Optimal Configuration of Tie Strength and Tie Breadth for Team Innovation: A Fuzzy Set Qualitative Comparative Analysis

BY

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Submitted in partial fulfillment of the requirements for the degree of Doctor of Business Administration at the Gordon Institute of Business Science, University of Pretoria

SUPERVISOR

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11 November 2013

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In memory of my father, Mr H Kowlaser

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Abstract

This research focused on collaborative ties in innovating teams in a research and development (R&D) environment of a technologically innovative R&D intensive manufacturing company. The purpose of the study was to determine the relative impact of, respectively, the strength of ties and the breadth of ties on the innovativeness of teams. Significant research has been carried out on strong and weak ties, and on ties related to social networks. The diversity of networks and their corresponding impact on innovation has also received attention. There has however been little focus in the academic literature on the simultaneous functioning of the strength of ties and breadth of ties and their impact on team innovation in the same study.

This research has employed an innovative approach to data collection and a fairly novel and recent methodology for the modeling of the simultaneous configurations of the strength and breadth of ties in enriching the understanding of their contribution to team innovation.

The innovativeness of work teams was determined through a team innovation survey administered to the heads of the groups in R&D and independent evaluators knowledgeable about the innovation activities of the teams rated

E-mail reports on engagement between teams were used to develop measures for both tie strength and tie breadth. Tie strength for an individual was determined by counting the number of repeated interactions firstly with one’s own team, secondly with the rest of teams in own R&D, thirdly with the rest of teams in the organization and finally with teams outside the organization. Tie breadth was determined from a count of the number of different people with whom communication took place for each individual. The same categories for tie breadth were created as for the tie strength for interactions above. Hypothesised relationships were tested through fuzzy-set qualitative comparative analysis.

The results showed that team innovation is mainly supported by tie strength within the organization. In terms of the simultaneous functioning of tie strength and tie breadth, the strongest results were obtained for the combinations of tie strength with the rest of own R&D and the organization, and tie breadth with the rest of own R&D and the

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organization. These interactions supported the hypothesis that a combination of strong ties and multiple ties provided the most conducive environment for optimal team innovation.

These findings taken together supported the broad view that in mature industries dependent on highly technological processes, interaction within teams and within the firm would predominate, because a shared understanding of a specific strategy and technology base was required. In such a context, cross-divisional interaction also had utility for innovation, as was confirmed by the statistical analysis. It was the combination of many strong ties that produced optimal team innovation. Total external interactions (tie breadth) showed a weaker impact alone. In summary, this has shown that tie strength has a greater impact on innovation than tie breadth.

These findings were derived from an R&D intensive mature industrial manufacturing context and variations in utility are likely to be context-dependent. However, should the company diversify its products or adopt newer technologies even in its mature state, then more external interaction has the potential to add value to the innovation process, as the literature suggests. Thus the study suggests indicated that internal collaboration is a key factor impacting positively on the innovativeness of teams.

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Declaration

I declare that this thesis is my own work. It is submitted in partial fulfillment of the requirements for the degree of Doctor of Business Administration at the Gordon Institute of Business Science, University of Pretoria. It has not been submitted before for any degree or examination in any other University.

I further declare that I have obtained the necessary authorization and consent to carry out this research.

Name of student: Keeran Kowlaser

Signature: 

Date: 11 November 2013

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Acknowledgements

I wish to express my sincere thanks to the many people who have provided assistance during the course of this study. In particular, I would like to thank the following:

- Professor Helena Barnard for her expert supervision, guidance and encouragement during the course of this study
- Dr Sven Godorr, his management team and team members of R&D that participated in this study
- Louis Naude and Alkesh Patel for assistance with information management requirements and agreements
- Louis Dancuart and Kate Farina for assistance with governance approval

Most importantly, I would like to thank my family for their patience, continuous support and encouragement throughout all my years of study!

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Chapter 1: Introduction to Research Problem

This chapter gives an outline of the motivation for the research, the specific research objectives and the scope and context thereof.

1.1 Motivation for research

Innovation contributes significantly to the competitiveness of companies. Innovation is important because it facilitates the production of new and better products and services, and the generation of more efficient production processes and improved business models. The absence of innovation can lead to business stagnation. For the economy as a whole, innovation is the key to higher productivity.

The importance of innovation raises the question of what forms its basis. The foundation of innovation in product, service or process is new and improved ideas, and it is people who "develop, carry, react to, and modify ideas" (Van de Ven, 1986). For such activity to be possible, networks between people need to be built: networking between individuals and organizations is one way of facilitating interactions that positively foster innovation. Network linkages are the conduits through which knowledge is shared, and offer evidence that individuals are talking to one another (Borgatti and Cross, 2003; Cummings and Cross, 2003) and potentially sharing information.

Firms have therefore embraced the importance of networking: a practice that is particularly important and relevant in the context of the exchange of knowledge and diverse ideas. There is growing awareness that for firms to gain access to novel ideas, resources and knowledge, collaboration is vital. “Innovation-driven collaboration is a particular form of inter-firm alliance that can range from informal arrangements initiated for specific problem solving or incremental innovations, to formal long-term strategic alliances for significant technological advances and radical innovations” (Sammara and Biggiero, 2008). Additionally, collaboration allows for the sharing of costs and risks, and the development of common industry standards.

Furthermore, the literature suggests that one of the most common reasons for collaboration is the acquisition of knowledge and capabilities from other firms (Hamel, 1991; Mowery et al., 1996; Hagedoorn, 2002). Different firms work from different

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knowledge bases; this difference is observed in both explicit and tacit knowledge (Dosi et al., 2000). Knowledge that can potentially form the basis of innovation is thus an element of all such collaborations. Diverse interactions, underpinned by common ground and trust, may generate novel ideas, and thus these interactions can be viewed as drivers of innovation at team, organisation and industry levels. Such interactions and outcomes may occur internationally as well as in the same locale (Rosenkopf and Nerkar, 2001).

At the team and firm level, role-players share common ground on which they can interact, derived from common organizational goals, shared organisational culture and mutual trust, even when the individuals have distinct identities. The exchange of ideas between these individuals results in a pool of novelty and diverse knowledge. Within organizations, all these factors allow teams to build on their core capabilities (Henttonen, 2010) by facilitating trust between role-players, and encouraging communication, interaction and the sharing of ideas. Teams may include members with highly diverse levels of education, skills and competencies and this contributes to the diverse knowledge composition of the organization overall. Miller et al. (2007) demonstrated that knowledge-sharing between divisions in a firm could positively impact on innovation. The impact of this inter-divisional knowledge interaction was shown to be stronger than that from using knowledge derived exclusively from within a division or from a source outside organisational boundaries, i.e. the knowledge was not completely novel, but not entirely familiar either.

At industry level, interaction between organisations allows access to a further diversity of ideas and knowledge across organisational boundaries, both within and outside any single specific locale. This diversity can offer access to knowledge and competencies either not available, or not core, to the organization. Such combinations of diversity and commonality in terms of knowledge also play an important role in innovation outcomes.

The literature has offered complementary perspectives on the relationship between interaction and innovation for firms. March (1991), and Nerkar and Roberts (2004) argued that successful innovation could be accomplished from two angles, with a firm first seeking locally for knowledge that contributes to the development of a commercially viable product (March 1991; Leonard-Barton, 1992). However, this context might limit

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firms in accessing specific knowledge and capacities. Thus researchers have also examined a contrasting argument: that a need for diverse and novel information necessitates seeking ‘distant knowledge” beyond its organizational boundaries (March, 1991). This can offer competencies not core to the firm, but possibly specific to another firm, either local or foreign. New combinations of distant knowledge may produce path-breaking innovations (Schumpeter, 1947; Galunic and Rodan, 1998; Fleming, 2001; Nerkar and Roberts, 2004), or enable the transition from an entrenched set of techniques and designs to a new technological paradigm (Abernathy and Utterback, 1978).

Summarised, the argument is that a shared business environment can contribute towards innovation, but too much commonality may lead to group-think and idea lock-in. However, excessive novelty arising from a disparate knowledge base and country context risks inspiring innovations unsuited to the market, or to the life-cycle of a specific industry (Grimpe and Kaiser, 2010).

1.2 Research objectives

In light of the critical role that collaboration has been found to play in innovation, contributing to new and improved products, processes and services for both organizations and the market, the objectives of this research have been framed through the “lens” of social network theory in addressing the research question on the relative impact of tie strength and tie breadth and their impact in various combinations, on team innovation (Figure 1).

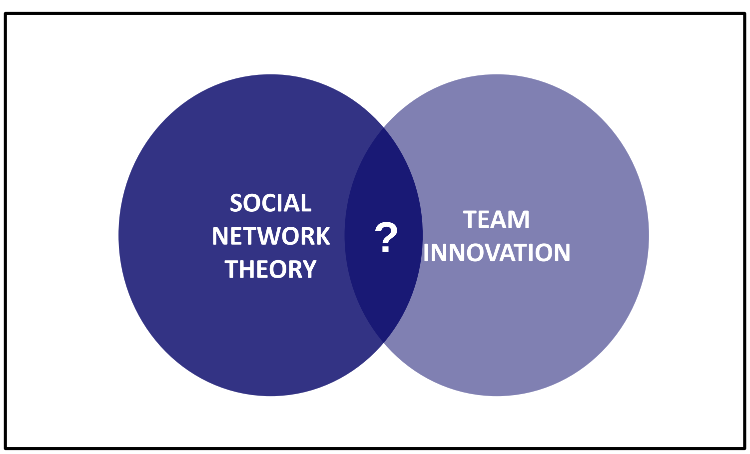

Figure 1: Team innovation through the lens of social network theory

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Although innovation can occur at individual, team and organizational levels, the focus of this research is team innovation. Organizations characterised by innovation are increasingly depending on teams to respond to changing market needs (Edmondson, 1999; West, 2002). “Teams can be hotbeds of creativity and innovation’’ (Bain et al, 2001). This is because teams, made up as they are of individuals with different backgrounds, knowledge, skills and expertise, provide a particularly fertile ground for the generation of novelty and improvement (Lipman-Blumen and Leavitt, 1999). When interaction occurs, either within a team or between a team member and some other, a tie is formed. These ties form the basis of networks. However, ties are not uniform in nature: a tie can vary in terms of the strength of interaction or the breadth of interactions. Determining the nature of ties at the team level is therefore the first objective.

The nature of ties has previously been studied within business network theory, with the relevance of ties to inter-firm collaboration and knowledge flows the focus of past research. Such studies have included the structural features of social networks and their impact on innovation; and the relationship between innovation and brokerage opportunities (Powell et al., 1996; McEvily et al., 1999; Ahuja and Katila, 2001; Zaheer and Bell, 2005). The focus of past research has thus been predominantly on the structural properties of networks, and “less on the specific knowledge content of relationships occurring between network nodes” (Borgatti and Cross, 2003).

This research has employed data from frequency reports of the e-mail interaction of team members within a single company to determine the tie strength and tie breadth linkages of teams. The reports provide data on interactions between people within the teams; interactions between people of differing teams; interactions with people in other parts of the organization; and interactions with people in other organizations situated both in SA and internationally.

Having determined the nature of ties, the second objective of the research moves on to address an interesting question, i.e. the combination of tie strength and tie breadth, and more especially their inter-relationships, which could provide new insights into how the innovation of teams can be enhanced. The objective was to determine which combination of tie strength and tie breadth was optimal for stimulating team innovation. The research was based on the assumption that strong ties and weak ties exist in

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combination, with both the strength and breadth of ties contributing to some extent to team innovation, but that some combinations had greater utility for innovation than others.

Tie strength is characterized by the amount of common ground and consequent trust role-players in an interaction share. Tie breadth is determined by the number of ties a role-player has, wider where there are many and narrower where there are few. Wider breadth of ties gives access to multiple diverse interactions, exposing the role-player to novel ways of thinking and ideas. Thus a combination of tie strength and tie breadth combines the knowledge, expertise and trust of shared ground with the novel perspectives of diverse contacts, to produce an optimal combination most conducive to team innovation. However, the most appropriate combination needs to be determined, because too little novelty encourages complacency while too much novelty may outweigh the common ground facilitating the integration of new knowledge into an organisation; both may impact negatively on innovation.

This research is useful to managers in many respects. Firstly, it suggests tools for determining whether teams interact mainly internally or mainly with others, and what the impact on team innovation is of these interaction patterns. This offers insight into the optimal structure for a team.

Secondly, the research provides an additional perspective on a dilemma managers frequently face: how much effort to invest in limiting or enabling the movement of people between teams. Moving an individual can facilitate the growth of that individual; retaining him or her within the team builds and sustains the core competencies and skills of that team. The research suggests the problem can be analysed in terms of a team's relative need for ties to be strengthened, or to be broadened.

Thirdly, the research also adds insights about how much effort and money a manager should invest to ensure diverse work networks that facilitate innovative team outcomes. Building networks can involve time away from the immediate work station, and the costs associated with getting to know other people, such as site visits and national and international networking at conferences. The research provides a new framework for

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evaluating these costs, related to the relative need for strengthening or for broadening ties.

1.3 Scope and context of research

This research was carried out within an integrated energy and chemical company that has both a local and international presence. The company has been a leader in technological innovation for over six decades and operates in a R&D intensive manufacturing environment that produces a diverse array of commodities. The precise location for this study was the R&D arm of the business.

1.4 Organisation of the research report

This report on research into the optimal combination of common and novel knowledge to facilitate innovation, through the combination of the strength of ties and breadth of ties, is organized as follows:

- Chapter 1 has provided an introduction to the study, defining the research problem and objectives, and the scope and context of the study.
- Chapter 2 focuses on a review of the literature on innovation, collaboration and networks, and on the strength and breadth of ties and its impact on innovation.
- Chapter 3 provides an outline of the research design and methodology adopted in this research.
- Chapter 4 details the results of the research carried out.
- Chapters 5 and 6 discuss the results and offer conclusions respectively.

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Chapter 2: Literature Review

2.1 Introduction

2.1.1 Literature synopsis

In an environment that has become globally competitive and is characterised by rapid technological advances, it has become critical for an organisation to innovate to respond to market needs and ensure their long-term survival. Without innovations, firms risk becoming redundant and losing their competitive edge (Galanakis, 2006). Innovation has also been identified as a driver of socio-economic growth and governments have attempted to promote innovation via new policy mechanisms (Woolthuis, Lankhuizen and Gilsing, 2005).

Globalisation has caused growing industrial interdependency across nations, offering new mechanisms for innovation via foreign direct investment, patenting activities, and technological and scientific collaborations. Globalisation has created production network linkages that facilitate international knowledge diffusion. These linkages permit combinations of domestic and international knowledge that can fill specific innovation gaps in a country. Ernst and Kim (2002) demonstrated that network linkages had facilitated the internationalization of some developing countries, for example through the activities of firms in East Asia, where technology, skills and market intelligence all supported exports.

Collaboration takes place between both private and public institutions, and between and with firms, universities and research centres. Private firms are involved in strategic technology partnerships where co-operation between suppliers, customers and even competitors, occurs. Networks of global inter-firm alliances have become increasingly prevalent (Hagedoorn, 2002).

In a globalised world, the development of networks then becomes instrumental in collaboration. To date, research on the network concept of the strength of a tie has received the most attention, that being the seminal publication by Granovetter (1973) on ‘The Strength of Weak Ties’. Further research has developed on the elements of trust and knowledge exchange underpinning tie strength, and how these impact on innovation

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(Reagans and Zuckerman, 2001; Landry, Amara and Amarai, 2002; Smith, Collins and Clark, 2005; Moran, 2005; Capaldo, 2007).

Additional to the network concept of tie strength is the concept of tie breadth, involving interaction with a diverse array of contacts or sources of information and ideas, situated either internally or externally to an existing network. This diversity has been found to be a facilitator of innovation (Chesbrough, 2003) and an influence on the resulting innovativeness of firms (Cohen and Levinthal, 1990).

This research has been positioned through the lens of social network theory in addressing the relative impact of tie strength and tie breadth and their impact in various combinations, on team innovation (Figure 2). This research framework is based on the hypothesis that innovation does not only occur through repeated interactions with others (behavior that contributes to tie strength) but also entails exposure to a diversity of knowledge (behaviour that contributes to tie breadth). Diverse and novel knowledge as well as a shared basis for collaboration are both required for innovation.

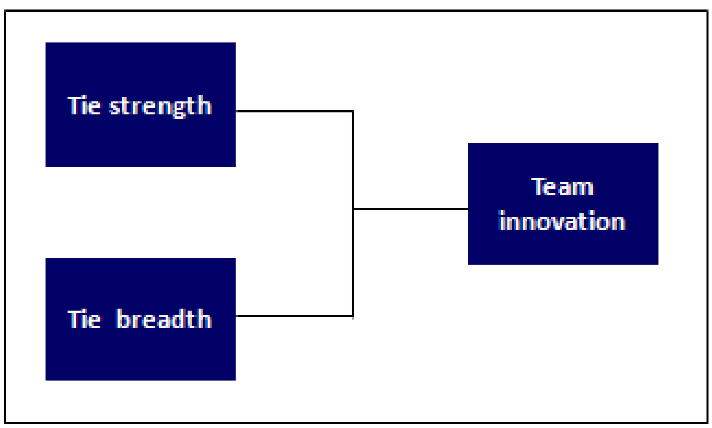

Figure 2: Research focus on tie strength and tie breadth effect on team innovation

The resulting hypotheses that were tested focus on the following:

- tie strength and team innovation
- tie breadth and team innovation
- varying combinations of the interaction components of tie strength and tie breadth and their respective impact on team innovation

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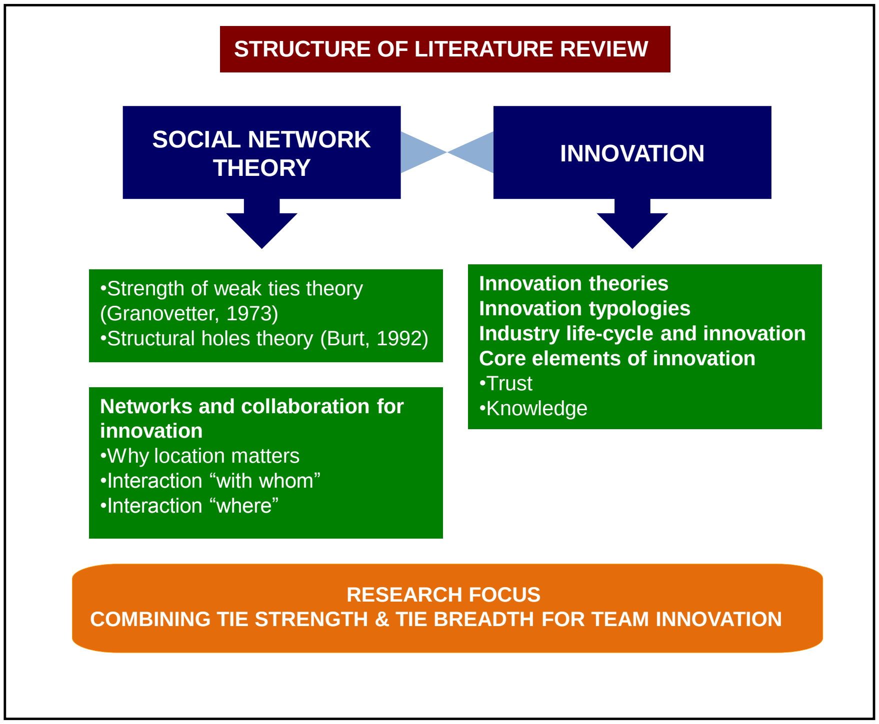

Figure 3: Structure of literature review

The literature review that follows has been structured towards the development of the hypothesis by means of a stage-by-stage motivation concerning the impact of tie strength and tie breadth on team innovation (Figure 3).

Section 2.1.2 begins with an overview of social network theory, including the two well-known network theories on the strength of weak ties theory (Granovetter, 1973) and Burt’s structural holes theory (1992).

Section 2.1.3 begins by clarifying the concept of innovation; specific innovation theories; and typologies, an input-process-output model for team measures, and common measures of team innovation.

Section 2.1.4 covers the core elements of innovation: trust plus novel knowledge.

Section 2.1.5 discusses the role of networks and collaboration in innovation. It outlines the concept of collaboration and why organizations collaborate. It also provides an overview of who interaction takes place with; how it impacts innovation; and where interaction can take place, with particular reference to proximity.

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Section 2.2 explores tie strength and innovation, focusing on the role that trust plays in the strength of ties. This forms the basis for the postulation of the first hypothesis.

Section 2.3 examines the knowledge that a wide breadth of ties provides and its implications for innovation, forming the basis of the second hypothesis.

Section 2.4 is the final section of the literature review. It covers the implications of varying combinations of tie strength and tie breadth on innovation, and forms the basis for the final hypothesis.

Chapter 2 concludes by noting the key findings from past literature which form the foundation of the research question and the objectives discussed in **Chapter 1**.

2.1.2 Social network theory

In the conceptualization of a network, a network consists of a set of actors or nodes with a set of ties that links these nodes. Networks are interconnected structures that provide engagement opportunities for the facilitation of innovative outcomes (Brass, Galaskiewicz, Greve and Tsai, 2004; Hoberecht, Joseph, Spencer and Southern, 2011; Klijn, Edelenbos and Steijn, 2010; Borgatti and Halgin, 2011; Provan and Lemaire, 2012). Simply stated, a network is defined as:

> *"a set of nodes and relationships which connect them" (Fombrun, 1982, p.280)*

Networks are formed for a number of reasons ranging from the need to achieve resource knowledge diversity to the need to lower costs and risks that are mitigated through networks that had a lower chance of being achieved should it have been done independently (Provan and Kenis, 2008). In terms of the types of networks, the terms formal and mandated, and informal and emergent networks seem to be used interchangeably in the literature. Isett, Mergel, Leroux, Mischen and Rethemeyer (2011) define informal and formal networks as follows:

> "*Formal networks are consciously created with some sort of binding agreement for participation, whereas informal networks are more organically derived—an outgrowth of organizational contingencies that multiple actors come together to address*" *(p. 162).*

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Emergent or informal networks have the potential to have higher levels of trust as role-players come together voluntarily). A number of factors that facilitate the development of strong network ties in an emergent network (Provan and Lemaire, 2012) and include:

- homophily (i.e., similarity based on reputation, service orientation, values, etc.);
- proximity (i.e., being physically close to each other form a tie);
- heterophily (i.e., enough diversity to provide a positive outcome);
- prior interaction experience; and,
- the need to gain access to key differing information and/or resources.

Social network analysis is used to study various attributes of networks such as density, centrality, tie strength, fragmentation, dyads and cliques (Provan, Veazie, Staten, and Teufel-Shone, 2005). Tools for network practitioners include an established social network analysis software package called UCINET, and a fairly new tool called PARTNER (Program to Analyze, Record, and Track Networks to Enhance Relationships).

There is no single all-encompassing social network theory however the field boasts two well-known network theories: Granovetter's strength of weak ties theory (Granovetter, 1973) and Burt's structural holes theory (Burt, 2004).

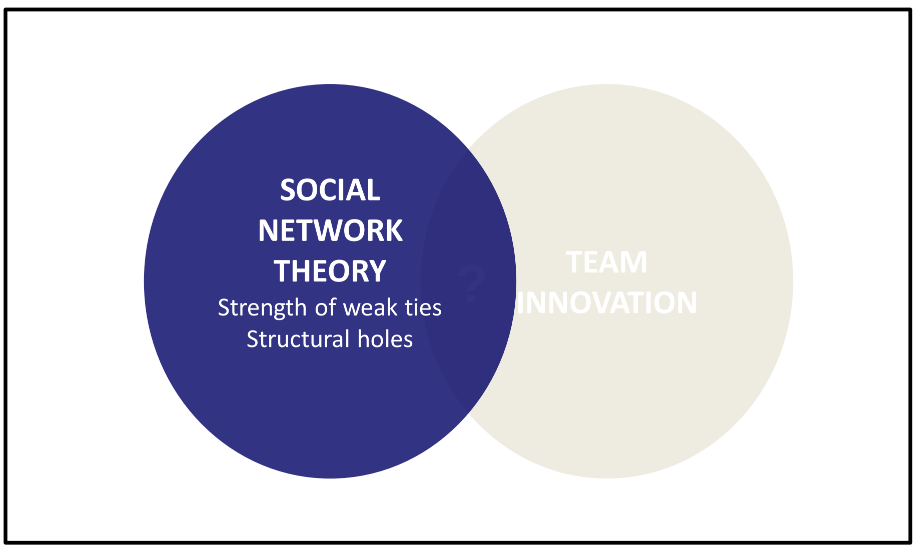

Figure 4: Well-known social network theories

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Strength of weak ties theory

Two points of note are mentioned here on the strength of weak ties theory. The first is that should there be a strong tie between two people (nodes), it is more than likely that they are interacting with the same other people. To illustrate this explanation, should persons A and B have a strong tie, and persons B and C have a strong tie, then it is more than likely that persons A and C are at least acquaintances of each other thereby having at least a weak tie. Secondly, is the concept of a bridging tie which is a tie that links a person that is not already in their network. A bridging tie is then the conduit through which new ideas and information can be channelled to an outcome such as innovation.

In combining the tie strength and bridging ties concept, Granovetter (1973) argues that a strong tie is highly unlikely to be the sources of novel information since it is information that is circulated within the same network. A weak tie then becomes most likely be the bridge into a pool where people would start accessing information which they normally would not have in their existing strong tie network. It is then the weak tie that becomes the basis for new information and ideas.

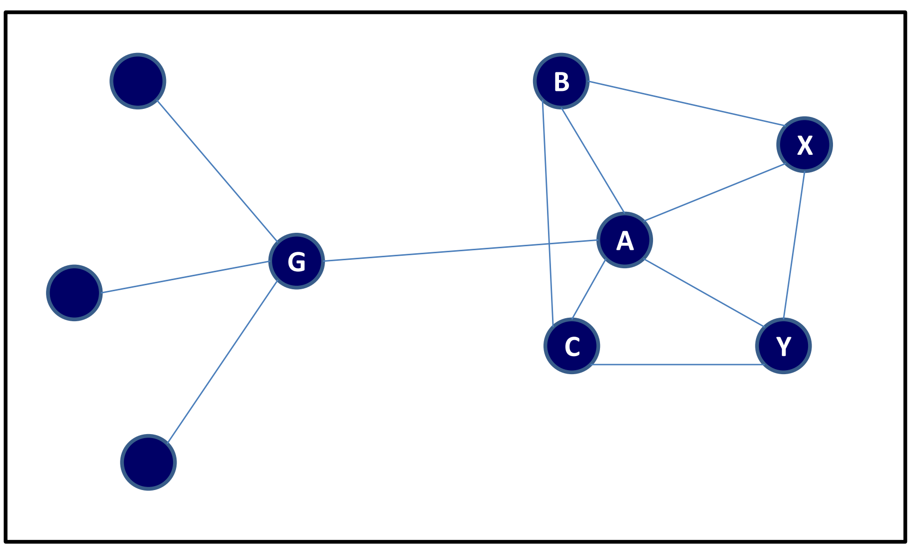

Figure 5: Illustrating strength of weak ties theory and structural holes theory (Borgatti and Halgin, 2011)

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Structural holes theory

Burt's (2004) structural holes theory of social capital discusses the nodes that surround a particular node in relation to one another and the type of information that they provide. This is commonly referred to as an ego network. In illustrating this, A's ego network is more than likely to provide A with more novel information or what is commonly called non-redundant information as compared to B (Figure 5). A is said to have more structural holes than B, and subsequently more non-redundant ties.

In summary, the message from both theories is the same, i.e. non-redundant or bridging ties are the source of novel information.

2.1.3 Innovation

It is has become common knowledge that companies that do not keep up to date with their innovation practices, whether it be the introduction of new or improved products, services, methods or processes run the risk of becoming redundant in a fast-moving technological environment. In light of this, more companies are channelling their investment towards R&D activities (Degen, 2009).

This section focuses on how innovation can be conceptualized, followed by an account of the historical development of innovation theories, and the classification of innovation into various typologies.

2.1.3.1 Concept clarification

Various researchers have defined the concept of innovation. The recurring common theme in these definitions is the concept of *newness,* in terms of ideas, processes or products.

West and Farr (1990) defined innovation as:

> *"... the intentional introduction and application within a job, work team, or organization of ideas, processes, products, or procedures, which are* ***new*** *to that job, work team, or organization and which are designed to benefit the job, the work team, or the organization" (p.23)*

Hivner, Hopkins and Hopkins (2003) define innovation as:

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> *"a **new** or innovative idea which is applied to initiating or enhancing a product, service or process" (p.80)*

while the UK's DTI Innovation Report (2003) defines product innovation as:

> *". . . goods and services introduced to the market which are either **new or significantly improved** with respect to fundamental characteristics. The innovations should be based on the results of **new technological developments**, **new combinations of existing technology** or utilization of other knowledge by your firm"*

However, the concept of the new is not always absolute; West and Farr (1990) stated that *"innovation implies novelty, but not necessarily absolute novelty."* While novelty in essence implies newness, an innovation may be new to a specific team, but not necessarily new to the firm or the industry. Alternatively, the innovation may new to the firm, but not to the industry. Similar to West and Farr's definition is that of Galanakis (2006):

> *"the creation of **new products, processes, knowledge or services by using new or existing scientific or technological knowledge**, which provide a degree of novelty either to the developer, the industrial sector, the nation or the world and succeed in the marketplace" (p.1223)*

In defining innovation at the team level of analysis, West & Wallace (1991) defined team innovation as:

> "*the intentional introduction and application within a team, of ideas, processes, products or procedures new to the team, designed to significantly benefit the individual, the team, the organization, or wider society*" *(p.306)*

More recently, Lin, Chuang, Chang and Yeh (2012) defined team innovation as:

> "*a working environment of innovative spirit, wherein all members of the team use the experience generated through the accumulation of knowledge individually or within the team to achieve a common vision or expected goals through mutual cooperation*" *(p.28)*

On the basis of these concepts, a range of innovation theories and typologies have been developed, as outlined briefly below in sections 2.1.3.2 and 2.1.3.3.

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2.1.3.2 Innovation typologies

The review by Garcia and Cantalone (2002) of technological innovation and the typology of innovativeness has been one of the most cited works on this area. Their findings demonstrated that a number of definitions (entailing inconsistencies) exist for types of innovation. For example, the terms that describe innovation as being 'radical' or 'really-new' are inconsistent with labels such as 'imitative', 'incremental' and 'discontinuous'. They expressed the view that this inconsistency in the terminology had led to the inconsistent classification of innovation, and that this had hindered knowledge development around the topic.

Additionally, innovation can be categorized in terms of the magnitude of the impact it has on a firm, i.e. it can be incremental, radical or disruptive. Incremental innovations build on existing knowledge and have the potential to lead to small improvements in products, services or processes. Song and Montoya-Weiss (1998) aptly defined an incremental new product as being the result of the "adaptation, refinement and enhancement of existing products and/or production and delivery systems." Radical innovations have the potential to fundamentally change products, services or processes. Disruptive innovations are the most extreme; these have the potential to transform an industry (OECD, 2005).

For the purpose of this research and review, the innovation typology described below and derived from the OECD Oslo Manual (OECD, 2005) has been adopted. This work demonstrated how innovations could be classified by their degree of novelty (OECD, 2005; Hidalgo and Albors, 2008) and that this novelty could vary depending on whether the innovation concerned a product, process, marketing or administration, i.e.

- New to the firm: new to a certain firm but not necessarily new to other firms
- New to the market: an innovation entering the market for the first time
- New to the world: an innovation new to both domestic and international markets and industries

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2.1.3.3 Innovation theories

Since the 1950's, numerous innovation theories have developed. Each focused on aspects particularly relevant or interesting to the scholars of these successive generations, as shown in Figure 6 below (Rothwell, 1994; Cantisani, 2006; Galanakis, 2006).

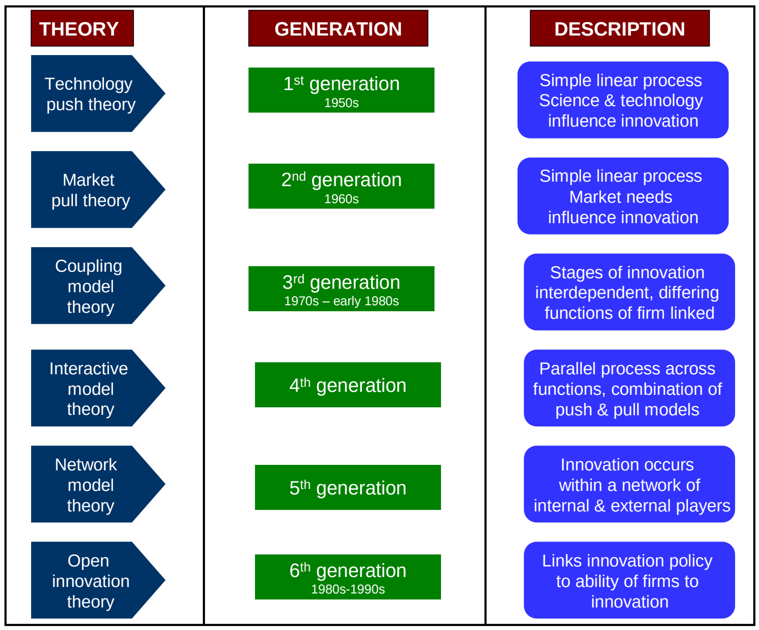

Figure 6: Development of innovation theories compiled from literature

(Based on work by Rothwell, 1994; Cantisani, 2006; Galanakis, 2006)

This research makes greatest use of the "5th generation" network model theory, which discusses innovation as taking place through interaction with both internal and external parties. This model has been selected as most pertinent for this research because it covers innovation outcomes resulting from interactions taking place within a firm and involving sources external to the firm, as discussed in Chapter 1.

2.1.3.4 Industry life-cycle and innovation

Further to innovation being classified according to typologies, there is also existing theory on the stage of an industry in its life-cycle and the subsequent implications for innovation. The life-cycle of an industry and its influence on innovation and resultant impact on economic growth are often viewed in isolation of each other (Bos, Economidou and Sanders, 2013).

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Industry life-cycle theory states that innovation is linked to the phase of the industry life-cycle and the innovation process develops over the life-cycle of the industry. Theory has stated two main themes (Klepper, 1996, 1997), firstly, “innovation is high when an industry is young and decreases as the industry matures” (Abernathy and Utterback, 1978), and secondly, “product innovations are expected to decrease with industry maturity, while process innovations are expected to increase with industry maturity” (Abernathy and Utterback, 1978; Anderson and Tushman, 1990; Cohen and Klepper, 1996).

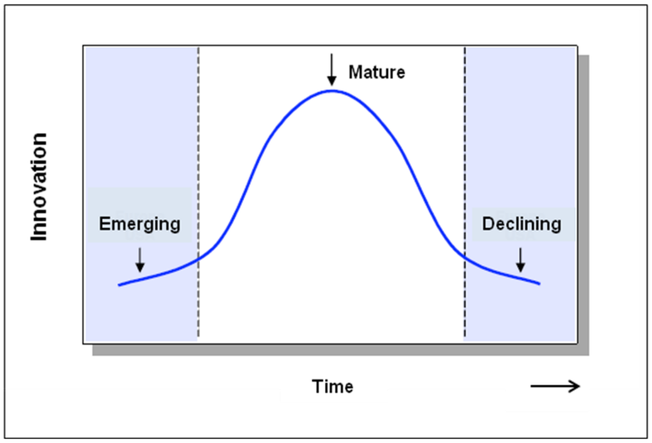

Figure 7: Industry life-cycle and innovation (Source: J. Estin, 2006)

One of the most prominent views is that of Utterback (1994, p.227) where the life cycle of an industry is said to be comprised of three development phases: fluid, transitional and specific (Table 1). The fluid phase has the potential for a high pace of innovation where ideas are developed into tangible products. The market is also in the development phase, with initially few competitors that grows over time. Process innovation takes a supporting role.

The transitional phase begins when a dominant product is produced. At this stage, product innovation rates decrease while process innovations increase. Interdependency between product and process innovations is also observed. Processes become established and products start to become more commodity-like, with a small degree of differentiation being observed. The specific phase is in essence the mature phase of an industry where the quality to cost ratio becomes the basis for competition and product innovation is incremental in nature. The Utterback (1994) model states that or product to

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produce radical innovations or to use the existing processes and products in new applications (Andrade-Coutinho, Bomtempo and de Química, 2006).

Table 1: Specific characteristics of each phase of the industrial innovation cycle (Source: Utterback, 1994)

	Fluid/Emerging Phase	**Growth/Transitional Phase**	**Maturity/Specific Phase**
Innovation	Frequent changes to product	Great changes to the process	Incremental innovation in the product and cumulative improvements to productivity and quality
Products	Variety of designs for specific clients	At least one design to generate a significant volume	Mostly standard, undifferentiated products
Production Process	Flexible and inefficient	Increasingly inflexible	Efficient, capital intensive and rigid; high cost of change
R&D	No specific focus	Focus on specific features of the project	Focus on incremental technologies for the product; emphasis on process technology

Furthermore, the industry life-cycle demonstrates varying knowledge which can be divided into two distinct "technological regimes" (Winter, 1984; Agarwal and Audretsch, 2001); firstly the 'entrepreneurial' regime early in the life cycle where knowledge comes from that which is different and not routine. This phase is characterised by radical and rapid technical change (Dosi, 1982; Tushman and Anderson, 1986). Secondly, the 'routinized' regime occurs at the mature and declining stage of the life-cycle. Innovation is underpinned by knowledge from existing processes and this stage demonstrates minimal radical innovation. The shift is towards process innovation and technological consolidation and stabilisation (Anderson and Tushman, 1990).

In relating industry life-cycle and innovation to network development in technological collaboration, using the biotechnology sector as an example, technological development

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for innovation in the fluid phase has been found to take place through inter-organisational networks (Powell, Koput and Smith-Doerr, 1996). During the exploration phase of innovation, networks of collaboration dominate. The different role-players explore the different options in this emerging phase resulting in the reduction of risk and cost while facilitating the sharing of knowledge, competencies and ideas. In this manner, a diversified knowledge and technological base is tapped into.

Towards the mature phase of the industry life-cycle, more internal learning networks are depended upon for innovation. The existing technology base that was acquired and developed through past collaborative networking is now used for incremental innovation (Nesta and Mangematin, 2003). Innovation is based more on internal R&D and internal networks since internal research competencies have been developed and flows through from the fluid phase. In relating industry life-cycle and innovation to R&D, the intensity of R&D decreases with industry maturity. R&D starts to play a role in efficiency improvements at this stage (Bos et al., 2013). “R&D does not necessarily create value in mature industries, especially for market followers” (Estin, 2006, p.1). R&D should ideally be related to the maturity of the industry (Figure 8). Although the function of different personal networks seems to be different at different levels of industry maturity, the importance of such networks remains.

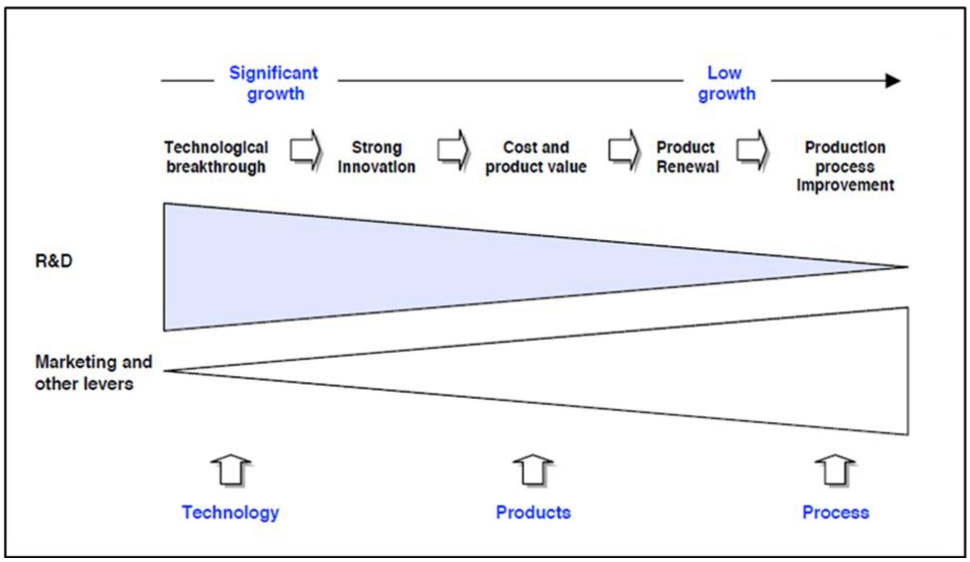

Figure 8: R&D and innovation across industry life-cycle (Source: Estin, 2006)

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2.1.3.5 Team innovation model

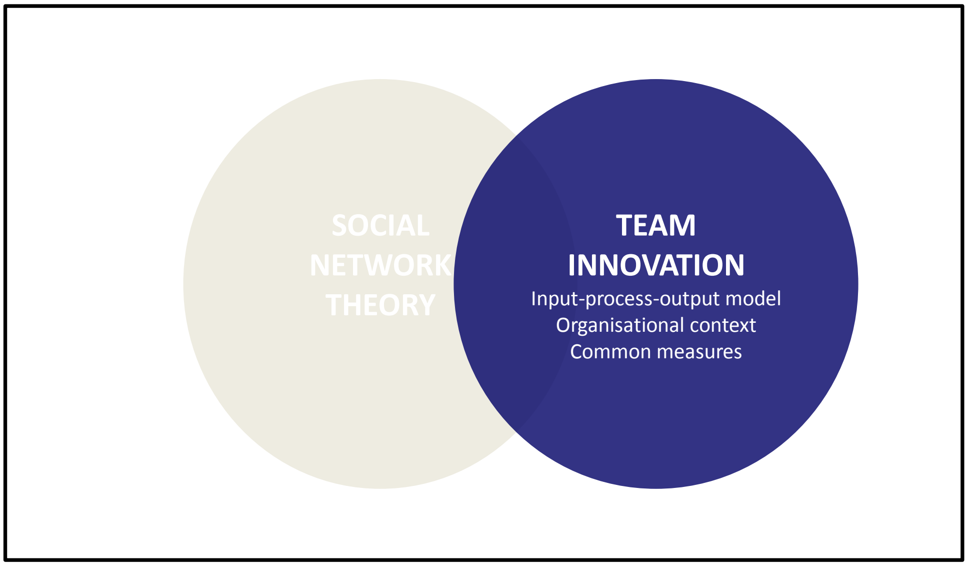

Figure 9: Team innovation literature focus

A frequently cited group innovation input-process-output model (Figure 10) was developed by West and Anderson (1996). The model provides a conceptual framework conceptualizes the inputs for team innovation (team composition, heterogeneity, size, team tenure, proportion of innovators, task complexity) the process for team innovation (clarity of and commitment to objectives, participation, task orientation, support for innovation), the output for team innovation (number of innovations, innovation radicalness, magnitude, novelty, effectiveness) and the organizational context for team innovation (climate for innovation, support for teamwork, resources and size).

Inputs

The heterogeneity of a team has been shown to be related to team innovation (Drach-Zahavy and Somech, 2001). Team size also is an influencing factor where smaller teams has been shown to lack in diversity of knowledge and skill whereas larger teams can become quite unstructured and scattered for effective knowledge exchange and interaction with other teams (Guzzo, 1988).

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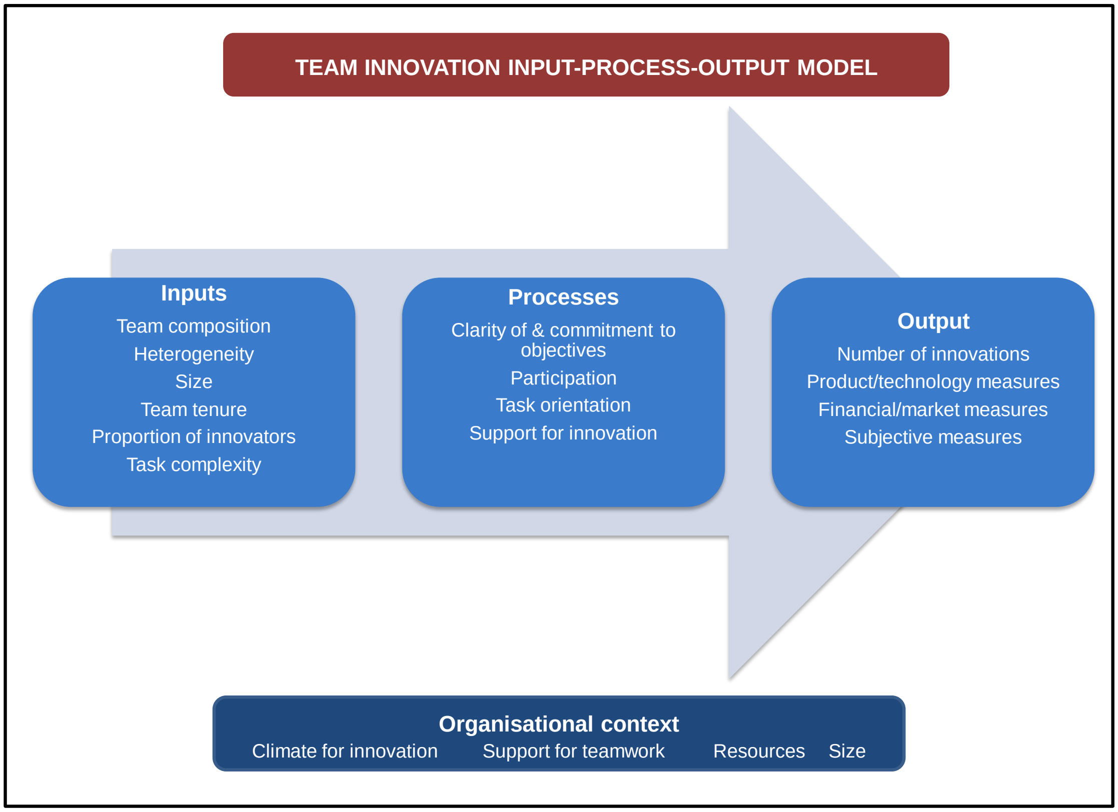

Figure 10: Team innovation input-process-output model (modified West and Wallace, 1991)

The duration of team membership can also viewed from a dual perspective. Fairly new members to the team (shorter team tenure) are in a position to challenge and improve on existing processes and methods through the combination of knowledge with existing longer term team members (Katz, 1982). The longer people are in a team together, the tendency becomes one of isolation where information is just circulated amongst the same team members resulting in a certain degree of group-think. This has the potential to result in lower degrees of innovation should there not be significant change in team membership. The literature provides evidence that team tenure moderates the relationship between task complexity and performance (Kozlowski and Hults, 1986).

The innovativeness of team members themselves is also a factor that influences team innovation, in that some team members may have greater innovative talent and tendencies than others (Burningham and West, 1995). Innovation in itself is a collective

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effort fostered by a team of people who come together with their differing ideas and knowledge base (Mumford and Gustafson, 1988). Also the challenge of the task itself to develop newer products and processes is sometimes motivation enough to drive members of a team towards innovative outcomes.

Processes

The most prominent process factor is the existence and communication of the goals and objectives of the team (Pritchard, Jones, Roth, Stuebing and Ekeberg, 1988). The communication of clear and specific goals has been found to influence outcomes (Weldon and Weingart, 1993). The participation of team members in the decision-making of the goal and objective setting process affords greater buy-in and commitment from team members (Coch and French, 1948; Bowers and Seashore, 1966; Lawler and Hackman, 1969) and facilitates the building of a cohesive team focused on an aligned innovation outcome (Locke, 1968; Latham and Yukl, 1975) and improved team performance (Weldon and Weingart, 1993). Team leaders are faced with lesser degrees of resistance to change should this participative approach to goal setting and decision-making be utilised (Coch and French, 1948; Bowers and Seashore, 1966; Lawler and Hackman, 1969). These factors lend itself to a supportive innovation environment (Amabile, 1983) where new ideas are unpacked and accepted by the team for further evaluation. Furthermore, team members become task-orientated when they interrogate the underlying activities of the shared team objectives and goals by facilitating debate on and giving due consideration to alternative solution in achieving the desired innovative outcome.

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Measures of innovation

Some of the most commonly used measures can be categorised into product/technology measures, financial measures, and subjective measures (Table 2). The subjective measures are those surveys where team members themselves or team managers/leaders were requested to rate the different aspect of innovative behavior.

Table 2: Commonly-used measures of innovation

Measure	Example study
Product/technology measures	
New products or product improvements	Elenkov and Manev (2009)
Patents or patent applications	Jung, Wu and Chow (2008)
Patent citations	Makri and Scandura (2010)
Invention disclosures or suggestions	Axtell, Holman, Unsworth, Wall and Waterson (2000)
Process innovations	West, Shapiro and Haward (2003)
Financial/market measures	
Ratio of sales of new products to total sales	Czarnitzki and Kraft (2004)
Ratio of sales of new products to R&D expenditures	Gumusluoglu and Ilsev (2009)
Total R&D spending	García-Morales, Mathías-Reche and Hurtado-Torres (2008)
Number of employees in R&D	García-Morales et al. (2008)
New markets entered	Elenkov and Manev (2009
Subjective measures	
Innovative work behavior	De Jong and Den Hartog (2010)
Team innovation	West and Wallace (1991) Burpitt and Bigoness (1997)

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Organisational context

The environment in which innovation takes place needs to be conducive to such activity. A climate conducive of innovation and teamwork such as good communication, teamwork and co-operation provides fertile ground for innovation (Ragazzoni, Paola, Maria, Anderson and West (2002). The size of the firm and its propensity to innovate has not provided clear evidence as to whether innovation is more conducive in smaller or larger companies. Larger companies have the finances to facilitate innovation whereas smaller companies have the flexibility to innovate and limited finances (Blundell, 1995; Wynarczyk, 1995).

2.1.4 Core elements of innovation

2.1.4.1 Trust

This section clarifies the concept of trust, explaining how trust develops and the most conducive environment for its development; why trust is important for innovation and what recent research has been carried out on this topic.

Trust is:

> *"the willingness of a party to be vulnerable." (Mayer, Davis and Schoorman, 1995, p.347)*

Trust is contained in relationships between people (Nahapiet and Ghoshal, 1998). An organisation with strong networks not only supports the building of trust among its members but also constantly reinforces its own shared values and frameworks. Trust also evolves from a shared past among individuals, which can include joint past experiences, competencies, reputation and familiarity between individuals in terms of goodwill and intentions (Arino, de la Torre and Ring, 2001; McAllister, 1995).

Levin and Cross (2004) outlined how trust has been linked to effective knowledge transfer. For these researchers, benevolence- and competence-based trust mediated between the strength of interaction and the receipt of knowledge, the latter form of trust being particularly important for tacit knowledge exchange. Competence-based trust is evident in common environments, shared goals and cultures, and forms a basis for sharing and knowledge exchange, which in turn impacts positively on the performance of individuals, teams and organizations.

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A range of other scholarly work (Abrams, Cross, Lesser and Levin, 2003; Levin and Cross, 2004; Nooteboom, 2004; Dovey, 2009; Mu, Peng and Love, 2008) has also underlined how trust is important for facilitating knowledge creation, sharing and transfer A greater degree of trust has been observed to facilitate a greater degree of knowledge exchange and learning. Trusting an individual depends on the development of a personal relationship and facilitates the sharing of knowledge.

Any interaction, but especially one that involves an individual's creativity and reveals his/her knowledge gaps, exposes the participant to a certain degree. Exposure may entail an idea being openly discussed; having loopholes pointed out; being rejected; or not even being given due consideration. The idea generator therefore opens him or herself up to the potentially embarrassing emotional risk of others considering them lacking in knowledge.

Individuals will thus engage in the innovation process if they believe their ideas will be listened to, and are less likely to participate if they do not trust the other individuals. Anticipating a positive response to their ideas will make people more likely to create and share innovative ideas (Clegg, Unsworth, Epitropaki and Parker, 2002). The building of interpersonal trust is based on having confidence in others' knowledge, skills and good intentions (Cook and Wall, 1980) and is instrumental in new knowledge development and learning, both within and between teams and organizations (Herting, 2002; Smid, Bijlsema-Frankema, Derksen and Bernaert, 2005).

Dovey (2009), and Mu et al. (2008) demonstrated that trust that is reciprocated is a prerequisite for efficient knowledge sharing. Since knowledge is one of the elements of innovation, exchanges that take place as part of the innovation process depend on a degree of interpersonal trust between role-players. Trust thus provides a solid base upon which innovation can be developed.

The indications from the trust literature are that trust is (to variable extents) necessary as a condition for knowledge and idea sharing. However, counter to this, Molina-Morales & Martinez-Fernandez (2009) showed that an excess of trust in relationships has the potential to produce negative effects for firms by weakening rigour. Social interactions

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and trust were used as indicators of social capital. More social interaction underpinned by trust had a decreasing effect on the creation of value in the firm.

2.1.4.2 Novel knowledge

The second key element forming a basis for innovation is knowledge. This section on knowledge will attempt to clarify the concept, and explain why knowledge is important for innovation and how it can be gained or developed.

Knowledge is:

> *"an organized combination of ideas, rules, procedures, and information" (Bhatt, 2000, p.16).*

Ample literature demonstrates that knowledge is considered one of the most important resources that can be held by organizations and individuals (Conner and Prahalad, 1996; Grant, 1996; Nahapiet and Ghoshal, 1998). The knowledge-based view of the firm argues that knowledge is the firm's most important strategic asset (Whelan, 2007). Other authors have stated that knowledge is most critical for innovation (Drucker, 1985; Bubner, 2001; Tsai, 2001) and is dependent on the accumulation of new knowledge in an organization (Kogut and Zander, 1996; Dougherty, Munir and Subramaniam, 2002; Smith et al., 2005). Furthermore, "*new knowledge is critical to developing new products or innovative ideas*" (Tsai, 2001).

Resources and capabilities internal to the firm have been the focus of the resource-based theory of the firm (Barney, 1991; Conner and Prahalad, 1996; Wernerfelt, 1995). Subsequent research extended this theoretical field to include resource exchange (including knowledge) (Roper and Crone, 2003; Teece, 1998; Grimpe and Kaiser, 2010). Nevertheless, to enhance its competitive advantage a firm requires a balance between inherent knowledge and the knowledge arising from external interactions (Grimpe and Kaiser, 2010).

Knowledge is neither completely stored in individuals nor in the organization (Bhatt, 2000). This is aligned with Blackler (1995), who proposed that "knowledge can either exist in the individual or outside them, i.e. in the organization itself. When located outside individuals, knowledge can exist in the culture, in routines or in symbols." The knowledge

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housed in individuals can be described in a different way, as either tacit or explicit (McAdam and McCreedy, 1999; Nonaka, 1991).

Explicit knowledge can be derived from a text such as a book or manual, and is considered fairly easy to communicate between individuals and organizations (Alonderiene, Pundzien and Krišinas, 2006). Tacit knowledge derives from an individual's inherent experience, skills and know-how (Nonaka & Takeuchi, 1995; Lim, 1999). A survey of R&D workers in 23 firms showed that tacit skills acquired on the job made a greater contribution to innovation than formal knowledge acquired from education via literature (Howells, 1996).

The ability of an organisation to manage, maintain and create knowledge has been shown to impact on the rate at which it puts new products out to the market (Cohen and Levinthal, 1990; Drazin and Rao, 2002). A certain degree of existing knowledge is required for new knowledge to be created (Boland and Tenkasi, 1995; Hargadon and Fanelli, 2002) and before the new knowledge has the potential to manifest itself in the form of new products or services.

Scholars have given differing accounts of how knowledge is accessed and employed. Sammarra and Biggiero (2008) showed that firms used collaboration to access differing knowledge bases with regards to technology, the market and processes (Cohen and Levinthal, 1990). This heterogenous knowledge which has a positive impact on innovation can be gained through inter- and intra-organizational interactions. Interactions sometimes not only involve the exchange of existing knowledge but also the acquisition of new and shared knowledge (Howells, 2002).

Various types of interactions support the acquisition of knowledge. These interactions may be facilitated through social networks (Liebeskind, Oliver, Sucker and Brewer, 1996), where they have been found to be a positive factor for innovation and learning (Wenger and Snyder, 2000). Trusted weak ties in a social network are often a source of novel knowledge useful in innovation (Granovetter, 1973; Levin and Cross, 2004).

Acquisition of such new knowledge may also be through interaction between individuals possessing disparate levels and kinds of knowledge (Nonaka, Von Krogh and Voelpel,

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2006). Knowledge transferred between groups can be realised in ideas and concepts new to all participants, thereby contributing to new products, processes or services (Hargadon and Sutton, 1997). One example of a context for such discoveries is the ‘communities of practice’ found in some companies, comprising individuals engaged in knowledge-sharing to support learning and innovation (Brown and Duguid, 1991). Irrespective of innovation type, gaining and learning, all these scholars have found new knowledge through collaboration forming a basis for innovation.

Thus despite these differently nuanced accounts of knowledge generation and transfer the literature supports the view that knowledge is critical for innovation. Accessing knowledge through networks, and collaboration for innovation forms the basis of further discussion in Section 2.1.5.

Bjork and Magnusson (2009) showed that interactions between people need support to increase the generation of innovative ideas. Repeated interactions between people become characterized by relationships founded on high levels of trust. In such settings, firms are more likely to innovate (Fountain, 1998; Knack and Keefer, 1997).

However, firms do not innovate in isolation, but draw on external sources of knowledge through networking to complement their internal knowledge capacity (Bidault and Cummings, 1994; De Bresson and Amesse, 1991; Freeman, 1991; Howells, 2002). These external sources of knowledge can be accessed through interaction with other teams within the organization, with research institutes, customers and even suppliers.

Thus the two elements underlying innovation are trust and novel knowledge. Trust between role-players facilitates enhanced interaction and recurring interaction often engenders trust which in turn forms the basis for the exchange of knowledge. In addition to this, access to a large number of diverse interactions provides a source of varying knowledge.

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2.1.5 Networks and collaboration for innovation

This section begins by clarifying the concepts of collaboration and networks and discussing why collaboration matters. It progresses by describing how collaboration takes place (open or closed networks). A broad survey of potential collaborators (including intra-firm or inter-firm interactions) here is followed a discussion of the significance of geographical or country proximity in collaboration.

Collaboration is:

> *"a process in which autonomous or semi-autonomous actors interact through formal and informal negotiation, jointly creating rules and structures governing their relationships and ways to act or decide on the issues that brought them together; it is a process involving shared norms and mutually beneficial interactions" (Thomson, Perry and Miller, 2007, p3).*

Gray and Wood (1991) define collaboration as occurring:

> *"when a group of autonomous stakeholders of a problem domain engage in an interactive process, using shared rules, norms, and structures, to act or decide on issues related to that domain" (p. 146)*

Bryson, Crosby and Stone (2006) define "cross-sectoral collaboration as:

> *"the linking or sharing of information, resources, activities and capabilities by organizations in two or more sectors to achieve an outcome that could not be achieved by organizations in one sector separately" (p. 44)*

Oliver (1990) mentioned six motives for organizational collaboration: meeting legal or regulatory requirements; the ability of an organisation to exercise power and control over another; a co-operation agreement; a bid to increase efficiency; a response to environmental uncertainties; and an attempt to improve image and reputation. Another very prominent motive for collaboration around innovation is the interdependency of resources (Ozman, 2009). In addition, collaboration may occur to access the partners' tacit knowledge, enable technology transfer to facilitate technological advances, or to increase the time to market of a new product innovation (Arias, 1995).

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2.1.5.1 Network types and innovation

When collaboration takes place, the resulting interaction creates a network. However, this leaves open question as to the optimal nature of the collaboration: whether to have an open network and share the inner workings of a company, or to adopt a closed network and work with only a select group. Each of these has its own advantages and risks. A closed network assumes that knowledge and idea generators have already been identified and that ready access to them already exists. An open network opens an organisation to a huge pool of ideas, with the consequent challenge of screening all these ideas at acceptable cost (Pisano and Verganti, 2008).

In the case of innovation-focused interactions, networking with diverse partners has increased significantly to become a dominant mode (Beck and Schenker-Wicki, 2013). A further set of questions relates to networks as local or globalised. Globalised networks comprise of individuals from different countries. However, the dynamics of a specific country's business behaviours can influence the communication and interaction behaviour of the individuals involved. This can impact on a team's innovation performance, and ultimately on a firm and country's innovativeness. Because networks and interconnections between individuals contribute to innovation, the role of extra-local networks as well as these behavioural aspects calls for further research (Bunnell and Coe, 2001).

External linkages have been discussed in terms of their being either strategic or relational linkages. All firms reside in multiple networks or another through their linkages with various other role-players. Strategic linkages (such as foreign direct investment) are those which permit firms to access resources in a foreign market. This purpose will impact on the choice of an FDI location, since a specific resource may be found in only a limited number of specific locations. Relational linkages are based on commonality between individuals and contribute to positive personal relations such as trust (Chen 2007).

A related field of study, cluster research, has focused on global-local linkages where knowledge, competencies and social capital emanate from outside the cluster. Research on global-local linkages so far has focused mainly on foreign direct investment, and mergers and acquisitions (Vang and Chaminade, 2007). In the global electronics

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industry, it was observed that rapid knowledge uptake and learning promotes positive relationships with local network linkages by multinationals. The multinational is selective in its choice of local role-players contributing to innovation (Castellani, 2002).

Thus linkages, whether residing in a firm's immediate locality, or spanning international boundaries, have been shown by research as capable of forming the basis for global, or global-local, networks, both open and closed.

2.1.5.2 Interaction: "With whom?"

In the development of either a global or a local network, collaboration has the potential to occur with a variety of partners. Collaboration resulting in the development of networks can take place within a firm overall, between team members in a particular group, and between team members across different groups. Collaboration can also take place and networks develop between firms or organizations situated in the same country, or between firms across international boundaries. Considerable research has focused on the importance for product and service innovation of both intra-firm collaboration (Gupta, Tesluk and Taylor, 2007; Karniouchina, Victorino and Verma, 2006) and inter-firm collaboration (Gupta et al., 2007; Menor and Roth, 2007) and this is examined below.

2.1.5.3 Intra-firm collaboration

Research has demonstrated that although inter-firm collaboration is important for innovation, intra-firm collaboration is key (Sanders and Premus, 2005; Hillebrand and Biemans, 2004). Interaction between individuals within a firm occurs not only inside a single division but also between individuals across divisions. Because these individuals carry knowledge specific to their divisional functions, a hybridization of this knowledge occurs, and it is this that makes such an important contribution to innovation. Such intra-firm interactions can take a variety of forms.

Multi-divisional firms frequently structure their divisions by specific activities and competencies making these divisions largely interdependent and more focused on resource sharing between divisions than resource combination. Cross-divisional innovation has in this way become compromised. Divisions may also be viewed as independent profit centres, so that any joint innovation activity needs to show profitability. However, innovation poses a challenge to these conceptual frameworks as

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benefits and profitability are not necessarily realized immediately, especially in the early stages of developing a new product or process. Innovation also demands the managed co-ordination of activities across divisions; for example, the conceptualization of an idea by R&D needs to be coordinated with new ideas from the strategy and marketing sections to anticipate both improved and new market requirements (Kleinbaum and Tushman, 2008).

However, the combination of resources between divisions holds significant potential for both innovation output and firm profitability if it is better understood. A review of the literature by Grote, Herstatt and Gemunden, (2012) noted that little research had been undertaken on cross-divisional collaboration and its impact on cross-divisional product development. Their subsequent research presented an argument for joint initiatives and the role of cross-divisional collaboration during the early stages of innovation. They provided robust evidence that cross-divisional integration mechanisms and reward systems influenced the degree of cross-divisional collaboration. Additionally, a strong and significant relationship was obtained between the extent of collaboration in the early stages of innovation and cross-divisional product development.

Similarly, the results of a study by Miller, Fern and Cardinal (2007) into the knowledge input towards patents, showed that a combination of knowledge from different divisions has a significant and positive impact on an invention and its subsequent technological developments. Inter-divisional knowledge, as opposed to knowledge from within a division or external to the firm, was also found to have the greatest impact on developments. Utilising inter-divisional knowledge, as opposed to knowledge exchange between firms, may also be potentially less costly and less risky in relation to internal intellectual property exchange. This is argued to be because it represents knowledge that is both fairly novel but also to some extent shared.

Well developed internal collaboration practices already operate in many firms among and between functional units (Poppo, Zhou and Ryu., 2008). Such practices may be based on an innovation stage model, requiring certain conditions to be satisfied before a new idea progresses to the next stage of development. Innovation may also involve the recombination of existing knowledge residing within a firm (Nerkar and Paruchuri, 2005). In this case, the firm draws upon complementary internal skills and processes residing

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within sometimes highly specialized functional units (Nijssen, Hillebrand, Vermeulen and Kemp, 2006). The specialized nature of these functional units allows distinct skill-sets to be integrated, even in the absence of high levels of trust in working relationships (Hansen, 2009).

However, in some firms, contact and interaction between different groups can be constrained by formal organisational structures. These structures can take the form of rules governing interaction and inflexible pre-ordained channels of communication. In such cases, group leaders become the channel through which useful information and knowledge are transferred (Mehra, Smith, Dickson and Robertson, 2006). The interpersonal ties and networks of these leaders facilitate the sharing of knowledge and the discussion of ideas derived from different parts of the organization. This process supports the promotion of interpersonal trust.

2.1.5.4 Inter-firm collaboration

This section highlights the benefits of inter-firm collaboration for innovation; considers what determines the strength of such interactions; and evaluates the risks associated with them.

Interaction between different firms impacts on innovation by bringing together a diverse set of individuals. The resulting network will be heterogenous in terms of technical skills and competencies, internal procedures and routines for inter-organizational interaction, and market perspectives in terms of existing geographical presence and strategies for diversification (Grant and Baden-Fuller, 2004; Beckman and Haunschild, 2002; Cohen and Levinthal, 1990).

The strength of an inter-firm relationship is determined by the frequency and the duration of the relationship (Capaldo, 2007). The longer a relationship has lasted, the more frequent the interactions and the stronger their intensity, the more individuals tend to trust each other. This has been observed more between firms where individuals, despite being situated in different companies, share a common background and are working towards similar goals. This commonality facilitates channels for idea and knowledge sharing and thus contributes to both the innovative capability of teams and the impact on firm innovativeness overall. One example was cited by Almeida, Hohberger and Parada

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(2011) in his research on the impact on patent output of inter-firm collaborations between biotechnology researchers. Almeida found that the total number of individual collaborations impacted positively on the number of published patents.

Strategic alliance studies have also demonstrated that inter-firm partnerships have a significant impact on new product development (Faems, van Looy and Debackere, 2005; Gerwin and Ferris, 2004; Schleimer and Schulman, 2010).

However there are risks in collaboration across firms. Continuous collaboration with the same partner can end up recycling redundant information or create dependency on a specific strategic partner (Nieto and Santamaria, 2007). Both these negatively impact innovation outcomes. Inter-firm collaboration may also involve time away from work (building networks, for example, at conferences and trade fairs) and less time contributing to core productivity (Nesta and Mangematin, 2003).

2.1.5.5 Co-occurring intra-firm and inter-firm collaboration

Most firms involved in new product and new service development engage in both intra-firm and inter-firm collaboration simultaneously (Schleimer and Shulman, 2011). Assessing the impact of simultaneous collaborations requires definitions of impact that take into account what is being developed; the type of collaboration and the specific aspect of collaboration. However, evidence assessing the relative contribution to innovative outcomes of each type of collaboration has to date been somewhat inconsistent. This inconsistency appears to derive from studies evaluating the impact of each type of collaboration separately, even when the engagements take place simultaneously. Some researchers have found that increased intra-firm collaboration sometimes may have a negative impact on performance (McEvily, Perrone and Zaheer, 2003; Das and Teng, 2004). Further, increased inter-firm efforts do not always increase innovation outcomes (Kale and Anand, 2006; Das and Teng, 1998).

The work of Schleimer and Shulman (2011) was one of the first quantitative research efforts to assess the impact on innovation of simultaneous intra-firm and inter-firm collaboration. Their research produced robust evidence that both intra-firm and inter-firm collaboration are important for new product and service development.

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So far, this discussion has not considered the geographical location of interacting partners. It is necessary now to discuss the impact of proximity on innovation in inter-firm interaction, beginning with a consideration of the ways in which location can influence the outcomes of interaction.

2.1.5.6 Interaction: “Where?”

This section discusses the concept of proximity, the tensions that can exist in cases of close proximity, and the impact of proximity on the exchange of knowledge and on innovation, including the benefits of cross-border interactions.

Proximity can be defined as the spatial or physical distance between actors. This can have both positive and negative effects on interactive learning and innovation. Close proximity (eg. between teams within an organization rather than situated externally to a firm, region or country) facilitates face-to-face interaction and the development of trust. Tacit knowledge is often grounded in a particular region because it is embedded in members of a workforce or organisation, and this grounded knowledge will dominate if the movement of the workforce is limited. However combinations of knowledge across distance are important for the acquisition of new information and capabilities, even though acquiring these may be time-consuming and costly (Gavetti and Levinthal, 2000; March, 1991; Miller et al., 2007).

Thus tensions exist between the two. Closer proximity facilitates greater trust, developing stronger ties between role- players and enhancing knowledge exchange. The closer individuals are to each other, the more they communicate, interact and network, facilitating learning and innovation. Geographical closeness also supports social proximity; face-to-face interactions reduce communication costs and develop stronger linkages.

Indeed a study by Ollus, Jannson, Karvonen, Uoti and Riikonen (2008) showed a correlation between close networking and innovation. Close proximity helps to bridge gaps in information, scientific knowledge, resources and competencies. The work by Ollus et al. (2008) also illustrated that the innovation process was interactive and non-linear, mirroring the dense informal interpersonal networks found among individuals in close proximity to each other in a firm. For a similar set of reasons, firms located in

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geographical clusters tend to exhibit better performance than those situated in isolation. Clustered firms can tap into diverse knowledge spillovers, skills and support systems, to maintain competitive advantage based on innovation (Beaudry and Breschi, 2003).

However, extended close interaction over a long period has the potential to lead to redundant knowledge exchange and a stagnant innovation environment. This may lead to lock-in, where role-players become more inward-looking, constraining their innovative capacity to such a degree that they cannot respond appropriately to the market changes and needs (Boschma, 2005; Visser and Boschma, 2004; Amin and Wilkinson, 1999).

Lock-in can be broken by individuals developing more geographically distant linkages, thereby creating a balance between local and non-local interactions (Oinas, 1999; Asheim and Isaksen, 2002). Networking between individuals that combines local and non-local interactions allows knowledge to be externalised, opening avenues for new combinations of ideas. Novel ideas are more likely to originate from networks including role-players from different backgrounds, e.g. international networks (Visser and Boschma, 2004).

The tension between close proximity and distance is further illustrated in a study by Callois (2008). The results of this study showed a bell-shaped relationship between proximity and the innovation performance of firms. The closer the firms were to each other, the more ideas could be shared, costs reduced and risks pooled. This resulted in improved process innovation and efficiency. However, there was an optimal point. Beyond that point, the closer the firms were to each other, the less diverse was their cognitive environment, resulting in less product innovation.

The advantage or otherwise of country or region proximity relates to the degree to which two countries differ on various dimensions, including the educational backgrounds of individuals, and personal, community and work culture. Different country environments may shape attitudes towards innovation, work philosophies and management styles. Thus interaction across country boundaries can potentially access more diverse knowledge: another important underpinning of innovation. Accessing knowledge external to a region is important for innovation, since certain pools of knowledge are embedded in

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specific regions. For all these reasons, the region where an interacting firm is based is important for innovation (Becheikh, Landry and Amara, 2006).

All the types of collaboration discussed above facilitate the development of networks. Networks comprise a series of relationships. Those relationships are termed ties and two specific dimensions of the tie – tie strength and tie breadth – and their impact on innovation form the basis of this research. These are discussed in Sections 2.2 and 2.3.

2.2 Tie strength and innovation

2.2.1 Tie strength, trust and innovation

Section 2.1.4.1 discussed the merits of trust as a core element of innovation. This section will first deal with the relationship of trust to tie strength, and then the link between tie strength and innovation, which forms the basis of the first hypothesis.

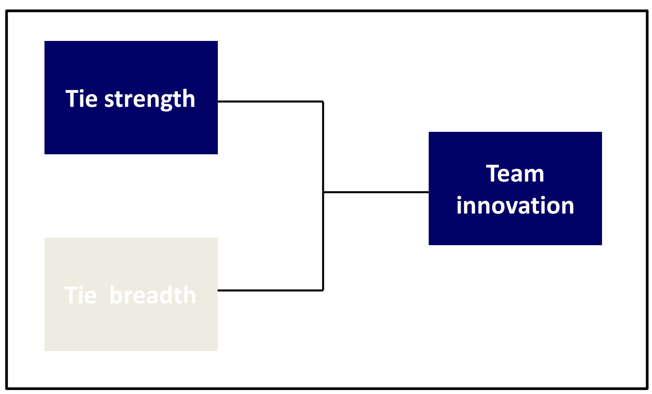

Figure 11: Relationship between tie strength and team innovation

One important point of departure for this discussion is to clarify the concept of a tie in terms of social network theory. A social network is comprised of a "set of people or groups of people known as 'actors' or 'nodes' that have a relationship, some type of interaction or 'tie' between them" (Hatala, 2006).

Researchers in the field of social network theory have long debated the relative value of strong and weak ties for groups and organizations (Ashman, Brown and Zwick, 1998).

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The field of social network analysis boasts three founding influential scholars, namely Burt, Coleman and Granovetter.

Granovetter (1973) differentiated the dimensions of tie strength as "a linear combination of amount of time, reciprocal services, intimacy (mutual confiding) and the emotional intensity which characterises the tie." Tie strength therefore incorporates both the element of the duration of the relationship and emotional intensity (Lowik, van Rossum, Kraaijenbrink and Groen, 2012; Marsden and Campbell, 1984). A common cognitive framework between tie partners develops over an extended period of interaction. The frequency of communication and its reciprocation and the information that is shared between partners all affect the strength of a tie, and all have implications for innovation.

Expanding on this concept, Granovetter (1973) also introduced the distinction between strong and weak ties. Frequent, information-filled, intense interactions form the basis of strong ties. These strong ties exhibit a dense network structure advantageous to the amassing of social capital (Coleman, 1988). Strong ties facilitate the transfer of "fine-grained" information, detailed knowledge and expertise (Dore, 1983; Mu et al., 2008; Levin and Cross, 2004).

Trust which has been conceptualised in Section 2.1.4.1 is an inherent quality of strong ties (Abrams, 2003). As a result of a trusting relationship, more knowledge exchange takes place, and this has the potential to contribute to innovation. The greater the frequency of this exchange, the better the innovation output (Moran, 2005; Reagans and Zuckerman, 2001; Smith, et al., 2005) and the degree of radicalness of the innovation (Landry et al., 2002).

Because of trust, strong ties are able to tap into and access details of the existing body of knowledge in an organization (Uzzi, 1997). When people trust those with whom they interact, they tend to be more accepting of the uncertainty surrounding innovation processes and outcomes. Any hesitation initially underlying such exchanges can be reduced (Coleman, 1988) thereby further enhancing trust.

Strong ties underpinned by trust (either benevolence-based or competence-based) provide the means through which useful knowledge is received. But once trust is instilled

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in even a weak relationship, it can also form the basis of what is called a trusted weak tie mechanism upon which knowledge exchange can also take place (Levin and Cross, 2004).

Weak ties are those occurring between individuals loosely and intermittently connected to one another. Weak ties, the so-called “contacts of contacts” are often secondary links that can be accessed and activated via strong ties (Jack, 2005). These ties nevertheless have the potential to be a source of novel ideas and opportunities to access information, both of which are critical for innovation (Burt, 2004; Granovetter, 1983).

Weak ties are useful for gaining new knowledge, in contrast to strong ties, which serve as conduits for in-depth information and tacit knowledge (Podolny, 2001; Reagans and McEvily, 2003; Uzzi, 1997). A weak tie therefore allows an individual to access what might otherwise be an inaccessible area of knowledge. Networks with many weak ties thus have the potential to introduce new ideas. This is not true of closed networks, however strong, if their ties duplicate non-novel information (Whelan, 2007).

Strong ties are thus initially more or less advantageous because of the workings of trust. But over time they create cohesive groups which may ultimately harden into internal cliques. This “over-embeddedness” and seclusion from the external environment limits interactions for those within the network. A critical input for innovation is lost with the loss of potential novel knowledge lying outside the network but sealed off from it by the network’s inward orientation (Gulati, 1995).

The more entrenched cliques become, the more this effect is felt. Burt (1992, p205) focused on network efficiency, demonstrating that strong ties formed redundant contacts, many of which carried the same information. This results in the circulation of repetitive information within the same cliques, and a declining impact on innovation. Dense networks are associated with high levels of in-group togetherness (Coleman, 1988). Thus while face-to-face interactions, shared knowledge and deep relationships enhanced knowledge flows between actors and formed the basis of strong ties (Reagans and McEvily, 2003), other researchers demonstrated how individuals who were part of the densest groups did not always generate a high number of innovative ideas (Bjork and Magnusson, 2009).

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McFayden and Cannella (2004) have shown that at high levels of tie strength, a curvilinear effect is observed the knowledge creation required for innovation decreases. Lowik et al. (2012) confirmed the inverted U-shaped relationship between tie strength and knowledge acquisition and creation, although they went on to say that new knowledge from strong ties could last for long periods of time. Thus it is possible that the relationship of tie strength with new knowledge acquisition may also not be simply an inverted U-shape, but rather an initial steep escalation, following by a linear gradient increase, since these findings suggest knowledge may be continuously regenerated.

However, the weaknesses of strong ties (cliques and redundant information) are balanced by the strengths of weak ties (novel knowledge and ideas) (Capaldo, 2007; Hansen, 1994). This provides strong support for a research framework founded on interrogating the integration of weak and strong ties as a foundation for innovation.

Weak ties need to be viewed in relation to existing strong ties. It is the mix of strong and weak ties, (the combination of common goals, culture and background with what is new) that creates an innovative network structure. Non-redundant “weak” ties function as bridges over which novel knowledge and ideas cross group and firm boundaries. And while forms of brokerage enable access to external knowledge and novel ideas, it is the “strong ties” (including redundant ties) within groups that facilitate the acceptance and integration of knowledge into the group (Laursen and Salter, 2006).

There is therefore interplay between redundant and non-redundant networks and the findings of Burt, Coleman and Granovetter can be viewed as complementary to one another. The implication (explored further in the conclusions to this paper) is that a company is best served by striving towards a balance between weak ties for novel knowledge and strong ties for the integration of knowledge (Gilsing and Duysters, 2008). Besides reinforcing Granovetter’s ‘strength of weak ties’ finding, the message is that a dual network has positive implications for innovation (Capaldo, 2007; Tiwana, 2008).

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2.2.2 Tie strength model

Within any team, members know each other relatively well because they share a common organisational background, and an understanding of goals and objectives. The inherent trust that has grown up between them facilitates a potentially greater number of interactions between team members and therefore stronger ties. Such stronger ties can in turn support enhanced innovation outcomes. However, as noted above, continued interaction limited to the group can produce a limiting inward focus that may have a negative impact on innovation outcomes.

This argument about the relative advantages and disadvantages of strong ties has also been found valid for team members situated within the same organisation but geographically distant, in another region or another country, eg. in other divisions. The commonality deriving from a familiar organizational background is beneficial for innovation to a certain point, but has the potential over time to weaken innovation. At the same time, weaker ties that are underpinned by a certain degree of trust will facilitate the exchange of new knowledge and information. This explains the inverted U-shaped relationship between tie strength and innovation shown in Figure 12 below. Up to a point, strong ties will enhance innovation outcomes. After this point, knowledge inputs gained from weaker ties will be most useful to further enhance innovation. If a network is based on strong ties alone, innovation will be restricted.

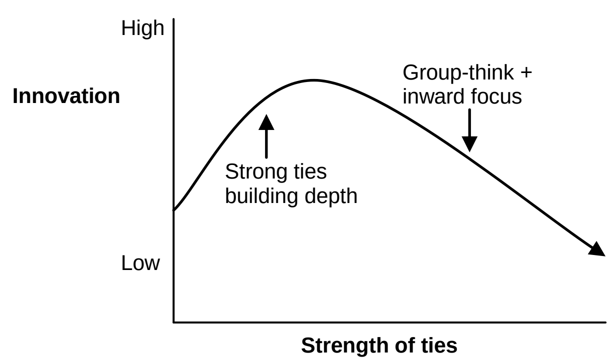

Figure 12: Changing strength of ties and impact on innovation

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The above argument forms the basis of the first hypothesis about the relationship of tie strength to team innovation:

Hypothesis 1a: *Team innovation is supported by tie strength with people in one's own team*

Hypothesis 1b: *Team innovation is supported by tie strength with people in other teams in own R&D*

The next section (Section 2.3) discusses the relationship between the breadth of ties and innovation, leading to the second hypothesis

2.3 Tie breadth and innovation

2.3.1 Tie breadth, knowledge and innovation

As Section 2.1.4.2 has discussed, knowledge is a core element of innovation. This section on tie breadth expands on the implications of the breadth of ties for the diverse knowledge important for innovation. This second section concludes with the second hypothesis.

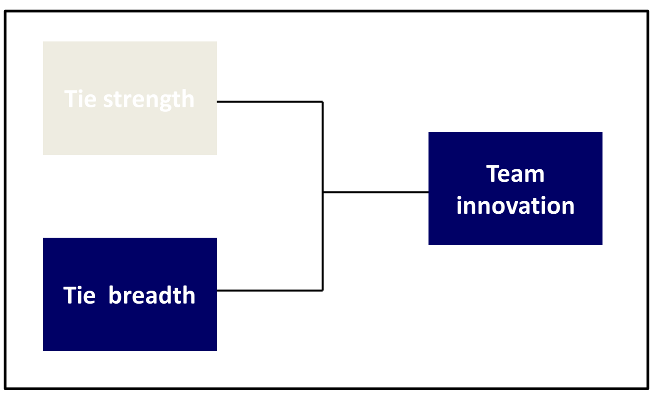

Figure 13: Relationship between tie breadth and team innovation

The breadth of a tie refers to the extensiveness of linkages: the number of different social ties that provide access to knowledge resources (Ricken, Schuler, Grandhi and Jones, 2010). Breadth of ties can, like strength of ties, offer both benefits to and constraints on innovation. Many ties (wider breadth) allow access to plentiful and diverse

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knowledge which can form building blocks towards innovation. However, too many ties can provide too many ideas and too much information, requiring rigorous filtering to extract the most suitable applications. Thus information and knowledge may also be wasted because the timing is not opportune for the market to take advantage of a potential innovation (Capaldo, Petruzzelli and Rotolo, 2009).

Firms that have access to only a narrow range of information sources through fewer ties are likely to repeatedly encounter the same information which, over time, may become redundant. Many ties, linking a firm to a large variety of information sources, can bring a firm into contact with information it otherwise might not have accessed if ties were few. In this way fewer ties (weaker tie breadth) limit the number, scope and usefulness of information sources. More ties provide more and more diverse information sources offering access to non-redundant information (Burt, 1992). These information sources may be found internally within the firm, in the market, or from other organisations.

Firms are increasingly using "open innovation" models: using external players and sources to facilitate innovation (Chesbrough, 2003). Having prior (existing) knowledge enables the firm to evaluate and assimilate new resources, with resulting positive commercial outcomes (Cohen & Levinthal, 1990), but the range (breadth) of network ties has also been shown to have a positive effect on absorptive capacity (Rejeb-Khachlouf, Mezghani and Quélin, 2011).

Research has found that large innovative firms combine knowledge from a variety of technological fields (Brusconi and Prencipe, 2001; Patel and Pavitt, 1997). Drawing this kind of knowledge from different fields is important for the development of new products (Schmikl and Kieser, 2008). That this process occurs more frequently in large innovative firms suggests that having a larger number of contacts facilitates access to these different fields.

Firms whose strength is the ability to identify and develop innovation opportunities have also been shown to have access to a larger variety of information sources (Venkataraman, 1997; Laursen and Salter, 2006; Becker and Dietz, 2004). Once more, these sources are the product of a greater number of contacts. "More specifically, we expect that firms which introduce innovations that are a world first (innovations which

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have the highest degree of novelty) are more likely to use a larger variety of sources of information to develop or improve their products or manufacturing processes than firms introducing innovations that are a first at the national level or a first for their firm" (Venkataraman, 1997). Thus, the greater the novelty of the innovation, the more likely it is that prior interaction with an external source of information has taken place (Amara, 2005; Nieto et al., 2007), because the diversity of knowledge offered by a greater number of contacts facilitates "novel associations and linkages" between diverse role-players (Rodan and Galunic, 2004). Conversely, firms with a low innovation output are characterised by a failure to complement their internal skills, competencies and knowledge with those from some external environment (Gemünden, Heydebreck and Herden, 1992).

The work of Laursen and Salter (2006) linked the breadth of a firm's external interactions to the firm's achievement of different levels of novelty. Breadth was defined as the number of external sources for search channels. The results showed that external search breadth was curvi-linearly linked (inverted U-shape) to innovative performance: with a diversity of knowledge innovation increased before decreasing.

One explanation for this link is that initially external players are unfamiliar with each other, but do possess knowledge and information not inherently lodged within the firm. As familiarity increases through repeated interactions, the external knowledge becomes better understood and levels of trust build up. Knowledge exchange becomes easier and this impacts positively on innovation. This process demonstrates implicit links between trust, knowledge assimilation and innovation. However, there are costs to developing and maintaining a large number of ties. Not only is it necessary to stay in touch with large numbers of people, which is time-consuming, but it also takes effort to make sense of and integrate all the new knowledge. More recent research by Leiponen and Helfat (2010) demonstrated diminishing returns on innovation for firms with a relatively large number of knowledge sources.

There are other, alternative forms of innovation for an organization, including the diversification of activities and products. Palich, Cardinal and Miller (2000) provided evidence for an inverted U-shape pattern for related diversification. In their study, innovative performance was positive up to a point for related diversification, after which a

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decrease was observed. Maintaining diversification beyond the optimal point is challenging since it bears a cost, and requires efficient management.

2.3.2 Tie breadth model

The argument above about the importance of the breadth of ties for accessing the novel knowledge critical for innovation leads to the second hypothesis that was tested, concerning the relationship of the breadth of ties to team innovation.

Hypothesis 2a: *Team innovation is supported by tie breadth with people in other teams in own R&D*

Hypothesis 2b: *Team innovation is supported by tie breadth with people in other teams in the organization*

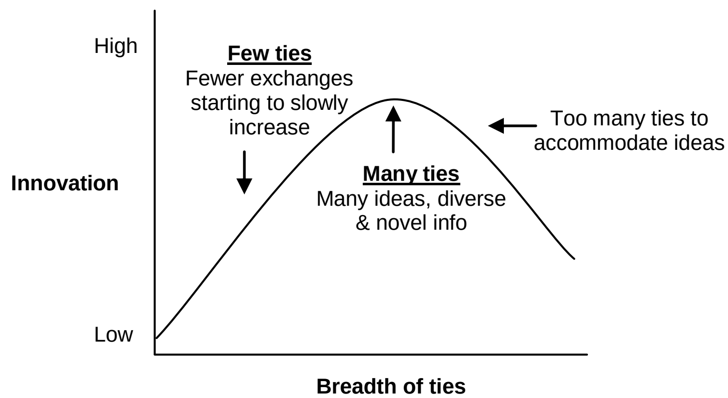

Figure 14: Changing breadth of ties and impact on innovation

To explain the curve in Figure 14, a narrower breadth of ties is characterized by fewer exchanges with counterparts within a specified period. These exchanges may be with people in the organization but outside the project team, and/or with other organizations both in and outside SA. Fewer interactions are not that conducive to significant innovation outcomes because there is only a limited degree of diversity in terms of knowledge, skill and ideas exchange. With a wider breadth of ties, there is increased sharing of embedded knowledge, which in turn has the potential to increase innovation outcomes.

Previous research has tended to conflate the effects of breadth of new knowledge and trust in the knowledge source. This research first studies these effects separately and

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then considers their combination effect. Section 2.4 covers the specific focus area of this research and the final hypothesis that has been tested: the various combinations of tie strength and tie breadth and which of these has the optimal impact on innovation.

2.4 Combining tie strength and tie breadth for innovation

In this the final section of this Chapter, the message is that for optimal innovation, some degree of similar knowledge combined with diverse knowledge is required, because knowledge that is too diverse may be difficult to understand and assimilate. Research providing robust evidence for this includes that from Sampson (2007), where the impact of technological diversity on innovation was studied. The results strongly suggested that combining diversity in terms of technological capabilities for innovation with common knowledge created the optimal conditions for innovation.

Figure 15 below attempts to schematically support the argument put forward on the combination of tie strength and tie breadth for optimal innovation. Simply explained, interactions that start to take place further away from the immediate team, i.e. with people in other teams in an R&D division, with people in other teams in the same organization and with people in other teams in other organisations results in networks exhibiting lower tie strength while exhibiting a wider breadth of ties, and subsequently a larger number of ideas and new knowledge. The literature to date that supports the above argument follows below.

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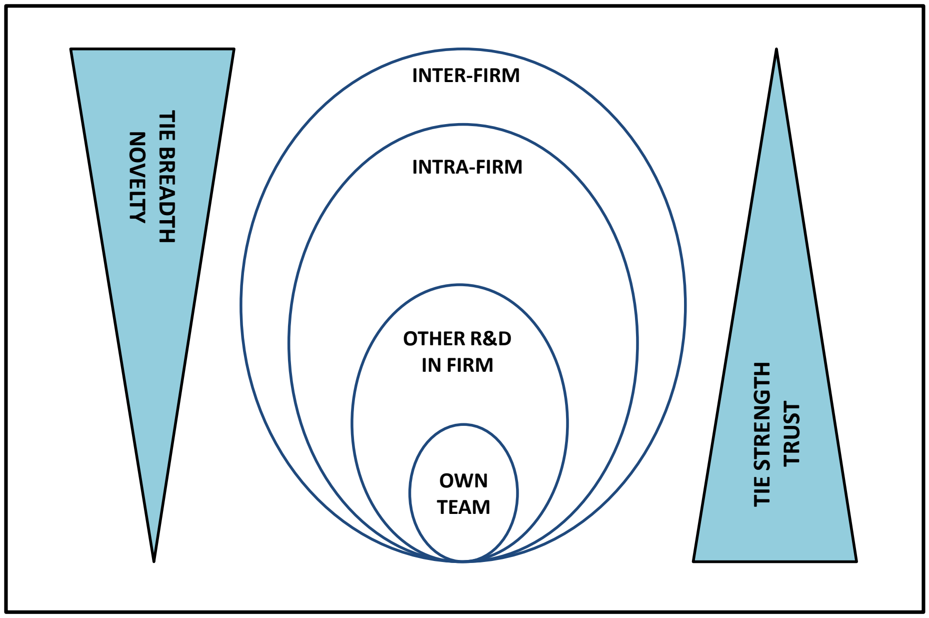

Figure 15: Changing tie strength and tie breadth with varying context

Networking across units within a firm is one valuable way to access complementary knowledge that can facilitate innovation (Frenken, 2000). Cowan, Jonard and Zimmerman (2006), through a simulation model, showed that two different network structures emerged when innovation was taking place. The first type of network demonstrated how diversity of knowledge, gained from a wider breadth of interactions or ties, was important. The second type of network demonstrated the value of the level of knowledge – in particular how ingrained knowledge was shared when frequent interaction took place between role-players who had developed trust via relationships over time. The most valuable interactions between people are therefore those that are underpinned by both detailed knowledge and breadth of knowledge (Moorthy and Polley, 2010).

Innovative ideas are now being commercialized through the use of both internal and external sources of information (Chesbrough, 2003). Internal interactions and information exchange are strengthened by strong ties underpinned by trust, but have the disadvantage that these strong ties can limit exchange to redundant information. Weaker ties allow new ideas to enter the network. Additionally, having a wider breadth of ties has

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the potential to produce greater innovation. The literature on innovation has shown that radical innovation in particular is best supported by external knowledge acquisition (Laursen and Salter, 2006).

However, the findings of Zhou and Li (2012) showed that a firm with a broad knowledge base, i.e. many ties, together with internal knowledge-sharing, i.e. strong ties, is able to produce radical innovations. Thus they concluded that the relative roles of knowledge breadth and detailed internal knowledge (interactions that exemplify tie breadth and tie strength respectively) depended on both external and internal knowledge integration mechanisms. A firm with a deep knowledge base can also produce radical innovations if it can effectively bring this knowledge base together with external market knowledge. For a firm that already possesses a diverse knowledge base, additional market knowledge does not hold the same potential for significant innovation outcomes.

Katila (2002) looked at the relationship between old knowledge and new knowledge. Old knowledge could render innovation activities redundant, but could also stimulate incremental innovation. Adding new knowledge through interaction with external industry players promoted innovation. Thus, for optimal innovativeness, some degree of old knowledge and some degree of new knowledge were both required. Ingrained, in-depth knowledge harvested through increased tie strength, combined with a range of external interactions (tie breadth) had the capacity to promote the optimal degree of innovation.

The density of a network is also relevant, and this concept must be differentiated from breadth of interaction. A dense network in one in which many direct ties exist between knowledge partners. A sparse network is one in which few ties exist between members of the network. Networks with strong ties in a dense network may hinder the creativity required for innovation (McFayden et al., 2004). When McFayden, Semadeni and Cannella (2009) extended their earlier study, they investigated the interaction between tie strength and the density of a network. Strong ties between knowledge partners in a sparse network (few ties) were shown to exhibit the greatest degree of knowledge creation.

The search for and transfer of knowledge across different divisions in a diversified firm has a greater impact on an invention than the use of knowledge from within a division

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alone (Miller et al., 2007). Social networks between role-players form the basis upon which these inter-divisional innovations take place and these networks facilitate the combination of technologies, skills and resources situated in different parts of the organization (Kleinbaum and Tushman, 2007). Cross-functional teams allow for easier knowledge-sharing and the development of trust (Love and Roper, 2009). This is a route by which breadth of knowledge can be acquired from inside organizational boundaries. Such broad knowledge remains grounded in the common ingrained knowledge of the division within which innovative research is being conducted.

The concepts of the strength and the breadth of ties has also been found useful in understanding the interaction patterns of entrepreneurs as reflected in the cohesion and diversity of their networks (Martinez and Aldrich, 2011). A network is considered cohesive when all the players within it are interconnected. Such a network tends to display a degree of tie redundancy (Alguezaui and Fillier, 2010). In relating network patterns to entrepreneurial activity, three stages of activity have been isolated: opportunity development; technology and organizational creation; and lastly exchange.

The opportunity stage covers the motivation to be entrepreneurial and the detection and access of an opportunity. At this initial stage, strong ties limit opportunities since these interactions may involve the circulation of the same ideas, which is associated with low levels of innovation. A broader diversity of ties can enhance both innovation and efficiency.

At the technology and organizational creation stage, teams tend to be homogenous and this fosters strong, trusting ties. At the final exchange stage, entrepreneurs need to maintain a balance between strong and weak ties for embedded and detailed knowledge, plus diverse ties that allow access to new information and market opportunities.

In all the situations described above, different combinations of tie breadth (many and few ties) and tie strength (strong and weak ties) have an impact on innovation related to the particular combination. It is on this basis that the final two-part hypothesis has been developed. In considering the simultaneous functioning of tie strength and tie breadth and their contribution to team innovation, two hypothesized dominant simultaneous

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function contributors of tie breadth and tie strength are tested in Hypothesis 3a-3d respectively.

Hypothesis 3a: *Team innovation is supported by the simultaneous functioning of tie strength with people in one's own team and tie breadth with people in other teams in own R&D*

Hypothesis 3b: *Team innovation is supported by the simultaneous functioning of tie strength with people in one's own team and tie breadth with people in other teams in the organisation*

Hypothesis 3c: *Team innovation is supported by the simultaneous functioning of tie strength with people in other teams in own R&D and tie breadth with people in other teams in own R&D*

Hypothesis 3d: *Team innovation is supported by the simultaneous functioning of tie strength with people in other teams in own R&D and tie breadth with people in other teams in the organisation*

For optimal team innovation, tie strength counter-balances the danger of teams failing to make an innovative effort because they rest on established relationships with frequent knowledge and information exchange, provided that there is novelty. The relationship between tie strength and tie breadth needs to work hand-in-hand meaning that a many ties-based knowledge and idea exchange needs to be combined with strong ties underpinned by trust for optimal team innovation results. This can be further analysed to capture the fact that ties differ based on where the alter is specifically located.

2.5 Key findings from the literature

Though diverse in focus, the literature offers consensus that trust and novel knowledge are core elements of innovation. Each contributes towards innovation to varying degrees depending on context.

Trust-filled relationships lead to frequent and smooth exchange of information, ideas and knowledge. These relationships develop in environments where shared goals and common objectives underpin the activities and where frequent interactions result in strong ties between role-players. However this closeness has the potential to compromise innovation output because the same information is repeatedly circulated.

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The most effective counterbalance to this tendency lies in extending interactions to a more diverse array of knowledge workers. In this way, new ideas, knowledge and skills can be accessed. This diverse interaction can be found in contexts external to the immediate operating environment: with other teams across the division, or across different functional units. Different functional units each have their own specialized knowledge which, if integrated with inputs from other units, can provides breadth of knowledge covering all aspects of an innovation from idea generation through development to commercialization.

Similar knowledge-carrying collaborations can occur with partners external with the firm, in the form of strategic alliances directed towards pooling diverse resources, minimizing costs and mitigating risks. Broader interaction (either within the firm or external to it) plus the recombination of existing knowledge that occurs internally in the context of frequent communication and trusting relationships, facilitates innovation.

2.6 Conclusion

In light of the literature that has been reviewed, the key ideas forming the backbone of this research are summarised below in Table 2.

Table 3: Summary of main argument underlying hypotheses

	WEAK TIES	**STRONG TIES**
MANY TIES	• Variety of info sources • Little or no trust ***MEDIUM INNOVATION***	• Variety of info sources • High trust ***HIGH INNOVATION***
FEW TIES	• Limited sources of info • Little or no trust ***LOW INNOVATION***	• Limited sources of info • High trust ***MEDIUM INNOVATION***

Chapter 3 outlines the steps taken in the design and methodology of the research to address these questions and objectives effectively.

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Chapter 3: Research design and methodology

This chapter gives details of the design of the research and the methodology used in addressing the research question and objectives. The chapter includes details of how the data for the outcome measure (team innovation), the independent measure (the nature – strength and breadth of ties) and the control measures were acquired and prepared for analysis.

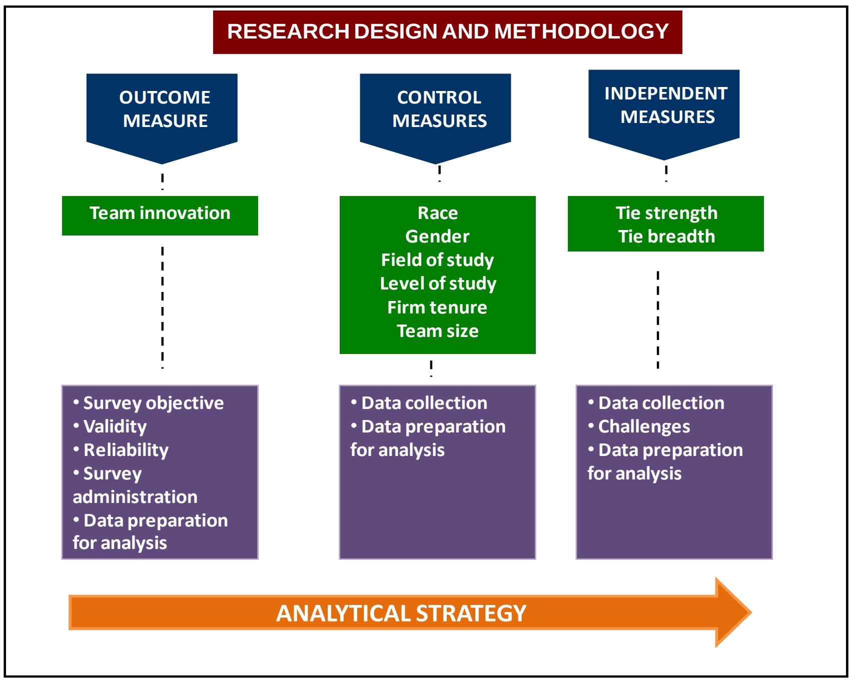

Figure 16: Outline of research design and methodology

The research question interrogates what combination of tie strength and tie breadth most effectively impacts team innovation:

"What combination of tie strength and tie breadth results in optimal team innovation?"

where the combination of such ties results from interaction between people in ones' own team and people in other teams in the own R&D division, and interaction between people in ones' own team and people in other teams in the organization, or interaction between people in ones' own team and people in teams external to the organization.

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3.1 Unit of analysis

The unit of analysis represents "the '*what'* of the study: what object, phenomenon, entity, process or event" (Mouton, 2001) is its focus. In this study the unit of analysis is the team. In social network analysis, the teams themselves are commonly known as nodes and members of the teams have ties, which is defined as a link between two people. Innovation is rarely achieved in isolation (Lipman-Blumen and Leavitt, 1999) therefore the focus on team innovation in this research study. Individuals with different skills knowledge and ideas come together to form project teams which interact and have the potential to result in innovation.

The research was empirical in nature, examining the various combinations of tie strength and tie breadth, and more specifically their inter-relationships and their impact on team innovation through questions derived from the hypotheses outlined in Chapter 2. The collection of primary data provided information relevant to the outcome measure (team innovation) and the independent measures (tie strength and tie breadth).

3.2 Research setting

This research is based in an R&D intensive manufacturing company that has been in operation for over six decades. The multi-national company has global operations based in multiple countries across the world.

This research was specifically based in the research and development section of this energy and chemicals business. The organization is knowledge-intensive in product and process innovation. Its innovation activity covers both an extension of existing products and processes, and new products and processes. Collaboration between teams facilitates resource, competency and knowledge exchange. Most innovation in the organization takes place in the R&D division.

The organization in which the research was carried out operates in an established area of its sector. Its core base technology is well established and the company is at the forefront of this specific technology. The organisation operates in a commodity-based environment and radical innovation is limited even within the R&D environment. Should radical innovation take place, commercialization will lie relatively far in the future.

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From a R&D perspective, activity is therefore focused on both existing and new business needs. A significant portion of the R&D budget is spent on the improvement of the base technology and associated processes. Compared to international norms, only a small percentage (2-3%) of overall company turnover is reinvested into R&D activity.

Some areas in the R&D section have more opportunity to be innovative than others. These areas have produced both incremental and radical innovation. Process development comprises the majority of the innovative activity. Limited product development takes place and when it does take place, the focus is generally on the development of better quality products for markets. Some specific teams operate in a more mature and developed technology, technique or process environment space and from this, limited innovation outcomes can be expected and consequently produced.

Some of the support areas in R&D focus primarily on cost improvement, whereas other areas examine ways of improving processes across R&D in its entirety. The Environmental Technology cluster applies new knowledge to ensure environmental compliance.

Significant cross-divisional interaction does take place. Idea generation and initial conceptualization takes place within the R&D division. However by-products from the core innovative process involve interaction with other divisions to further refine novel applications and to understand the specific market dynamics.

3.3 Sample representativeness

The R&D division is comprised of seven groups, each with a focus on a specific area of research. Each group contains distinct teams involved in innovation activities. These teams formed the sample for the research. The final sample comprised 43 individuals spread across 23 teams whose sizes ranged from 4 to 19 persons.

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Table 4: R&D team participation per area

Technology area	No. of teams	No. of teams participating
1	3	3
2	9	8
3	10	4
4	8	2
5	3	1
6	7	4
7	8	3

Stratified sampling was carried out to determine the representativeness of the sample. This is a sampling method appropriate when "the population is divided into sub-populations called strata. The strata do not overlap, and they constitute the whole population so that each sampling unit belongs to exactly one stratum. An independent probability sample from each stratum is drawn and the information pooled to obtain overall population estimates" (Lohr, 1999, p. 24). This allowed the representativeness of the sample to be demonstrated.

Demographic data were obtained for participants' genders, diversity, tenures in the organisation and qualifications. These data defined the dimensions of the different strata to determine sample representativeness. The strata were further sub-divided into substrata as defined in Section 3.4.2.2.

The number of individuals in the sample was divided into that in the overall population to determine what proportion of the whole population was under study. The percentages across the sub-strata were compared to each other to determine representivity in the selected dimensions.

Stratification along a single dimension was performed to determine sample representativeness; two further dimensions were used as a cross-check. The first dimension was education level; the subsequent two were race and age. The study generally achieves an adequately stratified sample for all sub-strata with a slight over-representation of those with basic degrees or diplomas. The results are shown below.

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Table 5: Stratification across dimension "education level"

	Total group	Total sample	%
Education level			
PhD	109	16	14.7
Masters	111	15	13.5
Hons	23	3	13.0
Degree/Diploma/BTech	53	9	17.0

Supporting stratifications dimension chosen were age and race. In terms of age, the study generally achieves a stratified sample for all sub-strata but with a slight over-representation of those in the 51-60 year age group. This could indicate a population that has been in the organization for a substantial period of time with well developed innovation expertise, and strong ties inside the organization.

Table 6: Stratification across dimension "age"

	Total group	Total sample	%
Age			
20-30	116	15	12.9
31-40	149	21	14.1
41-50	59	6	10.2
51-60	19	3	15.8

In terms of race, the study generally achieves a stratified sample for all sub-strata except the sub-strata representing "African" and "Coloured" individuals. Although the sample is not perfectly stratified, it is close enough to be broadly representative.

Table 7: Stratification across dimension "race"

	Total group	Total sample	%
Race			
White	201	27	13.4
Indian	30	4	13.3
Coloured	11	1	9.1
African	96	11	11.5

Fuzzy set qualitative comparative analysis (fsQCA) was the chosen analytical method where sample representativeness is minimized as a threat to the validity of the study similar to those reasons offered by Fiss (2011). For this research, three fundamental reasons are presented in supporting this statement. The first is that the R&D environment of the technologically innovative manufacturing company was used as a

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setting in which to test arguments relating to configurational theory, i.e. the R&D environment was used to test for the combinations of tie strength and tie breadth, and more specifically their inter-relationships for their impact on team innovation. Secondly, studies that have shaped the field on configurational theory, such as that on organizational configurations and performance (Ketchen, Thomas and Snow, 1993), and equifinality and organizational effectiveness (Doty, Glick and Huber, 1993) respectively, have made use of non-random sampling. Lastly, the analytical method of fsQCA employed in this research study, reduces the reliance on sample representativeness since the set theoretic approach in terms of set membership is based on "substantive knowledge" (Ragin et.al., 2008) as opposed to a sample mean in standard regression models.

3.4 Research model

Figure 17 represents the research model in outline. The focus of the research was the strength of ties and the breadth of ties of teams in a R&D environment, and the impact that these ties have on team innovativeness. Control measures accounted for included the race, gender, field of study, team size, firm tenure and level of study of team members.

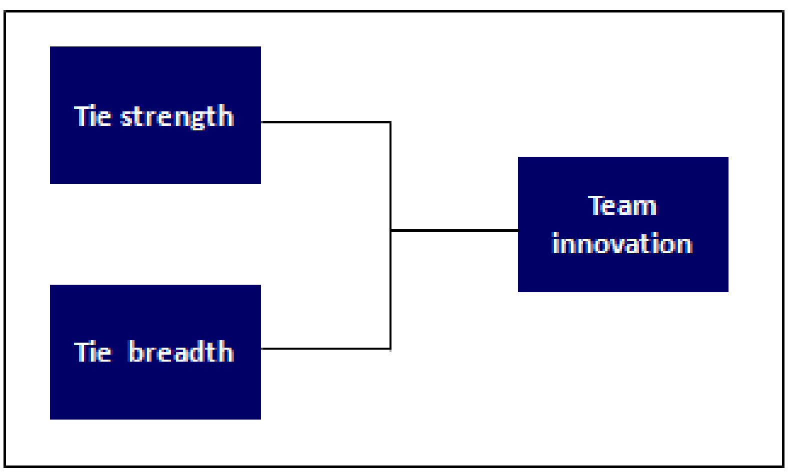

Figure 17: Research model

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3.4.1 Outcome measure: Team innovation

The organization currently has no formal instrument for measuring team innovation. Because any evaluation has the potential for bias, a measuring instrument that is both reliable and valid is required. Therefore to assess team innovation the ideal measure would be one that is comparable across teams.

In the organization under study, teams are structured by competencies and focus areas, eg. the development of processes, processing of raw materials, etc. Different teams in the organisation follow different intellectual property strategies, some of which involve patenting, others, publishing and yet others a reliance on trade secrets. Some projects run over a significant period of time with output varying at different stages. Projects also involve the integration of competencies from the different teams. The diversity of innovation projects ruled out the use of some of the well-known indicators of innovation such as patents or sales from new products. This specific environment posed challenges in developing an appropriate measure of team innovation leading to the decision to gather data from senior managers.

3.4.1.1 Team innovation survey

The survey that was eventually used to evaluate team innovation comprised a nine-item scale adapted from the questionnaire on team innovation developed by Burpitt and Bigoness (1997). Burpitt and Bigoness (1997) calculated the overall Cronbach's alpha for team innovation to be 0.89 indicating a good measure of reliability.

In applying the questions in the survey to this research, it became important that when the questions were adapted, they retained their capacity to be good measures of the construct under study: team innovation. Details of how the validity and reliability and of the measuring instrument were preserved follow in Section 3.4.1.2 and Section 3.4.1.3 below.

3.4.1.2 Validity

For a survey to be valid, the answers to questions should reflect what the questions aim to investigate, i.e. measure what is intended to be measured. This was ensured by pre-testing the adapted survey with a senior member of the R&D team for both technical relevance and the applicability of the questions to the specific business environment.

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The survey was further tested by an individual external to the R&D environment, though within the organization, to test for ease of interpretation and understanding.

3.4.1.3 Internal consistency

Items 1-9 with the statements as outlined in Table 8 formed the basis of the survey.

For a survey to be reliable it needs to be capable of obtaining the same or similar responses in similar situations – what is sometimes termed internal consistency. The questions in a survey must be framed to elicit consistent interpretation and answer-framing from each respondent. Inconsistency in responses introduces random error.

Table 8: Items in team innovation survey

Item	Statement
1	*Using skills they already possess, this team learns new ways to apply those skills to* ***develop new products or processes*** *that can help* ***attract and serve new markets***
2	*This team seeks out information about new markets, products, processes and technologies from* ***sources outside the organization***
3	*This team identifies and develops skills that can improve their ability to serve* ***existing*** *business needs*
4	*This team identifies and develops skills that can help attract and serve* ***new*** *business needs of the organisation*
5	*This team seeks out information and knowledge on products and techniques that are* ***new to the R&D business*** *and applies them to develop* ***new solutions to familiar problems***
6	*This team identifies and learns skills and technologies that may be useful in* ***solving unfamiliar problems***
7	*This team seeks out and acquires information that may be useful in developing* ***multiple solutions to problems***
8	*This team seeks out and acquires knowledge that may be useful in* ***satisfying needs unforeseen by the client***
9	*This team learns new ways to apply their knowledge of familiar products and techniques to* ***develop new and unusual solutions*** *to familiar, routine problems*

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The most common measure of internal consistency is Cronbach's alpha. It is most commonly used when a questionnaire has Likert-type questions, as with the team innovation survey used in this research. Internal consistency is deemed to be reliable if Cronbach's alpha is positive and as large as possible, ideally a threshold of 0.7 (Nunnally, 1978).

The test for reliability based on internal consistency gave a Cronbach's alpha of 0.80 indicating a good measure of reliability. This compares well to the Cronbach alpha value of 0.88 obtained by Burpitt and Bigoness (1997). The testing confirmed that the items in the survey were consistent with one another, and represented a single consistent construct: team innovation.

3.4.1.4 Survey administration

Data was collected for the dependent variable team innovation by administering the survey. Because innovativeness is a subjective quality, the decision was taken to develop an aggregate view. Senior managers, who were most knowledgeable in terms of evaluating the innovativeness of the teams in the R&D environment, were selected.

To eliminate any bias that could lead to some teams being rated as more innovative than others, evaluations were requested as follows. Teams in R&D are arranged into functional groups. The head of each functional group was requested to evaluate the team innovativeness of not only the teams in their function but also of all the other teams. Some interviewees chose not to rate certain teams since they were not knowledgeable about the activities of those teams. These were not included in the calculation of the average for the number of responses. Three other senior members from the R&D division, knowledgeable about the activities of the teams, also completed the survey. This rounded perspective served to counteract bias. An average of all completed assessments was used as an indicator of the degree of innovativeness of each team.

Completing the 9-item survey for 23 teams is a substantial time investment. For that reason, the surveys were completed in an interview-type set-up with the researcher and the members of the senior management team. In order to alert and reassure

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interviewees about the intention to interview them, an e-mail outlining the objective of the interview was sent out, covering:

- why the survey was being conducted
- why the person had been chosen to be interviewed
- how the results would be used
- when the subject might be available for the interview

Once an indication of the availability of interviewees had been obtained, an appointment for a one-hour slot was set up. It was open to the subject to confirm this or reschedule. At the interview, the purpose of the survey was further explained to the interviewee to make them feel comfortable. The confidentiality rules governing the information obtained were outlined and the interviewee signed an agreement to participate covering these areas. The researcher then guided the interviewee through the survey, providing clarification as necessary. Any additional qualitative comments were also noted by the researcher.

Each question (9 in total) in the team innovation questionnaire comprised a 5-point Likert item which interviewees were asked to rate from 'very frequently' to 'very rarely.' The items were tested in the following manner. For each of nine respondents rating the nine questions in the survey, the average for all teams for each question was calculated (eg, for respondent 1, the average for Question 1 across all teams was calculated; then the averages for Question 2-9. The same process was followed for respondents 2- 9).

3.4.1.5 Data preparation for analysis

As detailed above, the team innovativeness questionnaire had nine questions. Interviewees (nine in total) rated each team with respect to each question on a 5-point Likert scale where 1 = very rarely and 5 = very frequently. Ratings were obtained for all 23 teams. Subsequently, the average rating and standard deviation was calculated for each question response in each team. An average of the average for all the questions in each team was calculated to form the final innovation score for each team. The average and the standard deviations for each question were also calculated.

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3.4.2 Control measures

In a research environment focused on innovation, a number of factors may contribute to the final innovation outcome. Diversity factors identified in social network literature include gender, race, age, organizational tenure, education and team size (Reagans and Zuckerman, 2001; Mayo and Pastor, 2005). These factors have been found to impact innovation or team performance in some way and have been considered in this research as well.

The team diversity measures employed in this study were:

- Race
- Gender
- Field of study
- Level of study
- Firm tenure
- Team size

The knowledge held by a team is a function of the team's cumulative experience which in turn results from a combination of members levels of education, fields of study and tenures in the organization. In the participating R&D division, teams are arranged according to their competencies. When a new project is initiated, individuals from different teams combine to work on the project, bringing together different competencies.

Demographic data from the R&D division indicated the fields of study of team members. Typical fields of study in such an environment include Engineering, Science and Business, and this was evident in the data set. Given the importance of the fields of engineering and chemistry in this specific innovation environment, it is likely that teams dominated by individuals with strong engineering and chemistry qualifications will positively influence innovation outcomes.

Formal education is an indication of the stock of knowledge a person possesses (Obstfeldt, 2005). The designated categories for level of study were PhD, Masters degree, Honours degree, Bachelors degree, with Diploma deemed equivalent with a Bachelors degree. Any lower qualifications, such as a matriculation certificate, were designated 'other.'

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The period of time an individual spends in an organization impacts on the knowledge gained by that individual and ultimately on the quality of knowledge exchange. A reliable assumption is that the longer the tenure, the greater the extent and depth of an individual's knowledge (Reagans and Zuckerman, 2001; Mayo and Pastor, 2005). Spending a longer period of time in a firm also influences culture, individual and group dynamics, and the ability to assess the likely effectiveness of an innovation, derived from an understanding of the business environment (Hitt, Ireland, Camp and Sexton, 2001). Longer tenure can also foster group-think, reducing the ability to challenge the status quo. This negatively impacts on novel idea generation (Katz, 1982). It can also suggest that an individual has especially strong ties with colleagues. However, the demographic data in this research indicated that in several cases a person with a long tenure in the organization had spent a substantially shorter period at one specific level, which might mitigate the development of group-think.

Team size can affect a unit's performance and innovativeness. Team size in this case was simply determined by the number of members of each team. Reagans and Zuckerman (2001) also controlled for team size, because they postulated that "large teams have significantly less dense and less homogenous networks than do small teams."

3.4.2.1 Data collection

The personnel data was obtained from the human resources practitioner, populated in an Excel spreadsheet. The data covers the demographics of the teams in the R&D unit as discussed above.

3.4.2.2 Data preparation for descriptive analysis

Data for the control measures was collected for descriptive analyses.

- The sample comprised individuals across a wide race spectrum including White, African, Coloured and Indian;
- Levels of study in the sample ranged from PhD, Masters and Honours degrees;
- There were three fields of study, namely, Engineering, Science and other, eg. commerce or business qualifications;
- Firm tenure was represented by the number of months an individual had spent in the team;

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- Team size was the total number of members of a team.

3.4.3 Independent measures: Nature of ties

E-mail communication between individuals formed the basis for researching the strength of ties and the breadth of ties, since in this environment e-mail interaction very well captures the ties between individuals. Legal and compliance requirements (as described in Section 3.4.3.2) required individual consent prior to the monitoring of e-mail communication between and from members of the R&D division. This could have led to some self-selection bias which could potentially influence results – especially since team representation figures indicate that some teams participated more fully than others.

The independent measure for which data were collected was tie breadth and tie strength. Data for these were drawn from e-mail frequency reports provided by the IT service provider for the organization. The reports covered both sent and received communications of those individual members of teams in the study who had consented to have their e-mails monitored.

3.4.3.1 Data collection

Numerous studies have been conducted involving collecting data on the frequency of e-mail interactions of research participants (Wasko and Faraj, 2005; Adamic and Adar, 2005; Ahuja and Carley, 1998; Kleinbaum, 2006; Whelan, 2007). This process allows social networks to be mapped and network linkages to be illustrated. The data offers raw material for an account consistent with the definition of social networks as: *"…a specific set of linkages among a defined set of persons, with the additional property that the characteristics of these linkages as a whole may be used to interpret the social behaviour of the persons involved"* (Mitchel, 1969:2).

To date, the most common method of obtaining social network information has been through surveys (Cross, Borgatti and Parker, 2002). Administering a survey for social network analysis entails getting the participant to check on a questionnaire the names of those individuals with whom they most frequently interact, in defined categories of interaction. However, this approach is problematic in that the respondent is more likely to remember the individuals with whom they interact most regularly, while key yet less frequent interactions may be forgotten. They may also remember more strongly those

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with whom they recently interacted. The respondent may focus very consciously on his or her response, respondent bias and questionable objectivity may emerge (Arnold, Collier, Leech and Sutton, 2000; Ashton & Kennedy, 2002).

In providing a greater justification from the literature to support e-mail data collection as a methodological decision, to date, work on electronic communication network analysis has been limited and has seen a slow increase in more recent years. E-mail data collection may be motivated to be unobtrusive and relatively objective and, given current business communication practice, most suitable when research focuses on the flow of communication between people.

“Few network researchers have attempted to apply network theory concepts specifically to electronic networks” (Whelan, 2007). Significant studies where e-mail has been used as the method of data collection include the following that by Kleinbaum (2006) on network analysis where data was drawn from electronic communication archives that included e-mail, instant messaging and electronic calendars. Quintane and Kleinbaum (2011) have more recently re-iterated that the use of e-mail data in research has been under-utilised. Kleinbaum and Stuart (2013) have in their most recent study on the communication patterns of corporate staff and its impact on strategy implementation also employed e-mail data collection.

For the purposes of this research, data concerning e-mail exchanges was collected over a three-month period. Each individual had been informed of (and had consented to) the process in general terms, but was not aware of the way in which and when interactions were monitored. This made the method unobtrusive and the data less subject to bias, with a smaller risk of participants consciously modifying any particular interaction. The ensuing continuous data collection was appropriate in this research setting, since innovation outputs are realized over time. The research was cross-sectional, creating a ‘snapshot’ of activity over a 3-month period.

Collection of e-mail data however poses certain challenges. Firstly gaining access to e-mail communication is subject to legislative constraints. Secondly, handling the significant volume of data that is obtained may be onerous. The legal hurdles were smaller in this study, since the content of the messages was is not the subject of

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interest. Invasion of privacy was thus less of an issue. The laws pertaining to the interception of communication in SA are detailed in Appendix A. All legal requirements were met (see 3.4.3.2).

Subject to consent by the participants, the e-mail communication data was drawn by the information technology service provider and presented in a report. A typical e-mail report on a participant's mailbox comprised the following fields for items received by the individual:

- Name of server on which person was located
- Who sent the e-mails (the person's mailbox being monitored, eg. Person A)
- Date of message
- Time of message
- Subject of message
- Recipient (who the sent message was received from)
- Size of message (KB)

Example of fields for received items show below:

Mailbox DN	Originator	Date	Message time	Subject	Recipient	Size (KB)

The report also included items sent by the individual, in the same the fields, except that the 'Originator' and 'Recipient' categories were swapped.

3.4.3.2 Challenges in data collection

As well as the laws detailed in Appendix A, the regulatory environment of the organisation also governs e-mail monitoring. The information management section of the organization where this research was carried out confirmed that the organisation is aligned to national legislation and did not permit the review or monitoring of e-mails for personal purposes such as this study. Consent from each person whose mailbox would be monitored was thus required. Buy-in had first to be obtained from the managing director and senior management team, so that consent from employees could be solicited for the duration of the three month study period.

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3.4.3.2.1 Obtaining participation consent

Due to the somewhat sensitive nature of the study, it was critical that approval at all levels was obtained. The managing director of the R&D section agreed in principle to both the inboxes and outboxes of users being tracked, subject to advice and clearance from the company's Legal and Compliance section. The research idea and consent requirements were thereafter shared with the R&D management team. The collection and use of e-mail frequency reports was approved, subject to consent from each individual being obtained.

The next step was to obtain consent from the employees in R&D. The consent was communicated in the form of an individual e-mail request with an outline of the following:

- who the researcher was;
- an outline of the research that was being carried out;
- specific fields in an e-mail that consent was being requested for;
- how the data would be used;
- how confidentiality would be ensured; and,
- what consent options were being offered. (Participants could choose one response as follows: 'consent to all e-mails sent and received being monitored; consent to all e-mails sent and received being monitored plus consent to be interviewed on innovation; opt out of the study,' by means of a voting button") (consent request attached, Appendix B).

3.4.3.2.2 Response rates

The sampling challenge in this study was that consent to participate in the research had to be voluntarily given, because of legal requirements. Out of a total population of 337 potential subjects, 49 (14.5%) had consented to be part of the study. Of the 49, 16 (32%) were also prepared to be interviewed on innovation. 288 (85.5%) of the population did not respond to the consent request and this was interpreted as an active decline of the participation request.

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3.4.3.3 Data preparation for analysis

In relation to the independent measure and foci of this specific research, the e-mail data was processed to build a picture of tie strength and tie breadth as follows.

Take for example, in a group of three people, where person X communicates with 50 unique individuals, person Y communicates with 20 unique individuals, and person Z with 20 unique individuals. The average number of emails per person also differs. Person X may have an average of 10 e-mails per person, Y an average of 5 e-mails per person, and Z an average of 10 e-mails per person. Based on this data

- person X can be said to have the greatest tie breadth (X communicates with 50 unique individuals and therefore 50 ties, as opposed to persons Y and Z who communicate with 20 unique individuals each), and
- persons X and Z have the same tie strength (average of 10 e-mails per person therefore 10 ties) and both have a greater tie strength than person Y (average of 5 e-mails per person therefore 5 ties)

However tie strength is a function not only of the number of times people interact but also of the nature of interaction.

In order to present a more holistic measure of tie strength, the e-mail data set was filtered for both innovation-related and social interaction.

In terms of social interaction, social engagement is important in building up trust for information and idea exchange and thus holds potential for future innovative outcomes. Social engagement can be thought of as being in parallel with “emotional intensity” that was conceptualized as being one of the elements of the strength of a tie, amongst the others of “amount of time, intimacy (mutual confiding) and reciprocal services” (Marsden, 1974), and thus provides the motivation for inclusion in this study. Examples of social e-mails include those such as “Laugh a moment,” “Birthday braai” and “Favour please.” E-mails suggestive of social interaction were included in the measure of tie strength but not tie breadth.

For innovation-related interaction, the e-mail data set was filtered by the researcher based on knowledge of the innovation “language” of the organization, for example, technical terminology such as “solvent recovery” and “Decomposition and mass balance

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when using Zn." The number of partners with whom such innovation-related e-mails were exchanged was used as the basis for the tie breadth measure. In the case of tie strength, both innovation-related and social e-mails were included.

Company announcements such as "Safety walkabout" and "Pension fund bonus rates declaration – October 2010" were filtered out of the data set. Other mail such as "Medical aid claim acknowledgement" was also excluded from the data set.

In preparing the data for analysis and hypothesis testing, each e-mail communication for both sent and received items was also coded as follows for strength and breadth of ties, i.e. interaction with:

- own team
- other team in own R&D
- other team in organization
- ALL other, eg. other team in organisation but international; other team in SA but not in organisation; other team not in organisation and international

Thus for example, all communication that Person A had with members of his or her own team was coded as 'own team', all communication with people in other teams in own R&D division as 'other team in own R&D,' etc. Items sent to multiple recipients were separated out by recipient as single communications, and then coded.

After this filtering, the data set was coded into number of interactions with 'own team' represented the strength of the tie with people in ones' own team; the number of interactions with people in other teams in own R&D represented tie strength with 'other R&D," etc. To obtain the value for average tie strength, the values for both sent and received items were totaled per individual and then averaged across all coded categories for that individual.

For the breadth of ties, the coding principle was the same as for tie strength. The total number of different people with whom interaction took place within an individual's own team represented the value of the tie breadth for 'own team'; the number of different people with whom interaction took place in teams located in other parts of the organization represented the value of the tie breadth for 'other org,' and so on. To obtain

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the value for average tie breadth, the values for both the sent and received items were totaled per individual, and then averaged across all coded categories for that individual.

3.5 Analytical strategy

The analytical strategy employed three different techniques of analysis, as follows:

- Factor analysis was used to determine if any inter-relationships existed between the nine items in the team innovation survey (Table 8). The aim was to develop a single measure for team innovation and demonstrate internal consistency reliability.
- Bivariate correlation to determine any relationship that might exist between the dependent, independent and control measures. The strength of these relationships was indicated by the Pearson product-momentum correlation *r.* A correlation coefficient depicts the linear relationship between two variables, with values ranging from -1 to +1. In this analysis, SPSS gives the Pearson product-moment correlation *r* for relationship between variables. A negative correlation coefficient represents an indirect or negative relationship between the variables.
- Fuzzy set qualitative comparative analysis to investigate the joint combinations of tie strength and tie breadth necessary and sufficient for the outcome team innovation to test the hypotheses postulated in Chapter 2. The aim was to determine whether tie strength, or tie breadth, or some combination of the two, had the greatest utility as a predictor of the outcome measure of team innovation.

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A diagram of the analytical strategy followed is shown in Figure 18.

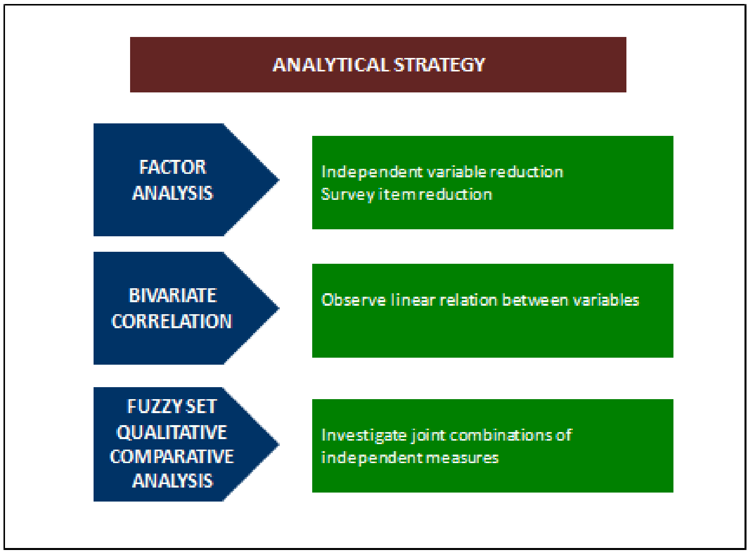

Figure 18: Analytical strategy

Fuzzy set qualitative comparative analysis (fsQCA) is a relatively new analytic technique and has received growing attention in comparative research especially over the past years (Fiss, 2011; Katz, Vom Hau and Mahoney, 2005; Kogut and Ragin, 2006; Pennings, 2003; Schneider and Wageman, 2006). The technique differs from traditional regression analyses in that it is based on set theory and logic, and not statistics.

3.5.1 Underlying method assumptions

There are three fundamental assumptions made by QCA:

- Firstly, there are many pathways to the same outcome, a term called equifinality.
- Secondly, each pathway contains different combinations or configurations of causal factors that are necessary and sufficient for the outcome. A condition (causal factor) is *sufficient* if it can produce the outcome (either external or internal team innovation orientation) by itself without the help of other conditions (causal factors) (Ragin and Strand, 2008; Schneider and Wagemann 2010). A condition is *necessary* if the outcome cannot be produced without the help of the conditions (causal factors).
- Thirdly, data is required to be carefully converted into measures of set membership. For example, a case can be fully out of the set (membership = 0), a full member of the set (membership = 1), or a partial member of the set (membership between 0

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and 1). A case may therefore have continuously varying degrees of membership in a given set. The value of fuzzy set theory is that it recognises that set membership is not always binary (either 0 or 1) but can be continuous (between 0 and 1).

Besides the ability to investigate the joint combinations of tie strength and tie breadth necessary and sufficient for the outcome team innovation in this research study, *fsQCA* is suitable in that it does not require statistical power and deals with a small number of observations, typically medium-sized datasets with samples or populations of 10 to 60 (Fiss, 2007; Rihoux, 2006; Verkuilen, 2005). The sample of 23 teams is used in this study.

3.5.2 Operationalising fsQCA

In operationalising fsQCA for this study, the following steps were followed (Pajunen, 2008). The first step is the calibration and conversion of each metric into a measure of set membership. Clear criteria for defining full membership, partial membership and exclusion from the set is therefore required and is key to the operationalisation of the outcome, team innovation and the causal conditions of tie strength and tie breadth. In defining membership set criteria, every effort should be made to base the calibration on substantive knowledge, defensible theory or empirical evidence. Furthermore, it is also acceptable to use the inspection of the metric's distribution to inform the selection of the calibration breakpoints of membership. Four- or six-level scales are often used (Ragin, 2006a).

In this study, a four-level membership set was applied to both the independent and dependent measures. The value of 0 was allocated to those values that were "fully out" of the membership set, 0.33 and 0.67 to those intermediate values that were "more out than in" and "more in than out" the data set respectively, and that which showed complete membership was allocated the value of 1 and described as "fully in" the membership data set (Table 9). The calibration in this study has been informed by the existing literature and qualitative analysis.

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Table 9: Membership set scales applied

Membership set scale	Membership set description
0	fully out
0.33	more out than in
0.67	more in than out
1	fully in

The second step in the analysis is the construction of a data matrix known as a truth table that lists all logical and possible combinations of the causal conditions. The truth table has 2^k rows, where k is the number of causal conditions used in the analysis. Each row gives the combinations of the causal conditions, tie strength and tie breadth associated with team innovation. Empirical evidence shows that some rows containing many cases, some rows contain just a few cases and some rows containing no cases of a particular combination of the causal conditions of tie strength and tie breadth.

In the third step, the number of rows in the truth table is then reduced on the basis of the following two conditions:

- *Condition 1: Minimum number of cases required for a solution to be considered*
  Combinations of tie strength and tie breadth that demonstrated at least one observation was set as the frequency threshold. A single observation is acceptable when building theory from a fairly small sample (Ragin, 2006). Causal combinations not demonstrated by any of the teams in the data set were deleted.

- *Condition 2: Consistency threshold*
  Consistency is a measure of the degree to which a combination of the causal conditions tie strength and tie breadth is reliably associated with the outcome of a team innovation (linking to necessary and sufficient conditions). Literature recommends consistency thresholds of at least 0.75 (Ragin, 2006) and up to 0.95 (Epstein, Duerr, Kenworthy, & Ragin, 2008).

  Fiss (2011) gives a simple way of calculating consistency, i.e. “the proportion of cases consistent with the outcome: i.e, the number of cases that exhibit a given configuration of attributes as well as the outcome divided by the number of cases that exhibit the same configuration of attributes but do not exhibit the outcome.” In applying this to this research study, it would mean “the proportion of cases consistent

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with team innovation: i.e, the number of cases that exhibit a given configuration of tie strength and tie breadth as well as team innovation divided by the number of cases that exhibit the same configuration of tie strength and tie breadth but do not exhibit team innovation.

In the fourth step, an algorithm based on Boolean algebra is used to logically reduce the truth table rows to simplified combinations as described by Ragin (2006) and Ragin and Strand (2008). This algorithm is based on what is called a counterfactual analysis of causal conditions, which has the advantage of allowing for a categorization of causal conditions into core and peripheral causes that gives us a better understanding of fine-grained interactions. A core condition is one which shows a strong relationship with the outcome condition. A peripheral condition is then a condition that demonstrates a weaker relationship with the outcome of interest.

In building upon the core-peripheral model for the causal conditions of tie strength and tie breadth in the final step, the analysis is taken a step further and considers the different possible interactions between the causal conditions of tie strength and tie breadth. Technically, there are 16 possible causal interactions of tie strength and tie breadth. These include interaction with people in ones' own team, with people in other teams in own R&D, with people in other teams in own organization and finally that with people in teams external to the organization, either based within or outside SA (Table 10).

Table 10: Technically possible component interactions

	TB 'own team'	TB 'own R&D'	TB 'other org'	TB 'all other'
TS 'own team'				
TS 'own R&D'				
TS 'other org'				
TS 'all other'				

In general, tie strength with an individual's own team may be expected to be strong, since the individuals concerned know each other well and have established relationships that are underpinned by trust. A similar outcome may be expected for interactions with other teams in own R&D, i.e. the same division. Tie strength with teams in other parts of the organization and with others outside the organization can be expected to be weak,

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but although interactions do not take place frequently, they may still be a source of new information and knowledge.

With respect to tie breadth, the expectation is of few ties within an individual's own team because of its smaller size but many with other parts of the R&D division and other parts of the organization because it is the search for knowledge diversity that motivates tie breadth. However, fewer ties may be expected with teams outside the organization because of the possibility that the knowledge on offer from these may diverge too far from needs, as opposed to knowledge cultivated within the organization. Many ties with other parts of the organization provide information and knowledge that are adequately diverse (because of the involvement of different divisions) yet usefully similar (because they derive from the shared culture and strategy of the organization).

Taking this into account, theory predicts that there are 6 especially likely possible interactions specifically in terms of strong and many ties as indicated by Models 1-6 (Table 11). These interactions are taken as the core combination conditions required for team innovation. All other interactions are considered peripheral conditions for team innovation.

Table 11: Theoretically likely significant component interactions in terms of strength of ties and breadth of ties

	TB 'own team'	TB 'own R&D'	TB 'other org'	TB 'all other'
TS 'own team'				
TS 'own R&D'	Model 1	Model 2	Model 3	
TS 'other org'	Model 4	Model 5	Model 6	
TS 'all other'				

Table 15 in Chapter 4 gives the raw fuzzy set membership coded data set for tie strength, tie breadth and team innovation.

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3.5.3 Fuzzy-set qualitative comparative analysis

In building upon the concept of fuzzy set membership into the analytical method of qualitative comparative analysis, the data set was input into the fsQCA 2.0 software for the determination of the various causal combinations of tie strength and tie breadth in their contribution to the outcome variable, team innovation. The process that was followed is as per the fsQCA user's guide by Ragin and Davey (2008) and is described below.

The data set comprising the values for team innovation and the different categories of tie strength and tie breadth was imported into the fsQCA 2.0 software from Excel. The number of possible combinations is 2^k where k represents the number of causal combinations, in this study being a total of 256 possible combinations. The numeric data set was then transformed into fuzzy variables by the process of calibration into the four value fuzzy set (0. 0.33, 0.67, 1) as described in Section 3.5.2. Basic statistics on the fuzzy data such as descriptive (mean, standard deviation, minimum, maximum), frequencies and cross-tabulations were generated.

QCA is based on Boolean algebra where a case is said to be either in or out of a set, or described as either the presence or absence of the various combinations of tie strength and tie breadth in their contribution to team innovation. In building up towards the actual combinatorial solutions, the following steps were followed:

- The truth table is reconstructed from the raw data matrix into the various combinations of the values of the independent measures, each combination contained as one row of the truth table
- The manner in which a truth table is constructed and managed is through the truth table algorithm and comprises the following steps: firstly, the software asks for the outcome and causal conditions to be specified. Once this is done, the software generates the full truth table which will have 2^k rows that capture all the possible combinations of the causal conditions with the 1s and 0s representing full membership and zero membership for each causal condition, in this study 256 possible combinations.

For each row (case), the software generates a value for each of the variables where "*number" gives* the number of cases that show the combination of causal conditions,

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"*consistency" gives* the proportion of cases in each truth table row that display the outcome. The column "*pre" is* an alternative measure of consistency (developed for fuzzy sets) based on a quasi proportional reduction in error calculation and "*product"* is the product of *consist* and *pre.*

Each row was then classified as some combinations (rows) that are relevant and others that are irrelevant, based on their frequency and consistency threshold. The frequency threshold was set at 1 and the consistency threshold at 0.90 (these have been explained in Section 3.5.2). The "delete and code'' function automates this application of the frequency and consistency threshold to generate the reduced truth table after eliminating configurations that do not meet the frequency and consistency threshold. Each row is then assigned an output value (a score of 1 or 0) based on the combination of the scores on the independent and dependent measures. Each row in the truth table is therefore the summary of the cases of the specific combinations of the independent measures.

The fsQCA software generates three solutions, the first two solutions being the complex and parsimonious solutions. The third solution is the intermediate solution where the software then performs counterfactual analysis based on information supplied by the researcher on either the presence or absence of a causal solution in producing the team innovation outcome. The software presents the researcher with a causal condition being either present, absent, or present or absent in the generation of the intermediate solution. This selection of the presence or absence of a causal condition is based on sufficient and substantive knowledge, and the concept of which causal conditions are core and peripheral in the generation of the solution for team innovation was applied here. This then ties back to Table 10 and Table 11 in Section 3.5.2 where the core-peripheral model for this research is explained. Five causal condition combinations are of interest in this research. In preparing to run the intermediate solution, the causal conditions tie breadth 'own team,' tie breadth 'own R&D,' tie breadth 'other org, tie strength 'own R&D' and tie strength 'other org' are considered as core conditions in producing the outcome team innovation, and was input as the conditions that needed to be present in the generation of the intermediate solution, all other causal conditions was chosen as either an option of being absent or present (peripheral conditions).

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Chapter 4: Results

This chapter contains the results obtained from implementing the research design to address the research question and hypotheses described in Chapter 2. This chapter includes a description of the outcome measure (team innovation scores), and the independent measures (tie strength and tie breadth).

Descriptive statistics for the control measures, race, gender, field of study, level of study, firm tenure and team size are also given. The analysis includes the results from the factor analysis, bivariate correlation and the testing of the hypotheses by fuzzy set qualitative comparative analysis for both of the independent measures of tie strength and tie breadth, and also those for the interaction between their respective components.

Interaction components included interactions with people in ones' own team, with people in other teams in own R&D and with people in other teams in the organization. Interaction with people in teams external to the organization either within SA or external to SA although it was found to have taken place in a few instances was also included in the analysis.

4.1 Outcome measure: team innovation

As explained in Chapter 3, innovation was assessed determined at the team level since by the virtue of its very nature that innovation is a collective process. It is difficult to directly access measures of individual innovation, and it is highly unlikely in a work team setting that any individual innovates on their own. It is particularly unlikely in multidisciplinary teams involving a diversity of team members and areas of expertise interacting to share and develop novel ideas. Individuals rather contribute to overall team innovation (Pirola-Merlo and Mann, 2004).

Table 12 thus shows the innovation scores at the overall team level. The highest team innovation score was 3.98 and the lowest 3.11, with an average of 3.52 and a standard deviation of 0.25. The average of team innovation across the 23 teams is 3.52 which is very close to the calculated median of 3.49 for team innovation.

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Table 12: Team innovation scores

Team number	Team innovation
1	3.11
8	3.13
15	3.21
4	3.24
18	3.25
16	3.35
14	3.37
12	3.42
23	3.43
20	3.44
22	3.45
19	3.46
3	3.47
21	3.54
10	3.67
13	3.71
5	3.75
7	3.76
9	3.76
2	3.83
6	3.83
11	3.86
17	3.98
High	3.98
Low	3.11
Average	3.52
SD	0.25

Little variance for team innovation scores were observed across the 23 teams. Apart from a regression to the mean, the optimistic ratings for team innovation by the senior managers may be explained by the phenomenon of social desirability bias (Norwood and Lusk, 2011; Fisher and Katz, 2000; King and Bruner, 2000; Nederhof, 1985), with interviewees not wanting to be seen as negative about the teams of other managers or judging their own teams too favourably. Social desirability is one of the most commonly encountered causes of response bias and occurs when interview or questionnaire respondents provide the answers they believe are socially desirable, making them 'look

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good'. This eagerness to please can result in distorted responses which may affect the validity of research findings.

When coding this data set for fuzzy set membership, theoretical and substantive knowledge is used to explain the membership set coding categories. As mentioned previously, the team innovation survey was made up of nine survey items that were rated on a five-point Likert scale from 'very frequently' to 'very rarely. Team innovation can therefore vary from a low of 1 to a high of 5. The team innovation scores showed a small standard deviation of 0.25.

The same principle is applied in the allocation of membership sets in the obtained data set. The outcome team innovation was transformed into calibrated sets comprised of four thresholds. In ordering the team innovations scores, the lowest score was 3.11 and the highest was 3.98. The cross-over point was calculated to be 3.52. The crossover point is the "the point of maximum ambiguity (i.e., fuzziness) in the assessment of whether a case is more in or out of a set" (Ragin, 2008: 30).

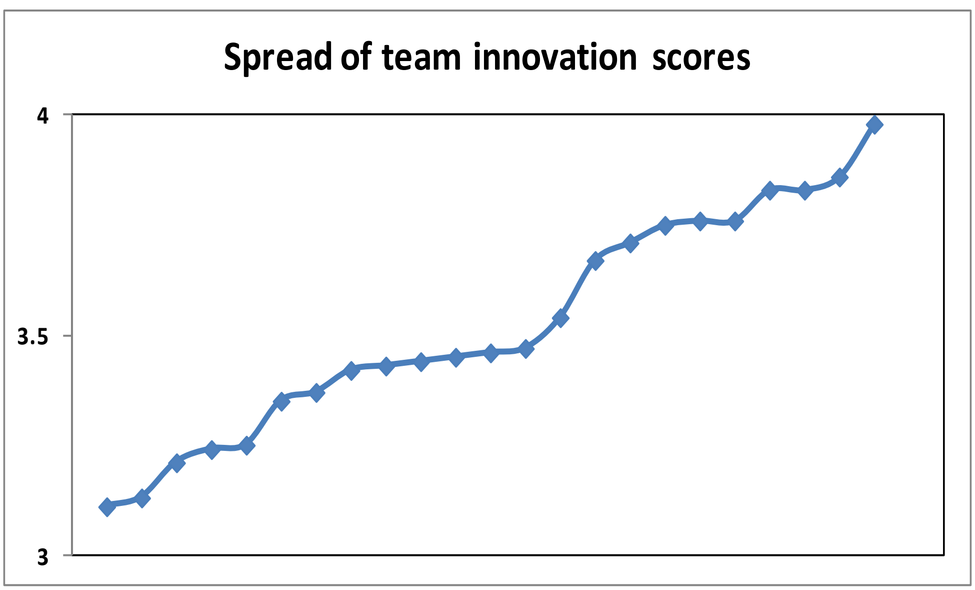

Figure 19: Spread of team innovation scores

The fuzzy set measures were broken up into percentiles. The first quartile anchor was 3.25. The value greater than or equal to the lowest team innovation score of 3.11 and

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the first quartile anchor of 3.25 was coded as 0 and is read as being fully out of the membership set. The second quartile anchor is read as being greater than the first quartile anchor 3.25 and less than or including the crossover point of 3.49. This range of values was coded as 0.33 and is read as being more out than in the membership set. The third quartile anchor was the team innovation value of 3.81. The third quartile anchor point was calculated to be 3.81 and the value greater than the crossover point and the third quartile anchor point was coded as 0.67 and is read as being more in than out of the membership set. The value between the third quartile anchor point and the highest team innovation value was coded as 1 and is read as being fully in the membership set. This membership set coding and the applicable ranges for team innovation is summarised in Table 13.

Table 13: Summary of membership set coding for team innovation

		Membership coding range	Membership sets	
Lowest value	3.11	>= 3 & 3.25	0	fully out
Value betw. 3 & 3.49	3.25	>3.25 <=3.49	0.33	more out than in
Crossover point	3.49	>3.49 <=3.81	0.67	more in than out
Value betw. 3.52 & 4.11	3.81	>3.81 <=4.11	1	fully in
Highest value	3.98			

4.2 Descriptive statistics

The descriptive measures in the study were race, gender, field of study, level of study, firm tenure and team size.

- 63% of the participants were of the white race, followed by African (26%), Indian (9%) and (2%) Coloured
- The majority of participants (79%) were male; 21% were female
- Very similar percentages of the participants were qualified in Science (47%) and Engineering (51%), with only 2% having a Business qualification
- Most of the participants had doctoral or Masters qualifications (37% and 35% respectively) followed by a 7% with Honours qualifications and 21% with a basic Bachelors degree.
- Firm tenure (the amount of time that the participant had been in the employ of the company) showed a wide range: from a high of 259 months to a short 5 months
- The size of teams varied from 3 team members to 19 team members

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4.3 Independent measures

In preparing the e-mail data that was collected for statistical analysis, it was necessary to first filter it into work-related and non-work-related interactions. After this, the work-related and potentially innovation-related communication could be coded into the respective categories for tie strength and tie breadth (see Section 3.4.3.3). This section first presents the descriptive results for the filtering of the e-mail data, then the observed patterns for the strength of ties and the breadth of ties.

4.3.1 Data filtering

For tie strength, interactions with subject headings that showed relevance to technology, process or product innovation and then also social interactions for both sent and received communication was filtered and retained for coding. The number of different work interactions was used for tie breadth. Overall, the average number of both sent and received e-mails over the three-month data collection period that included both work and social interactions was 1717. Approximately 28% of communication was work-related with 72% being viewed as other interactions.

4.3.2 Strength of ties

The strength of the tie was determined by the number of repeated interactions with persons in each category. Table 14 and Table 15 outlines the highest and lowest values for tie strength, and the average and standard deviation for all 23 teams and across the four categories into which the data was coded: tie strength "own team," tie strength "other team in own R&D," tie strength "other team in own org" and tie strength "all other." A higher spread of tie strength values is evident for interaction with other teams in own R&D and other teams in the organisation.

Table 14: Tie strength – work and other

Team number	Work	Other	Total
High	1107	2856	2907
Low	51	469	932
Average	481	1 235	1 717
SD	298	499	489

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Table 15: Tie strength across categories

Team number	Tie strength "own team"	Tie strength "own R&D"	Tie strength "other org"	Tie strength "all other"	Tie strength "average"
High	306	1011	643	153	528
Low	1	80	25	0	27
Average	73	305	190	58	157
SD	60	205	141	49	114

For the strength of ties, the average of all types of tie strength is 157 of which 568 ties are with individuals in the organization and 59 ties with individuals outside the organisation. Of the 58 ties with external individuals, these interactions were with "all other", whether these were with individuals in other organizations within or outside SA. Standard deviations across the four categories of tie strength "own team," tie strength "other team in own R&D," tie strength "other team in own org" and tie strength "all other" are also included.

The same fuzzy set membership coding principle as applied for the outcome measure team innovation was applied to the independent measure of tie strength. The independent measure of tie strength was transformed into calibrated sets comprised of four thresholds. In ordering the tie strength scores, the lowest score was 204 and the highest was 1454. The cross-over point was calculated to be 578.87.

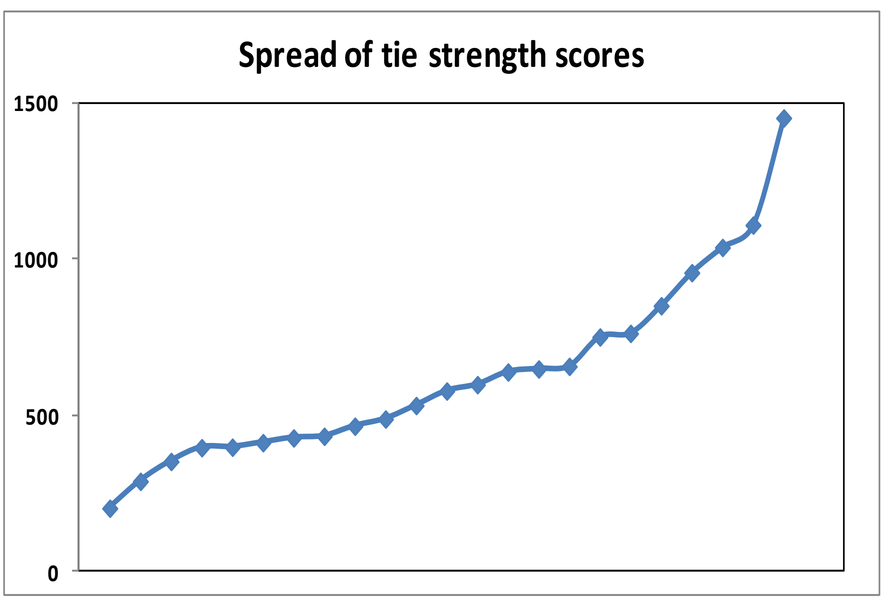

Figure 20: Spread of tie strength scores

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The fuzzy set measures were broken up into percentiles. The first quartile anchor was 413.49. The value greater than or equal to the lowest tie strength score of 204 and the first quartile anchor of 413.49 was coded as 0 and is read as being fully out of the membership set. The second quartile anchor is read as being greater than the first quartile anchor 413.49 and less than or including the crossover point of 578.87. This range of values was coded as 0.33 and is read as being more out than in of the membership set. The third quartile anchor point was calculated to be 757.76 and the value greater than the crossover point and the third quartile anchor point was coded as 0.67 and is read as being more in than out of the membership set. The value between the third quartile anchor point and the highest team innovation value was coded as 1 and is read as being fully in the membership set. This membership set coding and the applicable ranges for tie strength is summarised in Table 16.

Table 16: Summary of membership set coding for tie strength

		Membership coding range	**Membership sets**	
Lowest value	204	>= 204 & <413.49	0	fully out
Value betw. 204 & 578.87	413.49	>413.49 & <=578.87	0.33	more out than in
Crossover point	578.87	>578.87 & <=757.76	0.67	more in than out
Value betw. 578.87 & 1011.75	757.76	>757.76 & <=1454	1	fully in
Highest value	1 454			

4.3.3 Breadth of ties

The breadth of the tie was determined by the number different individuals with whom interaction took place in each category. Table 17 outlines the highest and lowest value for tie breadth, and the average and standard deviation across the four categories of tie breadth: "own team,"; "other team in own R&D"; "other team in own org"; and tie breadth "all other." A higher spread of tie breadth values was evident in ‘other teams in own R&D’ and ‘other org’ which makes sense since those are bigger populations.

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Table 17: Tie breadth across categories

	Tie breadth "own team"	Tie breadth "other team in own R&D"	Tie breadth "other team in own org"	*Tie breadth "all other"	Tie breadth "average"
High	12	61	84	30	44
Low	2	12	2	1	5
Average	4	28	22	9	16
SD	2	13	18	9	8

**'All other' refers to interactions with teams external to the organization either within SA or external to SA*

For the breadth of ties, the average tie breadth was 16, of which 54 ties were with individuals in the organization and 9 with individuals outside it. Of these 9 ties, interaction was with "all other", whether they were with individuals in other organizations within or external to SA. Standard deviations across the four categories of tie breadth "own team," tie strength "other team in own R&D," tie strength "other team in own org" and tie strength "all other" are also included.

The same fuzzy set membership coding principle as applied for the outcome measure team innovation was applied to the independent measure of tie breadth. The independent measure of tie breadth was transformed into calibrated sets comprised of four thresholds. In ordering the tie strength scores, the lowest score was 23 and the highest was 177. The cross-over point was calculated to be 60.

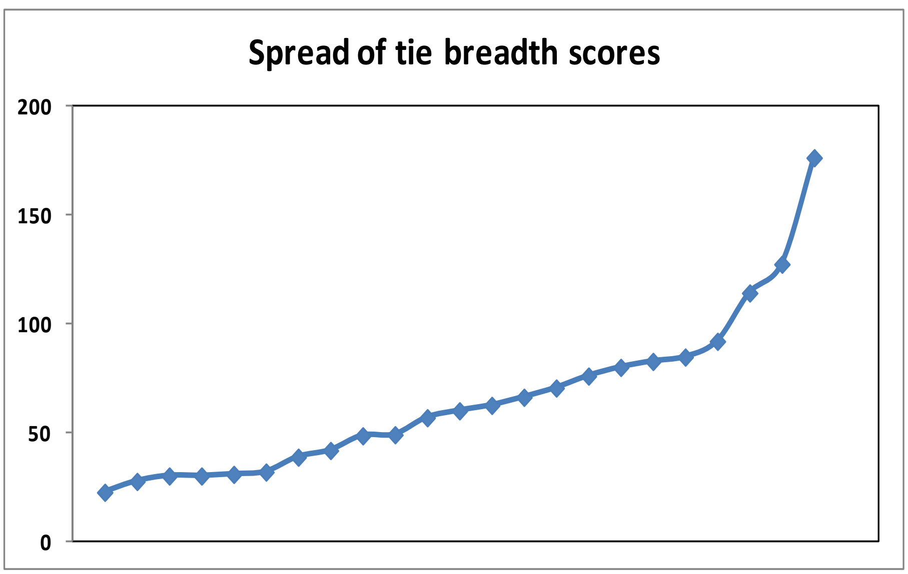

Figure 21: Spread of tie breadth scores

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The fuzzy set measures were broken up into percentiles. The first quartile anchor was 32. The value greater than or equal to the lowest tie breadth score of 23 and the first quartile anchor of 32 was coded as 0 and is read as being fully out of the membership set. The second quartile anchor is read as being greater than the first quartile anchor 32 and less than or including the crossover point of 60. This range of values was coded as 0.33 and is read as being more out than in the membership set. The third quartile anchor point was calculated to be 81 and the value greater than the crossover point and the third quartile anchor point was coded as 0.67 and is read as being more in than out the membership set. The value between the third quartile anchor point and the highest tie breadth value was coded as 1 and is read as being fully in the membership set. This membership set coding and the applicable ranges for tie strength is summarised in Table 18.

Table 18: Summary of membership set coding for tie breadth

		Membership coding range	**Membership sets**	
Lowest value	23	>= 23 & 32	0	fully out
Value betw. 23 & 60	32	>32 & <=60	0.33	more out than in
Crossover point	60	>60 & <=81	0.67	more in than out
Value betw. 60 & 81	81	>81 & <=177	1	fully in
Highest value	177			

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4.4 Determining the relationship between the nature of ties and team innovation

This section gives the results of the statistical analyses carried out to test the relationship between the strength of ties, the breadth of ties and team innovation. The description of the results obtained for the bivariate correlation and fsQCA follows.

4.4.1 Bivariate correlation

A bivariate correlation was done in SPSS to determine the Pearson product-moment coefficient that would give an indication of the relationship between the dependent variable team innovation, and the independent variables, the nature of ties (tie strength and tie breadth), and the control variables. The results also showed any correlations between the components of the independent variables.

If the Sig (2-tailed) value is less than or equal to 0.05, then a statistically significant correlation exists between the variables. Correlations at the 0.1 level (2-tailed) can also be considered significant, albeit marginally, these have been highlighted in the correlation table below as well.

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		Firm tenure	Size of team	Tie strength 'own team'	Tie strength 'own R&D'	Tie strength 'other org'	Tie strength 'all other'	Tie breadth 'own team'	Tie breadth 'own R&D'	Tie breadth 'other org'	Tie breadth 'all other'
Firm tenure	**Pearson Correlation**	**1**									
	Sig. (2-tailed)										
Size of team	**Pearson Correlation**	-.244	**1**								
	Sig. (2-tailed)	.114									
Tie strength 'own team'	**Pearson Correlation**	.253	-.020	**1**							
	Sig. (2-tailed)	.101	.898								
Tie strength 'own R&D'	**Pearson Correlation**	.078	-.217	.239	**1**						
	Sig. (2-tailed)	.618	.163	.122							
Tie strength 'other org'	**Pearson Correlation**	.162	-.194	.069	.622**	**1**					
	Sig. (2-tailed)	.300	.214	.658	.000						
Tie strength 'all other'	**Pearson Correlation**	.177	-.330*	.251	.540**	.520**	**1**				
	Sig. (2-tailed)	.257	.031	.105	.000	.000					
Tie breadth 'own team'	**Pearson Correlation**	-.002	.231	.608**	-.036	-.041	-.084	**1**			
	Sig. (2-tailed)	.988	.137	.000	.820	.794	.590				
Tie breadth 'own R&D'	**Pearson Correlation**	.204	-.169	.324*	.741**	.481**	.247	.145	**1**		
	Sig. (2-tailed)	.189	.277	.034	.000	.001	.111	.353			
Tie breadth 'other org'	**Pearson Correlation**	.390**	-.202	.260	.521**	.834**	.326*	.047	.588**	**1**	
	Sig. (2-tailed)	.010	.194	.092	.000	.000	.033	.763	.000		
Tie breadth 'all other'	**Pearson Correlation**	.369*	-.345*	.014	.374*	.680**	.603**	-.102	.482**	.674**	**1**
	Sig. (2-tailed)	.015	.023	.930	.013	.000	.000	.514	.001	.000	
Team innovation	**Pearson Correlation**	.322*	.173	.182	.340*	.248	.189	.098	.438**	.260†	.114
	Sig. (2-tailed)	.035	.267	.242	.026	.108	.225	.532	.003	.092	.466

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)
† Correlation is significant at the 0.1 level (2-tailed)

Table 19: Results of bivariate correlation

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The result of the bivariate correlation is shown in Table 19.

There is a significant correlation between team innovation and

- ✓ Firm tenure (r = .322, p=.035)
- ✓ Tie strength ‘own R&D’ (r = .340, p=.026)
- ✓ Tie breadth 'own R&D' (r = .438, p=.003)
- ✓ Tie breadth 'other org' (r = .260, p=.092)

The correlation between team innovation and the control variable firm tenure is acceptable and logical. The correlation between team innovation and the independent variables tie strength with people in other teams in own R&D, tie breadth with people in other teams in own R&D and tie breadth with people in other teams in the organisation respectively is expected, since tie strength is underpinned by trust and facilitates frequent information exchange, and tie breadth facilitates diverse information exchange.

There is also significant correlation between tie strength 'own team' and

- ✓ Tie breadth 'own team' (r=.608, p=.000)
- ✓ Tie breadth 'own R&D' (r = .324, p=.034)

This correlation between tie strength 'own team' and tie breadth 'own team' and tie breadth ‘own R&D’ suggests that even though strong ties between team members may exist it does not necessarily mean that it will be beneficial to innovation.

There is a significant correlation between tie strength 'other R&D' and

- ✓ Tie strength 'other org' (r=.622, p=.000)
- ✓ Tie strength 'all other' (r=.540, p=.000)
- ✓ Tie breadth 'own R&D' (r = .741, p=.000)
- ✓ Tie breadth 'other org' (r = .521, p=.000)
- ✓ Tie breadth 'all other' (r = .374, p=.013)

There is a significant correlation between tie strength 'other org' and

- ✓ Tie strength 'all other' (r = .520, p=.000)
- ✓ Tie breadth 'own R&D' (r = .481, p=.000)
- ✓ Tie breadth 'other org' (r = .834, p=.001)
- ✓ Tie breadth 'all other' (r = .680, p=.001)

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A number of cases exist where there is substantial correlation between the tie breadth and tie strength of a given type of tie. Firstly, the actual number of ties, i.e. the breadth, can only equal the maximum number of strong ties. Secondly, people tend to differ in terms of their propensity to network both in terms of the breadth and strength of their interactions.

In the instance where an individual worked in a specific team in R&D and has now moved to a section in the wider part of the organisation, contact with this person is still maintained and ideas are bounced off them since they have an understanding of the business and innovation culture of R&D. Furthermore, these people act as contact points with their associates for the person that is situated in R&D.

Through interaction with other parts of the division, value can also be added when referrals are made to other parts of the organisation that may be carrying out similar work, or may be doing research that will help to define the unique value proposition of the innovation the team is working on. Expansion of a personal network is done through people with whom a team member is familiar, and is based on a trust relationship. More frequent interactions result in increased tie strength.

In turn, this interaction may also form the basis of referrals to another part of the organisation situated outside the home country, to a firm situated abroad or with organisations within the country such as research institutes and universities ('all other'). Each of these has a different contribution to make in terms of differences in knowledge, experience, technology and research funding. The more diverse the knowledge experience, the better the potential for a positive innovative outcome.

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4.4.2 fsQCA

fsQCA was carried out to test the hypotheses postulated in Chapter 2 and the results are presented as follows:

- Descriptive statistics
- Fuzzy-set coded truth table and reduced truth table
- fsQCA complex, parsimonius and intermediate solution

The raw data matrix consisted of the membership set scores for all the configurations of tie strength and tie breadth. The reduced data matrix or truth table shown below (Table 20) gives the data set ordered from the highest to lowest membership set team innovation score. Also, the membership set scores for tie breath with one's own team was removed from the raw data set matrix since all but one observation was fully out of the membership set configuration for team innovation.

Combinations of tie strength and tie breadth that demonstrated at least one observation was set as the frequency threshold. The consistency threshold was set at 0.90 and is in line with the recommended literature values of at least 0.75 up to 0.95 (Ragin, 2006, Epstein et al., 2008).

Independent measures	**Independent measures (software coding)**
team innovation	ti
tie strength own team	tsot
tie strength other R&D	tsord
tie strength other organisation	tsoo
tie strength all other	tsao
tie breadth own team	tbot
tie breadth other R&D	tbord
tie breadth other organisation	tboo
tie breadth all other	tbao

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4.4.2.1 Fuzzy-set descriptive statistics

The descriptive statistics demonstrated the highest means for tie strength with other teams in R&D, tie strength with other teams in the organisation, tie breadth with other teams in R&D and tie breadth with other teams in the organisation. For both outcome measures of tie strength and tie breadth, interaction with other teams in R&D and in the rest of the organisation demonstrates greater frequencies.

Table 20: Fuzzy-set mean, standard deviation, minimum and maximum

Variable	Mean	Std Dev	Minimum	Maximum
Ti	0.4778261	0.3245191	0	1
tsot	0.216087	0.2522893	0	1
tsord	0.8417391	0.2372973	0	1
tsoo	0.6373913	0.3402457	0	1
tsao	0.1886957	0.2760168	0	0.67
tbot	0.01434783	0.06729727	0	0.33
tbord	0.683913	0.1195913	0.33	1
tboo	0.5517391	0.2543133	0	1
tbao	0.2747826	0.2543512	0	0.67

Table 21: Fuzzy-set frequencies results for the contribution of tie strength and tie breadth to team innovation

Variable	Membership set	Frequency	Percentage
tsot	0	11	47.8
	0.33	10	43.5
	0.67	1	4.3
	1	1	4.3
tsord	0	1	4.3
	0.67	8	34.8
	1	14	60.9
tsoo	0	2	8.7
	0.33	7	30.4
	0.67	5	21.7
	1	9	39.1
tsao	0	15	65.2

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	0.33	3	13.0
	0.67	5	21.7
tbot	0	22	95.7
	0.33	1	4.3
tbord	0.33	1	4.3
	0.67	20	87.0
	1	2	8.7
tboo	0	2	8.7
	0.33	6	26.1
	0.67	13	56.5
	1	2	8.7
tbao	0	9	39.1
	0.33	9	39.1
	0.67	5	21.7

Table 22: Fuzzy-set cross-table results for the contribution of tie strength and tie breadth to team innovation

	Team innovation
Tie strength "own team"	1.878 (5.15)
Tie strength "own R&D"	9.119 (25.02)
Tie strength "other org"	7.102 (19.49)
Tie strength "all other"	1.891 (5.19)
Tie breadth "own R&D"	7.469 (20.50)
Tie breadth "other org"	6.116 (16.78)
Tie breadth "all other"	2.868 (7.87)

**Percentages in brackets*

	Tie breadth ''own R&D''	**Tie breadth ''other org''**	**Tie breadth "all other"**	**Total**
Tie strength "own team"	2.663	2.323	1.211	6.198
Tie strength "own R&D"	11.166	9.370	4.881	25.417
Tie strength "other org"	8.700	7.472	3.881	20.053
Tie strength "all other"	2.789	1.898	1.449	6.136
Total	25.318	21.063	11.422	57.803

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4.4.2.2 Truth table reduction

The truth table gives 256 potential combinations of tie strength and tie breadth that produce the outcome measure of team innovation (Appendix F).

The reduced truth table is generated by application of a frequency threshold of 1 and the consistency threshold of 0.9. In interpreting the results of the reduced truth table, the most number of interactions in the entire data set are observed for:

- tsord*tsoo*tbord*tboo (6 observations)
- tsord*tbord (4 observations)
- tsord*tsoo*tbord*tboo*tbao (3 observations)

The dominant thread throughout these combinations confirm that observed in the frequency table, i.e. tie strength and tie breadth with teams in the rest of R&D and in the rest of the organisation. Evidence is also provided for the notable absence of tie breadth with one's own team and the small contribution of tie strength with one's own team and tie breadth with teams outside the organisation.

Table 23: Reduced truth table

tsot	tsord	tsoo	tsao	tbot	tbord	tboo	tbao	number	ti	raw consistency	PRI consistency	SYM consistency
0	1	1	1	0	1	0	0	1	1	1	1	1
0	1	0	0	0	1	1	0	1	1	0.916877	0.801205	0.801205
0	1	1	1	0	1	1	0	1	0	0.857759	0.507463	0.507463
0	1	1	0	0	1	0	0	1	0	0.840764	0.568965	0.568966
0	1	1	0	0	1	1	1	3	0	0.809793	0.568376	0.568376
0	1	0	1	0	1	1	1	1	0	0.795181	0	0
0	1	1	0	0	1	1	0	6	0	0.758123	0.537931	0.537931
0	1	0	0	0	1	0	0	4	0	0.74812	0.554817	0.554817
1	1	1	0	0	1	1	0	1	0	0.748111	0	0
0	1	0	1	0	0	0	0	1	0	0.744361	0	0
1	1	0	0	0	1	0	0	1	0	0.715517	0.34	0.34
0	0	0	0	0	1	1	0	1	0	0.711207	0.596386	0.596386
0	1	1	1	0	1	1	1	1	0	0.711207	0	0
2	12	7	5	0	12	8	3					

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4.4.2.3 fsQCA solutions

fsQCA yields three solutions: the first being the complex solution where cases (rows) that don't show any combinations are excluded, called remainders. The parsimonius solution uses the so-called remainders to give a solution demonstrating fewer combinations of the independent measures. The intermediate solution is generated on the basis of what is called "theoretical and substantive knowledge" as provided by the researcher. In this study the areas of interest are the core conditions of tie strength with own team (tsot), tie strength with other teams in R&D (tsord), tie strength with other teams in the organisation (tsoo), tie breadth with other teams in R&D (tbord) and tie breadth with other teams in the organisation (tboo). These causal conditions were input are those that would be present, with all other conditions selected as being either present or absent in the combinatorial solution as these interactions do take place simultaneously with each other in the research environment, hence the power of using fsQCA. The three solutions in this research at a frequency of 1 and a consistency threshold of 0.9 are shown in the tables that follow.

Complex solution

The complex solution generates two paths of acceptable consistency towards team innovation. The Boolean equation for team innovation for each path is:

Team innovation = ~tsot*tsord*~tsoo*~tsao*~tbot*tbord*tboo*~tbao (Path 1)

Path 1 is read as follows: team innovation results as a combination of the presence of tie strength with other teams in R&D, tie breadth with other teams in R&D and tie breadth with other teams in the organization, in the absence of tie strength with own team, tie strength with other teams in the organization, tie strength with teams external to the organization, tie breadth with own team and tie strength with teams external to the organization.

Team innovation = ~tsot*tsord*tsoo*tsao*~tbot*tbord*~tboo*~tbao (Path 2)

The second path is read as follows: team innovation results as a combination of the presence of tie strength with other teams in R&D, tie strength with other teams in the organization, tie strength with teams external to the organization and tie breadth with other teams in R&D in the absence of tie strength with own team, tie breadth with own team, tie breadth with other teams in the organization and tie breadth with teams external to the organization.

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Both paths provide evidence for the presence of tie strength and tie breadth with other teams in R&D in the absence of tie strength with own team, tie breadth with own team, and tie breadth with teams external to the organization. The path solutions are distinct in either the presence or absence of tie strength with other teams in the organization, tie strength with teams external to the organisation and tie breadth with other teams in the organization.

Table 24(a): fsQCA complex solution

COMPLEX SOLUTION			
Frequency cutoff	1		
Consistency cutoff	0.916877		
	Raw coverage	**Unique coverage**	**Consistency**
~tsot*tsord*~tsoo*~tsao*~tbot*tbord*tboo*~tbao	0.331210	0.211101	0.916877
~tsot*tsord*tsoo*tsao*~tbot*tbord*~tboo*~tbao	0.211101	0.090992	1.000000
Solution coverage	0.422202		
Solution consistency	0.933601		

Parsimonius solution

The parsimonius solution generates four paths of acceptable consistency towards team innovation. The Boolean equation for team innovation for each path is:

Team innovation = tsoo*tsao*~tboo (Path 3)

Team innovation = tsao*tbord*~tboo (Path 4)

The first path is read as follows: team innovation results as a combination of the presence of tie strength with other teams in the organisation and teams external to the organization in the absence of tie breadth with other teams in the organisation.

The second path says that team innovation results from a combination of tie strength with teams external to the organisation with tie breadth with other teams in R&D in the absence of tie breadth with other teams in the organisation. This path gives slight evidence for tie strength with teams external to the organizations and has the potential to hold true since this interaction could have been with teams of the same organization but situated internationally. Team members will know their counterparts situated distally therefore a certain element of trust is involved.

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Team innovation = tsord*~tsoo*tboo*~tbao (Path 5)

Team innovation =tsord*~tsoo*~tsao*tboo (Path 6)

Both paths 5 and 6 give evidence for the combination of tie strength with other teams in R&D and tie breadth with other teams in the organisation, in the absence of tie strength other teams in the organization and external to the organization, and tie breadth external to the organization.

In comparing the solutions across all four paths: the solutions provide evidence for the presence of tie strength with other teams in R&D, with teams in the rest of the organization and teams external to the organization, tie breadth with teams in other R&D and other teams in the organizations. The solutions differ from path to path in the absence of tie strength and tie breadth with other teams in the organization and external to the organization.

Table 24(b): fsQCA parsimonius solution

PARSIMONIUS SOLUTION			
Frequency cutoff	1		
Consistency cutoff	0.916877		
	Raw coverage	**Unique coverage**	**Consistency**
tsoo*tsao*~tboo	0.241128	0.000000	1.000000
tsao*tbord*~tboo	0.241128	0.000000	1.000000
tsord*~tsoo*tboo*~tbao	0.361237	0.000000	0.923256
tsord*~tsoo*~tsao*tboo	0.361237	0.000000	0.923256
Solution coverage	0.452229		
Solution consistency	0.937736		

Intermediate solution

The intermediate solution generated two combinatorial paths to the outcome measure team innovation. The Boolean equation for team innovation for each of the paths is:

Team innovation = ~tbao*tboo*tbord*~tbot*~tsao*~tsoo*tsord (Path 7)

Team innovation = ~tbao*~tboo*tbord*~tbot*tsao*tsoo*tsord (Path 8)

Path 7 provides evidence for the combination of tie breadth with other teams in the organization and in other teams in R&D, and tie strength with other teams in R&D in the

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absence of tie strength with other teams in the organization and teams external to the organization, and tie breadth with one's own team and teams external to the organisation. Path 8 provides evidence for the combination of tie strength with other teams in R&D and in the organsiation, teams external to the organization, and tie breadth with other teams in R&D in the absence of tie breadth with one's own team, with teams in the rest of the organization and external to the organization.

Overall, both paths provide evidence for the presence of tsord and tbord and the absence of tbot and tbao in their contribution to team innovation. Overall the intermediate solution provides evidence for tie strength and tie breadth with other teams in R&D and with teams in the rest of the organisation.

Table 24(c): fsQCA intermediate solution

INTERMEDIATE SOLUTION			
Frequency cutoff	1		
Consistency cutoff	0.916877		
Assumptions (present conditions)	tboo, tbord, tsoo, tsord, tsot		
	Raw coverage	**Unique coverage**	**Consistency**
~tbao*tboo*tbord*~tbot*~tsao*~tsoo*tsord	0.361237	0.211101	0.923256
~tbao*~tboo*tbord*~tbot*tsao*tsoo*tsord	0.241128	0.090992	1.000000
Solution coverage	0.452229		
Solution consistency	0.937736		

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fsQCA for hypothesis testing

Hypothesis 1 considers the relationship between tie strength and team innovation. The results show that only 5% of the contribution to team innovation is from tie strength with people in one's own team. The prominent tie strength contribution is that from people in other teams in own R&D and people in teams in other parts of the organization (25% and 20% respectively). Hypothesis 1a stating that team innovation is dominantly supported by tie strength with people in one's own team is not supported. Hypothesis 1b stating that team innovation is dominantly supported by tie strength with people in other teams in own R&D is supported. In addition, evidence is also provided for the contribution to team innovation from people in teams in other parts of the organization.

Hypothesis 2 considers the relationship between tie breadth and team innovation. The two hypothesized dominant contributors to team innovation are tie breadth with other teams in own R&D and tie breadth with other teams in the organization are both supported with a contribution 21% towards team innovation from tie breadth with other teams in own R&D and a 17% contribution to team innovation from other teams in the organisation.

In considering the simultaneous functioning of tie strength and tie breadth and their contribution to team innovation, Hypothesis 3 states that it is the simultaneous functioning of tie strength and tie breadth that contributes to team innovation. The fuzzy-set cross-table presents the results for the various combinations of tie strength and tie breadth contributing towards team. Firstly, the cross-table results confirms the dominant contribution of tie strength with other teams in own R&D, tie strength with other teams in the organization, tie breadth with other teams in own R&D and tie breadth with other teams in the organization.

Figure 22 below give the evidence-confirmed component interactions of tie strength and tie breadth for optimal innovation.

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	Solution 1	Solution 2
Tie strength "own team"	⊗	
Tie strength "own R&D"	●	●
Tie strength "other org"	⊗	●
Tie strength "all other"	⊗	•
Tie breadth "own team"	⊗	
Tie breadth "own R&D"	●	●
Tie breadth "other org"	●	⊗
Tie breadth "all other"	⊗	⊗

Black circles indicate the presence of a condition, and circles with “” indicate its absence. Large circles indicate core conditions;small ones, peripheral conditions. Blank spaces indicate “don’t care.”

In terms of the presence of a condition: black circles indicate the presence of a condition. The absence of a condition is usually shown by circles with “x” and since all conditions are demonstrated, this is obviously not shown in the table. For core and periphery conditions, large circles indicate core conditions and small ones, peripheral conditions. Blank spaces indicate that this is not consequential.

Figure 22: Evidence-confirmed configurations for optimal team innovation

Furthermore, the results provide evidence that the simultaneous functioning of the following tie strength and tie breadth combinations contribute optimally to team innovation:

- Tie strength with other teams in own R&D and tie breadth with other teams in own R&D (Hypothesis 3c)
- Tie strength with other teams in own R&D and tie breadth with other teams in the organization (Hypothesis 3d)
- Tie strength with other teams in the organization and with tie breadth with other teams in own R&D (new)
- Tie strength with other teams in the organization and tie breadth with other teams in the organization (new)

Evidence is therefore provided for Hypothesis 3c and 3d. Hypothesis 3a and 3b testing whether team innovation is dominantly supported by the simultaneous functioning of tie

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strength with people in one's own team and tie breadth with people in other teams in own R&D, and tie breadth with people in other teams in the organization respectively is not supported.

4.4.3 Summary of results

The factor analysis confirmed the single measure for team innovation and demonstrated a good measure of reliability (Cronbach's alpha 0.80). The results of the bivariate correlation gave significant correlations with team innovation and firm tenure, tie strength with other teams in R&D, tie breadth with other teams in own R&D and tie breadth with other teams in own organisation.

Hypothesis 1a that stated that the tie strength with one's own team dominantly contributes to team innovation is not supported. The fsQCA however does provide evidence in support of Hypothesis 1b that tie strength with other teams in own R&D dominantly contributes to team innovation. Additionally, the tie strength with other teams in the organization is also shown to dominantly contribute to team innovation.

The second hypothesis (Hypothesis 2), postulating that tie breadth with other teams in own R&D and tie breadth with other teams in the organization contribute the most to team innovation is supported.

For the investigation of the possible combinations of tie strength and tie breadth for optimal team innovation, four of the sixteen theoretically possible interactions were supported by fsQCA. The results provide evidence that optimal team innovation is supported by the combinations of tie strength with people in other teams in own R&D and tie breadth with people in other teams in own R&D and tie breadth with people in other teams in the organization respectively (Hypothesis 3c and Hypotheses 3d).

Furthermore, evidence is also provided for the combination of tie strength with people in other teams in the organization, and tie breadth with people in other teams in own R&D and tie breadth with people in other teams in the organization respectively. Minimal evidence is provided for the combinations of tie strength with own team and the other own R&D and other organisation tie breadth combinations (Hypothesis 3a and Hypothesis 3b not supported). Combinations of tie strength and tie breadth with all other

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parties external to the organization also provide minimal support for contribution to team innovation.

Table 25: Summary of results for tie strength and tie breadth component interactions

Hypothesis	Result	Tie strength-tie breadth combination
3a	Not supported	[TS 'own team'] [TB 'own R&D']
3b	Not supported	[TS 'own team'] [TB 'other org']
3c	Supported	[TS 'other R&D'] [TB 'own R&D']
3d	Supported	[TS 'own R&D'] [TB 'other org]
New finding	Supported	[TS 'other org'] [TB 'own R&D']
New finding	Supported	[TS 'other org'] [TB 'other org]

Theory states that between-division interaction within an organization is better for innovation outcomes than within divisional interaction or external interaction. The evidence in this research differs slightly in that it provides support for both within division and between-division interaction within an organization and holds potential for innovative outcomes rather than interaction within a team or interaction external to the organization. The results of the fsQCA should be understood in the context of the research context, i.e. a mature organization in the manufacturing industry active predominantly in process innovation. The next chapter discusses these findings.

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Chapter 5: Discussion of results

The purpose of this chapter is to discuss the results highlighted in Chapter 4. This chapter begins with a discussion of the results obtained for the hypotheses that were tested and offers a contextualised explanation for the findings compared to research already documented in the literature.

The chapter concludes by highlighting the contribution that this research had made to the body of knowledge related to the strength and breadth of ties as factors in team innovation, and suggests areas identified as holding potential for future research.

5.1 Results of hypothesis testing

5.1.1 Hypothesis 1

Hypothesis 1a which stated that "team innovation is dominantly supported by tie strength with people in one's own team" was not supported and Hypothesis 1b which stated that "team innovation is dominantly supported by tie strength with people in other teams in own R&D was supported." Additionally, the evidence provides support for the engagement of tie strength with teams the rest of the organization in their contribution to optimal team innovation. The explanation of these results within the research context follows below.

The current research setting is one in which the organization has an established and unique technology that has given them a competitive advantage over other similar companies in the energy and chemicals sector. Furthermore, the organization functions in a mature industry. As is characteristic of mature industries, process innovation tends to be the form of dominant innovation as in this company as opposed to product innovation in an emerging industry ((Abernathy and Utterback, 1978; Anderson and Tushman, 1990; Cohen and Klepper, 1996). It can therefore be expected that the demonstrated interaction would be based more internally with counterparts within the company due to the already established relationships, understanding of the company strategy, objectives and innovation aspirations. This common understanding is further underpinned by trusting relationships that have developed over time whilst different role players initially get to know each other and then begin to engage on knowledge ideas. Process innovation involves understanding the intricacies of the already existing

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knowledge underpinning the technology and processes and conceptualizing ways on which to improve thereon.

The opportunities for interaction with counterparts within the company in such a context can vary from engagement with one's immediate team, with other teams in own R&D and other teams in the organization. Detailed fine-grained knowledge is part of the tacit knowledge possessed by the different teams. Each person has an inherent wealth of knowledge and skills built up over time and thus interactions between people allow a "stock" of knowledge to be built up, comprising both of old (accumulated) knowledge, and new knowledge and information (Katila, 2002). This information exchange holds significant potential for innovative outcomes within a mature industry.

However, it is not only internal knowledge possessed by a team that is an essential contributor to innovation but also the access to "external" knowledge lying with other teams in the R&D section and the rest of the organisation. In this mature industry context where the research has been carried out, strong ties developed mostly through within-team interactions are underpinned by trusting relationships and the shared knowledge of the environment. This is beneficial for innovation up to a certain point where group-think starts to become an obstacle for product innovation (Gulati, 1995). This explains why the tie strength with one's own team has not emerged as the dominant contributor to team innovation, and the non-support of Hypothesis 1a. The engagement however with other teams in own R&D and the rest of the organization provides sufficient strength of interaction and variation of knowledge for optimal team innovation and is evident from the results.

In an instance where an industry is still evolving, it is likely that a single organization will not have access to, and indeed an awareness of all the knowledge required to successfully innovate in that industry. This is where critical inputs for innovation become lost as individuals lose out on potential novel knowledge that may lie outside the network.

The results obtained for Hypothesis 1 above make sense within the context of a mature industry because teams within the R&D section are constructed in terms of specific knowledge, competencies and skill-sets. The teams draw together the knowledge

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experts in each specific field. Team members generally get to know each other quite well and develop cordial and trusting relationships where information is freely exchanged. Although their knowledge is not necessarily diverse or novel, members possess fine detailed knowledge which has the potential to make meaningful changes to existing manufacturing processes.

5.1.2 Hypothesis 2

Hypothesis 2 considers the contribution of tie breath for optimal team innovation. The two hypothesized dominant contributors to team innovation are tie breadth with other teams in own R&D and tie breadth with other teams in the organization and are tested in Hypothesis 2a and Hypothesis 2b respectively, both of which was supported by the evidence.

Hypothesis 2 was based on assumptions derived from the literature that initial access to a wide range of sources of information, ideas, knowledge and information has the potential to convert to an innovative outcome (Venkataraman, 1997; Laursen and Salter, 2006; Becker and Dietz, 2004). Greater novelty of innovation is more likely in the event of interaction having taken place with external parties (Amara and Landry, 2005; Nieto and Santamaria, 2007). Literature has also provided evidence for the diminishing returns on innovation for a relatively large number of sources of knowledge (Laursen and Salter, 2006; Leiponen and Helfat, 2010).

The obtained result concurs with the findings in earlier research documented in the literature and supports theory that inter-divisional knowledge is key for team innovation, in addition to engagement with other teams in the R&D division. The implication for theory is many-fold: new people do not necessarily mean new types of knowledge. Interaction with a number of people also does not necessarily mean new types of knowledge but can impact innovation positively if these people are situated in a different organization or in ones' own organization but within different divisions. Comparatively, interaction with members of ones' own team with many others in the same division like R&D, will not necessarily contribute that much different knowledge. However, should the interaction be between a team in own R&D and with others in another division, i.e. not in R&D the implications for innovation can result in significantly greater innovation outcome.

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Too much diversity of knowledge for a mature industry stage as in this research context may not be suitable. As noted in the literature and demonstrated by the research context, mature industries engage in more process innovation than product innovation. The breadth of ties does not necessarily become the interaction of choice. And since novelty of innovation has been associated with external interactions, the extent of the 'external' interactions in this research context of a mature industry would be the interaction with parties in one's own division or in other divisions.

Players in a network acquire information from more new ties. This information demands evaluation before it can be assimilated. The new ideas may not be relevant to existing innovation activities and require processing and development. Thus the impact of the fresh ideas on innovation will not be immediate, since they are in the process of being understood, developed and assimilated. At this initial stage, a slight increase in innovation may be observed. However as the relevant information is sifted, processed and assimilated into the team's existing knowledge pool, it undergoes a positive transformation and an increase in innovation may then be observed.

Another possible explanation specific to the existing mature manufacturing industry context is that the nature of R&D in this setting leads to important differences between the outcomes for incremental and radical innovation. In this specific environment, a single radical innovation can occupy several years of work before commercialization is possible. Incremental innovation, however, occurs on a more frequent basis since it derives from an established base technology with improvements in processes frequently being made. The organization itself is a technology leader in its industry sector. From these specific context factors it is possible to take the view that for radical innovations, time will pass before new ideas from novel contacts are effectively transformed into innovation outcomes (low innovation outcomes at early stages). Conversely, for incremental innovations, the need for interaction with external players is limited, since the technology is unique to the business and the most knowledgeable individuals are already within the organization. The implications of the obtained result for wider applicability mean that should another company have specific technology and intellectual property unique to its business, similar results can be expected.

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5.1.3 Hypothesis 3

Hypothesis 3 was derived from findings in the literature suggesting that trust and novelty both contribute to innovation. Notably, cross-divisional innovation, either across the same division or across different divisions, was the collaboration behavior that was most associated with innovation.

Hypothesis 3 considered the simultaneous functioning of tie strength and tie breadth and their contribution to team innovation. Of the total of six possible fine-grained detailed combinations that were conceptually theorized to bring together a mix of strong ties and many ties for optimal innovation (Figure 25), the following combinations were confirmed by the evidence.

- Hypothesis 3c: Tie strength with people in other teams in own R&D and the tie breadth with people in other teams in own R&D
- Hypothesis 3d: Tie strength with people in other teams in own R&D and tie breadth with people in other teams in the organization
- Tie strength with people in other teams in the organization and tie breadth with people in other teams in own R&D
- Tie strength with people in other teams in the organization and tie breadth with people in other teams in the organization

In addition, the evidence for the combination of tie strength with ones' own team and tie breadth with people in other teams in own R&D and tie breadth with people in other teams in the organization respectively, was found not to be the dominant interactions.

In linking the above tie strength-tie breadth conceptualization to patterns of collaboration, considerable work cited in the literature has highlighted the importance of intra-firm collaboration for innovation, specifically multi-divisional or cross-functional collaboration (Sanders and Premus, 2005; Hillebrand and Biemans, 2004). The results that were obtained concur with that which was stated in the theory. Simply explained, meaningful interaction between individuals within a firm can not only occur within a single division but also between individuals across divisions. These individuals carry knowledge specific to their divisional function and it is this hybridization of this knowledge that makes a contribution to innovation.

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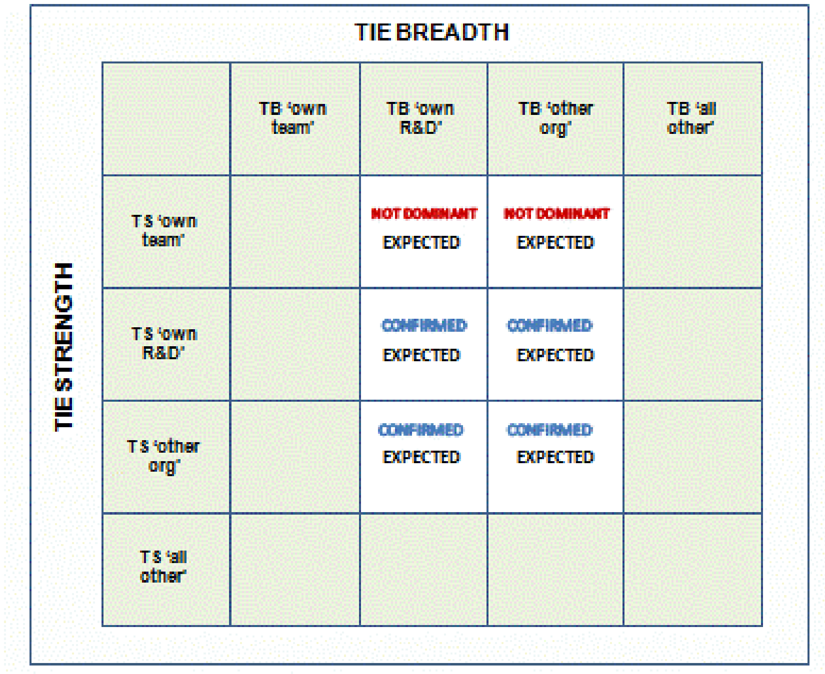

*'Other org' = other divisions in organization 'All other' = external to organisation

Figure 23: Schematic of expected results versus confirmed findings

The following four points of discussion follow from the findings that were obtained.

Firstly, the significant interaction obtained for the combination of tie strength with ones' own teams in own R&D and the tie breadth with other teams in the organization concurs with that from the theory (Miller et al., 2007) where it was stated that interaction inside an organization matter. New knowledge can also be accessed through the interaction with external players such those in other divisions. (Frenken, 2000; Sampson, 2007). Therefore, the search for novel ideas, information and knowledge has been shown to occur with interaction with parties situated in the same organization but outside the immediate R&D sphere.

Secondly, the significant interaction obtained for both the combination of tie strength and tie breadth with other teams in the organization concurs with that from the theory (Miller et al., 2007) where it shows once again that interaction inside an organization matters. Some degree of old knowledge and some degree of new knowledge are both required for innovativeness, both of which can be obtained from within organization boundaries (Katila, 2002).

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Thirdly, the significant interaction obtained for the combination of tie strength with other teams in own R&D and the tie breadth with other teams in own R&D is an area of potential robust dialogue. The result is complementary to that by Miller and Cardinal (2007) which stated that the combination of inter-divisional knowledge as opposed to either knowledge from within a division or external to the firm was more beneficial or innovation. More people in the same division do not necessarily mean new knowledge. The R&D division may be filled with scientists and engineers and begs the question as to how much different this knowledge pool would be within the same division.

The result obtained however has the potential to make sense in this research context since innovation is mostly process-orientated in a mature industry. Interaction with other teams in R&D was high due to familiarity between team members. Each individual's own team in R&D shared a common cognitive and knowledge framework for R&D which formed the basis for interaction. Members all understood the objectives of the larger R&D group in working towards better technology and innovation outputs. This was exhibited in the greater familiarity amongst the team members, a trusting relationship, and frequent interactions facilitating the incremental knowledge changes required for process innovation in a mature industry.

The environment for this research also had other similarities with contexts discussed in the literature. Cross-divisional and cross-organisational interactions have been discussed extensively by, for example, Poppo et al. (2008) who described collaboration practices developed internally among and between functional units. Such practices may represent an innovation stage model demanding certain requirements are satisfied before progressing to the next stage of development. In this specific research environment, members from a different division such as marketing or legal may become involved at different stages in the R&D process, in order to advance the development of an innovation.

Further interesting points to note are the considerations are to why ties within an organization would be as strong and viewed in the same light as ties within a division. The answer may lie in the matter of organizational mobility, as is the case in this research environment where people can and do move across different divisions. These individuals are still 'visible' to their previous team since they carry with them an inherent

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stock of knowledge (Almeida and Rosenkopf, 2003). This area holds potential for future research.

Finally, interaction with teams outside the organisation was found to be not significant even though sporadic external interaction does occur. Because the industry is mature, the novelty of ideas is perhaps less important since it is the fine-grained knowledge underpinned by strong ties that allow competitive advantage to be grown through incremental process innovation. Therefore the result that the external breadth of ties is not important probably concurs with industry life-cycle theory. Mature industries tend to be more process-oriented where the people within the organization understand the intricacies and potential development areas for existing processes.

In holistically evaluating the research context against that in the literature, multi-divisional firms are frequently structured according to specific activities and competencies (Kleinbaum and Tushman, 2008), making them largely interdependent and focused on resource sharing between divisions rather that resource combination. The research environment was a multi-divisional firm however and contrary to that stated above, both resource sharing and resource combination is evident. This inter-divisional collaboration facilitates the bringing together of technologies, skills and resources that are situated in different parts of the organization.

One example of these processes in action in the selected research environment might be a process innovation from the chemicals processing team requiring input from the wider chemicals section in the organization on the feasibility of the idea and how it could, when commercialized, address either a substantial or niche need in the market. Legal technology experts situated centrally in the organisation might also be solicited for inputs. Thus a wider breadth of internal organisational ties would bring together different knowledge aspects to facilitate the decision-making process, development and ultimate commercialization of the innovation.

Similarly, the results of a study by Miller et al. (2007) into the knowledge input towards patents, showed that a combination of knowledge from different divisions has a significant and positive impact on an invention and its subsequent technological developments. Inter-divisional knowledge, as opposed to knowledge from within a

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division or external to the firm, was also found to have the greatest impact on developments. Utilising inter-divisional knowledge, as opposed to knowledge exchange between firms, may also be potentially less costly and less risky in relation to internal intellectual property exchange. This is argued to be because it represents knowledge that is both fairly novel but also to some extent shared.

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Chapter 6: Conclusion

This chapter provides an overview of the research objectives and a summary of the findings. It also discusses the limitations of the research, the contribution it makes to the field, recommendations to stakeholders and guidelines for future research.

6.1 Summary of findings

Innovation has been found to be one of the key contributors to the competitiveness of companies and the progress of an economy. The basis of innovation is new and improved ideas. These ideas reside within individuals and for innovation to take place, collaboration between these knowledge workers is important. This is in the form of networks between people where knowledge and information is exchanged. This research has employed an innovative approach to the collection of data, the analytical method and a new perspective in enriching the understanding of the relationship between tie strength, tie breadth and innovation to test the assertions mentioned above.

This research empirically investigated three assertions linking the social network and innovation literature. Theory has shown that both the strength and breadth of ties have the potential to contribute to team innovation. This study examines those findings. However, the main contribution of this research is that tie strength and tie breadth was considered together in the same study. This formed the basis upon which the following research question was developed:

"What configuration/s of tie strength and tie breadth results in optimal team innovation?"

Such ties could occur as result of interaction between members of ones' own team and members in other teams in own R&D division, and interaction between members in ones' own team and members in other teams in own R&D and the organization.

The research was based in a manufacturing company in a mature industry predominantly involved in process innovation. The competitive advantage of the company is based on a technology developed approximately half a century ago.

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The findings of the interaction between tie strength and tie breadth and its impact on team innovation supported evidence published to date on theory related to within-firm collaboration. As theorized, these interactions were underpinned by strong and many ties. Collaboration across and between divisions have been found to be most favourable for innovation in similar settings. This implies that innovation results not only from common knowledge underpinned by strong ties, but is also effectively enhanced by new knowledge accessed through broader interactions that can be accessed through within-firm collaboration.

Based on the findings, the following conclusions can be drawn. Firstly, tie strength has a greater impact on innovation than tie breadth. This holds true in a mature industry where it has been theorized that process innovation forms most of the innovation activity, as in the case of this research context. The findings are warranted since people would tend to build on the basis of the existing stock of knowledge that is part of existing relationships, to facilitate improvements in processes.

Secondly, it is the combination of many strong ties as demonstrated by both within- and across division interaction that provides the fertile ground for optimal innovation. This supports the merits of the existing body of knowledge on intra-firm collaboration for innovation.

6.2 Recommendations to stakeholders

In the R&D environment that was the location for this study, anecdotal comments from interviewees included that 'solving crises has often been the most fertile ground for innovation.' When a specific crisis is being addressed, other novel ideas surface that would have not otherwise been considered. However, these ideas cannot be immediately translated into innovation. They require prior documentation and subsequent development to further innovation activity in the R&D environment.

The fact that people in the research setting occupy positions for long periods of time has both advantages and drawbacks. It is advantageous to an extent, in that detailed knowledge and relationships with others both develop well. However it can become problematic when blind-spots to problems grow, hampering first the identification of existing problems and second the origination of solutions. This challenge intensifies

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when unfamiliar problems requiring innovative solutions surface. The research findings imply that rotating individuals across the different knowledge areas will permit them to view issues from different perspectives. This may be beneficial not only for their own growth and development but also for their potential contribution to innovation. Organisational mobility of people will still allow the existing knowledge base to be tapped into irrespective of where the person is based through the already existing social network.

A tailor-made measure of innovation does not currently exist at either group or team level. This was a constraint on the research and also hampers the organisation’s grasp of its own innovativeness. It is recommended that such a measure be developed.

6.3 Contribution of research

This research has made five innovative contributions to the field. The first contribution is methodological in nature: the data collection method employed to determine the strength and breadth of ties. E-mail data collection rather than a survey was used to gather information on social contacts. To date, the survey has been the most commonly employed method (Quintane and Kleinbaum, 2011; Johnson et al., 2012), but given changing business communication practices in a digital environment and the greater potential susceptibility of surveys to respondent bias.

The second contribution is related to the application of a fairly novel and recent methodology for the modeling of the causal core and periphery conditions of tie strength and tie breadth and contributes towards a better understanding of the optimal simultaneous configurations of these conditions to team innovation (Fiss, 2011; Katz, Vom Hau and Mahoney, 2005; Kogut and Ragin, 2006; Pennings, 2003; Schneider and Wageman, 2006).

The third contribution is in providing support for a previously relatively thin area of research: that into cross-divisional collaboration (Gemünden et al., 2012; Miller et al., 2007). The finding that the combination of strong and many ties are important for innovation strengthens what is known about this topic.

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The fourth contribution is related to the nature of ties to team innovation. Research to date has tended to exclusively consider the respective links of tie strength, detailed knowledge, and the cohesiveness and the density of networks to innovation. This research has gone further by also considering the impact of tie breadth, in various combinations with these factors in the same study, on team innovation. This novel aspect of the investigation resulted in findings that a combination of strong and many ties are significant for team innovation in this type of research environment.

The final contribution is a fresh research perspective: one that considered the impact of both intra-firm and inter-firm collaboration simultaneously. Previous research has provided inconsistent results for the relative contributions of intra-firm and inter-firm collaboration to innovation, in particular, to new product and new service development. This inconsistency resulted from the fact that these were investigated separately (Schleimer and Shulman, 2011). This research investigated the two simultaneously and moves towards a more integrated view of their relationship in fostering innovation.

6.4 Limitations of the research

The following limitations were identified in this specific research context. In terms of data, a single objective measure of team innovativeness across all the teams was not available from the organisation. The research and development activities of the teams vary across the different groups, with diverse outputs (such as patents, publications and trade secrets) being considered as indicators of their level of innovativeness. An already published team innovation survey administered to architectural firms was modified for use in this study.

In terms of the timeframe over which the study was carried out, major innovation output in this specific R&D environment sometimes only materializes after years of work. The team innovation survey was administered six months after the collection of the e-mail data, and this could have resulted in a loss of information on further incremental output. E-mail data was also only collected for a three-month period (partially due to time constraints and the cost implications of collecting data over a longer period).

In terms of participation, the request for the collection of e-mail communications could have been construed as sensitive or personally invasive, constraining some individuals

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from participation. The sample size was limited because individuals in R&D had to explicitly give their consent to allow their mailboxes to be monitored.

In terms of what data was analysed, e-mail communication between the teams was considered as the main mechanism through which information, knowledge and ideas were exchanged towards innovation outcomes. To gain a more holistic view of all avenues contributing to team innovation, other types of interaction (such as meetings and face-to-face interactions) would also require analysis.

The obtained results are reflective of communication in a mature industry where process innovation dominates and strong and many ties are the dominant interaction type. The applicability of this in different stages of an industry life cycle requires further research.

6.5 Guidelines for future research

Seven areas have been identified for future research.

The first area is related to social network analysis. A complete social network analysis study covering both sent and received patterns of communication can provide a socio-gram that will give an indication of key players in the network, and where bottlenecks exist. Additional social network dimensions such as density, cohesion and centrality can provide insight into the communication patterns of innovating teams.

The second area is the impact of social interaction alone on trust and ultimately on innovation. In the current research, social communication between team members either within the teams, with other teams in R&D, and with other teams in the same organization formed 68% of the total electronic communication. Social interaction has the potential to facilitate the growth of trust between individuals over time and the potential to develop into idea-generating and knowledge-sharing interactions that have a longer-term positive influence on innovation. Such social engagement presents an area with strong potential for future research.

The third area is a consideration of all interaction types including written and face-to-face communication, meetings, and discussions for their joint contribution to innovation. As described above this research was limited to e-mail communication.

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The fourth area is the same study but conducted over a longer period of time: a longitudinal study to determine if and how the innovation trajectory changes over time. Vast literature has provided evidence in support for an inverted U-shaped relationship of both tie strength and tie breadth with innovation. Longitudinal research could discover whether this pattern is supported and if the pattern repeats itself over time, and what mechanisms trigger either a repeat pattern, a declining, or an ascending trend. Should this research have been performed over a longer duration than over a three-month period, i.e. a longitudinal study, the innovation curve may have demonstrated an increase in innovation. This implies that the link between the nature of ties and innovation is time-bound. Further research would be required to determine if this would hold true.

The fifth area relates to the human resource pool with the greatest potential to innovate. Scientists are believed to be the idea generators, and engineers to be limited largely to the implementation and commercialization of ideas. Current research perspectives thus acknowledge that both are involved in a certain stage of the innovation process. The current organization that was the setting for this research is currently composed of both scientists and engineers: the scientists work in R&D and the engineers on cutting-edge process development. A study investigating the innovativeness and dominant tie type in each of these two groups would provide useful resource management information about how to optimally combine these areas of knowledge work for optimal innovation.

The sixth area relates to the testing of which combinations of tie strength and tie breadth in an innovation environment might work best for radical innovation, incremental process innovation, or product innovation respectively. This research showed that strong and many ties are the dominant interaction type where process innovation dominates. A different research environment engaged simultaneously in all three innovation types would need to be identified for such a study.

The final area for future research, related to the above should consider the optimal combination of tie strength and tie breadth in an innovation environment at different stages of the industry life-cycle and the types of innovation outputs.

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The numerous avenues for future research all suggest that this project has started addressing an important gap in the literature by providing evidence for the merits of collaboration-based innovation as demonstrated by tie strength and tie breadth, and their respective within-firm interaction. This study in addressing an interesting question especially the combination of tie strength and tie breadth, and more specifically their simultaneous functioning for innovation, could provide new insights into how the innovation of teams can be enhanced.

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Appendices

Appendix A: SA regulatory environment relating to information technology

South African laws relating to information technology include the Electronic Communications and Transactions Act of 2002 (“ECT ACT”) which makes all electronic–based information the legal equivalent of documentary information. The Regulation of Interception of Communications and Provision of Communication - related Act (“RICA”) became effective on the 1 July 2009. Section 2 of RICA provides that “no person may intentionally intercept or attempt to intercept, or authorise or procure any other person to intercept or attempt to intercept, at any place in the Republic, any communication in the course of its occurrence or transmission.”

RICA contains a number of exceptions to the general prohibition on interception as contained in section 5(1) and 6. Section 5(1) provides that “any person, other than a law enforcement officer, may intercept any communication if one of the parties to the communication has given prior consent in writing to such interception, unless such communication is intercepted by such person for purposes of committing an offence.” A “party to a communication” is defined to include the sender or recipient or intended recipient of an indirect communication, as well as any other person, who at the time of the “occurrence” of the communication is in “the immediate presence of the sender or recipient or intended recipient of the indirect communication.”

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Appendix B: Consent request for e-mail data

I am employed as a specialist strategy analyst but am also a doctorate student at the Gordon Institute of Business Science. In my research, I plan to investigate the e-mail communication patterns of R&D users in particular to establish if these patterns may be linked to underlying innovation mechanisms. For example, we know that some contact outside a project team can bring in new ideas, but we do not know how much effort should be placed on communication outside versus inside the project team.

I am NOT interested in what people communicate via e-mail – I am simply interested in who communicates with whom. The nature of the study is such that details will not at any point be made public and will not be linked back to an individual. Raw data will be coded before data analysis, and will only be reported in the aggregate.

Consultation with the company Information Management has confirmed that their policy is aligned to The Regulation of Interception of Communications and Provision of Communication-related Act (RICA). RICA provides that "*no person may intentionally intercept at any place in the RSA, any communication in the course of its occurrence or transmission,* ***unless one of the parties to the communication has given prior consent in writing to such interception.***"

In light of RICA, I am therefore requesting your consent to allow the collection of some basic e-mail data.

Please note:

- NO content in the body of ANY e-mail will be visible and/or captured.
- Under "from" we will capture the e-mail address of the sender.
- The e-mail addresses of recipients TO, CC and BC will be captured, and if external will be marked as external.
- The subject line, date and time sent will be captured – the subject line will enable us to establish that the communication is related to innovation.
- Attachment SIZE (if any) will be captured, but not the content.

Furthermore, collection and use of e-mail frequency reports for 3 months within the system has been approved in principal by the management of R&D (14 May 2009). The relevant excerpt from the minutes is as follows:
"Written consent to be obtained from each individual involved. Confirmation that additional interviews with team leaders would be restricted to one hour of their time. All e-mail communication to addresses outside the company should be note as 'external' and should not contain any indications of the companies or organizations with whom we work."

The tab options provide for different levels of consent. Please us the voting buttons to indicate the level of consent that you choose. In making your selection, please bear in mind that the more comprehensive the population we study, the more useful the study will be to the organization. Therefore I would urge you to select option 3 as it will add immense value to the data collected. *Again, no personal details will be reported, and no content of any e-mails will be captured*
Option 1: Yes – permission given
Option 2: No – will not participate
Option 3: Yes – will participate and prepared to be interviewed

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Appendix C: Team innovativeness evaluation survey

Team innovativeness evaluation

Keeran Kowlaser
Gordon Institute of Business Science
Doctorate in Business Administration

Professor Helena Barnard
Gordon Institute of Business Science

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Introduction

This questionnaire asks for the assessment of team innovation with respect to products and processes. Innovation is an idea, process, technology or business practice, which on implementation at the individual, group or organizational level, adds value to the organization. Added value can be viewed in terms of revenue generation, tapping into new markets, customer benefits and partnerships to disseminate the innovation into the sector in which the organization is operational.

This survey considers technological innovation based on the results of new technological developments, new combinations of existing technology or utilisation of other knowledge held or acquired by your firm. We would like you to consider innovation activity ***at the team level***, including the interaction patterns that teams display.

Informed consent

Please be advised that participation in this survey is strictly voluntary on your part AND YOU CAN WITHDRAW AT ANY TIME WITHOUT PENALTY. Your individual responses in this survey are confidential and will not be connected with you as an individual in any reporting of this data.

Please sign and date below indicating your agreement to participate in this interview.

Thank you,

Name (signature): ________________________________ Date: _______________________

Please note: *In the actual questionnaire, the areas were identified by name (eg. Environmental Technology) and the teams with reference to the team leaders (eg. John Smith)*

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Group Head Name: ____

Date: ____

This questionnaire is comprised of 9 questions. Please rate the teams in R&D with respect to each of the questions on a scale of 1 to 5, where 5 = very frequently and 1 = very rarely.

A1: *Using skills they already possess, this team learns new ways to apply those skills to* ***develop new products or processes*** *that can help* ***attract and serve new markets***

	Very frequently	Frequently	Occasionally	Rarely	Very rarely
Area 1					
Team 1					
Area 2					
Team 2					
Team 3					
Team 4					
Area 3					
Team 5					
Team 6					
Team 7					
Team 8					
Team 9					
Team 10					
Team 11					
Team 12					
Area 4					
Team 13					
Team 14					
Team 15					
Team 16					
Area 5					
Team 17					
Team 18					
Area 6					
Team 19					
Team 20					
Area 7					
Team 21					
Team 22					
Team 23					

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A2: *This team seeks out information about new markets, products, processes and technologies from* ***sources outside the organization***

	Very frequently	Frequently	Occasionally	Rarely	Very rarely
Area 1					
Team 1					
Area 2					
Team 2					
Team 3					
Team 4					
Area 3					
Team 5					
Team 6					
Team 7					
Team 8					
Team 9					
Team 10					
Team 11					
Team 12					
Area 4					
Team 13					
Team 14					
Team 15					
Team 16					
Area 5					
Team 17					
Team 18					
Area 6					
Team 19					
Team 20					
Area 7					
Team 21					
Team 22					
Team 23					

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A3: *This team identifies and develops skills that can improve their ability to serve* ***existing*** *business needs*

	Very frequently	Frequently	Occasionally	Rarely	Very rarely
Area 1					
Team 1					
Area 2					
Team 2					
Team 3					
Team 4					
Area 3					
Team 5					
Team 6					
Team 7					
Team 8					
Team 9					
Team 10					
Team 11					
Team 12					
Area 4					
Team 13					
Team 14					
Team 15					
Team 16					
Area 5					
Team 17					
Team 18					
Area 6					
Team 19					
Team 20					
Area 7					
Team 21					
Team 22					
Team 23					

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***A4**: This team identifies and develops skills that can help attract and serve **new** business needs of the organization*

	Very frequently	Frequently	Occasionally	Rarely	Very rarely
Area 1					
Team 1					
Area 2					
Team 2					
Team 3					
Team 4					
Area 3					
Team 5					
Team 6					
Team 7					
Team 8					
Team 9					
Team 10					
Team 11					
Team 12					
Area 4					
Team 13					
Team 14					
Team 15					
Team 16					
Area 5					
Team 17					
Team 18					
Area 6					
Team 19					
Team 20					
Area 7					
Team 21					
Team 22					
Team 23					

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A5: *This team seeks out information and knowledge on products and techniques that are* ***new to the R&D business*** *and applies them to develop* ***new solutions to familiar problems***

	Very frequently	Frequently	Occasionally	Rarely	Very rarely
Area 1					
Team 1					
Area 2					
Team 2					
Team 3					
Team 4					
Area 3					
Team 5					
Team 6					
Team 7					
Team 8					
Team 9					
Team 10					
Team 11					
Team 12					
Area 4					
Team 13					
Team 14					
Team 15					
Team 16					
Area 5					
Team 17					
Team 18					
Area 6					
Team 19					
Team 20					
Area 7					
Team 21					
Team 22					
Team 23					

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A6: *This team identifies and learns skills and technologies that may be useful in solving* ***unfamiliar problems***

	Very frequently	Frequently	Occasionally	Rarely	Very rarely
Area 1					
Team 1					
Area 2					
Team 2					
Team 3					
Team 4					
Area 3					
Team 5					
Team 6					
Team 7					
Team 8					
Team 9					
Team 10					
Team 11					
Team 12					
Area 4					
Team 13					
Team 14					
Team 15					
Team 16					
Area 5					
Team 17					
Team 18					
Area 6					
Team 19					
Team 20					
Area 7					
Team 21					
Team 22					
Team 23					

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A7: *This team seeks out and acquires information that may be useful in developing* ***multiple solutions to problems***

	Very frequently	Frequently	Occasionally	Rarely	Very rarely
Area 1					
Team 1					
Area 2					
Team 2					
Team 3					
Team 4					
Area 3					
Team 5					
Team 6					
Team 7					
Team 8					
Team 9					
Team 10					
Team 11					
Team 12					
Area 4					
Team 13					
Team 14					
Team 15					
Team 16					
Area 5					
Team 17					
Team 18					
Area 6					
Team 19					
Team 20					
Area 7					
Team 21					
Team 22					
Team 23					

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A8: *This team seeks out and acquires knowledge that may be useful in* ***satisfying needs unforeseen by the client***

	Very frequently	Frequently	Occasionally	Rarely	Very rarely
Area 1					
Team 1					
Area 2					
Team 2					
Team 3					
Team 4					
Area 3					
Team 5					
Team 6					
Team 7					
Team 8					
Team 9					
Team 10					
Team 11					
Team 12					
Area 4					
Team 13					
Team 14					
Team 15					
Team 16					
Area 5					
Team 17					
Team 18					
Area 6					
Team 19					
Team 20					
Area 7					
Team 21					
Team 22					
Team 23					

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A9: *This team learns new ways to apply their knowledge of familiar products and techniques to develop new and unusual solutions to familiar, routine problems*

	Very frequently	Frequently	Occasionally	Rarely	Very rarely
Area 1					
Team 1					
Area 2					
Team 2					
Team 3					
Team 4					
Area 3					
Team 5					
Team 6					
Team 7					
Team 8					
Team 9					
Team 10					
Team 11					
Team 12					
Area 4					
Team 13					
Team 14					
Team 15					
Team 16					
Area 5					
Team 17					
Team 18					
Area 6					
Team 19					
Team 20					
Area 7					
Team 21					
Team 22					
Team 23					

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Appendix D: Respondent informed-consent forms

Signed copies are available from researcher

Appendix E: Respondents that gave permission to monitor e-mail communication

Appendix E1: Participants - E-mail data

No.	Participants: E-mail data
1	Person A1
2	Person B1
3	Person C1
4	Person D1
5	Person E1
6	Person F1
7	Person G1
8	Person H1
9	Person I1
10	Person J1
11	Person K1
12	Person L1
13	Person M1
14	Person N1
15	Person O1
16	Person P1
17	Person Q1
18	Person R1
19	Person S1
20	Person T1
21	Person U1
22	Person V1
23	Person W1
24	Person X1
25	Person Y1
26	Person Z1
27	Person A2
28	Person B2
29	Person C2
30	Person D2
31	Person E2
32	Person F2
33	Person G2
34	Person H2
35	Person I2
36	Person J2
37	Person K2
38	Person L2
39	Person M2

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40	Person N2
41	Person O2
42	Person P2
43	Person Q2
44	Person R2
45	Person S2

Appendix E2: Participants - Team innovativeness evaluation

Area	Participants Team innovativeness evaluation
1	Interviewee 1
2	Interviewee 2
3	Interviewee 3
4	Interviewee 4
5	Interviewee 5
6	Respondent unavailable
7	Interviewee 6
	Interviewee 7
	Interviewee 8
8	Interviewee 9

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Appendix F: Truth table

tsot	tsord	tsoo	tsao	tbot	tbord	tboo	tbao	number	ti	raw consistency	PRI consistency	SYM consistency
0	1	1	0	0	1	1	0	6		0.758123	0.537931	0.537931
0	1	0	0	0	1	0	0	4		0.74812	0.554817	0.554817
0	1	1	0	0	1	1	1	3		0.809793	0.568376	0.568376
1	1	1	0	0	1	1	0	1		0.748111	0	0
1	1	0	0	0	1	0	0	1		0.715517	0.34	0.34
0	1	1	1	0	1	1	1	1		0.711207	0	0
0	1	1	1	0	1	1	0	1		0.857759	0.507463	0.507463
0	1	1	1	0	1	0	0	1		1	1	1
0	1	1	0	0	1	0	0	1		0.840764	0.568965	0.568966
0	1	0	1	0	1	1	1	1		0.795181	0	0
0	1	0	1	0	0	0	0	1		0.744361	0	0
0	1	0	0	0	1	1	0	1		0.916877	0.801205	0.801205
0	0	0	0	0	1	1	0	1		0.711207	0.596386	0.596386
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1	1	1	0	1	0	0	0	0				
1	1	1	0	0	1	1	1	0				
1	1	1	0	0	1	0	1	0				
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1	1	1	0	0	0	1	1	0				

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1	0	1	1	0	1	1	1	0				

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