There is a tendency in the high-tech industry to believe that the technological superiority of a product is the determining variable in its commercial success (Davies and Brush, 1997). Nevertheless, as high-tech products are more complicated, they require greater customer education and more product information. This necessity results in greater effort on the part of marketing to adequately convey the necessary information as well as greater effort on the part of the consumer to digest the information (Rosen et al., 1998). Therefore, stronger consideration for the marriage of marketing and technology is essential for the firms studied in this research.

Besides opportunities recognized by applying SHA, there are opportunities for professional firms to put themselves in positions that NFs are weak at and deliver services most needed by NFs. One of these positions is for a consulting firm specialized in high-tech marketing to provide NFs with related services and empower them in marketing their products and as a result extend the marketing competencies of the whole network.

5.2.9 Managerial Cooperation

As depicted in figure 4-16 very few number of NFs are involved in relationships that provide them managerial consultation and assistance. One of the reasons, as mentioned

by the NF managers, might be the absence of a professional consulting firm specialized in high-tech industries. Other influential factor on not cooperating with others on managerial issues could be the negative attitude of NF managers toward this type of cooperation. Being a SME and having limited monetary resources may also affect on managers' decision in spending for getting consultation.

5.2.10 Foreign Ties

The sociogram representing foreign ties of NFs (figure 4-18) revealed prominent actors in that network (i.e. Germany and Russia). This should be noted by policy makers and NF managers because of the fact that if economic relations with these countries become constrained, as a result of some factors like sanction, NFs will lose their foreign partners in the mentioned countries.

5.3 Limitations and Future Research Directions

Like all research this study is not without its limitations. This research studies the alliance network of Nanotech SMEs in Iran at a particular time; therefore, the results represent a static picture of NF partnerships and their opportunities and challenges in the current status. These relationships evolve in future and new alliances might be formed. So, the drawn managerial implications and discussions are confined to the time of the study. As a future research direction, a dynamic type of research is suggested to monitor the changing of the alliances that enables us to perform continuous analysis of the network. This type of research assists managers, decision makers, marketers, etc. to be sensitive to the changes of the network and react accordingly. Furthermore, this kind of research produces snapshots of network over time. By comparing them, it will be possible to reveal and understand the main trends in the network.

The data on relationships of NFs with their partners, used in this study, are claims of NF managers and are not validated. This limitation could be transcended by devising a model to keep record of firms' partnerships and officially register their alliances. This way, sound and precise data on NF partnerships would be available and the resulting analysis and implications would also have greater validity.

An interesting study would also be to compare this network with the Nanotech business networks in other countries, to see whether or not the same characteristics surface in different countries.

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7 Appendix

Appendix A

Questions of semi-structured interviews

1. Which firms, universities, research centers, or laboratories does your company have joint research and development activities with?
2. Which investors or financiers does your company have cooperation with?
3. Which companies are your suppliers for raw materials or instruments?
4. Which companies does your firm have joint production activities with?
5. With which of your industrial companies do you have alliances?
6. Does your company have a distribution network? Name domestic or foreign branches or sales representatives.
7. Which companies are your firm's partners in the field of marketing?
8. Does your company cooperate with others for logistics?
9. Which companies are your firm's partners for managerial cooperation?
10. Which companies does your firm collaborate with on standardization issues of Nanotech products?
11. Do you outsource any of your firm's activities to other companies? Name the company and the type of activity outsourced.
12. Does your firm have any other relationships or alliances with other companies not covered in previous questions?

Appendix B

Iranian Nanotech SMEs attributes and codes are shown in the table 7-1. Number of Employees indicates on the number of SME employees work in Nanotech field.

Table 7-1. Nanotech SMEs code numbers and attributes

No.	Company Name	Code	Type	Product	Year of Establishing	No. of Employees
1	Nano Pac Persia Co.	101	Manufacturing company	Nano treatment solutions for air/water/soil, Nano air conditioning filter and Nano sized photo catalysts	2006	17
2	Nano Nasb Pars Co.	102	Manufacturing company	Nano silver in colloidal and powder forms (Nanocid)	2003	43
3	Pishgaman Nano Aria Co.	103	Manufacturing company	Motor oil supplement based on Nano diamond particles	2006	5
4	Kaveh Float Glass Co.	104	Manufacturing company	Nano coating glasses such as Low-E, Solar control and tamable	2005	40
5	Noavaran Catalyst Co.	105	Manufacturing company	Nano Zinc Oxide	2001	3
6	Bonyan Nano Fanavaran Pars Co.	106	Manufacturing company	Fuel supplement based on Nano emulsion to reduce fuel consumption	2006	5
7	Chitotech Co.	107	Manufacturing company	Wound care products based on Nano silver particles	2004	4
8	Nano System Pars Co. (Natsyco)	109	Manufacturing company	Scanning Tunneling Microscope (NAMA-STM)	2006	7

No.	Company Name	Code	Type	Product	Year of Establishing	No. of Employees
9	Baspar Nano Bon Co.	112	Manufacturing company	industrial compound based on Nano materials	2006	4
10	Narmin Shimi Co.	113	Manufacturing company	Nanosilver particles and TiO2	1999 (Nano division: 2007)	5
11	Nano Sina Co.	114	Manufacturing company	Breast Cancer Diagnosis Kit	2006	8
12	Jazika Co.	117	Manufacturing company	Alumina Nano Particles	2006	5
13	Nano Pars Spadana Co.	125	Manufacturing company	Metal oxide Nano particles like Zinc Oxide	2007	7
14	Panatech Co.	115	Import/Export company	Nano additives which make paints and coatings anti-bacterial, self clean coatings	2007	2
15	Fanavaran Araz Tajhiz Co.	123	Import/Export company	Import and distribution of Nanomaterials and instruments	2005	2
16	Nano Star Tech Co.	124	Import/Export company	Nanomaterials import	2006	7
17	Nanoshop Virtual Store	127	Import/Export company	Selling Nano materials	2003	1
18	Fanavari Behnour Sazan Mahyad Co.	120	Import/Export company	Nanotech instruments import	2004	12
19	Fargen Pouyesh Co.	121	Import/Export company	Nanotech instruments import	2003	7
20	Pousheshhaye Nano Sakhtar Co.	110	Incubator Firm	TiO2 Nano particle solutions, vacuum coating systems	2006	7
21	Asia Technology Pioneers Co.	111	Incubator Firm	Nano additives for paint, ink, coating, etc.	2004	3

No.	Company Name	Code	Type	Product	Year of Establishing	No. of Employees
22	Iramont Co.	108	Incubator Firm	Nanoclay and super absorbing hydro gels	2005	6
23	Tamam Mavad Mohandesi Co.	118	Technology development Service Firm	Antibacterial, self-cleaning and anti-fog coatings	2007	2
24	Tedsei Co.	119	Technology development Service Firm	Consulting services in using high technologies in construction fields	2006	2

Code numbers and names of all other actors in the network are presented in table 7-2.

Table 7-2. Actors' code numbers and names

Code	Name
201	University of Tehran – Nano Science & Technology Research Center
202	Iran Polymer and Petrochemical Institute
204	Japanese Research Centers
205	Oil Industry Research Center
206	ITRAK
207	IPKO
208	SAIPA Research & Innovation Center
209	Sharif University of Technology - Institute for Nano-science & Nanotechnology
210	Montreal University
211	Canada Polytechnic University
212	Amir Kabir University - Nanotechnology Research Center
213	Shaheed Beheshti University
214	Razi Metallurgy Research Center
215	Alborz Bulk Laboratory
216	Azad University
217	Canada National Research Council
218	Building and Housing Research Center
219	Iran-Composite Network
220	Material and Energy Research Center
221	Chemistry and Chemical Engineering Research Center of Iran
222	Stazione Sperimentale
223	Tarbiat Modares University
224	Industries and Mines R&D Center
225	University of Water & Electricity Industry
226	Institute for Colorants, Paint and Coatings (ICPC)
227	Niroo Research Institute
228	Iran University of Medical Science
230	Iran Science & Technology University - Center of Excellence for Advanced Materials
231	Khaje Nasir University - Nanotechnology & Advanced Materials Research Lab
233	Orumieh University of Technology
234	Saadat Abad Microbiology Lab
236	Esfahan University
239	Moscow University
240	Saint Petersburg University
241	Jahad Daneshgahi Technology Development Research Center
242	Imam Hussein University
247	Tehran University of Medical Science - Medical Nanotechnology Research Center
248	Koln University, Immunology Institute
249	Ministry of Agriculture Research

Code	Name
	Institute
250	Pastor Institute of Iran
251	Esfahan University of Technology - Nanotechnology & Advanced Materials Research Center
252	Isfahan Science & Technology Town
254	Mashhad University
301	Etka Org
304	Amir Kabir Petrochemical Company
305	Bandar Imam Petrochemical Company
306	Tabriz Petrochemical Company
307	Bakhtar Petrochemical Company
308	Maroon Petrochemical Company
309	Arak Petrochemical Company
310	Baspar Nano Bon Tehran Branch
311	Baspar Nano Bon Mashhad Branch
312	NanoVita Moscow
313	Iranian Nanotech Initiative Council (INIC)
314	Nanotech French Co.
315	Bonyade Daneshpajoohan Institute
316	National Iranian Oil Products Distribution Company (NIOPDC)
317	Nokhbegan Technology Development Institute
319	Standard Institute of Iran
320	Fan Niroo Co.
321	Daeteb Co.
322	Zarin Namaye Majd Co.
323	Bond Tape Co.
324	AS Composite Co.
325	Salehan Ati Negar Co.
326	CBR Plus North America Inc.
327	AsiaBioTech Co.
328	Kasaeian Trading Co.
329	Sypher Co.
330	Alborz Investment Co.
332	Iramont Ghazvin Branch
333	Iramont Mashhad Branch
334	Iramont Kerman Branch
335	Iramont Shiraz Branch
336	Iramont Boushehr Branch
337	Iramont Tehran Branch (NanoAB)
338	Iramont Isfahan Branch
339	Iramont Kermanshah Branch
340	Iramont Yazd Branch

Code	Name
341	Iramont Azarbayjan Branch
342	Iramont Khouzestan Branch
343	Inno-centre Co.
344	Applied Materials Germany
345	Kansaran Binalood Co.
346	Farafan Gaz Co.
347	Jahad Daneshgahi Sharif
348	Modares Intellectual Property Services Institute
349	Industrial Management Org.
350	Perkin Elmer Co.
351	Sharpless Co.
352	Applied Science Co.
353	Sama Micro Co.
354	IMACO
355	FaraSot Sanat Co.
356	Kaveh Float Egypt Branch
357	Kaveh Float Armenia Branch
358	Kaveh Float Turkemanistan Branch
359	Kaveh Float Afghanistan Branch
360	Kaveh Float Kwait Branch
361	Kaveh Float Romania Branch
362	Iranian fuel conservation company (IFCO)
363	Mineral Producers & Exporters Union
364	Iran-Iraq Commerce Room
365	Iran-Russia Commerce Room
366	Iran-Saudi Arabia Commerce Room
367	Castoli Institute
368	Diamat metal Co.
369	Korean Trade Company
370	European SGS Co.
371	IGI Co.
372	Mahar Fan Abzar Co.
373	Farayand Sabz Co.
374	NikTex Co.
375	American Nanotech Association
376	Bidestan Alcohol Producing Co.
377	Fluka Co.
378	Merck Co.
379	Valapoosh Co.
380	Teriko Sport Co.
381	Kasper Co.
382	Falate Ghareh Co.
383	Caspian Co.
384	Gerad Afarin Co.

Code	Name
385	Narmin Shimi Shanghai Branch
386	Narmin Shimi Dubai Branch
387	Narmin Shimi Ahvaz Branch
388	Narmin Shimi Mashhad Branch
389	Ministry of Health
397	Rangine Pars Co.
398	Novin Shimi Yar Co.
399	Barghgire Toos Co.
401	UAE
403	Russia
404	Japan
405	Canada
406	South Africa
407	China
408	Korea
409	Switzerland
410	USA
411	Germany
413	England
414	India
415	Turkey
419	Iraq
420	Ukraine
421	Indonesia
422	Australia
423	Taiwan
424	Austria
425	Sweden
426	Malaysia
427	Belgium
428	Netherland
429	Bahrain
430	Egypt
431	Jordan
432	Kuwait
433	Lebanon
434	Qatar
435	Saudi Arabia
436	Sudan
437	Somalia
438	Syria
439	Yemen
440	Afghanistan
441	Singapore
442	Romania
443	Denmark
444	Ireland

Code	Name
445	New Zealand
446	Azerbaijan
601	Bazaar - Tehran
605	Bazaar - Isfahan
606	Bazaar - Tabriz
3104	Lamp Producing Chinese Co.
3105	Biosera Co.
3106	Nano Group Co.
3107	Goharfam Ceramics
3108	Rangin Zereh Sepahan Co.
3109	Ala Baft Co.
3110	Afratab Co.
3115	Panatech Tabriz
3116	Pajhan Mehre Tehran Co.
3117	Sina Tile Co.
3118	Vesta Organano Co.
3121	Petro chemistry Co.
3122	Ministry of Defense
3123	Sepahan Oil Refinery Plant
3124	LIQUI MOLI Co.
3127	Khoy Pishgaman Nano Aria Branch
3128	Gorgan Pishgaman Nano Aria Branch
3129	Zahedan Pishgaman Nano Aria Branch
3130	Saravan Pishgaman Nano Aria Branch
3131	Ardebil Pishgaman Nano Aria Branch
3132	Orumieh Pishgaman Nano Aria Branch
3133	Qom Pishgaman Nano Aria Branch
3134	Kordestan Pishgaman Nano Aria Branch
3135	Shahrekord Pishgaman Nano Aria Branch
3136	Bushehr Pishgaman Nano Aria Branch
3137	Parsi tech Co.
3138	Pouya Moshaver Co.
3140	Atomic Energy Organization of Iran
3141	Karaj Chitotech
3142	Razak Teb Co.
3143	Mahyan Teb Co.
3144	Pars Shafa Co.
3145	Nour Teb Co.
3146	Peyman Co.

Code	Name
3147	Semnan Instruments Co.
3148	Razi Co.
3149	Rezaee Bakhtiari Co.
3150	Darinush Instruments Co.
3151	Tehran Teb Co.
3152	Kavosh Khalagh Co.
3153	Gharb Sugery Instruments Co.
3154	Sina Instruments Co.
3155	Hafezi Co.
3156	Kia Teb Gharb Co.
3157	Ekram Medical Instruments Co.
3158	Farjen Pouyesh Mazandaran Branch
3159	Farjen Pouyesh Azarbayjan Branch
3161	Nanotech Russia Co.
3162	MMI Co.
3163	IAI-RAS Institute
3164	ATC Co.
3165	SPS Co.
3166	Nanotechnology Korea Co.
3167	Micromod Co.
3168	Fanavaran Araz Tajhiz Russia Branch
3169	Tamam Tarh Co.
3170	HarekateSabz Co.
3171	Arvis Co.
3173	Electronic dienner Co.
3174	Ankersmid Co.
3175	Oxford plasma Co.
3176	LABNICS Equipments Co.
3178	Agilent Co.
3179	Spectrolab Co.
3180	Mitsubishi Co.
3181	Yamato Co.
3182	Xrayassociate Co.
3185	Iran Nanotechnology Association
3186	Polymer Co., Startech Partner
3187	Plasmachem GmbH
3188	NanoCare Co.
3189	Iran Veterinary Organization
3191	Mahiran Co.
3192	Behdam Veterinary Hospital
3193	Mehregan Veterinary Hospital
3194	Environment Protection Organization
3195	Health Secretary of Qom Holy Shrine

Code	Name
3196	Malvern Instruments Co.
3197	Mahvar Ghane Co.
3198	Nanovatis Co.
3199	Ecnline Co.
3200	Neozelekt Co.
3201	Gilan Gloves Co.
3202 - 3360	NanoNasb Branches in Iran
3361	NanoNasb Branch - France
3362	NanoNasb Branch - Sweden
3363	NanoNasb Branch - Turkey
3364	NanoNasb Branch - Malaysia
3365	TUV Institute
3366 - 3548	Kaveh Float Branches in Iran
3549 - 3554	Jazika Branches in Iran
3555	Isfahan UCF
3556	Bayer Co.
3557	Basf Co.
3559	Besat Defense Ind. Co.
3560	Isfahan Defense Ind. Co.
3561	Alvar Plast Co.
3562	Nano Pac Co. Korea
3563	Kimiaye Shargh Co.
3564	Aldrich Co.
3565	Reef Iran Co.
3566	Iran Polymer Co.
3567	Khodrang Co.
3568	Nano pars zayandehrood Co.
3569	Andishe Sabz Spaneh Co.
3570	Tehran Farmer House
3571	Malaysian Co.
3572	Iran Organization of Industries and Mines
3573	Fraunhofer Co.
3574	Sina Gene Co.

Appendix C

Results of structural hole analysis for nodes 104 and 102 in Nanotech SME network are presented in tables 7-3 and 7-4 respectively. Tables 7-5, 7-6, and 7-7 show the results for nodes 102, 223, and 209 in R&D network.

Table 7-3. Structural Hole Analysis for node 104 in SME network

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
205	0.005	0.00002	0.0046
209	0.005	0.00002	0.0046
212	0.005	0.00002	0.0046
220	0.005	0.00002	0.0046
221	0.005	0.00002	0.0046
222	0.005	0.00002	0.0046
223	0.005	0.00002	0.0046
313	0.005	0.00002	0.0046
344	0.005	0.00002	0.0046
345	0.005	0.00002	0.0046
346	0.005	0.00002	0.0046
348	0.005	0.00002	0.0046
349	0.005	0.00002	0.0046
350	0.005	0.00002	0.0046
351	0.005	0.00002	0.0046
352	0.005	0.00002	0.0046
353	0.005	0.00002	0.0046
354	0.005	0.00002	0.0046
355	0.005	0.00002	0.0046
356	0.005	0.00002	0.0046
357	0.005	0.00002	0.0046
358	0.005	0.00002	0.0046
359	0.005	0.00002	0.0046
360	0.005	0.00002	0.0046
361	0.005	0.00002	0.0046
362	0.005	0.00002	0.0046
363	0.005	0.00002	0.0046
364	0.005	0.00002	0.0046
365	0.005	0.00002	0.0046
366	0.005	0.00002	0.0046
3366	0.005	0.00002	0.0046
3367	0.005	0.00002	0.0046
3368	0.005	0.00002	0.0046
3369	0.005	0.00002	0.0046
3370	0.005	0.00002	0.0046
3371	0.005	0.00002	0.0046
3372	0.005	0.00002	0.0046
3373	0.005	0.00002	0.0046
3374	0.005	0.00002	0.0046
3375	0.005	0.00002	0.0046
3376	0.005	0.00002	0.0046
3377	0.005	0.00002	0.0046
3378	0.005	0.00002	0.0046
3379	0.005	0.00002	0.0046
3380	0.005	0.00002	0.0046
3381	0.005	0.00002	0.0046
3382	0.005	0.00002	0.0046
3383	0.005	0.00002	0.0046
3384	0.005	0.00002	0.0046
3385	0.005	0.00002	0.0046
3386	0.005	0.00002	0.0046
3387	0.005	0.00002	0.0046
3388	0.005	0.00002	0.0046
3389	0.005	0.00002	0.0046
3390	0.005	0.00002	0.0046
3391	0.005	0.00002	0.0046
3392	0.005	0.00002	0.0046
3393	0.005	0.00002	0.0046
3394	0.005	0.00002	0.0046
3395	0.005	0.00002	0.0046
3396	0.005	0.00002	0.0046
3397	0.005	0.00002	0.0046

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
3398	0.005	0.00002	0.0046
3399	0.005	0.00002	0.0046
3400	0.005	0.00002	0.0046
3401	0.005	0.00002	0.0046
3402	0.005	0.00002	0.0046
3403	0.005	0.00002	0.0046
3404	0.005	0.00002	0.0046
3405	0.005	0.00002	0.0046
3406	0.005	0.00002	0.0046
3407	0.005	0.00002	0.0046
3408	0.005	0.00002	0.0046
3409	0.005	0.00002	0.0046
3410	0.005	0.00002	0.0046
3411	0.005	0.00002	0.0046
3412	0.005	0.00002	0.0046
3413	0.005	0.00002	0.0046
3414	0.005	0.00002	0.0046
3415	0.005	0.00002	0.0046
3416	0.005	0.00002	0.0046
3417	0.005	0.00002	0.0046
3418	0.005	0.00002	0.0046
3419	0.005	0.00002	0.0046
3420	0.005	0.00002	0.0046
3421	0.005	0.00002	0.0046
3422	0.005	0.00002	0.0046
3423	0.005	0.00002	0.0046
3424	0.005	0.00002	0.0046
3425	0.005	0.00002	0.0046
3426	0.005	0.00002	0.0046
3427	0.005	0.00002	0.0046
3428	0.005	0.00002	0.0046
3429	0.005	0.00002	0.0046
3430	0.005	0.00002	0.0046
3431	0.005	0.00002	0.0046
3432	0.005	0.00002	0.0046
3433	0.005	0.00002	0.0046
3434	0.005	0.00002	0.0046
3435	0.005	0.00002	0.0046
3436	0.005	0.00002	0.0046

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
3437	0.005	0.00002	0.0046
3438	0.005	0.00002	0.0046
3439	0.005	0.00002	0.0046
3440	0.005	0.00002	0.0046
3441	0.005	0.00002	0.0046
3442	0.005	0.00002	0.0046
3443	0.005	0.00002	0.0046
3444	0.005	0.00002	0.0046
3445	0.005	0.00002	0.0046
3446	0.005	0.00002	0.0046
3447	0.005	0.00002	0.0046
3448	0.005	0.00002	0.0046
3449	0.005	0.00002	0.0046
3450	0.005	0.00002	0.0046
3451	0.005	0.00002	0.0046
3452	0.005	0.00002	0.0046
3453	0.005	0.00002	0.0046
3454	0.005	0.00002	0.0046
3455	0.005	0.00002	0.0046
3456	0.005	0.00002	0.0046
3457	0.005	0.00002	0.0046
3458	0.005	0.00002	0.0046
3459	0.005	0.00002	0.0046
3460	0.005	0.00002	0.0046
3461	0.005	0.00002	0.0046
3462	0.005	0.00002	0.0046
3463	0.005	0.00002	0.0046
3464	0.005	0.00002	0.0046
3465	0.005	0.00002	0.0046
3466	0.005	0.00002	0.0046
3467	0.005	0.00002	0.0046
3468	0.005	0.00002	0.0046
3469	0.005	0.00002	0.0046
3470	0.005	0.00002	0.0046
3471	0.005	0.00002	0.0046
3472	0.005	0.00002	0.0046
3473	0.005	0.00002	0.0046
3474	0.005	0.00002	0.0046
3475	0.005	0.00002	0.0046

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
3476	0.005	0.00002	0.0046
3477	0.005	0.00002	0.0046
3478	0.005	0.00002	0.0046
3479	0.005	0.00002	0.0046
3480	0.005	0.00002	0.0046
3481	0.005	0.00002	0.0046
3482	0.005	0.00002	0.0046
3483	0.005	0.00002	0.0046
3484	0.005	0.00002	0.0046
3485	0.005	0.00002	0.0046
3486	0.005	0.00002	0.0046
3487	0.005	0.00002	0.0046
3488	0.005	0.00002	0.0046
3489	0.005	0.00002	0.0046
3490	0.005	0.00002	0.0046
3491	0.005	0.00002	0.0046
3492	0.005	0.00002	0.0046
3493	0.005	0.00002	0.0046
3494	0.005	0.00002	0.0046
3495	0.005	0.00002	0.0046
3496	0.005	0.00002	0.0046
3497	0.005	0.00002	0.0046
3498	0.005	0.00002	0.0046
3499	0.005	0.00002	0.0046
3500	0.005	0.00002	0.0046
3501	0.005	0.00002	0.0046
3502	0.005	0.00002	0.0046
3503	0.005	0.00002	0.0046
3504	0.005	0.00002	0.0046
3505	0.005	0.00002	0.0046
3506	0.005	0.00002	0.0046
3507	0.005	0.00002	0.0046
3508	0.005	0.00002	0.0046
3509	0.005	0.00002	0.0046
3510	0.005	0.00002	0.0046
3511	0.005	0.00002	0.0046
3512	0.005	0.00002	0.0046
3513	0.005	0.00002	0.0046
3514	0.005	0.00002	0.0046

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
3515	0.005	0.00002	0.0046
3516	0.005	0.00002	0.0046
3517	0.005	0.00002	0.0046
3518	0.005	0.00002	0.0046
3519	0.005	0.00002	0.0046
3520	0.005	0.00002	0.0046
3521	0.005	0.00002	0.0046
3522	0.005	0.00002	0.0046
3523	0.005	0.00002	0.0046
3524	0.005	0.00002	0.0046
3525	0.005	0.00002	0.0046
3526	0.005	0.00002	0.0046
3527	0.005	0.00002	0.0046
3528	0.005	0.00002	0.0046
3529	0.005	0.00002	0.0046
3530	0.005	0.00002	0.0046
3531	0.005	0.00002	0.0046
3532	0.005	0.00002	0.0046
3533	0.005	0.00002	0.0046
3534	0.005	0.00002	0.0046
3535	0.005	0.00002	0.0046
3536	0.005	0.00002	0.0046
3537	0.005	0.00002	0.0046
3538	0.005	0.00002	0.0046
3539	0.005	0.00002	0.0046
3540	0.005	0.00002	0.0046
3541	0.005	0.00002	0.0046
3542	0.005	0.00002	0.0046
3543	0.005	0.00002	0.0046
3544	0.005	0.00002	0.0046
3545	0.005	0.00002	0.0046
3546	0.005	0.00002	0.0046
3547	0.005	0.00002	0.0046
3548	0.005	0.00002	0.0046
101	0.002	0.00001	0.0023
218	0.002	0.00001	0.0023
224	0.002	0.00001	0.0023
347	0.002	0.00001	0.0023
370	0.002	0.00001	0.0023

Table 7-4. Structural Hole Analysis for node 102 in SME network

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
107	0.005	0.00013	0.0047
108	0.005	0.00005	0.0048
109	0.005	0.00003	0.0048
110	0.005	0.00003	0.0048
111	0.005	0.00003	0.0048
112	0.005	0.00003	0.0048
113	0.005	0.00003	0.0048
114	0.005	0.00003	0.0048
115	0.005	0.00003	0.0048
116	0.005	0.00002	0.0048
117	0.005	0.00002	0.0048
118	0.005	0.00002	0.0048
119	0.005	0.00002	0.0048
120	0.005	0.00002	0.0048
121	0.005	0.00002	0.0048
122	0.005	0.00002	0.0048
123	0.005	0.00002	0.0048
124	0.005	0.00002	0.0048
125	0.005	0.00002	0.0048
126	0.005	0.00002	0.0048
127	0.005	0.00002	0.0048
128	0.005	0.00002	0.0048
129	0.005	0.00002	0.0048
130	0.005	0.00002	0.0048
131	0.005	0.00002	0.0048
132	0.005	0.00002	0.0048
133	0.005	0.00002	0.0048
134	0.005	0.00002	0.0048
135	0.005	0.00002	0.0048
136	0.005	0.00002	0.0048
137	0.005	0.00002	0.0048
138	0.005	0.00002	0.0048
139	0.005	0.00002	0.0048
140	0.005	0.00002	0.0048
141	0.005	0.00002	0.0048
142	0.005	0.00002	0.0048
143	0.005	0.00002	0.0048
144	0.005	0.00002	0.0048

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
145	0.005	0.00002	0.0048
146	0.005	0.00002	0.0048
147	0.005	0.00002	0.0048
148	0.005	0.00002	0.0048
149	0.005	0.00002	0.0048
150	0.005	0.00002	0.0048
151	0.005	0.00002	0.0048
152	0.005	0.00002	0.0048
153	0.005	0.00002	0.0048
154	0.005	0.00002	0.0048
155	0.005	0.00002	0.0048
156	0.005	0.00002	0.0048
157	0.005	0.00002	0.0048
158	0.005	0.00002	0.0048
159	0.005	0.00002	0.0048
160	0.005	0.00002	0.0048
161	0.005	0.00002	0.0048
162	0.005	0.00002	0.0048
163	0.005	0.00002	0.0048
164	0.005	0.00002	0.0048
165	0.005	0.00002	0.0048
166	0.005	0.00002	0.0048
167	0.005	0.00002	0.0048
168	0.005	0.00002	0.0048
169	0.005	0.00002	0.0048
170	0.005	0.00002	0.0048
171	0.005	0.00002	0.0048
172	0.005	0.00002	0.0048
173	0.005	0.00002	0.0048
174	0.005	0.00002	0.0048
175	0.005	0.00002	0.0048
176	0.005	0.00002	0.0048
177	0.005	0.00002	0.0048
178	0.005	0.00002	0.0048
179	0.005	0.00002	0.0048
180	0.005	0.00002	0.0048
181	0.005	0.00002	0.0048
182	0.005	0.00002	0.0048

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
183	0.005	0.00002	0.0048
184	0.005	0.00002	0.0048
185	0.005	0.00002	0.0048
186	0.005	0.00002	0.0048
187	0.005	0.00002	0.0048
188	0.005	0.00002	0.0048
189	0.005	0.00002	0.0048
190	0.005	0.00002	0.0048
191	0.005	0.00002	0.0048
192	0.005	0.00002	0.0048
193	0.005	0.00002	0.0048
194	0.005	0.00002	0.0048
195	0.005	0.00002	0.0048
196	0.005	0.00002	0.0048
197	0.005	0.00002	0.0048
198	0.005	0.00002	0.0048
199	0.005	0.00002	0.0048
200	0.005	0.00002	0.0048
201	0.005	0.00002	0.0048
202	0.005	0.00002	0.0048
203	0.005	0.00002	0.0048
204	0.005	0.00002	0.0048
205	0.005	0.00002	0.0048
206	0.005	0.00002	0.0048
207	0.005	0.00002	0.0048
208	0.005	0.00002	0.0048
209	0.005	0.00002	0.0048
210	0.005	0.00002	0.0048
211	0.005	0.00002	0.0048
212	0.005	0.00002	0.0048
213	0.005	0.00002	0.0048
214	0.005	0.00002	0.0048
215	0.005	0.00002	0.0048
216	0.005	0.00002	0.0048
217	0.005	0.00002	0.0048
218	0.005	0.00002	0.0048
219	0.005	0.00002	0.0048
220	0.005	0.00002	0.0048
221	0.005	0.00002	0.0048

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
222	0.005	0.00002	0.0048
223	0.005	0.00002	0.0048
224	0.005	0.00002	0.0048
225	0.005	0.00002	0.0048
226	0.005	0.00002	0.0048
227	0.005	0.00002	0.0048
228	0.005	0.00002	0.0048
229	0.005	0.00002	0.0048
230	0.005	0.00002	0.0048
231	0.005	0.00002	0.0048
232	0.005	0.00002	0.0048
233	0.005	0.00002	0.0048
234	0.005	0.00002	0.0048
235	0.005	0.00002	0.0048
236	0.005	0.00002	0.0048
237	0.005	0.00002	0.0048
238	0.005	0.00002	0.0048
239	0.005	0.00002	0.0048
240	0.005	0.00002	0.0048
241	0.005	0.00002	0.0048
242	0.005	0.00002	0.0048
243	0.005	0.00002	0.0048
244	0.005	0.00002	0.0048
245	0.005	0.00002	0.0048
246	0.005	0.00002	0.0048
247	0.005	0.00002	0.0048
248	0.005	0.00002	0.0048
249	0.005	0.00002	0.0048
250	0.005	0.00002	0.0048
251	0.005	0.00002	0.0048
252	0.005	0.00002	0.0048
253	0.005	0.00002	0.0048
254	0.005	0.00002	0.0048
255	0.005	0.00002	0.0048
256	0.005	0.00002	0.0048
257	0.005	0.00002	0.0048
258	0.005	0.00002	0.0048
259	0.005	0.00002	0.0048
260	0.005	0.00002	0.0048

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
261	0.005	0.00002	0.0048
262	0.005	0.00002	0.0048
263	0.005	0.00002	0.0048
264	0.005	0.00002	0.0048
265	0.005	0.00002	0.0048
266	0.005	0.00002	0.0048
267	0.005	0.00002	0.0048
268	0.005	0.00002	0.0048
269	0.005	0.00002	0.0048
270	0.005	0.00002	0.0048
271	0.005	0.00002	0.0048
272	0.005	0.00002	0.0048
273	0.005	0.00002	0.0048
274	0.005	0.00002	0.0048
275	0.005	0.00002	0.0048
276	0.005	0.00002	0.0048
277	0.005	0.00002	0.0048
278	0.005	0.00002	0.0048
279	0.005	0.00002	0.0048
280	0.005	0.00002	0.0048
281	0.005	0.00002	0.0048
282	0.005	0.00002	0.0048
283	0.005	0.00002	0.0048
284	0.005	0.00002	0.0048
285	0.005	0.00002	0.0048
286	0.005	0.00002	0.0048
287	0.005	0.00002	0.0048
288	0.005	0.00002	0.0048
289	0.005	0.00002	0.0048
290	0.005	0.00002	0.0048
291	0.005	0.00002	0.0048
292	0.005	0.00002	0.0048
293	0.005	0.00002	0.0048

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
294	0.005	0.00002	0.0048
295	0.005	0.00002	0.0048
296	0.005	0.00002	0.0048
297	0.005	0.00002	0.0048
298	0.005	0.00002	0.0048
299	0.005	0.00002	0.0048
300	0.005	0.00002	0.0048
301	0.005	0.00002	0.0048
302	0.005	0.00002	0.0048
303	0.005	0.00002	0.0048
304	0.005	0.00002	0.0048
305	0.002	0.0001	0.0023
306	0.002	0.00004	0.0024
307	0.002	0.00002	0.0024
308	0.002	0.00001	0.0024
309	0.002	0.00001	0.0024
310	0.002	0.00001	0.0024
311	0.002	0.00001	0.0024
312	0.002	0.00001	0.0024
313	0.002	0.00001	0.0024
314	0.002	0.00001	0.0024
315	0.002	0.00001	0.0024
316	0.002	0.00001	0.0024
317	0.002	0.00001	0.0024
318	0.002	0.00001	0.0024
319	0.002	0.00001	0.0024
320	0.002	0.00001	0.0024
321	0.002	0.00001	0.0024
322	0.002	0.00001	0.0024
323	0.002	0.00001	0.0024

Table 7-5. Structural Hole Analysis for node 102 in R&D network

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
201	0.033	0.0011	0.0319
202	0.033	0.0011	0.0319
209	0.033	0.0011	0.0319
214	0.033	0.0011	0.0319
220	0.033	0.0011	0.0319
221	0.033	0.0011	0.0319
223	0.033	0.0011	0.0319
226	0.033	0.0011	0.0319
228	0.033	0.0011	0.0319
230	0.033	0.0011	0.0319
246	0.033	0.0011	0.0319
247	0.033	0.0011	0.0319
248	0.033	0.0011	0.0319
249	0.033	0.0011	0.0319
250	0.033	0.0011	0.0319
389	0.033	0.0011	0.0319
3140	0.033	0.0011	0.0319
3189	0.033	0.0011	0.0319
3191	0.033	0.0011	0.0319
3192	0.033	0.0011	0.0319
3193	0.033	0.0011	0.0319
3194	0.033	0.0011	0.0319
3195	0.033	0.0011	0.0319
3196	0.033	0.0011	0.0319
3197	0.033	0.0011	0.0319
3198	0.033	0.0011	0.0319
3199	0.033	0.0011	0.0319
3200	0.033	0.0011	0.0319
404	0.016	0.0003	0.0157
415	0.016	0.0003	0.0157
422	0.016	0.0003	0.0157
426	0.016	0.0003	0.0157
441	0.016	0.0003	0.0157

Table 7-6. Structural Hole Analysis for node 223 in R&D network

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
102	0.111	0.0123	0.0987
104	0.111	0.0123	0.0987
105	0.111	0.0123	0.0987
107	0.111	0.0123	0.0987
111	0.111	0.0123	0.0987
113	0.111	0.0123	0.0987
117	0.111	0.0123	0.0987
118	0.111	0.0123	0.0987
121	0.111	0.0123	0.0987

Table 7-7. Structural Hole Analysis for node 209 in R&D network

Actors	p_{ij}	c_{ij}	$p_{ij} - c_{ij}$
102	0.154	0.024	0.13
104	0.154	0.024	0.13
108	0.154	0.024	0.13
110	0.154	0.024	0.13
113	0.154	0.024	0.13
119	0.154	0.024	0.13
106	0.077	0.006	0.071

Appendix D

Detailed information on who is connected to whom in the Nanotech SME network is presented in table 7-8. Numbers under 'Node 1' and 'Node 2' columns refer to actors' code number shown in tables 7-1 and 7-2. 'Link type' numbers indicate on the cooperation type between two nodes described earlier in table 3-1. 'Link strength' column shows strong and weak ties by '1' and '0.5' values respectively.

Table 7-8. All ties in the Nanotech SME network

Node 1	Node 2	Link Type	Link Strength
112	201	1	1
112	202	1	1
112	301	1	1
112	204	1	1
112	601	3	1
112	304	3	1
112	310	6	1
112	311	6	1
112	312	6	0.5
112	401	6	0.5
112	304	7	1
112	305	7	1
112	306	7	1
112	307	7	0.5
112	308	7	0.5
112	309	7	0.5
112	313	2	1
112	314	4	0.5
112	125	4	0.5
106	315	1	1
106	205	1	1
106	206	1	1
106	207	1	1
106	208	1	1
106	319	1	1
106	316	1	1
106	209	1	0.5
106	315	2	1
106	601	3	1
106	316	5	1
106	315	9	1
106	317	9	1
106	313	2	1
106	320	8	1
108	209	1	1
108	210	1	1
108	211	1	1
108	212	1	1
108	213	1	1
108	214	1	1
108	215	1	1
108	205	1	1
108	202	1	1
108	406	1	1
108	216	1	1
108	406	3	1
108	407	3	1
108	408	3	1
108	409	3	1
108	321	3	1
108	322	3	1
108	323	3	1
108	324	4	1
108	325	4	1
108	326	4	1
108	327	4	1
108	328	4	1
108	329	4	1
108	330	4	1
108	332	6	1
108	333	6	1
108	334	6	1

Node 1	Node 2	Link Type	Link Strength
108	335	6	1
108	336	6	1
108	337	6	1
108	338	6	1
108	339	6	1
108	340	6	1
108	341	6	1
108	342	6	1
108	343	9	1
108	217	9	1
108	218	11	0.5
108	219	1	1
108	313	11	0.5
104	344	1	1
104	209	1	1
104	345	1	1
104	220	1	1
104	221	1	1
104	205	1	1
104	346	1	1
104	222	1	1
104	212	1	1
104	223	1	1
104	347	1	0.5
104	348	1	1
104	349	1	1
104	350	3	1
104	351	3	1
104	352	3	1
104	353	3	1
104	354	3	1
104	355	3	1
104	356	6	1
104	357	6	1
104	358	6	1
104	359	6	1
104	360	6	1
104	361	6	1
104	362	7	1
104	218	10	0.5
104	224	11	0.5
104	101	4	0.5
104	363	11	1

Node 1	Node 2	Link Type	Link Strength
104	364	11	1
104	365	11	1
104	366	11	1
104	370	10	0.5
104	313	2	1
104	3366	6	1
104	3367	6	1
104	3368	6	1
104	3369	6	1
104	3370	6	1
104	3371	6	1
104	3372	6	1
104	3373	6	1
104	3374	6	1
104	3375	6	1
104	3376	6	1
104	3377	6	1
104	3378	6	1
104	3379	6	1
104	3380	6	1
104	3381	6	1
104	3382	6	1
104	3383	6	1
104	3384	6	1
104	3385	6	1
104	3386	6	1
104	3387	6	1
104	3388	6	1
104	3389	6	1
104	3390	6	1
104	3391	6	1
104	3392	6	1
104	3393	6	1
104	3394	6	1
104	3395	6	1
104	3396	6	1
104	3397	6	1
104	3398	6	1
104	3399	6	1
104	3400	6	1
104	3401	6	1
104	3402	6	1
104	3403	6	1

Node 1	Node 2	Link Type	Link Strength
104	3404	6	1
104	3405	6	1
104	3406	6	1
104	3407	6	1
104	3408	6	1
104	3409	6	1
104	3410	6	1
104	3411	6	1
104	3412	6	1
104	3413	6	1
104	3414	6	1
104	3415	6	1
104	3416	6	1
104	3417	6	1
104	3418	6	1
104	3419	6	1
104	3420	6	1
104	3421	6	1
104	3422	6	1
104	3423	6	1
104	3424	6	1
104	3425	6	1
104	3426	6	1
104	3427	6	1
104	3428	6	1
104	3429	6	1
104	3430	6	1
104	3431	6	1
104	3432	6	1
104	3433	6	1
104	3434	6	1
104	3435	6	1
104	3436	6	1
104	3437	6	1
104	3438	6	1
104	3439	6	1
104	3440	6	1
104	3441	6	1
104	3442	6	1
104	3443	6	1
104	3444	6	1
104	3445	6	1
104	3446	6	1

Node 1	Node 2	Link Type	Link Strength
104	3447	6	1
104	3448	6	1
104	3449	6	1
104	3450	6	1
104	3451	6	1
104	3452	6	1
104	3453	6	1
104	3454	6	1
104	3455	6	1
104	3456	6	1
104	3457	6	1
104	3458	6	1
104	3459	6	1
104	3460	6	1
104	3461	6	1
104	3462	6	1
104	3463	6	1
104	3464	6	1
104	3465	6	1
104	3466	6	1
104	3467	6	1
104	3468	6	1
104	3469	6	1
104	3470	6	1
104	3471	6	1
104	3472	6	1
104	3473	6	1
104	3474	6	1
104	3475	6	1
104	3476	6	1
104	3477	6	1
104	3478	6	1
104	3479	6	1
104	3480	6	1
104	3481	6	1
104	3482	6	1
104	3483	6	1
104	3484	6	1
104	3485	6	1
104	3486	6	1
104	3487	6	1
104	3488	6	1
104	3489	6	1

Node 1	Node 2	Link Type	Link Strength
104	3490	6	1
104	3491	6	1
104	3492	6	1
104	3493	6	1
104	3494	6	1
104	3495	6	1
104	3496	6	1
104	3497	6	1
104	3498	6	1
104	3499	6	1
104	3500	6	1
104	3501	6	1
104	3502	6	1
104	3503	6	1
104	3504	6	1
104	3505	6	1
104	3506	6	1
104	3507	6	1
104	3508	6	1
104	3509	6	1
104	3510	6	1
104	3511	6	1
104	3512	6	1
104	3513	6	1
104	3514	6	1
104	3515	6	1
104	3516	6	1
104	3517	6	1
104	3518	6	1
104	3519	6	1
104	3520	6	1
104	3521	6	1
104	3522	6	1
104	3523	6	1
104	3524	6	1
104	3525	6	1
104	3526	6	1
104	3527	6	1
104	3528	6	1
104	3529	6	1
104	3530	6	1
104	3531	6	1
104	3532	6	1

Node 1	Node 2	Link Type	Link Strength
104	3533	6	1
104	3534	6	1
104	3535	6	1
104	3536	6	1
104	3537	6	1
104	3538	6	1
104	3539	6	1
104	3540	6	1
104	3541	6	1
104	3542	6	1
104	3543	6	1
104	3544	6	1
104	3545	6	1
104	3546	6	1
104	3547	6	1
104	3548	6	1
117	201	1	1
117	225	1	1
117	223	1	1
117	367	1	1
117	368	1	1
117	201	2	1
117	369	3	1
117	113	11	1
117	411	10	0.5
117	313	11	1
117	3549	6	1
117	3550	6	1
117	3551	6	1
117	3552	6	1
117	3553	6	1
117	3554	6	1
113	226	1	1
113	205	1	1
113	202	1	1
113	227	1	1
113	371	1	1
113	372	1	1
113	212	1	1
113	373	1	1
113	374	1	1
113	375	1	1
113	228	1	1

Node 1	Node 2	Link Type	Link Strength
113	201	1	1
113	223	1	1
113	209	1	1
113	309	3	1
113	376	3	1
113	377	3	1
113	378	3	1
113	601	3	0.5
113	379	4	1
113	379	4	1
113	380	4	1
113	381	4	1
113	382	4	1
113	383	4	1
113	384	5	1
113	385	6	1
113	386	6	1
113	387	6	1
113	388	6	1
113	313	2	1
113	389	10	0.5
113	102	11	0.5
105	223	1	1
105	214	1	1
105	220	1	1
105	348	1	1
105	397	3	1
105	398	3	1
105	399	4	1
105	403	1	1
105	313	11	1
105	420	1	1
115	3104	1	1
115	3105	1	1
115	3106	1	1
115	230	1	1
115	212	1	1
115	110	1	0.5
115	226	1	1
115	410	3	1
115	407	3	1
115	414	3	1
115	105	3	1

Node 1	Node 2	Link Type	Link Strength
115	3107	3	1
115	313	2	1
115	3108	4	1
115	3109	4	1
115	3110	4	1
115	3115	6	0.5
115	419	6	0.5
115	3116	7	1
115	3117	11	1
111	313	11	0.5
111	205	1	1
111	201	1	1
111	223	1	1
111	231	1	1
111	228	1	1
111	226	1	1
111	3118	3	1
111	212	1	0.5
111	407	3	1
111	421	3	0.5
111	415	3	0.5
111	411	3	0.5
111	409	3	0.5
111	3121	11	1
111	401	11	0.5
103	313	2	1
103	213	1	1
103	216	1	1
103	403	1	0.5
103	3122	3	1
103	3123	3	1
103	3124	4	1
103	3127	6	1
103	3128	6	1
103	3129	6	1
103	3130	6	1
103	3131	6	1
103	3132	6	1
103	3133	6	1
103	3134	6	1
103	3135	6	1
103	3136	6	1
103	3137	7	1

Node 1	Node 2	Link Type	Link Strength
103	3138	7	1
110	313	2	1
110	209	1	1
110	213	1	1
110	378	3	1
119	313	11	0.5
119	233	1	1
119	201	1	1
119	209	1	1
119	205	1	1
119	407	3	0.5
119	422	3	0.5
119	423	3	0.5
107	313	11	0.5
107	212	1	1
107	223	1	1
107	234	1	1
107	3140	1	1
107	102	3	1
107	3141	6	1
107	3142	6	1
107	3143	6	1
107	3144	6	1
107	3145	6	1
107	3146	6	1
107	3147	6	1
107	3148	6	1
107	3149	6	1
107	3150	6	1
107	3151	6	1
107	3152	6	1
107	3153	6	1
107	3154	6	1
107	3155	6	1
107	3156	6	1
107	3157	6	1
121	313	11	0.5
121	223	1	1
121	213	1	1
121	102	6	0.5
121	3158	6	1
121	3159	6	1
121	424	6	0.5

Node 1	Node 2	Link Type	Link Strength
121	423	6	0.5
121	411	6	0.5
121	3160	10	1
121	3161	3	1
121	3162	3	1
123	313	11	0.5
123	239	1	1
123	240	1	1
123	3163	3	1
123	3164	3	1
123	3165	3	1
123	3166	3	1
123	3167	3	1
123	3168	6	1
123	425	3	1
123	420	3	1
123	103	11	0.5
127	313	2	1
127	411	3	1
127	407	3	1
127	423	3	1
127	410	3	0.5
127	422	3	0.5
127	426	3	0.5
127	103	3	1
127	102	3	1
127	403	3	0.5
127	424	3	1
127	427	3	0.5
118	230	1	1
118	201	1	1
118	223	1	1
118	241	1	1
118	372	1	1
118	378	3	0.5
118	601	3	0.5
118	3169	7	1
118	3170	7	1
118	3171	1	1
118	313	11	0.5
118	212	11	0.5
118	242	11	0.5
120	3173	3	1

Node 1	Node 2	Link Type	Link Strength
120	3174	3	1
120	3175	3	1
120	3176	3	1
120	350	3	1
120	3178	3	1
120	3179	3	1
120	3180	3	1
120	3181	3	1
120	3182	3	1
120	3185	11	1
120	313	11	0.5
124	3186	4	0.5
124	419	6	0.5
124	401	6	0.5
124	428	6	0.5
124	429	6	0.5
124	430	6	0.5
124	431	6	0.5
124	432	6	0.5
124	433	6	0.5
124	434	6	0.5
124	435	6	0.5
124	436	6	0.5
124	437	6	0.5
124	438	6	0.5
124	439	6	0.5
124	440	6	0.5
124	3187	3	1
124	3188	3	1
124	201	11	0.5
124	313	11	0.5
102	3189	1	1
102	228	1	1
102	389	1	1
102	246	1	1
102	247	1	1
102	248	1	1
102	201	1	1
102	3140	1	1
102	249	1	1
102	3191	1	1
102	3192	1	1
102	3193	1	1

Node 1	Node 2	Link Type	Link Strength
102	250	1	1
102	3194	1	1
102	3195	1	1
102	220	1	1
102	202	1	1
102	221	1	1
102	209	1	1
102	3196	1	1
102	223	1	1
102	214	1	1
102	230	1	1
102	3197	1	1
102	226	1	1
102	3198	1	1
102	3199	1	1
102	3200	1	1
102	415	1	0.5
102	441	1	0.5
102	404	1	0.5
102	422	1	0.5
102	426	1	0.5
102	427	3	1
102	3201	4	1
102	3202	6	1
102	3203	6	1
102	3204	6	1
102	3205	6	1
102	3206	6	1
102	3207	6	1
102	3208	6	1
102	3209	6	1
102	3210	6	1
102	3211	6	1
102	3212	6	1
102	3213	6	1
102	3214	6	1
102	3215	6	1
102	3216	6	1
102	3217	6	1
102	3218	6	1
102	3219	6	1
102	3220	6	1
102	3221	6	1

Node 1	Node 2	Link Type	Link Strength
102	3222	6	1
102	3223	6	1
102	3224	6	1
102	3225	6	1
102	3226	6	1
102	3227	6	1
102	3228	6	1
102	3229	6	1
102	3230	6	1
102	3231	6	1
102	3232	6	1
102	3233	6	1
102	3234	6	1
102	3235	6	1
102	3236	6	1
102	3237	6	1
102	3238	6	1
102	3239	6	1
102	3240	6	1
102	3241	6	1
102	3242	6	1
102	3243	6	1
102	3244	6	1
102	3245	6	1
102	3246	6	1
102	3247	6	1
102	3248	6	1
102	3249	6	1
102	3250	6	1
102	3251	6	1
102	3252	6	1
102	3253	6	1
102	3254	6	1
102	3255	6	1
102	3256	6	1
102	3257	6	1
102	3258	6	1
102	3259	6	1
102	3260	6	1
102	3261	6	1
102	3262	6	1
102	3263	6	1
102	3264	6	1

Node 1	Node 2	Link Type	Link Strength
102	3265	6	1
102	3266	6	1
102	3267	6	1
102	3268	6	1
102	3269	6	1
102	3270	6	1
102	3271	6	1
102	3272	6	1
102	3273	6	1
102	3274	6	1
102	3275	6	1
102	3276	6	1
102	3277	6	1
102	3278	6	1
102	3279	6	1
102	3280	6	1
102	3281	6	1
102	3282	6	1
102	3283	6	1
102	3284	6	1
102	3285	6	1
102	3286	6	1
102	3287	6	1
102	3288	6	1
102	3289	6	1
102	3290	6	1
102	3291	6	1
102	3292	6	1
102	3293	6	1
102	3294	6	1
102	3295	6	1
102	3296	6	1
102	3297	6	1
102	3298	6	1
102	3299	6	1
102	3300	6	1
102	3301	6	1
102	3302	6	1
102	3303	6	1
102	3304	6	1
102	3305	6	1
102	3306	6	1
102	3307	6	1

Node 1	Node 2	Link Type	Link Strength
102	3308	6	1
102	3309	6	1
102	3310	6	1
102	3311	6	1
102	3312	6	1
102	3313	6	1
102	3314	6	1
102	3315	6	1
102	3316	6	1
102	3317	6	1
102	3318	6	1
102	3319	6	1
102	3320	6	1
102	3321	6	1
102	3322	6	1
102	3323	6	1
102	3324	6	1
102	3325	6	1
102	3326	6	1
102	3327	6	1
102	3328	6	1
102	3329	6	1
102	3330	6	1
102	3331	6	1
102	3332	6	1
102	3333	6	1
102	3334	6	1
102	3335	6	1
102	3336	6	1
102	3337	6	1
102	3338	6	1
102	3339	6	1
102	3340	6	1
102	3341	6	1
102	3342	6	1
102	3343	6	1
102	3344	6	1
102	3345	6	1
102	3346	6	1
102	3347	6	1
102	3348	6	1
102	3349	6	1
102	3350	6	1

Node 1	Node 2	Link Type	Link Strength
102	3351	6	1
102	3352	6	1
102	3353	6	1
102	3354	6	1
102	3355	6	1
102	3356	6	1
102	3357	6	1
102	3358	6	1
102	3359	6	1
102	3360	6	1
102	3361	6	1
102	3362	6	1
102	3363	6	1
102	3364	6	1
102	411	6	0.5
102	424	6	0.5
102	442	6	0.5
102	443	6	0.5
102	444	6	0.5
102	405	6	0.5
102	413	6	0.5
102	404	6	0.5
102	422	6	0.5
102	445	6	0.5
102	401	6	0.5
102	446	6	0.5
102	403	6	1
102	3365	9	0.5
102	370	10	1
102	3160	10	1
102	313	2	1
125	205	1	1
125	202	1	1
125	236	1	1
125	251	1	1
125	3555	1	1
125	252	1	1
125	601	3	0.5
125	605	3	0.5
125	606	3	0.5
125	378	3	0.5
125	3556	3	0.5
125	3557	3	0.5

Node 1	Node 2	Link Type	Link Strength
125	316	4	1
125	3559	5	0.5
125	3122	5	0.5
125	3560	5	0.5
125	3140	5	0.5
125	102	11	0.5
125	113	11	0.5
125	112	11	0.5
125	313	2	1
101	236	1	1
101	250	1	0.5
101	254	1	0.5
101	3561	1	0.5
101	3562	1	1
101	313	2	1
101	3563	3	1
101	378	3	1
101	3564	3	1

Node 1	Node 2	Link Type	Link Strength
101	3565	4	0.5
101	3566	4	0.5
101	3567	4	0.5
101	3568	6	1
101	3569	6	1
101	3570	7	0.5
101	3571	9	1
101	3572	10	1
101	3562	10	1
114	3573	1	1
114	313	2	1
114	411	3	1
114	3574	7	1
109	313	2	1
109	401	3	0.5
109	410	3	0.5
109	413	3	0.5