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Knowledge Sharing Framework for Sustainability of Knowledge Capital

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature: ………………………………………….

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Summary of the Thesis

Knowledge sharing is one of the most critical elements in a knowledge-based society. With huge concentration on communication facilities, there is a major shift in world-wide access to codified knowledge. Although communication technologies have made great strides in the development of instruments for accessing required knowledge and improving the level of knowledge sharing, there are still many obstacles which diminish the effectiveness of knowledge sharing in an organization or a community. The current challenges include: identification of the most important variables in knowledge sharing, development of an effective knowledge sharing measurement model, development of an effective mechanism for knowledge sharing reporting and calculating knowledge capital that can be created by knowledge sharing. The ability and willingness of individuals to share both their codified and uncodified knowledge have emerged as significant variables in knowledge sharing in an environment where all people have access to communication instruments and have the choice of either sharing their own knowledge or keeping it to themselves.

This thesis addresses knowledge sharing variables and identifies the key variables as: willingness to share or gain knowledge, ability to share or gain knowledge, complexity or transferability of the shared knowledge. Different mechanisms are used to measure these key variables. Trust mechanisms are used to measure the willingness and ability of individuals to share or acquire knowledge. By using trust mechanisms, one can rate the behavior of the parties engaged in knowledge sharing and

subsequently assign a value to the willingness and ability of individuals to share or obtain knowledge. Also, ontology mechanisms are used to measure the complexity and transferability of a particular knowledge in the knowledge sharing process. The level of similarity between sender and receiver ontologies is used to measure the transferability of a particular knowledge between knowledge sender and receiver. Ontology structure is used to measure the complexity of the knowledge transmitted between knowledge sharing parties.

A knowledge sharing framework provides a measurement model for calculating knowledge sharing levels based on trust and ontology mechanisms. It calculates knowledge sharing levels numerically and also uses a Business Intelligence Simulation Model (BISIM) to simulate a community and report the knowledge sharing level between members of the simulated community. The simulated model is able to calculate and report the knowledge sharing and knowledge acquisition levels of each member in addition to the total knowledge sharing level in the community.

Finally, in order to determine the advantages of knowledge sharing for a community, capital that can be created by knowledge sharing is calculated by using intellectual capital measurement mechanisms. Created capital is based on knowledge and is related to the role of knowledge sharing in increasing the embedded knowledge of individuals (human capital), improving connections, and embedding knowledge within connections (social capital). Also, market components (such as customers) play a major role in business, and knowledge sharing improves the embedded knowledge within market components that is defined as market capital in this thesis. All these categories of intellectual capital are measured and reported in the knowledge sharing framework.

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Chapter 1: Introduction

1.1 Overview

As knowledge is becoming increasingly important in knowledge-based societies, it affects all aspects of modern societies including business, education, communication, transport and, most importantly, the lifestyles of humans. It is believed in many cultures that better educated individuals with a high level of knowledge will contribute to faster and more sustainable development and in most countries people with better education and skills earn more and have more opportunities in the job market in comparison with those who have low levels of knowledge (Soubbotin, 2004). Many studies have been conducted to investigate how knowledge can be created, managed and shared, and to determine the best tools to accomplish these tasks in a cost- and time-efficient manner. This thesis deals with knowledge sharing and indicates the most important variables in the knowledge sharing process. Due to the importance of accurate measurement and clear definitions and control of the issues related to knowledge sharing, this research focuses on measurement technologies to find numeric techniques to measure those variables that impact on the effectiveness of knowledge sharing. This thesis explores the ways by which the main variables in knowledge sharing can be measured and the results of the measurement can be reported to decision makers and managers. It also examines knowledge capital that is created by knowledge sharing and the way that this capital can be calculated in a business.

It is important to know more about knowledge and arrive at a clear understanding of knowledge. This chapter focuses mainly on knowledge definition, different types of knowledge, and the role of knowledge sharing in knowledge management.

Chapter 1 begins with a brief discussion of the importance of knowledge in modern society and explores the basic definitions of knowledge, information and data. Subsequently, the next part of the chapter describes different types of knowledge including tacit knowledge (uncodified knowledge) and explicit knowledge (codified knowledge), both of which are investigated in detail. We then explore the notion of knowledge sharing and the importance of knowledge sharing in knowledge management. Paradigms related to knowledge management, and relations between knowledge sharing and different components of knowledge management, are discussed in detail. In this chapter, we also discuss various concerns in knowledge sharing such as measurement of subjective variables. This is particularly important since knowledge sharing is going to be an interesting and popular domain in business where updated knowledge is shared between employees, and also in society in general, given the many social networks that have rapidly emerged in the last few years. Hence, there are motivations to focus on knowledge sharing, some of which are discussed in this chapter. Finally, the thesis structure is set out, and a brief summary of each chapter is presented.

1.2 Importance of knowledge in modern society

In a post-capitalism society, power comes from transmitting information to make it productive (Drucker, 1995). It is estimated that more than 50 per cent of Gross Domestic Product (GDP) in the major economies is now knowledge-based (Organization For Economic and Development,1996). Knowledge is therefore an important element in a knowledge-based economy. It creates a strong competitive advantage in dynamic business environments where knowledge is changing rapidly and organizations need to keep abreast of changes. In a knowledge based-economy, knowledge is a resource just like other resources such as raw materials and postulates as an input resource that will have a greater impact than physical capital in the future (Drucker, 1993). Many social scientists have come to characterize the world as a knowledge society and central to this claim is the notion that new social uses of information, and in particular the application of scientific knowledge, are transforming social life in fundamental ways (Rule and Besen, 2008). From the individual's personal perspective, knowledge is the main source of progress and from the business perspective, knowledge helps organizations to build core competencies and create more opportunities. Knowledge helps to find new strategies for increasing the continuous improvement, innovation and performance of businesses, so as to create sustainable competitive advantages (Johannessen et al., 2001). It should come as no surprise that the most valuable asset for any business is the knowledge of its employees. The focus on knowledge has led to increased attention on information technology (IT) to increase knowledge exchange between knowledge holders. In order to facilitate knowledge-based social and economic analysis, distinctions can be made between different kinds of knowledge which are important. It is necessary to have a clear definition of knowledge and to discuss the different types of knowledge. This part of the chapter explores the definition of knowledge, and specific approaches to the description of knowledge, information and data are examined.

1.3 Knowledge basics

Knowledge is a combination of information and a person's experience, training and expertise (Kurbalija , 1999). It is important to mention that most discussions within Information Technology (IT) and definitions of knowledge in the literature, begin with data and information (Alavi and Leidner, 2001). Data is defined as raw (Raisinghani, 2000), isolated facts (Tuomi, 1999) or as the results of observations (Den Hertog and Huizenga, 2000). Data would represent numbers, words or figures that are organized in such a manner as to produce useful results such as statistics (Brooking, 1999). Data is a raw product and a set of discreet objective facts about events and a collection of any number of required observations on one or more variables (Davenport and Prusak, 1998). Data has been categorized as structured, semi-structured, or unstructured. Structured data is organized in a highly regular way, such as in tables and relations, where the regularities apply to all the data in a particular dataset (Losee, 2006). Semi-structured data does not have regular structures. It can be neither stored nor queried easily and efficiently in relational or object-oriented database management systems. Unstructured data, such as text or images, contain information but have no explicit structuring information, such as tags. However, these tags may be assigned using manual or automatic techniques, converting the unstructured data to semi-structured data (Losee, 2006). Data can be changed to information through conceptualization and categorization (Jarke et al., 2001) or when data is placed in a specific meaningful context (Den Hertog and Huizenga, 2000). Moreover, when data is processed to provide certain useful contexts, it becomes the information and can be used in decision-making (Standards Australia, 2001). Further processing of information leads to deeper understanding and represents a reality that is defined as knowledge. Information becomes knowledge when it is understood and comprehended at a deeper level as a result of human mental activity and further analysis of the information including association with other data and information (Jarvis, 2000). Knowledge is defined as a mix of experiences, values and contextual information that provides a framework for incorporating new experiences (Davenport and Prusak, 1998). Knowledge is the power to act and to make value-producing decisions that add value to the enterprise (Kanter, 1999; Vail, 1999). Knowledge is also defined as "the insights, understandings, and practical know-how that we all possess -- is the fundamental resource that allows us to function intelligently" (Wiig, 1996). There are different types of knowledge and the exploration of these different types is very important in order to know more about the characteristics of particular types of knowledge and to determine how knowledge can be used productively. In next section of this chapter, different types of knowledge are examined.

1.4 Types of knowledge

1.4.1 Tacit and explicit knowledge

Knowledge is classified according to different types. Some types of knowledge are developed for use in market commodities or economic resources and are appropriate for economic production functions. On the other hand, some types of knowledge are difficult to codify, measure and slot into production functions (Lundvall and Johnson, 1994). Some knowledge refers to facts and some refers to scientific knowledge about the principles and laws of nature. These kinds of knowledge can be codified and acquired by reading books, papers and news on the Internet and in the media, attending lectures and by means of traditional and/or modern education systems. One type of knowledge refers to the skills and competency of individuals to create innovative knowledge and such knowledge is highly dynamic, hard to explain, and cannot be identified easily. This kind of knowledge is acquired through involvement in social relationships and knowing about the actual resources and individuals who have this knowledge and want to share it. Moreover, two divisive issues are looked at more particularly, including the knowledge that can be seen and codified opposed to the knowledge that can be seen and becomes a personalized internal property of individuals. These two types of knowledge are termed ‘tacit knowledge’ and ‘explicit knowledge’ (Tiwana, 2000). Explicit knowledge refers to codified knowledge that is transmittable in formal, systematic language and is easily transferred by using Information Technology (IT) (Polanyi, 1966). Explicit knowledge, is easy to articulate, capture and distribute in different formats, since it is formal and systematic (Sunassee and Sewry, 2003). This kind of knowledge can be formulated and documented. It is the type of knowledge that an individual has acquired mainly at school and university. It implies factual statements about such matters as material properties, technical information, and tool characteristics and can be expressed in words and numbers (Koskinen et al., 2003). Moreover, Knowledge that can be uttered, formulated in sentences, and captured in drawings and writing is explicit. Knowledge relating to the senses, movement skills, physical experiences, intuition, or implicit rules of thumb, is tacit (Polanyi, 1967). On the other hand, tacit knowledge is hard to formalize and communicate and has been emphasized and regarded as the important strategic resource that assists one to accomplish a task (Sternberg et al., 2000). A simple description of tacit knowledge is ‘every type of knowledge that cannot be codified’. Tacit knowledge is highly personal, context-specific and housed in the human brain and includes expertise, understanding, or professional insight formed as a result of experience (Polanyi, 1966). Tacit knowledge is the form of knowledge that is subconsciously understood and applied, difficult to articulate, developed from direct experience and action and usually shared through highly interactive conversation, storytelling and shared experience (Sunassee and Sewry, 2003). It is a comprehensive justification of beliefs that are embedded in the human body and mind leading to such characteristics as ‘‘gut feelings” (Varela et al., 1991) and it is deeply rooted in action, commitment, and involvement (Nonaka et al., 1994). The key to knowledge creation lies in the mobilization and conversion of tacit knowledge to explicit knowledge (Nonaka and Takeuchi, 1995). Converting tacit knowledge to explicit knowledge is often time consuming and problematic (Herschel et al., 2001). Tacit knowledge is dynamic and becomes static when it is converted to explicit knowledge (Sveiby, 1997).

1.4.2 Individual and social knowledge

Although scholars differentiate individual knowledge from social knowledge, the issue of distinction and relation between individual knowledge and memory of a group or community is not always clear. Personal knowledge and justification is based on the coherent integration of individual information but, social knowledge and justification is based on the coherent aggregation of social information, that is, the information of individuals belonging to the social group (Lehrer, 1987). In social knowledge, truth is not to be found inside the head of an individual person; it originates from people collectively searching for truth, in the process of their dialogic interaction (Bakhtin, 1984). Individual knowledge refers to an individual’s experience and expansion of explicit knowledge to create a high and deep level of tacit knowledge. In this thesis, these two kinds of knowledge are not differentiated and both of them are used interchangeably.

1.4.3 Commonsense and expert knowledge

Commonsense knowledge is general knowledge that every member of a society is expected to know. It includes the vast body of knowledge that all of us possess regarding entities like space, time, quantities, qualities, flows, chemicals, biological beings, goals, plans, needs, beliefs, intentions, actions, interpersonal relations, the complex interactions between them, and our innate ability to perform different styles of subtle reasoning with these entities (Davis, 1990). Expert knowledge is knowledge understood by limited numbers of experts and when experts' knowledge is diffused to the population at large, it becomes commonsense knowledge (Ein-Dor, 2006). One example of this is the use of personal computers. When they first appeared, computers were used by professionals who were considered to be computer experts. Nowadays, most people worldwide use personal computers and computer knowledge now approximates commonsense knowledge.

Knowledge of any type needs to be managed effectively to create capital and produce a competitive advantage in a knowledge-based economy. Knowledge management covers different processes of managing a particular type of knowledge. The process includes knowledge creation, knowledge discovery, knowledge sharing and dissemination, use and reuse of knowledge and related techniques in each part of the processes. This part of the thesis examines knowledge management and different parts of the knowledge management process to explore the role of knowledge sharing in knowledge management and relate knowledge sharing with other parts of knowledge management.

1.5 Knowledge sharing role in knowledge management

During the 1990s, due to the requirements of a knowledge-based economy, knowledge management (KM) emerged as a concept to help managers improve their competitive business advantages by concentrating on leveraging the knowledge within their employees. KM mobilizes intangible assets (intellectual capital) of an organization that is often of greater significance to the organization than its tangible assets (Egbu et al., 2001). Organizations realized that utilizing the knowledge within their organization is often problematic and they were losing their competitive advantages through employee attrition (Alavi and Leidner, 2001). Leveraging the knowledge is not limited to using high-level communication technology. Technology has been defined as a key enabler of KM, whereas it may also be a disabling influence if aspects such as social change and politics are considered (Swan et al., 2000). Moreover, knowledge leveraging can be discussed in two main domains. First, it can be considered in terms of technology hardware such as instruments, facilities and tangible requirements. On the other hand, its 'soft' aspects can be explored by discussing why individuals share their knowledge and how it can be improved. Knowledge cannot be extracted from individuals as it is embedded in social relationships (Hunter and Beaumont, 2002). Since knowledge is a key resource that provides a competitive advantage, an effective management system should be designed to acquire, share and use knowledge. The purpose of knowledge management is to manage this strategic resource in business. Ives et al. (1998) defined KM as:

> "...the effort to make the knowledge of an organization available to those within the organization who need it, where they need it, when they need it, and in the form in which they need it in order to increase human and organizational performance"

KM comprises activities necessary to discover, acquire, store, manage, develop, disseminate and use knowledge (Rademacher, 1999). Also, it is defined as a KM system; Alavi (1999) states that:

> "...an IT-based system developed to support and enhance knowledge management processes of knowledge generation, knowledge codification and knowledge transfer"

Quintas et al. (1997) define the KM system as "the process of continually managing knowledge of all kinds to meet existing and emerging needs, to identify and exploit existing and acquired knowledge assets to develop new opportunities".

KM includes different processes. Generating, codifying and transferring knowledge are the most important processes of KM (Rogers, 1995). Egbu et al. (2001) state that KM is "about the processes by which knowledge is created, captured, stored, shared, transferred, implemented, exploited and measured to meet the needs of an organization". It is also defined by Tiwana as "create new, package and assemble, apply, and reuse and revalidate knowledge" (Tiwana, 2002). In this chapter, ten main categories in the process of knowledge management have been explored.

1.5.1 Knowledge creation

Knowledge creation is the first step in knowledge management processes. Knowledge is dynamic and in today's competitive market, new and innovative knowledge is necessary to increase the efficiency and efficacy of the core business process. This can lead to sustainability of business in future. Knowledge creation is not only the first step in KM, but also has far-reaching implications for subsequent steps in the KM process and it makes knowledge creation an important focus area within KM (Wickramasinghe, 2006). Knowledge creation has been discovered by different theories from three main perspectives including people, processes and technologies (Wickramasinghe, 2006). Moreover, knowledge can be created by people or technologies and can be embedded in processes, and interaction between these components can increase knowledge creation. In trying to create and manage knowledge, it is important to understand the nature of knowledge. As was discussed in Section 1.4, different types of knowledge can exist such as explicit knowledge or tacit knowledge and also objective knowledge or subjective knowledge (Malhotra, 2000). The objective elements of knowledge can be thought of as primarily having an impact on process, while the subjective elements typically impact on innovation (Wickramasinghe, 2006). Knowledge creation theories can be divided into two categories including psycho-social driven theories and procedureic theories. The main theories from the psycho-social perspective are: Nonaka's knowledge spiral, Spender's and Blackler's theories. According to Nonaka's theory, knowledge creation is based on the transfer of existing tacit knowledge to new explicit knowledge and existing explicit knowledge to new tacit knowledge, or the transfer of the subjective form of knowledge to the objective form of knowledge (Nonaka and Nishiguchi, 2001). Figure 1.1 shows the knowledge spiral theory and its different parts.

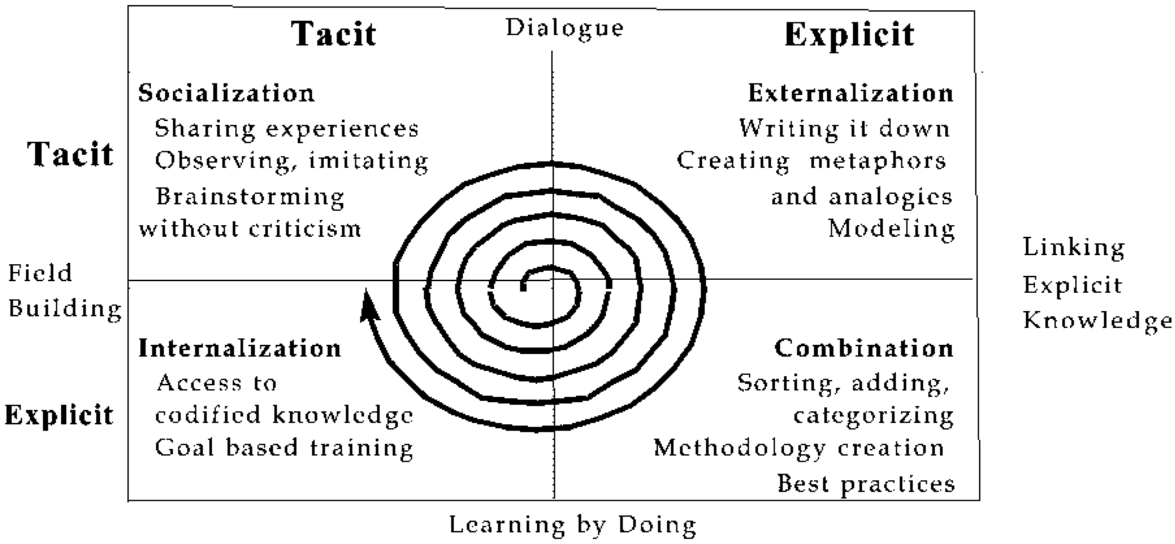

Figure 1.1: Nonaka's spiral of knowledge (Hildreth and Kimble, 2002)

The model depicted in Figure 1.1 includes four modes of socialization, combination, externalization and internalization (Nonaka and Nishiguchi, 2001). In the socialization step, tacit knowledge transfers between individuals. For example, a teacher passes his/her skill to the apprentice. This kind of knowledge can be transferred by observation, imitation and practice. In the next step, externalization is triggered by dialogue or collective reflection and relies on analogy or metaphor to translate tacit knowledge into documents and procedures (Hildreth and Kimble, 2002). Internalization occurs as new explicit knowledge is understood thoroughly and can be used to broaden and extend an individual’s tact knowledge. Lastly, combination occurs in the normal education system with the learning of facts where knowledge is explicit and the learner needs to learn it in an explicit format.

Nonaka's model does not differentiate between individual knowledge and social knowledge and knowledge is categorized by knowledge context. On the other hand, Spender (Spender, 1996) has proposed another theory based on individual and social kinds of knowledge and claimed that each of them can be implicit or explicit (Newell et al., 2002). Also, Blackler's theory (Blackler, 1995) views knowledge creation from an organizational perspective, noting that knowledge can exist as encoded, embedded, embodied, encultured and/or embrained.

In contrast to the psycho-social perspective, the procedureic perspective is more technology-based and knowledge discovery in databases (KDD) plays a main role in knowledge creation. In particular, "the KDD process focuses on how data is transferred into knowledge by identifying valid, novel, potentially useful, and ultimately understandable in data" (Becerra-Fernandez and Sabherval, 2001). From this perspective, knowledge is created by model building, or by finding patterns and relationships in data using various techniques such as clustering, Delphi and system dynamics drawn from the domains of computer science, statistics and mathematics (Cabena et al., 1998). KDD processes are close to data mining processes and they are often used interchangeably. Both of them try to create knowledge by exploring how data is transferred into information and knowledge, and propose patterns for interpreting and evaluating data.

Several other theories are proposed to accelerate knowledge creation. Significant findings show that the collaborative nature of multidisciplinary team members leads to new knowledge creation (Fong, 2006). According to this theory, team members from different domains share their knowledge from different viewpoints to create new knowledge. Communication and interaction between team members is at the core of this theory and team members are from different domains and various disciplines. The theory is based on the notion of boundary crossing and explains that the importance of boundary crossing is reflected in solving the boundary paradox (Quintas et al., 1997). Also, some theories have explored the role of drawing and schematic representation of knowledge for new knowledge creation and to express a new idea. Results of studies carried out by different researchers confirm the positive role of schematic representation of knowledge such as sketch-based geographical query languages (Blaser and Egenhofer, 2000) and sketch- based user interface editors such as SILK (Landay and Myers, 2001).

It is clear then, from knowledge creation theories, that there is a strong relationship between knowledge creation and knowledge sharing. For example, knowledge can be created by sharing knowledge between team members from different knowledge domains. As a result, communication and sharing of knowledge are key issues in knowledge creation.

1.5.2 Knowledge discovery

The volume of information is increasing rapidly and vast amounts of data are produced every day or even by the hour or minute. There is a tsunami of data that is crashing onto the beaches of the civilized world (Wurman, 1996). The tsunami is a wall of data: data produced at greater and greater speed, vaster amounts to store in memory, on tape, on disks, increasingly and faster, and increasingly more (Wurman, 1996).

The task of classifying and extracting useful knowledge from this huge amount of data is becoming impossible to do by manual processes and the manual analysis of large scale data repositories is very difficult, time consuming and expensive.

However, evidently all the produced data is not valuable to business in terms of products, market development, processes, decision-making and other related issues. Organizations need intelligent tools to accumulate and process data and make use of it. These intelligent tools should retrieve the large amount of data from a wide range of sources to help identify relationships and to seek solutions to different problems.

Knowledge discovery is the process of discovering useful information from data in order to provide appropriate information for business decision makers. Figure 1.2 shows the different stages of the knowledge discovery process.

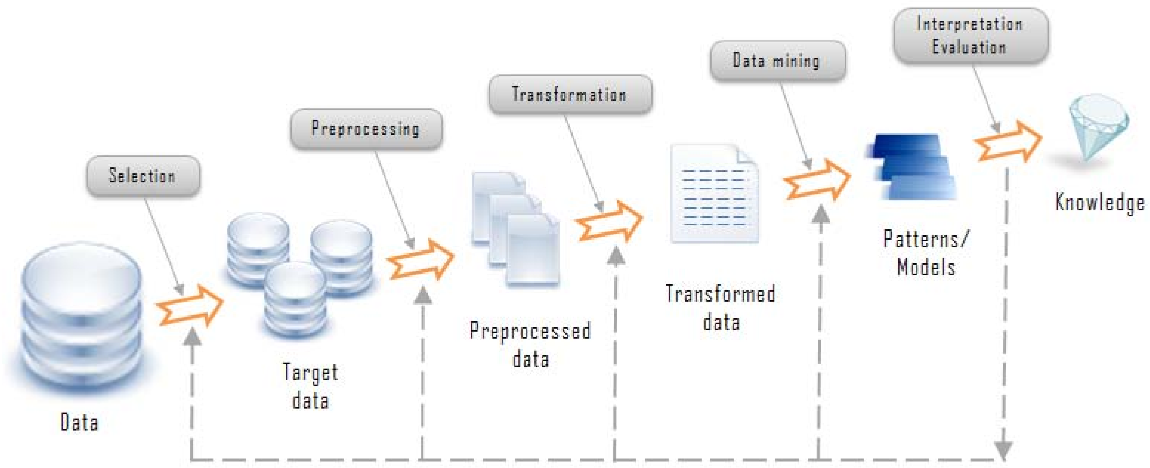

Figure 1.2: Knowledge discovery process (Rithm business intelligent solutions, http://www.rithme.eu/?m=home&p=kdprocess&lang=en)

Figure 1.2 shows that knowledge discovery includes different stages and uses several automated analytical approaches that have been developed in recent years such as data warehousing management, data mining (DM), decision support systems (DSS) and business intelligence (BI). The business intelligence concept is used to simulate a knowledge sharing report system in this thesis. Business intelligence systems enable the analysis and exploration of business information in order to support and improve management decision-making across a broad range of business activities (Elbashir et al., 2008). Nowadays, in competitive business environments, traditional decision-making applications cannot satisfy the requirements of new business environments for effective decision-making and increased productivity. The traditional business ecosystem is going to change to a digital business ecosystem and it is going to change the structure and business elements of the firms. In a digital business ecosystem, decision makers need access to real and on-time data and they cannot limit themselves to analyzing previous data and making a future forecast based on past events. The business world is moving more quickly and becoming more complicated. As a result, the supporting technology is more complex. Also, a huge amount of data is available in the business world and effective applications are required to manage the clutter of data and to answer the needs of decision makers. Business Intelligence (BI) is playing an increasingly important role in business operational analysis and decision support (Inmon, 2002). Business intelligence turns data into meaningful information. It is a business management term, which refers to applications and technologies that are used to gather, provide access to, and analyze data and information about company operations and performance. BI systems refer to an important class of systems for data analysis and reporting that provide managers at various levels of the organization with timely, relevant, and easy to use information, which enables them to make better decisions (Hannula, 2003). BI systems give companies a more comprehensive knowledge of the factors affecting their business such as metrics on sales, production, internal operations, and they can help companies to make better business decisions. If a business intelligence system can be successfully implemented, it can play its expected role in four areas, namely, understanding of business status, measuring the organization's performance, improving stakeholder relationship and creating profitable opportunities (Wang, 2005). BI covers a wide range of tools the main components of which are reporting and predictive analytics. In overall, BI delivers the right information to the right person at the right time (Eckerson, 2005).

Knowledge discovery tools can make knowledge understandable and help individuals to understand and share knowledge faster. Also, business intelligence systems are able to provide effective tools to report the knowledge sharing level between employees to be used in the decision-making process and help managers to obtain a better view of issues in their organization related to knowledge sharing.

1.5.3 Knowledge gathering

Organizations need to acquire knowledge from different knowledge holders to solve their problems. From an internal perspective, most investigation has focused on gathering the knowledge stored within the minds of individual employees (Nidumolu et al., 2001). On the other hand, competitive intelligence(CI) is the process of gathering usable knowledge about the external business environment and, although most information collected during a competitive intelligence investigation is used in immediate decision making, it must be integrated with internal knowledge systems to provide a sustainable resource when companies attempt to detect trends or adapt to changes in their environment (Aware, 2004). Knowledge about the external business environment, and taking into account this kind of information in the decision-making process, is important as internal knowledge resources within organizations. As the competition in a knowledge-based economy is increasing and the business environment is dynamic and change rapidly, it is becoming increasingly important to acquire external knowledge in order to analyze behaviors of market components such as competitors, suppliers and customers.

Competitive intelligence is the activity of monitoring the environment external to the firm for information that is relevant for the decision-making process of the company (Gilad, 1988). It is the process of monitoring the competitive environment that includes, but is not limited to, competitors, customers, suppliers, technology, political and legal arenas, and social and cultural changes (Miller, 2001). CI is a legal attempt to provide information about the environment and is associated with a detailed code of ethics (Richardson and Luchsinger, 2007). Hence, it is not to be confused with espionage which is unlawful and unethical behavior. Hendrick takes ethical issues into consideration in his definition of CI as: “Competitive intelligence means ethically collecting, analyzing, and disseminating accurate, relevant, specific, timely, foresighted, and actionable intelligence regarding the business environment, competitors, and the organization itself” (Hendrick, 1996). Figure 1.3 shows the different stages of CI processes.

Figure 1.3: Competitive Intelligence System (Xavier & Associates Inc., 2010)

CI is not just a process for gathering and analyzing information. It can also be a product. As a product, CI is the set of legal and ethical methods used by decision makers to explore information that helps them to achieve success in a global dynamic environment. From this perspective, "CI provides information about competitors' activities from public and private sources, and its scope is the present and future behaviors of competitors, suppliers, customers, technologies, acquisitions, markets, products, and services, and the general business environment" (Vedder et al., 1999).

In a high-level-of-knowledge-sharing environment, knowledge gathering can be faster and more effective. However, competitive intelligence is usually discussed in terms of gaining knowledge about competitors.

Another interesting issue in knowledge sharing is when competitors do not trust each other enough to share their valuable knowledge and they fear losing their value by sharing their knowledge.

1.5.4 Knowledge calibration

Accurate knowledge is an essential factor in knowledge management. Inaccurate data leads to poor decision-making and data should be refined and calibrated to decrease the probability of error in strategic decisions. Most studies report that people are systematically over-confident about the accuracy of their knowledge and judgment, and over-confidence is considered as a stylized fact of human cognition (Goldsmith and Pillai, 2006). Low confidence in one's own knowledge may be a motivating factor leading to a search for further information in order to validate the prevailing situation (Chaiken et al., 1989). On the other hand, if an individual has a high confidence level in his/her own knowledge, but the knowledge is inaccurate, s/he does not try to acquire new knowledge and any decision will not be accurate. Table 1.1 shows correspondence between accuracy of knowledge and confidence in knowledge:

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">Confidence</td></tr>
<tr><td>High</td><td>Low</td></tr>
<tr><td rowspan="2">Accuracy</td><td>High</td><td>Good calibration</td><td>Poor calibration</td></tr>
<tr><td>Low</td><td>Poor calibration</td><td>Good calibration</td></tr>
</table>

Table1.1: Accuracy-confidence matrix (Goldsmith and Pillai, 2006)

Table 1.1 indicates that when accuracy and confidence are either high or low, calibration is good. Low confidence and low accuracy cause decision makers to recognize their poor knowledge and avoid making a decision based on inaccurate knowledge. Over-confidence or under-confidence leads to poor calibration (Einhorn and Hogarth, 1981) and optimal levels of confidence should be applied. Accuracy is dependent on one's ability or expertise and reflects what one knows. However, confidence reflects what one thinks she/he knows and it is also based on expertise, although other factors, including experience, may influence confidence while leaving accuracy unchanged (Alba and Hutchinson, 2000). Trust can be used to express the level of experience confidence, knowledge confidence and recommendation confidence (Su et al., 2009). Trust plays an important role in knowledge confidence. Trust in data resources and trust in people from whom individuals acquire knowledge are very important in creating confidence. Knowledge that is validated by more effort, or that depends on highly trusted sources, may raise confidence levels. Accuracy and confidence are very important variables in knowledge sharing, and confidence motivates individuals to share knowledge and increases their willingness to share knowledge.

1.5.5 Knowledge integration

The volume of knowledge is rapidly increasing and individuals cannot be professional or expert in all knowledge domains. Due to the characteristics of learning processes, individuals are able to become experts only in fields in which they are actively involved (Lave and Wenger, 1991). As a result, employees within an organization have different experiences, skills and background. Knowledge is dispersed over organization members (Tsoukas, 1996) and multiple disciplines and perspectives are available in an organization. These different disciplines and perspectives should be integrated in order to develop a product or service, and the integration of specialized knowledge that is distributed among individuals is an important task for managers (Carlile, 2002). Knowledge integration is the task of identifying how new and prior knowledge within team members interacts and combines knowledge into a new knowledge set while incorporating this with a deep knowledge of their own disciplines and an appreciation for the relevance and importance of their teammates' knowledge (Wijnhoven, 1999). As seen in Figure 1.4, managers should integrate a wide range of knowledge from different knowledge sources and from different disciplines of an organization to use in their decision-making processes and explore the best strategy to succeed in a business environment.

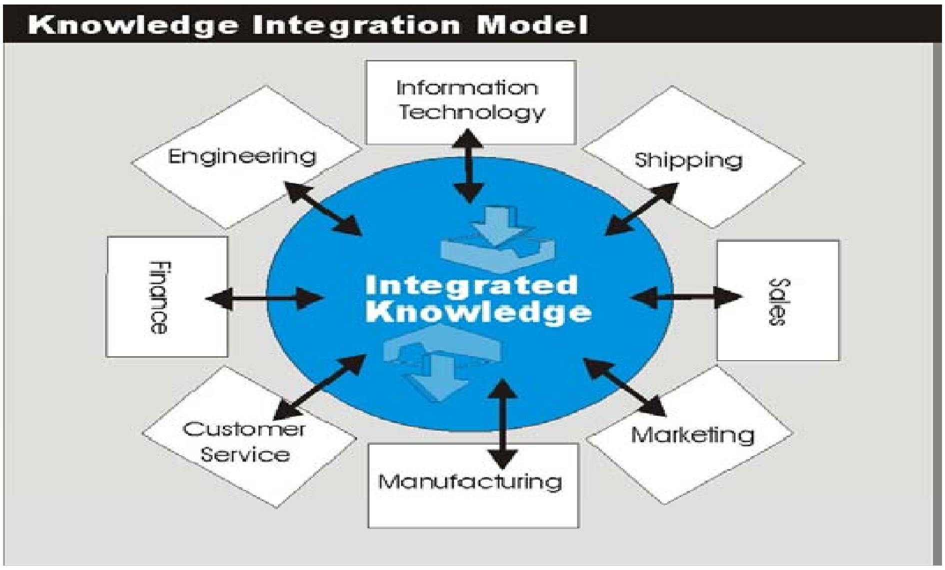

Figure 1.4: Knowledge integration model (Gartner Group, 2006)

Several scholars have proposed different knowledge integration mechanisms and methodologies, some of which include:

1.5.5.1 Sequencing

This mechanism integrates knowledge by assigning a fixed sequence in which the ‘inputs’ into the common process are delivered (Becker, 2003).

1.5.5.2 Decision support system

This is more information technology-based knowledge integration. With this mechanism, specialists embed their codified knowledge in a decision support system and the original knowledge can be integrated in the practice of other specialists (Davenport and Glaser, 2002).

1.5.5.3 Rules and directives

This mechanism is more appropriate for hierarchy-based organizations or when specialists implement rules to guide the behavior of non-specialists. With this mechanism, tasks are not assigned by the system of demand and supply, but by authorized supervisors. The problem is that a hierarchy and its underlying mechanism, authority, in principle is not a good way to integrate specialist knowledge – even although it might be a good way to co-ordinate and integrate labor inputs (Becker, 2003).

1.5.5.4 Thinking along

Thinking along takes place when someone has a problem and others propose solutions, ideas or hypotheses to resolve this specific problem.

1.5.5.5 Group problem solving

This mechanism is based on teams (groups) and interaction between team members. Members from different disciplines and perspectives conduct discussions in order to make a decision or solve a problem.

This type of knowledge management is also related to knowledge sharing where the knowledge receiver gains knowledge from different knowledge senders with different backgrounds and knowledge domains and wants to integrate all the received knowledge and arrive at a common understanding.

1.5.6 Knowledge transfer

Knowledge transfer is a mechanism of knowledge integration that explores transfer of knowledge between specialists from different disciplines and discusses how knowledge receivers from different backgrounds are able to absorb transferred knowledge, combine it with their existing knowledge, and change it to tacit knowledge to improve their skills and experiences and create competitive advantages in an organization. Different variables that affect the transfer of knowledge such as trust, motivation, willingness, competency and other related characteristics are the main concerns of this thesis and the first part of this research focuses on the main variables that affect knowledge transfer between individuals.

Knowledge integration mechanisms differ in the degree of involvement of other organization members and Figure 1.5 shows those mechanisms which need strong involvement from the organization members.

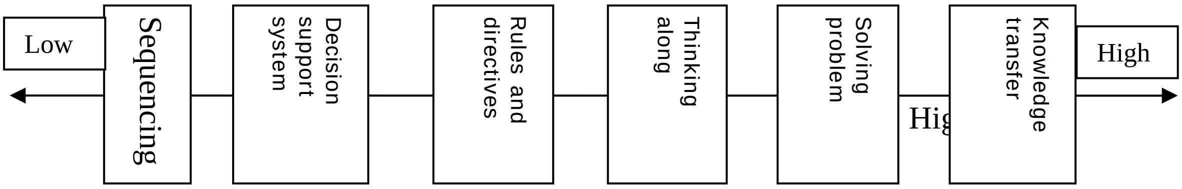

Figure 1.5: Required degree of involvement of other organization members

1.5.7 Knowledge dissemination

The efficient and effective transfer of tacit knowledge such as personal experience, and explicit knowledge such as updated publications to experts and decision makers, can create value and competitive advantage for an organization. However, without the dissemination of this knowledge, the efforts put into knowledge acquisition are wasted. Hence, dissemination of knowledge is just as important as knowledge production. Explicit knowledge can be disseminated more easily than tacit knowledge and there are the methods of classic library science to disseminate well-established knowledge via text books, published papers and so on (Taylor, 2000). Also, official policy and procedures can be disseminated by flowing top-down to individuals through “command and control” processes and this can also be used by certain industries to control processes for special classes of information such as product data, drawing and producing accepted documents (Woods et al., 2006). On the other hand, tacit knowledge is hard to disseminate and it is extremely important to transfer this kind of knowledge through mentoring between technical specialists and target communities.

Dissemination is achievable and successful only if, from the outset, there is a shared vision and common understanding of what one wants to disseminate, together with a way of describing that to those who stand to benefit from it (Ordonez and Serrat, 2009). It is important to define the target audience and explore their interests, disseminate knowledge based on their requirements, make the disseminated knowledge accessible for the audience, and apply it to solve their problems. Also, knowledge should be disseminated with reasonable resource consumption in terms of time and cost. Overall, several variables affect the value of dissemination within a discipline; these include time, concentration/dispersion patterns, target audiences, source options, content (e.g. its accuracy or utility), and channels for knowledge dissemination (Holsapple and Joshi, 2010). Different channels have been used for knowledge dissemination including books, magazines and journals, videos, radio, posters, group meetings and so on. Recently, online knowledge dissemination channels such as E-learning, online chat rooms and numerous web sites related to different domains such as health and science, have become more popular. Online dissemination channels provide an opportunity for organizations to plan lifelong learning at low cost to increase their global competitive advantages.

Several techniques have been proposed to leverage knowledge dissemination. One of the important techniques is using ontology to organize disseminated knowledge in a way that is consonant with the information categories of multiple existing systems (Woods et al., 2006). Ontologies are able to create common understanding in the form of a corporate taxonomy and can be applied to leverage knowledge dissemination by making the disseminated knowledge understandable to all parties. Another technique to leverage knowledge dissemination is by text classifier. An automatic text classifier chooses part of a text memo and determines the category to which that text should be assigned. In this way, produced knowledge can be grouped according to relevant categories and the relationships among categories can also be explored. This helps overcome a substantial obstacle to knowledge dissemination within a large enterprise and basic users can accomplish cataloging tasks without much training, time, or effort, and are therefore more likely to do so (Woods et al., 2006).

1.5.8 Knowledge reuse

The reuse of knowledge is made possible when specific knowledge is transferred from a knowledge holder to a knowledge seeker in order to make use and re-apply the knowledge or design in different contexts (Oshri, 2006). Knowledge reuse processes include capture, storage and retrieval of knowledge in order to use it again. Organizations develop knowledge reusing techniques to exploit internal capabilities and improve the effectiveness of their exploration activities (March, 1999). The effectiveness of knowledge reuse also depends on the effectiveness of knowledge sharing and different types of knowledge such as explicit knowledge or tacit knowledge. For explicit knowledge, documenting, sharing, verifying and retrieving knowledge is easier than for tacit knowledge, and in people-based activities or in informal communication through social networks it can be captured, shared and further reused.

Reuse of knowledge has some advantages for organizations. It can reduce research and development (R&D) costs, increase capability to design and develop new products in shorter time and at lower risk of failure (Nightingale, 2000). It also increases responsiveness to customer needs (Datar et al., 1997). On the other hand, reusing of knowledge has some disadvantages and may adversely affect organizations because of a lack of explorative activities that are crucial for the future development of organizations (March, 1999). Reuse of knowledge can take place between individuals, teams or groups, and organizations, and depends on several issues one of which is the trust between supplier and receiver of the knowledge.

Knowledge sharing is a key issue in providing useful knowledge to all members and helping them to capture and understand the shared knowledge. This can help them to change the explicit shared knowledge to tacit knowledge and reuse it in their daily duties.

1.5.9 Knowledge sharing

As discussed previously, knowledge sharing is a key issue in knowledge management and plays a main role in different processes of knowledge management. In a knowledge-based economy, organizations have been forced to take a step back and re-evaluate their core competencies and ability to innovate and create new organizational knowledge as a valuable strategic asset in a modern business environment (Haghirian, 2003). An organization needs to develop ways to share the created knowledge among employees who need or will need that particular knowledge for their normal duties or for future tasks. Improving the efficiency of knowledge sharing is the main knowledge management challenge of organizations. Effective knowledge sharing leads to a smarter organization. In a smart organization, all tasks are planned, executed, and checked based on updated knowledge including updated strategies, researches and experimental knowledge. Knowledge sharing occurs between individuals within a team or organizational unit and teams can be formal or informal. Also, the sharing of knowledge may be differentiated in terms of the sharing of explicit knowledge and tacit knowledge (Nonaka et al., 1994). Different variables have been discovered by scholars in terms of knowledge sharing management. Levina (2001) identifies the following variables that reduce knowledge sharing: low trust, lack of contextual clues, memory loss, discontinuity in progress toward goals, inability to voice relevant knowledge, unwillingness to listen, differences in unit and culture, specialized languages, national cultures and languages. Similarly, Barson et al. (2000) indicate the variables of trust, risk, fear of exploitation and losing power or resources, costs, technology, culture and rewards. Overall, different variables can be grouped in three categories: social, economic and technological. Social variables relate to social concepts such as trust, culture willingness to share, language. Economic variables such as cost of sharing knowledge, rewards, management support are also important issues. Also, technological variables related to creating networks and easy communications are key issues in knowledge sharing management. Based on these variables different theories have been suggested by scholars to leverage knowledge sharing in an organization. The most important theories are the economic exchange theory and the social exchange theory. From the economic exchange perspective, it is common to view knowledge exchange in terms of economic value. Based on this theory, knowledge transmitter and knowledge receiver can acquire economical benefits from the other party. This perspective emphasizes the importance of motivators such as monetary incentive, promotion, and educational opportunity in shaping knowledge-sharing behavior (Bock et al., 2005). Here, an individual is treated as a rational and self-interested party who may behave in ways to maximize his or her utility (Bock et al., 2005) and minimize costs (Kankanhalli et al., 2005). Unlike the economic exchange theory, the social exchange theory has its foundation in social strong relationships. This theory proposes that individuals believe that the action will be reciprocated at some future time, though the exact time and nature of the reciprocal act is unknown and unimportant (Turnley et al., 2003). The major difference between social and economic exchange theories is that there is no guarantee in social exchange that the cost invested will be returned by sharing knowledge and that individuals believe that the other party will reciprocate as expected. With the social exchange theory, trust is the most important variable and the knowledge sharing level can be determined by the trust level of individuals. However, knowledge sharing as the main process in knowledge management needs to be studied further. In particular, the main concerns of this research are knowledge sharing measurement and the design of an accurate model to numerically measure knowledge sharing.

1.5.10 Knowledge synthesis

Nowadays, organizations are presented with a huge amount of knowledge related to organizational problems or questions. This knowledge has been created by different individuals with different backgrounds and disciplines. Some concepts may be opposite to other concepts and organizations need to produce a final concept that embraces or merges all acceptable concepts of the current knowledge. The systematic combination of different concepts to form a coherent whole knowledge is called 'knowledge synthesis'. Individuals need to synthesize knowledge in order to develop new forms of knowledge from current knowledge that is embedded in others. Two key variables in knowledge synthesis are analyzability and variability. Perrow classifies knowledge into four categories based on analyzability and variability of knowledge. Figure 1.6 shows these subtypes (Perrow, 1970).

		Analyzability	
		High	Low
variability	High	**Engineering**	**Non-routine**
	Low	**Routine**	**Craft**

Figure1.6: Classification schema of knowledge tasks based on Charles Perrow theory (Perrow, 1970)

Routine tasks are easy to synthesise and little search behavior is required to handle it (Vat, 2003). Similarly, engineering tasks are easy to find a solution for and synthesize although a high level of expectations are encountered in engineering tasks. On the other, hand craft tasks require a high level of search activities as well as non-routine tasks that are the most complex in Perrow's classification (Vat, 2003).

Knowledge synthesis is also important in knowledge sharing to determine which kinds of classified knowledge are able to be shared more easily between individuals, and to ascertain the differences between sharing routine knowledge and craft knowledge.

1.5.11 Discussion of knowledge management process

Different processes of knowledge management were examined in order to obtain a better understanding of the role of knowledge sharing in knowledge management. Knowledge creation as the first step in knowledge management, and knowledge discovery as a technique to discover and mine data between huge amounts of data (a tsunami of data), were explored. Then, the different methods of gathering related and necessary knowledge and integrating knowledge from different disciplines were investigated. Individual knowledge should be shared between individuals in order to improve performance and increase productivity. It is not possible for everyone to acquire needed knowledge through personal experience, so an individual needs to obtain knowledge from different knowledge resources and other individuals. The entire process of knowledge management is linked to knowledge sharing and as was discussed in the definitions of different processes, knowledge sharing plays a main role in each of those processes.

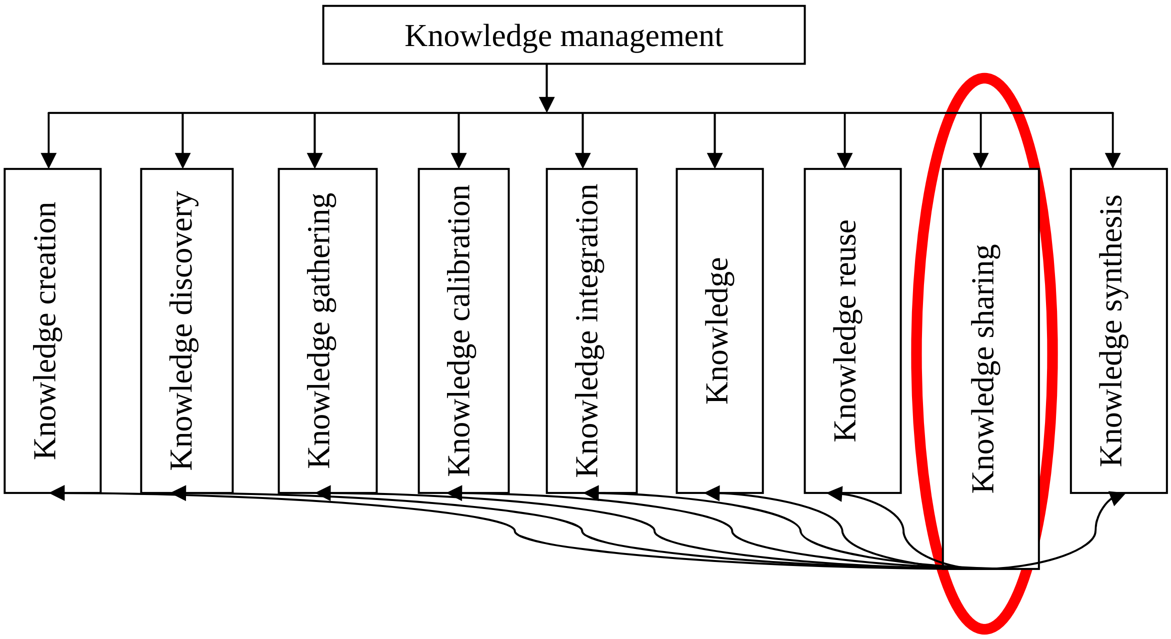

Figure 1.7: Knowledge sharing role in knowledge management processes

As seen in Figure 1.7, different processes of knowledge management are connected with knowledge sharing, and knowledge sharing is one of the key concepts in knowledge management.

1.6 The concerns that need to be addressed in knowledge sharing

With the advent of the Internet and its penetration into every industry and business as well as society, traditional ecosystems are going to be replaced by digital ecosystems. Managers, governments and business owners have understood that knowledge is the only resource that can create competitive advantage and ensure their success in future. Hence, their concerns have emerged in terms of knowledge sharing and in this research; these concerns are classified in four categories:

1. The effect of variables on knowledge sharing effectiveness

2. Knowledge sharing measurement
3. Reporting of knowledge sharing
4. Knowledge-based capital created by knowledge sharing

1.6.1 The effect of variables on knowledge sharing effectiveness

In digital ecosystems, knowledge creates and loses its value rapidly and the main concern is how created knowledge can be disseminated very quickly. As previously discussed, knowledge sharing is one of the most important processes in knowledge management and is fundamental to improving other processes. Also, due to the strong relationship between knowledge sharing and other processes, it can be used as an indicator to evaluate other processes. For example, knowledge creation reduction causes knowledge sharing reduction and the problem can be detected by measuring the knowledge sharing level within a community or an organization.

In digital ecosystems, individuals are free to share their knowledge or keep it to themselves, and no-one can be forced to disclose knowledge without his/her willingness to share it. As a result, a major concern is how to motivate individuals to share their knowledge and which variables are most important to encourage knowledge and idea owners to share their knowledge with others and collaborate in a knowledge-based society.

1.6.2 Knowledge sharing measurement

The following concerns are related to measuring and reporting the level of knowledge sharing within a community or an organization. Pioneer businesses and organizations are concerned with finding ways by which the knowledge sharing level can be measured. Business is going to be more virtualized and in a virtual organization, trust and knowledge sharing are important issues that should be measured and reported to decision makers. Therefore, the measurement and reporting of the knowledge sharing level are the main concerns of this research.

1.6.3 Reporting of knowledge sharing

Decision makers and strategic planners need to be aware of the knowledge flow in their organization or their community. As knowledge is becoming the main resource, effective systems should be put in place to report the current level of knowledge. However, the main concern in reporting knowledge sharing is related to the entity of the variables that affect knowledge sharing. Most of the variables are subjective and may not make sense for decision makers in their decision-making process. Hence, a primary concern is the development of a suitable report system to provide reliable as well as sensible data for decision makers.

1.6.4 Knowledge-based capital created by knowledge sharing

The last concern of this research is related to the knowledge-based capital that is produced by knowledge sharing. Concerns are more related to addressing business requirements in a knowledge-based economy and the best business scenario that organizations need to stress or emphasize the most. Therefore, organizations need to use effective systems to create knowledge capital, measure and report it, maintain and improve it. This is a main concern of business owners in future.

1.7 Motivation for developing a framework for knowledge sharing measurement

Knowledge sharing is becoming more and more important in today's world. Social networks are developing very fast and individuals share their ideas as well as their knowledge with others and gain the shared knowledge from others. Motivations for this research are classified in four main categories including:

1. Improving knowledge sharing
2. Measuring knowledge sharing
3. Managing reporting of knowledge sharing
4. Knowledge capital and knowledge sharing

1.7.1 Improving knowledge sharing

Knowledge needs to flow and be shared in an organization, society or group. The knowledge life cycle in today's world is too short and one of the motivations behind this research is the need to improve the effectiveness of knowledge sharing. This means that knowledge should be broadly disseminated within a short time and at low cost. Effective dissemination of knowledge can help organizations to reduce costs such as training and promotional costs and help them to increase their revenue by sharing new and innovative ideas within their organization. Also, in online knowledge sharing such as social networks, improvement of knowledge sharing can have global effects on human lifestyles and the future world.

1.7.2 Measuring knowledge sharing

Measurement is a key issue in controlling and improving knowledge sharing. Unless the effectiveness of sharing is measured, any barriers to this sharing cannot be detected and removed. As a result, another motivation for this study is related to developing a numeric measurement model for knowledge sharing to measure the knowledge sharing level numerically and also determining the variables that have the most positive impact on knowledge sharing as well as those that have a negative impact.

1.7.3 Managing knowledge sharing reporting

It is necessary for managers to understand the importance of knowledge sharing within their organization and consider this issue in their strategic planning and daily decisions. However, managers need to have an effective report system to provide reliable information about the current level of knowledge sharing within their organization. Also, they need to access a reliable system to measure their effect of their decisions on their employees' knowledge sharing level. The system should not be limited to employees and should be developed for other business components such as customers. For example, managers need to analyze a particular knowledge that is used to promote a new product to their customers, and it is important to know the effectiveness of sharing this particular knowledge with their customers. This is another motivation for the research in this thesis.

1.7.4 Knowledge capital and knowledge sharing

In a knowledge-based economy, knowledge has become a main resource that enables a business to increase its effectiveness and efficiency and increase its competitive advantages. A firm's resources may be both tradable and non-tradable resources (Dierickx and Cool, 1989). Tradable resources such as unskilled labor and raw materials are mobile and can be acquired easily, but non-tradable resources such as specific skills/capabilities, reputation and customer trust are immobile and must be developed and maintained over a period of time (Hunt, 2000). Also, a firm's resources include capital which includes financial capital, physical capital, human capital and organizational capital (Berney, 2002). Financial capital refers to money resources and physical capital includes physical technology, building and land. Human capital refers to the training, experience intelligence and judgment of individuals, while organizational capital includes culture and reputation as well as informal relationships between group members (Berney, 2002). Another classification of resources is defined by Bontis who classified different organizational resources into human capital, structure capital and customer capital (Bontis, 2002). Customer capital refers to the relationship between a firm and its customers. As seen in several definitions of intellectual capital, knowledge is the key issue in different categories of intellectual capital. In human capital, different types of knowledge such as explicit or tacit knowledge play a main role; in organizational capital, sharing knowledge between group members is a key issue. Sullivan defines knowledge management as value creation and intellectual capital management as value extraction, adding that intellectual capital is knowledge that can be converted into benefit (Sullivan, 2000). To sum up, knowledge and management of knowledge becomes part of the organization's intellectual capital. Knowledge management tries to create knowledge and share, reuse or disseminate knowledge within an organization. Intellectual capital management tries to measure the value of knowledge as a resource. Knowledge management is not concerned with the value of produced knowledge. On the other hand, intellectual capital focuses more on the knowledge that can be transferred into value. As knowledge is becoming the main resource in business, traditional capital is going to be replaced by knowledge-based capital. Knowledge can create human capital and individuals can acquire this capital in different ways such as education, on the job training, short term workshops or reading web pages and other knowledge resources. It can also change traditional business processes. For example, in traditional marketing, billboards and posters as advertising tools are important. However, in a knowledge-based economy, new marketing tools such as online marketing, using social networks to design and apply customer-to-customer promotion (words of mouth) are more effective than traditional marketing techniques. Moreover, knowledge-based capital is more important than physical capital nowadays, and one of the motivations for this study is to discover the role of knowledge sharing and trust in creating capital for an organization. Also, this study examines ways by which the produced capital can be measured and reported. The results of this research can be applied in different business domains to measure the effects of knowledge sharing and trust in businesses and ascertain the results of this application in the real world.

1.8 Research objectives

In the previous sections, the motivations for and the concerns of this research were examined. Four main concerns were stated in the last section including the main variables in knowledge sharing, knowledge sharing measurement, reporting of knowledge sharing level, and knowledge capital that is obtained by knowledge sharing. The purpose of this thesis is to address the main concerns in knowledge sharing within a community or an organization. Therefore, this research has four objectives as follows:

Objective 1 - To develop a conceptual framework for knowledge sharing in order to cover the main variables' effect on knowledge sharing. A conceptual framework is proposed in Chapter 4 and the proposed framework is developed in Chapter 7.

Objective 2 - To develop an ontology- and trust-based model to measure knowledge sharing. The trust-based model to measure benevolence and competence to share knowledge is discussed in Chapter 5. An ontology-based model to measure knowledge complexity and knowledge transferability is discussed in Chapter 6. The result of the measurement models are discussed in Chapter 8.

Objective 3 - To develop an effective knowledge sharing report system to provide reliable information about knowledge sharing behavior in a community or an organization. A simulation model is developed in chapter 9 to simulate knowledge sharing behavior.

Objective 4 - To develop a model to calculate and report knowledge capital in an organization. Intellectual capital techniques are used to measure knowledge value within an organization that can be produced by knowledge sharing. These techniques are discussed in Chapter 10.

1.9 Scope of the research

By means of research presented in this thesis we develop a method that enables a member of a community or an organization to share a particular knowledge, and decide whether or not to interact with a specific member by taking into account both the context and the time at which the knowledge sender intends to carry out the interaction.

It is important to note that this thesis focuses only on proposing and verifying a model by which the knowledge sender or knowledge receiver determines whether or not to share or acquire knowledge in an agreed way. However, it is assumed that all engaged parties act based of their willingness and no-one wants to force another deliberately to share or gain a particular knowledge.

1.10 Thesis structure

The thesis is structured as follows:

Chapter 2-

The literature relating to the knowledge sharing concept is thoroughly examined in Chapter 2. In this chapter, the definition of knowledge sharing and current theories and methodologies for knowledge sharing measurement are investigated. The chapter explores the variables that affect knowledge sharing including positive variables that improve knowledge sharing and the negative variables that decrease knowledge sharing. This chapter presents a critical review of current literature pertaining to the variables that affect knowledge sharing. The chapter then examines the measurement models for knowledge sharing presented in the literature. Finally, the chapter examines current systems for reporting knowledge sharing and calculating knowledge capital created by knowledge sharing.

Chapter 3-

Chapter 3 is concerned with the problem definition. Four problems facing knowledge sharing are identified. The first problem is related to the research issue of the numeric variables that affect knowledge sharing. The second problem is related to the research issue of knowledge measurement to arrive at a unified numeric knowledge sharing measurement. The third problem is related to the research issue of designing a report platform to control the variables in knowledge sharing. The fourth problem relates to the research issue of capital produced by knowledge sharing. The initial ideas proposed as possible solutions to these problems are also presented. The solution requirements are also determined including: underlying knowledge representation, knowledge complexity and knowledge transferability measurement, trust measurement and model validation. The chapter concludes with a discussion of possible research approaches and explains the choice of an engineering-based research approach for this study.

Chapter 4-

The proposed solution is outlined in Chapter 4 and here we determine the techniques which support the research issues identified in Chapter 3. These techniques include ontologies to measure complexity and transferability of knowledge, and trust techniques to measure the willingness and competency of individuals to share knowledge. In this chapter we also propose simulation techniques to simulate and design a business intelligence technique to report the measured value of knowledge sharing and trust. Finally, intellectual capital techniques are presented to measure the capital produced by knowledge sharing in a business.

Using these techniques, we illustrate the conceptual framework of the model of knowledge sharing development. The overall strategy of the model for knowledge sharing measurement, which is divided into four principles, is presented. These principles are: conceptual modeling of the ontology-based measurement, trust-based techniques and methods, combination of ontology and trust techniques to measure knowledge sharing, and validation and verification of the proposed framework.

Chapter 5-

Chapter 5 illustrates the trust concept to measure willingness and ability to share knowledge. Trust measurement and trust matrices are discussed in this chapter.

Chapter 6 –

The ontology concept is discussed and used to measure the complexity and transferability of a particular knowledge. An ontology structure is used to measure complexity and is presented in this thesis. Also, ontologies similarity is proposed to measure transferability of a particular knowledge in a specific time slot.

Chapter7-

In this chapter, an ontology and trust-based knowledge sharing model is presented and includes the developed model with all components, flowcharts and relationships between all variables and the research objectives and outcomes.

Chapter 8-

This chapter focuses mainly on the way by which the measured variables can be reported to the decision makers and how a business intelligence model can be developed to create related techniques. In this chapter, a community with four different ontologies (for example an organization with four different departments such as marketing, finance, human resource) is simulated to create a dashboard whereby managers are able to control the related variables.

Chapter 9-

In this chapter, some proof-of-concept experiments and results based on the model are presented. The results are presented in both Fuzzy and Crisp systems. Due to the fuzzy entity of the variables, a fuzzy system is developed to measure knowledge sharing and the result is presented in this chapter. Then, a Java-based program is developed to measure complexity and transferability based on ontology repositories. The results for sample ontologies including software engineering ontology and pizza ontology are presented.

Chapter 10-

This chapter is focused on the knowledge-based capital that trust and knowledge sharing can created for a business. The intellectual capital concept is used to discover the produced assets and the main dimensions of intellectual capital including human, social and market capital. Human capital is related to capital that knowledge sharing and trust can contribute to increasing an individual’s knowledge; social capital is related to value in connections and relationships and role of trust and knowledge sharing in improving the connections; finally, market capital relates to the role of trust and knowledge sharing in creating brand awareness in customers and using customer-to-customer marketing to promote a business.

Chapter 11-

The thesis is concluded with a discussion of the contributions made by this dissertation, and proposes future work. In the proposed future work, we present several ideas which can be developed for real world contexts and online social networks such as Facebook.

1.11 Conclusion

In this chapter, the role of knowledge sharing in knowledge management was explored. Also, some basic definitions of knowledge, information, and data were all examined from a number of approaches and different theories. Different types of knowledge such as tacit knowledge and explicit knowledge, as well as individual knowledge and social knowledge, or commonsense knowledge and expert knowledge, were discussed in detail. It was mentioned that tacit knowledge is uniquely personal and based on individual experience. This type of knowledge cannot be codified. On the other hand, explicit knowledge can be codified and shared easily.

This chapter also has provided an introduction to knowledge sharing and the importance of knowledge sharing in today's world. Knowledge management and different processes of knowledge management were discussed in order to understand the role of knowledge sharing and the relationship between knowledge sharing and other processes.

Chapter 2 focuses on the literature relating to knowledge sharing in order to define in more detail the problems in sharing knowledge. The ways in which the problems are approached is discussed in Chapter 3.

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Chapter 2: Literature Review of Knowledge Sharing

2.1 Overview

Knowledge capital is now commonly discussed as a factor of no less importance than the traditional economic inputs of labor and finance (Forbes, 1997). As a result, organizations need to create, develop and evaluate this capital and over the past two decades knowledge management has become most important in the knowledge-based economy. In most of the knowledge management definitions, knowledge sharing is one of the main stages. Scholars and practitioners in various fields have turned their attention to knowledge management systems (KMS) as a means of sharing knowledge in organizations (Alavi, 1999). Empirical interest has been growing in organizational ability to create new knowledge that derives from organizational knowledge-sharing (KS) processes (Argote et al., 2003). Finding a reasonably comprehensive, empirically grounded, and practically applicable theoretical foundation for developing, exploring, and evaluating knowledge management processes is a challenging task (Cecez-Kecmanovic, 2004). This challenge also exists in knowledge sharing which is key process in knowledge management. This chapter expands on the research objectives that were presented in the first chapter and is divided into five sections based on the research objectives for modeling knowledge sharing. These five different sections are:

1. Knowledge sharing definition
2. Variables in knowledge sharing
3. Knowledge sharing measurement
4. Knowledge sharing reporting
5. Measurement of knowledge-based capital in knowledge sharing

The first section is focused on key definitions of knowledge sharing, and concepts and models to explore, develop and evaluate knowledge sharing. The second section of the literature review explains the barriers to knowledge sharing and the key variables that affect knowledge sharing. The third section examines knowledge sharing measurement approaches to investigate theories, methodologies and different models in knowledge sharing measurement. Knowledge sharing is investigated from three main perspectives: technological, social and economic. From the technological viewpoint, organizations tend to develop effective applications of technological knowledge sharing tools such as ERP systems and document management systems to better coordinate knowledge sharing. Employees in these kinds of organizations force to enter their knowledge into an IT system (Loew et al., 2007) to be shared between other employees, and the knowledge sharing measurement is related to their level of success in updating and sharing knowledge via their IT systems. However, these IT applications and tools do not necessarily motivate employees to share their knowledge or engage in KS processes (Duffy, 2000). The social viewpoint focuses more on people than technology and is based more on social concepts. Here, people share their knowledge because of economic or social benefits. Different theories such as economic exchange theory and social exchange theory are proposed in this viewpoint to measure the level of knowledge sharing between individuals. This chapter explores these theories in detail and examines the different problems that arise with each approach. The social exchange theory is thoroughly explored and different key variables such as trust are identified. Trust, a mutual expectation that partners will not exploit the vulnerabilities created by cooperation (Sako, 1998), has been recognized as an important factor affecting knowledge sharing (Ridings et al., 2002). Similarly, the economic exchange model is discussed and key variables in this model are discussed in detail. To sum up, measurement as a key issue in knowledge sharing is investigated in detail and different methodologies in knowledge sharing measurement are explored.

The fourth section of this chapter is related to the reporting and calculation of the capital that can be created by knowledge sharing. This section is focused on current available systems of reporting and several new approaches to calculating knowledge power as a financial resource in a business. Intellectual capital is a new science in financial management and knowledge is the most important variable in intellectual capital measurement. Works related to different categories of intellectual capital, and a definition of each category as well as the role of knowledge sharing in each category, are examined in the last section of the chapter.

Overall, this chapter defines knowledge sharing, explores different theories concerning knowledge sharing, examines models of knowledge sharing measurement, evaluates reporting systems to show knowledge sharing level within a community or organization and calculates the capital produced by knowledge sharing. These issues are based on the research objectives and of this thesis and lead to the next chapter in defining the research problems.

2.2 Knowledge sharing definition

Knowledge sharing is one of the most critical elements of effective knowledge processing and organizations often face difficulties when trying to encourage knowledge sharing behavior (Saraydar, 2002). It has been estimated that at least $31.5 billion are lost per year by Fortune 500 companies as a result of failing to share knowledge (Babcock, 2004). Knowledge sharing is defined as the process of exchanging knowledge (skills, experience, and understanding) among knowledge holders (Lily Tsui, 2006). It refers to the provision of task information and know-how to help and collaborate with others to solve problems, share ideas, or implement policies or procedures (Cummings, 2004). It is the fundamental means through which employees can contribute to knowledge application, innovation, and ultimately the competitive advantage of the organization (Jackson et al., 2006). Davenport and

Prusak consider knowledge sharing as equivalent to knowledge transfer and sharing amongst members of the organization (Davenport and Prusak, 1998). This can lead organizations to develop skills and competencies and create sustainable competitive advantage. It is important for companies to be able to develop skills and competence, increase value, and sustain competitive advantages due to the innovation that occurs when people share and combine their personal knowledge with that of others (Matzler et al., 2007). The importance of knowledge sharing raises the issue of how organizations can effectively encourage individual knowledge sharing behavior and what factors enable, promote or hinder the sharing of knowledge.

Knowledge sharing has been considered in relation to future reciprocal monetary and non-monetary benefits (Gouldner, 1960). Reciprocal exchange motivates employees to obtain knowledge and cooperate in knowledge exchange processes. By exchanging knowledge over time, employees can obtain valued resources such as knowledge that increases their productivity, not by way of hierarchical authority or contractual obligation, but because the norm of reciprocity is so strongly upheld (Flynn, 2003).

Knowledge sharing can occur in different forms such as written correspondence, face-to-face communications or through networking with other experts, documenting, organizing and capturing knowledge for others (Cummings, 2004). Face-to-face communication is a suitable method for transferring tacit knowledge and written correspondence is an effective method for transmitting explicit knowledge. Based on different types of knowledge and the importance of each type, different strategies can be applied to increase knowledge sharing contribution and encourage community members to share their knowledge with a system instead of keeping it to themselves.

However, knowledge sharing definitions in the literature fail to consider different components of the knowledge sharing process. In other words, the current definitions of knowledge sharing fail to determine the role of knowledge in terms of the knowledge sharing context. An appropriate definition of knowledge sharing would encompass or reflect that knowledge sharing by individual A with individual B originates as a result of their competence and willingness (benevolence) to share knowledge in a given context and at a given point in time. The disadvantages of current definitions can be listed as:

1. Knowledge context is not considered in current definitions of knowledge sharing. Knowledge sharing between two individuals may be different in various knowledge domains and it should be taken into consideration in a knowledge sharing definition.
2. Knowledge sharing level is dynamic and a knowledge sharing definition should address this dynamic entity of knowledge sharing.
3. In current definitions of knowledge sharing, the roles of knowledge sender or receiver in the knowledge sharing process are not addressed.

4. Available knowledge sharing definitions are more focused on knowledge exchange rather than knowledge sharing and do not give a clear understanding and exact meaning of “sharing”. The meaning of ”sharing” in this research is a common understanding of knowledge by all parties that are engaged in the knowledge sharing process.

Knowledge sharing in this research is defined as: the transfer and sharing of a particular knowledge amongst specific members of a community or organization within a specific time slot where the members understand the shared knowledge has a unique meaning.

Knowledge sharing occurs in communication between knowledge sender and knowledge receiver. Hence, it is necessary to study the communication process and understand the process of transmitting a particular knowledge from sender to receiver. Communication is the transmission of a message from a sender to a receiver in a suitable way. Figure 2.1 shows the four key components of the communication process: encoding, transmission channel, decoding, and feedback. Two key factors are the message sender and message receiver.

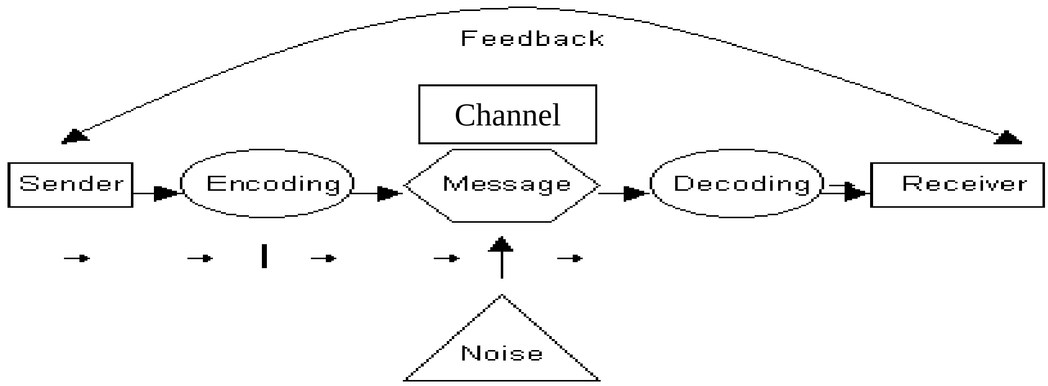

Figure2.1: Communication process (Wanis, 2000)

The communication process begins with the sender and ends with the receiver. The message sender can be an individual, group, team or agents who initiate the communication. This message may be the sender's explicit knowledge, tacit knowledge such as skill, experience, attitude or general information and data. In the first step, the sender needs to encode the message, which means translating information into a message in the form of symbols that represent ideas or concepts (Sanchez, 1995). This process makes the ideas or concepts understandable to others in the form of languages, words, or symbols. In this stage, the sender's belief in the receiver's ability to absorb the message is very important and also it is important that the sender use common symbols that are familiar to the intended receiver. A good way for the sender to improve the encoding of the message is to mentally visualize the communication from the receiver's perspective (Sanchez, 1995).

In the next stage, the sender has to choose a channel to transmit the message. To begin transmitting the message, the sender can use different available oral, written or virtual channels such as telephone, Internet, paper, fax, radio, face-to-face speech and etc. Some of these channels such as face-to-face communication or oral communication like telephone can facilitate feedback and some channels such as written forms like email can be transmitted to a large group of people simultaneously. The communication channel that is selected depends on the purpose of the communication.

Consequently, once the message is received, the receiver examines the message and interprets it according to his or her background and environment. It is the responsibility of the receiver to choose the right code to decode the message and successful communication takes place when the receiver correctly interprets the sender's message.

In the final stage, the receiver responds to the sender and sends feedback to the sender via a different feedback channel such as a spoken comment, a long sigh, a written message, a smile, or some other action. The point of feedback in communication process is that without feedback, the sender cannot confirm that the receiver has interpreted the message correctly and knowledge is shared between communication parties. Feedback can be direct such as a smile, a written message or can be indirect such as performance improvement after receive a particular knowledge.

Successful and effective knowledge sharing depends on improving communication skills through the communication process, and avoiding the various obstacles to communication. These barriers may relate to: the sender’s lack of ability or willingness to share knowledge, issues of encoding or decoding, communication channels and technology, or other problems related to different stages of the communication process as shown in Figure 2.1.

The next part of this chapter explores in detail the main variables that affect knowledge sharing.

2.3 Approaches to knowledge sharing

To improve knowledge sharing effectiveness, different theories from different approaches are proposed. In this section, proposed models are classified into three categories: social-based models, economic-based models and technology-based models. Social-based models are focused on key social issues in knowledge sharing such as culture, trust and the individual's willingness and attitude to sharing knowledge. Economic-based models are focused on the monetary benefits or costs of knowledge sharing. Technology-based models assume that more comfortable and accessible knowledge sharing channels lead individuals to a higher level of knowledge sharing. This section examines these approaches and different models in each approach.

2.3.1 Social approach

Several social theories including social exchange, social capital, social cognitive; network theory, expectancy theories, and theory of reasoned action/theory of planned behavior (TRA/TPB), are reviewed in order to explore the notion of knowledge sharing.

2.3.1.1 Social exchange theory

Social exchange theory is the most popular theory in knowledge sharing management and has become one of the most important social theories.

This theory is based on the premise that human behavior or social interaction is an exchange of activity (Homans, 1961). It also examines the processes of establishing and sustaining reciprocity in social relations, or the mutual gratifications between individuals (Zafirovski, 2005). The theory views interpersonal interactions from cost-benefit interactions but, it also deals with the exchange of intangible social costs and benefits such as friendship rather than monetary benefits or costs. Social exchange theory is similar to economic exchange theory and both assume that an individual's exchange behavior depends on the reciprocal and equivalent rewards gained in return. However, the major difference is that social exchange gives no guarantee that the reciprocal rewards in return will be equivalent to the cost invested (Wu et al., 2006). The persistence and extension of social exchange are conditioned by bonds based on personal trust (Zafirovski, 2005) and not on predefined rules and obligations. Hence, social exchange requires trust and trust is considered to be the key variable in this theory.

Knowledge sharing is an activity that is dependent on the interaction between individuals and within an organization; the amount and quality of interactions between employees defines the success of knowledge sharing. Social exchange theory is used to investigate the amount and quality of interactions between employees and their willingness to share knowledge. Social exchange theory has been used to investigate perceived benefits and costs as well as the effects of organizational justice and trust on knowledge sharing (Wang and Noe, 2010). The generalized social exchange perspective may be useful for investigating the dynamic development of trust as it relates to knowledge sharing (Wang and Noe, 2010). Based on this theory, trust plays a main role in knowledge sharing.

However, this theory has several disadvantages that are listed below.

1. The theory mentions that only trust is an important variable in knowledge sharing and there is no clarification of how trust can affect knowledge sharing. Also, trust is defined in different dimensions and the effect of these different dimensions on knowledge sharing should be studied. Moreover, further research is needed to identify and examine the potential mechanism through which trust may influence knowledge sharing (Mayer and Gavin, 2005).
2. The theory does not mention the importance of knowledge itself in knowledge sharing. For example, knowledge sharing between two members of a team from different cultures or languages is not explored by this theory.
3. The theory does not discover the common meaning of the shared knowledge between members who are engaged in the knowledge sharing process.
4. The theory does not consider the dynamic nature of knowledge sharing.
5. The individual’s ability is not explored by this theory.

2.3.1.2 Social Capital

Social capital theory is based on the idea that social relationships among people can be productive resources (Coleman, 1988). Social capital increases the willingness to share knowledge and accelerate co-operation for mutual benefits. It is defined as “the sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit” (Nahapiet and Ghoshal, 1998). Social capital increases interaction among community members and improves the sharing of knowledge as a valuable resource and helps to disseminate productive and innovative ideas. Social capital is part of an organization’s intellectual capital and has three distinct dimensions: structural, relational and cognitive (Nahapiet and Ghoshal, 1998). The structural dimension explores the overall patterns of connections between actors and is manifested as social interaction ties, the relational dimension defines the kind of personal relationships that people have developed with each other through a history of interactions is manifested as trust, norm of reciprocity and identification, and the last dimension, cognitive, explores those resources providing shared representation, interpretation, and system of meaning among parties and is manifested as shared vision and shared language(Compeau and Higgins, 1995) It is understood by several definitions; social capital is developed over time on the basis of trust in communities. Trust is an important variable in social capital (Leana and Van Buren, 1999) and trust quality has received much attention in knowledge sharing research.

This theory includes some of the positive aspects of the social exchange theory in knowledge representation and unique meaning of the shared knowledge among parties. However, this theory has several disadvantages as listed below.

The theory assumes that social relationships are capital that increases knowledge sharing among members in social interactions. However, how this capital can be calculated is not mentioned.

1. Different dimensions of trust and their role in social interactions are not discovered by applying this theory.
2. Social capital is dynamic and changes over time. Although it is acknowledged that social capital can be developed over time, it may also increase or decrease over time and this fluctuation needs to be further explored.
3. The social capital theory affects other intellectual assets such as human capital and market capital and relations between social capital and other intellectual capital categories need to be further explored.
4. Although the theory has defined knowledge representation and given a unique meaning to the knowledge shared among parties, the role of knowledge itself in knowledge sharing is not clearly defined.
5. Social capital theory thoroughly explains interpersonal relationships but gives less consideration to the personal cognitive perspective.

6. The individual's ability to share knowledge is not determined by this theory.

2.3.1.3 Social cognitive

Although social capital theory explains the interpersonal relationship quite well, it gives less consideration to personal cognitive perspective, which is comprehensively covered by the social cognitive theory (Huang et al., 2009). This theory focuses on a person's cognitions such as expectations and beliefs as the main factors that shape and control that person's behavior. This theory proposes two major personal cognitives that guide people's behavior: self-efficacy and outcome expectations (Compeau and Higgins, 1999). Self- efficacy is defined as" the belief one has about his capability to perform a particular task" (Bandura, 1997) and regarding the knowledge sharing concept, this theory focuses on one's ability to pass along a message which is valuable to people. According to this theory, if individuals were not confident in their ability to share knowledge, then they would be unlikely to perform the behavior, especially when knowledge sharing is voluntary (Bandura, 1982). Outcome expectations is defined as ''a judgment of the likely consequences (one's own) behavior will produce" (Bandura, 1997). With the knowledge sharing concept, different outcome expectations such as image and effective emerge. Image outcome expectations are related to expectations of change in image, status or reputation due to the shared message (Kankanhalli et al., 2005).

Effective outcome expectations are those related to the receivers' effective expressions due to the shared message. Moreover, social cognitive theory is more focused on knowledge senders and receivers and their ability and expectations. However, there are some key issues that are not covered by this theory and several disadvantages are listed below.

1. The theory has ignored the importance of social network influence. This theory is limited in addressing the components of social network impact on knowledge sharing and how they influence an individual's behavior in sharing knowledge(Chiu, 2006).
2. The theory is not focused on knowledge itself to investigate the role of knowledge type in knowledge sharing.
3. The theory does not explore the dynamic nature of knowledge sharing.
4. The theory does not address the role of trust and trust dimensions in knowledge sharing.
5. The theory has not presented solutions to knowledge representation or provides a common meaning of the shared knowledge among parties.

2.3.1.4 Theory of reasoned action/theory of planned behavior (TRA/TPB)

The theory of reasoned action is more focused on the relationship between beliefs and attitude about an object and argues that there are two possible reasons for the failure of predicting behavior from attitude. First, the attitude might be measured inappropriately and second, the behavior under study might be completely or partially unrelated to attitude

(Fishbein, 1967). Two fundamental assumptions are made in the theory of reasoned action. First, human beings are rational and make systematic use of the information available to them. Second, most actions of social relevance are under volitional control and hence, a person's intention to perform or not to perform a behavior is an immediate determinant of the action (Ajzen and Fishbein, 1980). Based on this theory, attitude and subjective norms are derived from beliefs and then turn to behavior. Attitude is a personal determinant of behavioral intention while subjective norms reflect social influence (Ajzen and Fishbein, 1980). The theory of reasoned action has been applied in many research domains such as knowledge management and knowledge sharing. Research outcomes show that personal construct-based factors influence the willingness to share knowledge (Ding et al., 2007). Also, they confirm that trust plays a main role in influencing knowledge sharing in a group (Ma et al., 2008). New findings pertaining to this theory show that the effect of attitude on knowledge sharing is much greater on architects' willingness to share knowledge than are subjective norms (Zhikun and Fungfai, 2009). Individuals care more about their ideas and judgment than others so, it is logical for attitude toward knowledge sharing to outweigh subjective norms. It is more important to build a high level of trust between receiver and sender in knowledge sharing.

It is obvious that several social theories are more focused on sender and receiver in knowledge sharing and discuss individual's willingness to share and obtain knowledge and different social factors such as individual trust, ability trust, subjective norms and cultural issues, individuals' attitude and beliefs and other social factors affect on knowledge sharing in a group or team. However, the disadvantages of this theory are as follows:

1. The importance of knowledge in knowledge sharing is not discovered by this model.
2. The theory has not any defined solutions to knowledge representation and common meaning of the shared knowledge among parties.
3. The theory does not explore the dynamic nature of knowledge sharing.

Overall, some of the theories focus more on interactions and networking to explain knowledge sharing and some theories focus more on individual attitudes and willingness in order to explain knowledge sharing level among parties. However, most of the theories are not related to knowledge itself and important aspects of knowledge such as its complexity in knowledge sharing. Also, the dynamic entity of knowledge sharing is not addressed in the social-based theories.

In the following sections, economic theories related to knowledge sharing are discussed in detail.

2.3.2 Economic approach

The most important theory in the economic approach to knowledge sharing is economic exchange theory, discussed in the next section.

2.3.2.1 Economic exchange theory

This theory is based on the assumption that individuals participate in exchange behavior because of the rewards that they think justify their cost. Hence, if their achievement is less than their cost, they will stop the transaction and, based on this theory, benefits and achievement should be tangible. Unlike a social exchange theory, an economic exchange is not based on trust and involves transaction.

Knowledge sharing can be explained by economic exchange theory. According to this theory, individuals are rational and self-interested, and if the benefits exceed the costs, people may be willing to share knowledge (Constant, 1994). Economic benefits of knowledge sharing are extrinsic rewards such as bonuses, improved payment and job security (Kankanhalli et al., 2005). According to this theory, a reward system can improve knowledge sharing within and between group members. Group members need to expend time and one of the economic costs of knowledge sharing is the time consumed in a sharing transaction (Goh, 2002). The cost can be direct such as the amount of money that individuals spent on sharing knowledge in a restaurant or it can be indirect such as potential loss of value and bargaining power.

The weaknesses of this theory are listed below.

1. It is difficult to place an economic value on all rewards and costs in a social setting and a comparison of rewards and cost is difficult (Kumar et al., 2004).

2. Willingness to share knowledge is limited to monetary incentives where many social factors should be considered in knowledge sharing.
3. Trust is a main issue in knowledge sharing that is not addressed in the economic exchange theory.
4. Knowledge and common understanding of knowledge have not been explained in this theory.
5. Fluctuation in knowledge sharing is explained only by economic variables whereas social variables such as norms can affect this fluctuation.

The theories were discussed from different approaches and based on these theories several of the main variables in knowledge sharing are discussed in the next section.

2.3.3 Critical review of approaches in knowledge sharing (integrated review)

This section reviews the variables related to knowledge sharing based on different stages in communication processes. Accelerating knowledge sharing between individuals is not easy. Senders' willingness to share and integrate their knowledge is one of the main barriers (Lam and Lambermont-Ford, 2010). Individuals from different cultures including both national and organizational cultures commit to different levels of knowledge sharing and their willingness to share knowledge is different. Another issue concerns the motivating of senders to share their new ideas with others. They have spent time and money to create and share knowledge such as writing and publishing created knowledge or posting it to the corporate computer network and etc. Also, loss of knowledge power and future benefits of new ideas may prevent knowledge sharing. Sometimes, the knowledge sender may worry about the misuse of the shared knowledge and this also affects knowledge sharing (Husted and Michailova, 2002). As a result, sufficient incentives and monetary rewards should be used to encourage the sharing of new ideas and knowledge. These issues affect the sender's willingness to share new ideas. Also, the receiver's ability and capacity to absorb shared knowledge and community members' belief in this absorption is categorized as competency to gain knowledge.

Some problems in knowledge sharing relate to communication channels in which technology plays a major role. New technologies in communication management such as Internet technology facilitate knowledge sharing (Newell et al., 2001). However, technology must be implemented with sensitivity to the nature of the work and the nature of its practitioners (Davenport et al., 1996).

Other variables concern the encoding and decoding of shared knowledge in the communication process. Errors in decoding and understanding of shared knowledge (Dixon, 2002), difficulty in decoding shared knowledge due to the language difference(Levina, 2001), inability to decode due to the information overload (Golen et al., 1984) and several other issues are the most significant variables in this category. Table 2.1 shows some of the issues in knowledge sharing based on communication processes.

Category	Study	Issues
Sender	(Blagdon, 1973)	Power and status relationships, Information ownership
	(Golen and Boissoneau,1987)	Low willingness to share knowledge due to poor organization of ideas, position
	(Gupta and Govindarajan, 2000)	Motivational disposition, perceived value of source unit's knowledge
	(Johlke et al., 2000)	Ambiguity regarding ethnical situations, peers, or rewards
	(Lewis and Weigert, 2000)	Communicating goal achievement
Encoding	(Bennet and Gabriel, 1999)	Poor communication skills
	(Hulbert, 1994)	Cultural differences
	(Buckman, 1998)	Culture
Channel	(Westmeyer et al., 1998)	Effectiveness of the channel
	(Weiss, 1999)	Static/dynamic channel
Feedback	(Messmer, 1998)	Improper feedback
Decoding	(Rogers & Roethlisberger, 1991)	Tendency to listen and evaluate
	(Golen & Boissoneau, 1987)	Information overload, inability to understand, differences in perceptions

	(Messmer, 1998)	Passive listening, state of mind
Receiver	(Golen & Boissoneau, 1987)	Lack of credibility, lack of trust, resistant to change
	(Gupta and Govindarajan, 2000)	Absorptive capacity
	(Lewis, 2000)	Establishing legitimacy
Noise	(Blagdon, 1973)	Physical distance
	(Buckman, 1998))	Structural barriers due to hierarchical structure
	(Lewis, 2000)	Creating vision

Table2.1: Knowledge sharing barriers based on communication processes (Lindsey, 2006)

Variables and key issues in knowledge sharing may be due to economic reasons such as lack of time to share knowledge or fear of losing power and information ownership or position. In this case, senders should make sure that sharing knowledge is more beneficial to them than keeping it; also, receivers should believe in the benefits of heeding the shared knowledge.

2.4 Variables in knowledge sharing

In this part of the chapter, variables that affect knowledge sharing are reviewed in detail. Variables are examined from different perspectives: social, economic, and technological. Elements of culture, trust and skills are the main variables discussed in the social approach. Time, budget, management support and required skills are discussed in the economic approach and knowledge sharing channels are discussed in relation to the technology approach. Also, the major variables of common understanding and language are discussed in terms of encoding or decoding a particular knowledge in knowledge sharing.

2.4.1 Cultural elements

Culture is defined as the shared values, beliefs and practices of the people (Schein, 1985) in a particular group, community or organization. People cannot be forced to share their ideas and knowledge and it is necessary to build a culture where people assume that the sharing of ideas is the right thing to do and this approach is understood at a deeper level and becomes a value. Some cultures encourage collectivism while others value individualism. Several different researches have confirmed that employees from collectivistic cultures are more inclined to share their knowledge with others that are employees from individualistic cultures (Michailova and Hutchings, 2006). Also, organizational culture affects knowledge sharing and the benefits of a new technology appear to be limited if long-standing organizational values and practices did not encourage knowledge sharing across units (De Long and Fahey, 2000). Therefore, a knowledge sharing culture needs to be created and nurtured within the organization. Some requirements are needed to create this knowledge sharing culture. The major issue concerns the creation of absorptive capacity and improving the receiver's ability to understand an idea (Cantoni and Chiara Frigerio, 2001).

Cultural differences affect the willingness to seek information from team members. Among a number of cultural factors that influence knowledge sharing, trust is identified as being the most important; hence, it is discussed separately. Research has shown that organizations with cultures that emphasize innovation can facilitate knowledge sharing between employees more efficiently than others (Bock et al., 2005). Also, a learning culture is very important in knowledge sharing. Several studies have confirmed that a climate that encourages new ideas and focuses on learning from failure is positively related to effective knowledge sharing (Taylor and Wright, 2004). Another important element is the norm of reciprocity with research finding that reciprocity to be positively associated with individuals' sharing of knowledge (Wasko and Faraj, 2005). Cultural differences in communication styles (some cultures prefer graphic style while some cultures prefer oral presentation or other styles) can produce tensions and frustrations among individuals. Maximizing team performance and improving knowledge sharing require that individuals find ways to minimize the effects of these differences and establish norms for knowledge sharing that transcend cultural differences. Overall, trust, learning culture, norms that support knowledge sharing, communication style in each culture and willingness to seek information in each culture are the most important elements that encourage knowledge sharing between individuals. Trust is considered as the most important element and is discussed next.

2.4.2 Trust

Of the many cultural dimensions that influence knowledge sharing, trust is the most important dimension and it has been found that a culture that emphasizes trust help alleviate the negative effect of perceived cost of sharing (Kankanhalli et al., 2005). Trust is defined as the belief in, and willingness to depend on, another party (Mayer et al., 1995). ”Trust” has been recognized as being “at the heart of knowledge sharing” (Davenport and Prusak, 1998) and “the gateway to successful relationships” (Wilson and Jantrania, 1993). High levels of trust are the key to effective communications as trust improves the quality of dialogue and discussions (Dodgson, 1993). Trust comprises not only individuals’ beliefs about others, but also their behavior and their willingness to use knowledge to influence future action (Lewis and Weigert, 1985). Trust improves the willingness to share knowledge and willingness is a key issue in knowledge sharing (Connelly and Kelloway, 2003). Individuals with a high level of trust are more interested in sharing useful information and their ideas with others. The quantity and quality of knowledge sharing is directly influenced by the levels of trust among team members (Rosen et al., 2007). Trust is a key variable that leads to an increase in overall knowledge exchange with less cost, and makes knowledge more understandable. As a result, new knowledge acquired from a colleague is sufficiently understood and absorbed and it facilitates the reuse of the new knowledge by individuals (Abrams et al., 2003). Many factors can influence the trust level between individuals. For example, people who meet face-to-face for the first time may have higher trust compared with people who communicate via the Internet or phone. Trust has different dimensions including willingness trust, competency trust, integrity trust and etc. Each dimension of trust has different effects on knowledge sharing.

2.4.3 Skills

In interpersonal and team contexts, willingness to share knowledge depends more on the level of team cohesiveness (Bakker et al., 2006) and diversity of team members (Ojha, 2005). On the other hand, the diversity of a team may cause difficulties when team members with different backgrounds and skills try to share knowledge. Staff members with different skills and at different levels of the organizational hierarchy often struggle to share knowledge. If skills differ significantly in regards to specialist areas and/or in regards to levels, it may hamper the processes and tools through which knowledge is shared within and between levels (Du Plessis, 2008). It has been concluded by several researches that the ability and competency to share knowledge and to send or receive knowledge is the most critical issue in knowledge sharing (Jap, 2001). Also, team members should believe in other team members' ability to share or absorb knowledge. This is the competency dimension of trust mentioned previously and plays a key role in knowledge sharing. The reason is that competency trust refers to how the partner is expected to perform, or does perform, and is the underlying function of the relationship (Heffernan, 2004). Competency trust refers to whether a partner has the capability and expertise to undertake the purpose of relationship and meet the obligations of the relationship (doney and Cannon, 1997).

Most of the variables that were examined in this section were related to sender and receiver in the communication process. Variables such as cultural elements, trust, competency, willingness, skills and etc., are more related to sender or receiver of the knowledge. However, some variables are related to economic theories such as individual benefits, fear of power losses, management support, cost and time of knowledge sharing.

2.4.4 Management supports

Managers play a major role in facilitating knowledge sharing by creating a suitable environment in which employees feel safe to share ideas and offer constructive criticism. In the long term, this can create a knowledge sharing culture in an organization and affect the other related variables such as trust between employees. Different researches show that management support affects both the level and quality of knowledge sharing by influencing employee willingness to make a commitment (Lin, 2007). Moreover, in the organizational context, willingness to share knowledge can be improved by management support, rewards and incentives and organizational structure (Wang and Noe, 2009). It has been noted by researchers that management support specific to knowledge sharing can be used to predict employees' knowledge sharing behavior and supervisory control is a significant predictor of individual effort which was related to the frequency of knowledge sharing (King and Marks, 2008). It is also very important that employees believe in their manager's ability to absorb their shared ideas and believe in the manager's skills and expertise to understand the knowledge that they want to share. This is considered to be competency trust between employees and managers and is explored in detail in the next chapter. Liao (2008) argues that rewards for desired behavior and the employees' belief that the manager has knowledge and expertise in the area (i.e., expert power) were positively related to employees' self-reported knowledge sharing.

2.4.5 Time, Budget, Constraints and Competing Deadline Pressures

Obviously, resources such as time and budget are finite. Moreover, knowledge sharing consumes a certain amount of cost and time. Hence, variables that affect knowledge sharing are not limited to social and individual variables and time as well as cost should be considered in any knowledge sharing concept. Team members have limited time and availability to share and/or process all of the information they receive (Rosen et al., 2007). In most communications, each individual member can only share knowledge with another member at a given time and managers seek optimized solutions to maximize overall knowledge sharing level of their organization based on their limited time. Several researchers have proposed mathematical equations to maximize knowledge sharing between community members within a limited time (Ting Huang et al., 2004). Budget constraint is also important in knowledge sharing. Knowledge sharing costs may be direct or indirect. Direct costs are the costs incurred when people spend time and effort sharing particular knowledge in a particular place. For example, conference cost to share knowledge, meeting cost in a restaurant, coffee shop and etc. Indirect cost such as opportunity cost relates to the benefits that people lose during the sharing time. For example, the money that they could be earning by doing other jobs rather than sharing knowledge is considered as an indirect cost.

2.4.6 Fear of losing knowledge value

Knowledge can be considered as a source of power and superiority (Gupta and Govindarajan, 2000) and produces benefits for the knowledge owner. In many cases, individuals are not interested in sharing their unique knowledge due to a fear of losing their advantage in having that particular knowledge compared to others. The willingness of individuals to share their knowledge from the power perspective is very important. It is also argued that although individuals may refrain from sharing knowledge for fear of losing power, it is also feasible that individuals can increase their expert and referent power by sharing knowledge (Wang and Noe, 2010). Based on this idea, individuals are more likely to share their ideas with someone in a higher position such as their mentor or supervisor than their peer colleagues or co-workers. However, based on different theories such as social exchange and economic exchange theories, individuals evaluate the benefits such as monetary benefits or social credit benefits such as increasing the likelihood of receiving personal recognition and the cost of losing their knowledge and decide to share their unique knowledge or to keep it to themselves.

Also, in the literature there are several variables related to encoding/decoding that can affect knowledge sharing. Encoding and decoding of knowledge are major variables in knowledge sharing. It is very important that sender and receiver encode and decode knowledge in a common way for other party. This can be relevant to the type of knowledge such as explicit or tacit knowledge or the nature of that particular knowledge. Knowledge sharing depends on the nature, definition and properties of knowledge, which influence how easily knowledge can be shared and accumulated (Argote et al., 2003). In general, knowledge can be classified as explicit or tacit knowledge according to the ease with which people can share it with others (Nonaka, 1994; Nonaka and Takeuchi, 1995). Explicit knowledge consists of facts, rules, and policies that can be expressed and codified in writing or symbols and can be easily shared (Zander and Kogut, 1995). As a result, individuals encode/decode explicit knowledge easier than other types. However, most knowledge is tacit and cannot be codified. This is a key issue in knowledge sharing and shows that high level of encoding/decoding requires knowledge senders to use more explicit knowledge and change tacit knowledge to explicit as much as they can in order to increase effectiveness of knowledge sharing. Also, according to the economic value of knowledge, knowledge can be classified as either general or specific knowledge (Becella-Fernandez et al., 2004). General knowledge is held by a large number of individuals and can easily be codified and shared but, specific knowledge is possessed by a very limited numbers of individuals and is not easily shared (Yang and Wu, 2008).

Specific knowledge may be technical or contextual and includes the knowledge of tools and techniques for addressing problems in a particular area such as medicine or engineering (Yang and Wu, 2008). Language and shared understanding of knowledge are explored in the literature.

2.4.7 Language

Due to the globalization and new communication technologies such as the Internet, knowledge sharing between individuals from different countries and different languages has become significant a global issue. Many globalized organizations employ staff from different countries and their staff lives in many regions of the world and speak many different languages. Language plays a crucial role in communication between employees (Plessis and Boon, 2004). Some languages, especially in traditional cultures, are based more on oral communication; they use more tacit knowledge in their communication and knowledge sharing occurs in face-to-face oral conversation (Du Plessis, 2008). In this case, it would be very difficult to decode the shared knowledge, if the receiver speaks another language.

2.4.8 Common understanding of the shared knowledge

It is very important, especially in large organizations whose members come from a variety of backgrounds, skills and cultures, that individuals have a common understanding of the shared knowledge (Lang, 2001). It cannot be taken for granted that when people talk about a particular topic, they mean the same thing or have the same concept in mind (Mason and Pauleen, 2003). The shared knowledge should be understandable for individuals who are seeking shared knowledge and they should be clear about the sender's meaning. It is common for people from different backgrounds and cultures to use symbols and words with different meanings, thereby producing misunderstanding and miscommunication between knowledge sharing parties.

Choosing a suitable and effective channel to send a message and sharing the particular knowledge is the last step in knowledge sharing. In a traditional community, face-to-face oral communication is the most common way to send a message and share the ideas. However, noticeable development in communication technology has created numerous communication channels such as telephone, email, voice chat, Video conference and etc. Individuals have many options from which to choose their communication channels to share their knowledge more efficiently. In this section, the role of technology in knowledge sharing is examined.

2.4.9 Knowledge sharing channel and technology-related variables

Technology plays an important role in knowledge sharing. Educating people to learn about new channels in communication is a challenge. Skills and behaviors that need to be acquired include filtering information overload, reading and note taking, analysis and synthesis, making effective decisions as well as knowledge communication skills (Dawson, 2000). It is very important to provide the ''right'' communication technology that is simple, user friendly and accessible to all members within a team or community. Organizations can use technology to encourage their employees to share their ideas and comments. For example, an internal website can be developed to gather the ideas, or different electronic chat rooms can be developed to facilitate brain storming between employees and help managers to reach on a right decision. This can also help employees to become familiar with more colleagues and co-workers and know more about their skills and their personalities which, in the long term, can increase the level of trust between employees. On the other hand, using and updating technology can be very expensive. New instruments as well as updated software can be a significant issue in using technology in knowledge sharing management. Technology develops rapidly and organizations need to invest in new technologies that facilitate knowledge sharing.

2.4.10 Critical review of variables in knowledge sharing (integrated review)

The most important variables that affect knowledge sharing were investigated from different viewpoints. Regarding the different stages of communication processes, there are some problems associated with variables in knowledge sharing that are not addressed in the literature. The key problems of the variables related to sender or receiver of the shared knowledge in the social domain are listed below.

1. Current studies are more focused on validating the relationship between the variables and knowledge sharing. However, the way that these variables affect knowledge sharing and formulas for determining the relations between them are not detected in the literature.

2. Trust as an important variable in knowledge sharing is discussed in the literature. However, the way that trust and trust dimensions affect knowledge sharing is not clarified.
3. Culture was found to be an important variable in the willingness of an individual to share knowledge. However, it is not clarified how culture affects the receiver's willingness to acquire new knowledge as well. Also, the relationship between culture and one's willingness to share knowledge at a significant level is not discussed in the literature.
4. Skill and competence to share knowledge are considered as crucial variables in knowledge sharing. On the other hand, the role of competence in acquiring knowledge, and the relationship between the competence of the receiver and sender in the knowledge sharing process is not discussed in the literature.
5. The dynamic nature of variables affecting knowledge sharing is not considered in the current works.

Also, the problems that are associated with variables affecting knowledge sharing from the economic perspective are listed below.

6. It is difficult to place an economic value on all variables. For example, it is difficult to measure the value that the knowledge sender loses by sharing knowledge.
7. Variables are dynamic and should be discussed in dynamic systems. For example, fear of losing knowledge is dynamic and is different at different times.

8. The competence of both knowledge sender and receiver is important in economic variables. For example, the time and budget that knowledge sender uses to share knowledge or the time and budget that the knowledge receiver spends on gaining knowledge varies from person to person and this issue is not addressed in the literature.

Another important stage in the communication process is the encoding or decoding of the shared knowledge. The common way to encode or decode a particular knowledge is by using language tools that are assumed as a main variable in the literature. Some of the problems that are associated with encoding or decoding variables are listed below.

1. There is no numeric variable in current works for measuring the complexity of a particular knowledge.
2. Common understanding of knowledge is dynamic and changes based on knowledge complexity and also differ from person to person. This dynamic nature of variables related to common understanding is not addressed in the literature.
3. Language makes knowledge more transferable. However, transferability of a particular knowledge is not adequately examined in the literature.
4. Although the variables indicate the importance of knowledge representation and common meaning of the shared knowledge among parties in knowledge sharing, the role of knowledge itself in knowledge sharing is not addressed in the literature.

Based on the above discussion, Table 2.2 presents a summary of the problems related to variables definition in knowledge sharing.

Category		Variable	Issues
Sender/ Receiver	Social based theories	Culture	The way that this variable affects knowledge sharing and related formulas to define the relations between them. Clarify how culture improves receiver's willingness to gain new knowledge. Relations between culture and willingness to share knowledge. Dynamic nature of variable.
		Trust	Trust dimensions effect on knowledge sharing. Dynamic nature of trust. Formulate the relations between trust and knowledge sharing
		Required skills	Role of competence to gain knowledge. Formulate the relationship between competence of receiver and sender with knowledge sharing. Dynamic nature of required skills to different knowledge.
	Economic	Management	Place economic value on the variable.

	based theories	supports	Dynamic entity of the variable.
		Time &Budget	Role of competence in required time and budget. Dynamic entity of the variable.
		Loose value of knowledge	Place economic value on the variable. Dynamic entity of the variable. Individual’s personality.
Encoding/decoding		Language	No numeric variable to measure transferability of a particular knowledge. Relations between language and competency of knowledge sharing parties and formulate the relations.
		Common understanding	No numeric variable to measure transferability of a particular knowledge. Role of knowledge itself in knowledge sharing. Dynamic nature of common understanding related variables.
Channel		Common technology	Choose right communication channel based on competency. Increase transferability of knowledge. Reduce complexity of knowledge.

		Develop methodologies in common understanding of the shared knowledge. Lack of technology to collect, index, store and distribute explicit knowledge electronically and seamlessly to where and when knowledge is needed (Ryan and Prybutok, 2001)

Table 2.2: Effect of variables on knowledge sharing based on communication process

Based on the variables discussed in this section, some measurement models are explored in the literature that are proposed as different models to measure the level of knowledge sharing from the social and economic perspectives. In the next part of the chapter, models related to knowledge sharing are studied.

2.5 Knowledge sharing measurement

Measurement of knowledge sharing is a crucial issue and it is becoming increasingly important to have an effective model to measure knowledge sharing level as knowledge sharing is becoming a key issue in knowledge management. In this section, different models and measurement tools for knowledge sharing are discussed and the variables or issues that are not covered by these current models are examined. However, there are a few special measures for knowledge sharing because it is not easy to formulate knowledge sharing activities (Du.R and Ren, 2007).

Most of the knowledge sharing measurement models have proposed different frameworks to show which variables affect knowledge sharing.

These models are based on hypotheses and seek relationships between their proposed variables and knowledge sharing. Some of these frameworks are investigated in this chapter. Some of the knowledge sharing measurement models have proposed metric tools to evaluate the importance of each variable in knowledge sharing and measure knowledge sharing fluctuation based on dynamicity of variables. Some of these models are examined in this chapter. And the last group of models in knowledge sharing measurement involves mathematical formulas and equations to show the exact relationships between different variables and knowledge sharing.

2.5.1 Non-numeric measurement models

Most of the proposed frameworks for knowledge sharing measurement are based on social theories. They propose variables that affect knowledge sharing and validate the relationship between these variables and knowledge sharing by formulating a hypothesis.

As discussed previously, social theories are established from social perspective and the variables are therefore more closely related to social issues. Figure 2.2 shows the variables in the theory of reasoned action.

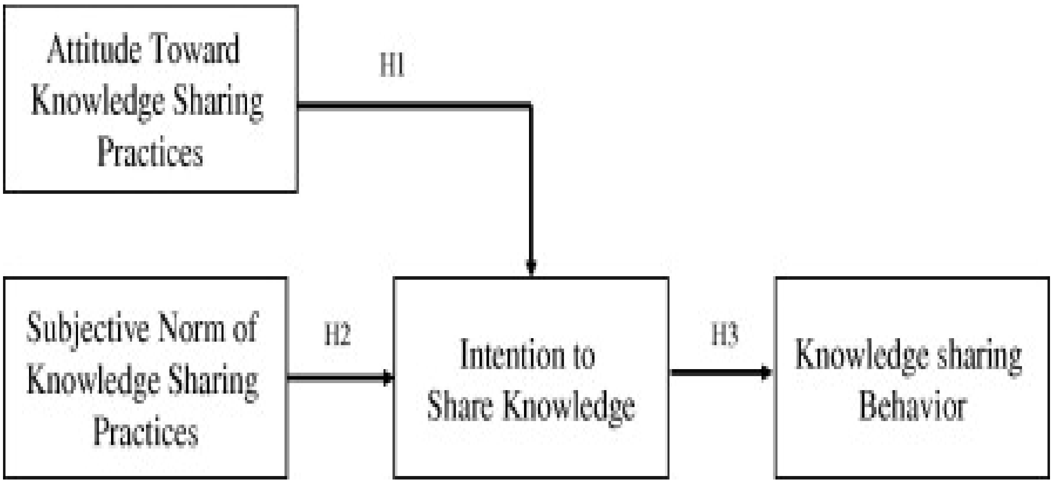

Figure 2.2 Variables in the theory of reasoned action (Kuo and Young, 2008).

As depicted in Figure 2.2, two main variables in this theory are: attitude and subjective norms. Attitude represents a psychological object such as good–bad, harmful–beneficial, pleasant–unpleasant, and likeable–unlikeable, while the subjective norms are defined as the perceived social pressure to perform or not perform the behavior in question (Kuo and Young, 2008). These two main variables indicate a strong intention to share knowledge.

Another theory is the theory of planned behavior.

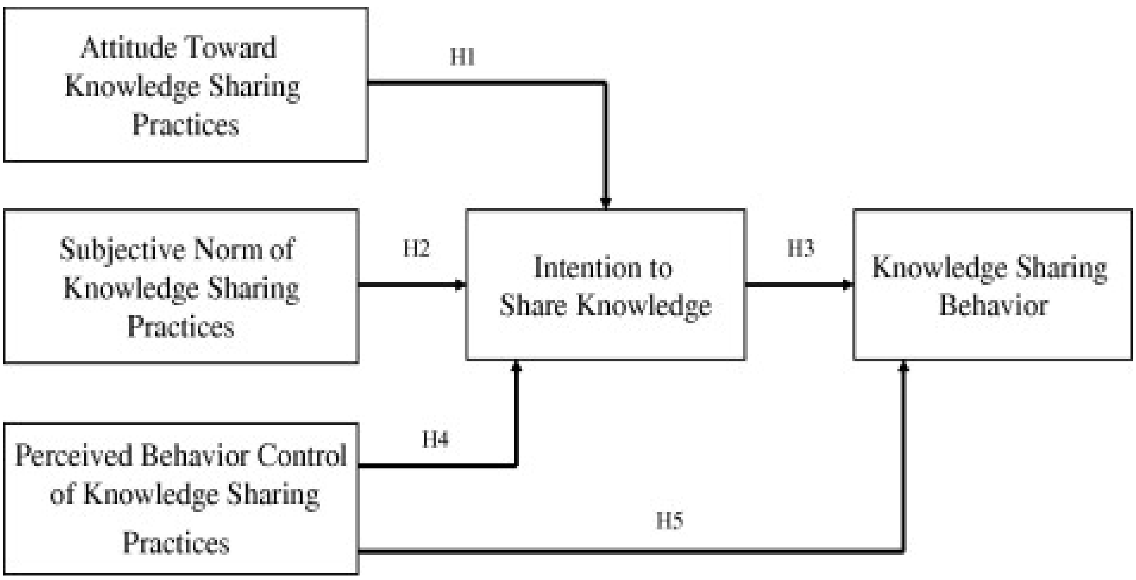

Figure 2.3: Variables in the theory of planned behavior (Ajzen, 1985)

As seen in Figure 2.3, variables in this theory are: attitude, subjective norms and perceived behavior control. Perceived behavioral control (PBC) refers to the difficulty of performing the behavior and the amount of control one has over the achievement of personal goals; this variable pertains to situations in which people may lack complete volitional control over the behavior (Ajzen, 1991). These three variables improve the individual's intention to share knowledge. These three variables were increased to four variables in the revised version of this theory as can be seen in Figure 2.4.

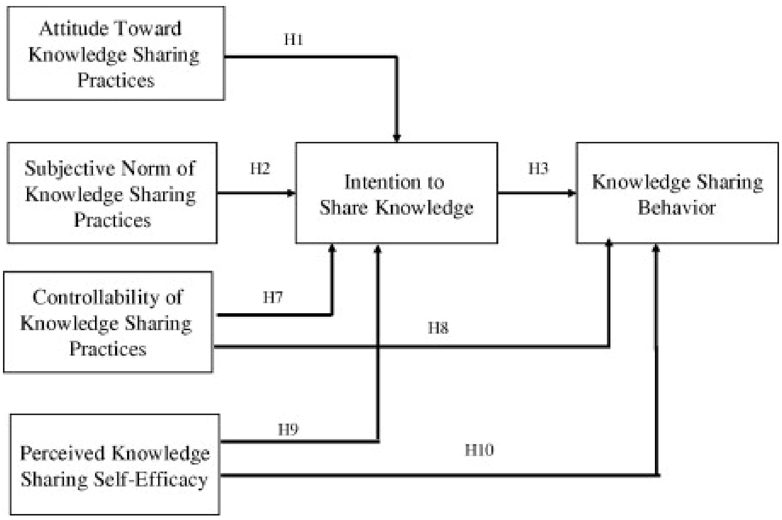

Figure 2.4: Revised version of the theory of planned behavior (Ajzen, 2002)

Figure 2.4 shows that self-efficacy is the fourth variable in the revised version of planned behavior theory. Perceived self-efficacy is defined as "people's judgment of their own capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986).

Further studies have shown that most of the variables in the mentioned theories are influenced by another key variable and this variable is trust. As shown in Figure 2.5, there is a crucial relationship between trust and variables related to personal perceptions. Therefore, knowledge sharing can be facilitated by improving trust between individuals.

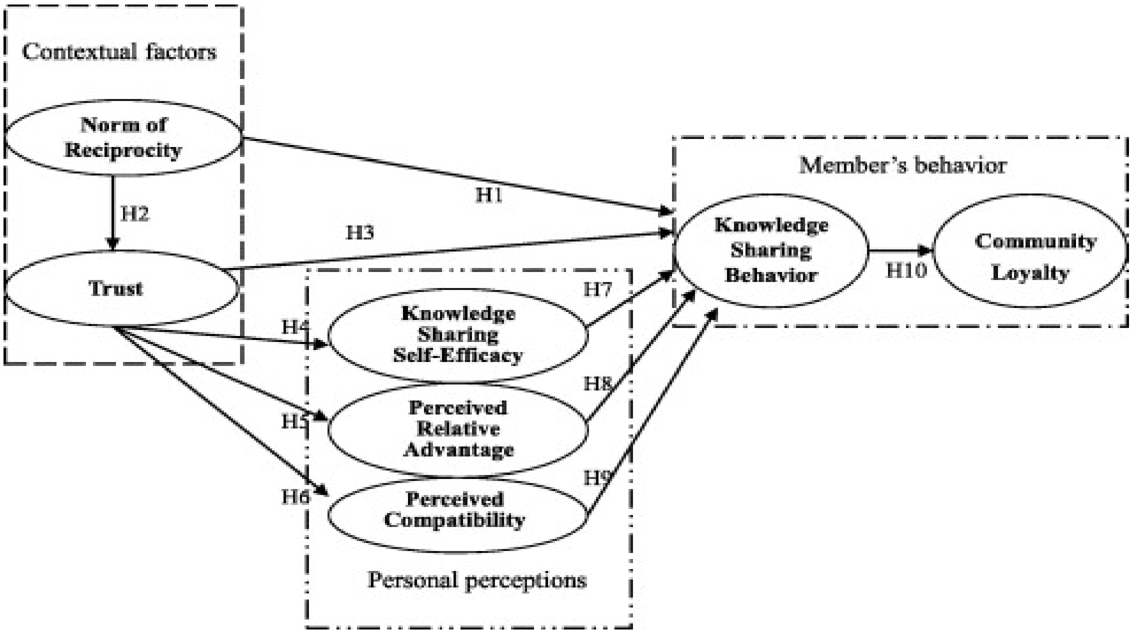

Figure 2.5: Role of trust in knowledge sharing measurement models (James Lin et al., 2009)

The idea that trust is a major variable in the creation of knowledge sharing behavior is supported by other studies and research outcomes. As indicated in Figure 2.6, social trust can improve attitude toward knowledge sharing as well as subjective norms.

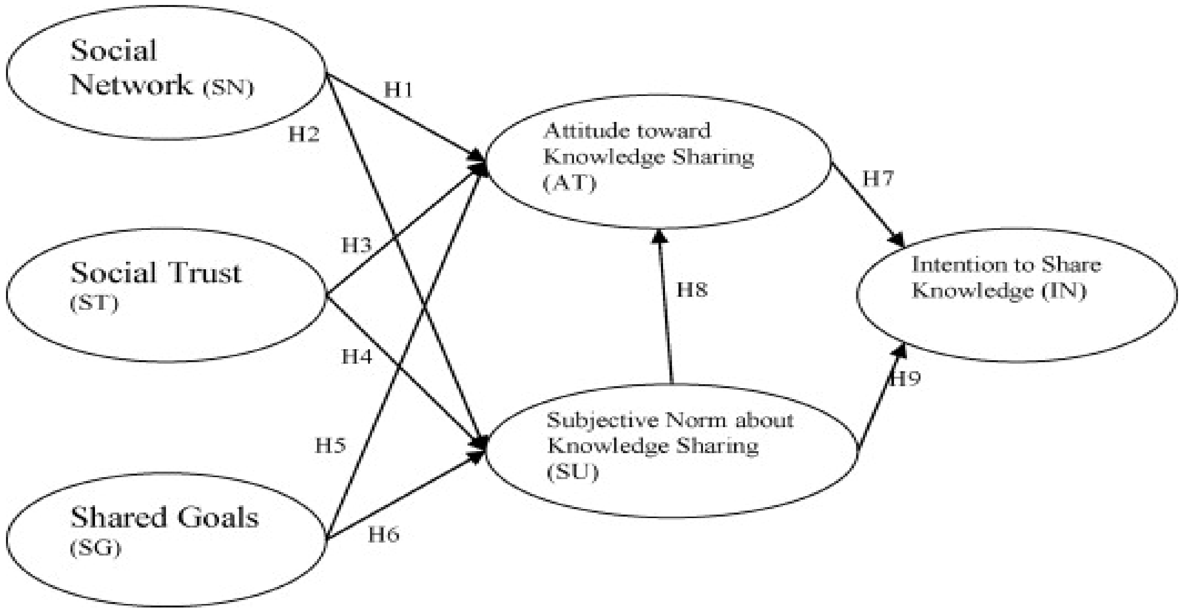

Figure 2.6: Trust and intention to share knowledge (Chow and Chan, 2008)

Nowadays, trust is accepted as a major variable and in most of the recent studies it is assumed as one of the variables in knowledge sharing measurement. Different frameworks are proposed in which trust plays a main role in knowledge sharing. One of these frameworks has been proposed by Wang. This model classified variables into 3 categories including environmental, individual characteristics and motivational variables. As evident from Figure 2.5, variables are also divided into indirect and direct variables influencing knowledge sharing. Environmental factors are divided into three sub-sections: organizational context, interpersonal and team characteristics and cultural characteristics. These factors are more related to the environment of an organization to which the sender and receiver of a specific knowledge belong, and it is defined by social behavior. These factors cannot be controlled by individuals but they can have an influence on individuals' knowledge sharing. Some of these variables are related to hierarchy of organizations such as rewards, management supports, leadership characteristics etc. Some relate to all of the people who are working in that environment and include the ability of co-workers to create a team, share knowledge between team members and develop their relations to produce a strong social network.

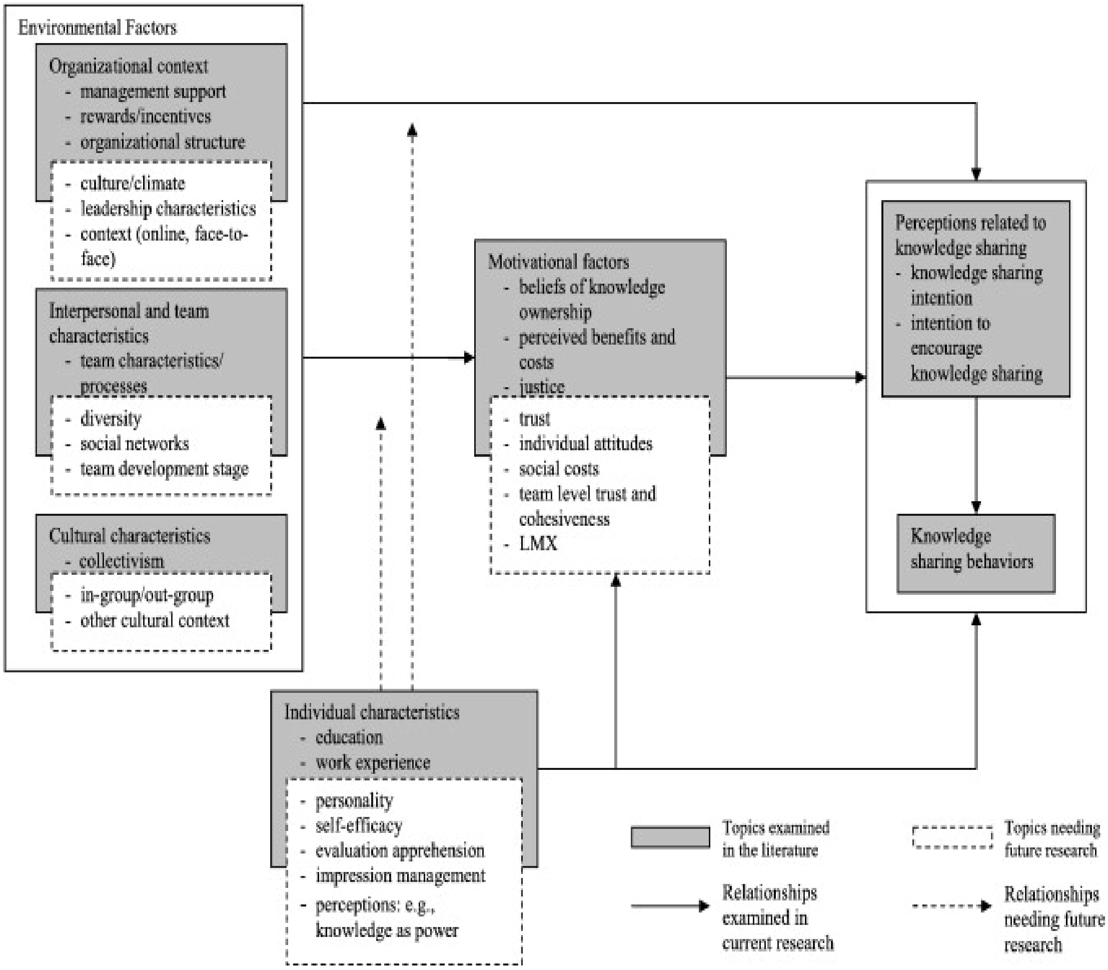

Figure 2.7: A framework showing influence of variables on knowledge sharing

(Wang and Noe, 2010)

Figure 2.7 demonstrates that individual characteristics such as self-efficacy, personality, work experience, education and etc. are important variables in knowledge sharing measurement. Finally, variables such as perceived benefits, trust, individual attitude etc., are motivational factors that affect knowledge sharing between individuals. Trust is the variable that is assumed in this model and needs further research.

A trust issue that deserves more attention is the role of the trust dimensions in knowledge sharing. Trust has different dimensions such as willingness trust, competency trust, integrity trust etc. and their roles need to be further explored. Some initial models are proposed to find the relationship between knowledge sharing and trust dimensions. As shown in Figure 2.8, benevolence- and competence-based trust are the variables that affect knowledge contribution.

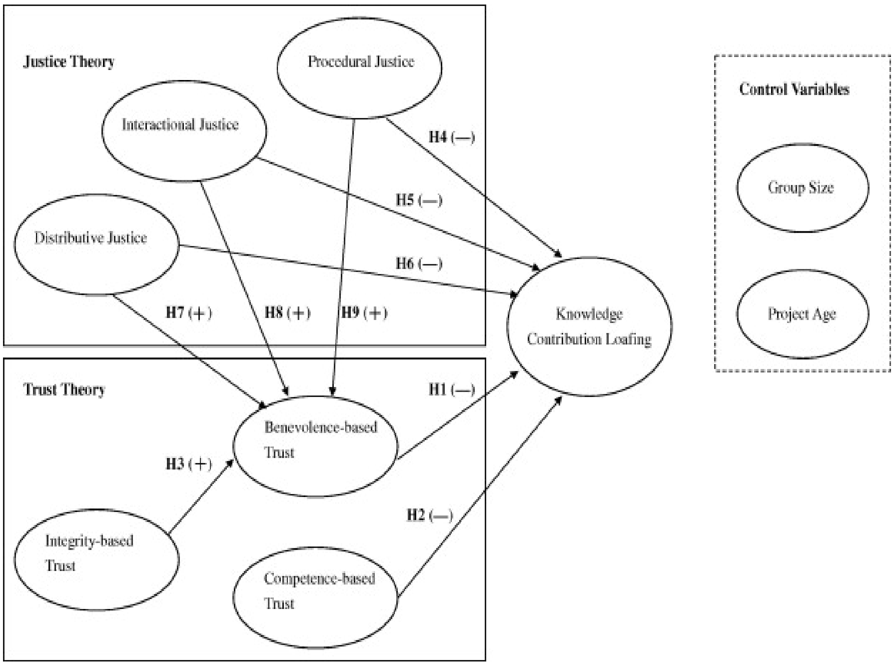

Figure 2.8: Trust dimensions' roles in knowledge contribution (Lin and Huang, 2009)

The role of trust dimensions in knowledge sharing measurement is an important consideration in knowledge management. As shown in Figure 2.9, ability and benevolence are two key dimensions. Ability refers to the skills or competencies that enable an individual to have influence in a certain area, and benevolence is the expectation that others (i.e. trusted parties) will have a positive orientation or a desire to do good to the trustee (Ridings et al., 2002). It is also accepted that without positive reciprocation that is related to benevolence of members, a community would not exist.

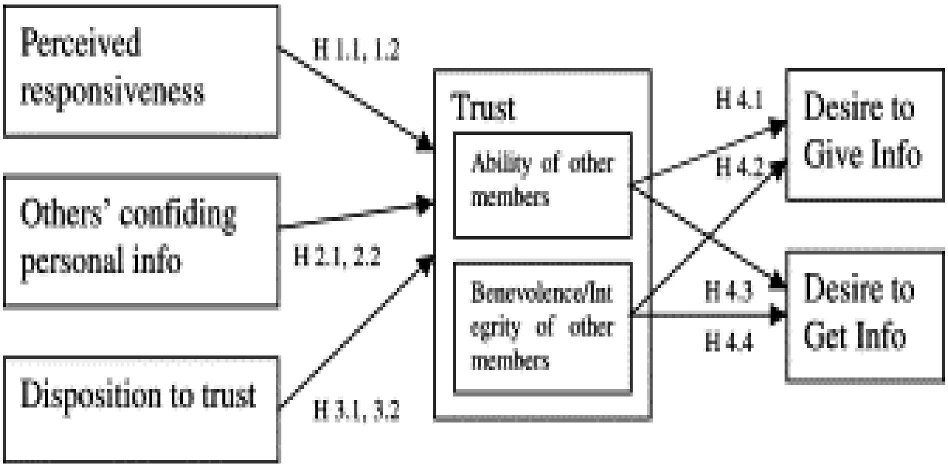

Figure 2.9: Relationship between trust dimensions and knowledge sharing (Ridings et al., 2002)

Further studies are needed to explore trust dimensions and the impact of these dimensions on knowledge sharing. In particular, attention must be paid to the way that these dimensions and their impact on knowledge sharing can be measured. These questions are addressed and discussed in detail in Chapter 5.

However, some metric and mathematical models are proposed to measure the effectiveness of knowledge sharing within and between communities. In the next section, some of these models are reviewed in detail.

2.5.2 Numeric measurement models

Based on different variables that influence knowledge sharing, some metric models are proposed for knowledge sharing measurement.

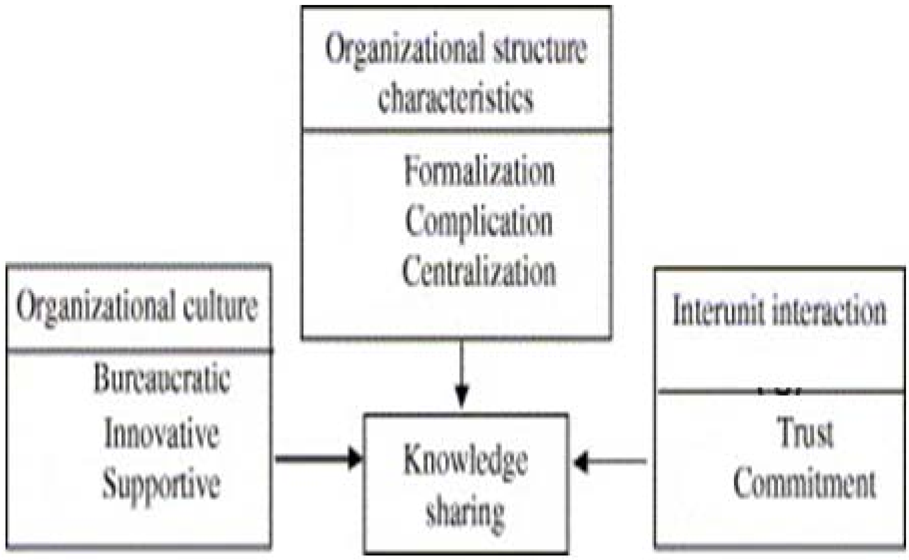

Figure 2.10: Variables influence on knowledge sharing measurement (Lin, 2007)

Figure 2.10 shows how knowledge sharing is being formulated by the three different types of variables. First, the organizational structure comprises formalization, complication and centralization (Robbins, 1990) Formalization is related to limitations that internal regulations, rules, procedures, and other formal norms of an organization can impose on working activities. Complication means the labor division involved in working activities, and centralization refers to the distribution of decision-making power within an organization (Lin, 2007). Second, there are inter-unit interaction characteristics that include trust and commitment. Trust in this model is assumed to be the willingness of individuals to share their knowledge with other community members. The last variables are related to organizational cultures such as bureaucratic, innovative and supportive organizations. A bureaucratic culture is based more on power and hierarchical top-down control. In these kinds of organizations, most of the work is standardized and operates on the basis of control and power.

Innovative culture creates a challenging and innovative environment and organizational members are encouraged to be adventurous and exercise initiative. A supportive culture creates an open and harmonious working environment.

As shown in Figure 2.11, this model has developed a non-linear fuzzy neural network to formulate the variables and measure knowledge sharing.

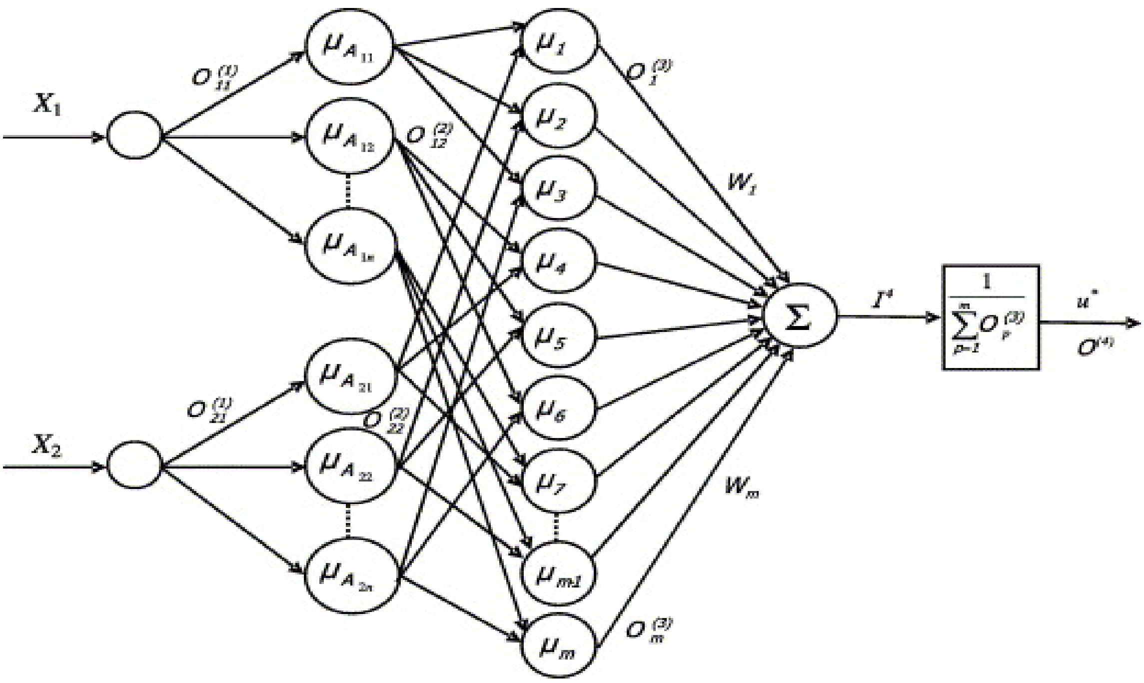

Figure2.11: Structure of the non-linear fuzzy neural network: (1) input layer; (2) linguistic term layer; (3) rule layer and (4) output layer (Lin, 2007)

In this model, different factors that influence organizational structure, interaction and culture are analyzed and the more related factors are used as input into the fuzzy network model. The value of factors can be low, medium or high. The factors input into the model are processed to fuzzification, fuzzy inference and fuzzy decision in four layers as seen in Figure 2.11. Moreover, this model can assign a fuzzy value to the related variables and measure membership function of variables to measure knowledge sharing.

Another metric measurement model uses economic exchange theory to measure knowledge sharing and was introduced by Du et al. The model is based on 6 key variables including: 1. expenditure on inter-units and inter-organizational training; 2. expenditure on collaborative trials and experiments of non-R&D departments; 3. expenditure on intentional activities for communicating and transferring knowledge; 4. frequency of importing workers; 5. frequency of job rotation. 6. expenditure on collaborative R&D (Du.R and Ren 2007). Knowledge sharing is characterized quantitatively by a vector, X(x1, x2, x3, x4, x5, x6), which is determined by six measures. Hence, knowledge sharing is a function of these 6 variables and can be shown by the equation below:

$$Y=F(X)$$

(Equation2.1)

The purpose of this model is to maximize Y and the objective function is:

$$\mathrm{Max}\, Y = F(X).$$

(Equation2.2)

Similarly, another model is proposed based on economic exchange theory. This model consists of the three following key components (Yang and Wu, 2007):

1. The basic value of knowledge for receivers, denoted by R, where R≥0;

2. The synergetic value describing the degree to which each agent gains because of the mutual knowledge sharing, is represented by S, where S≥0;
3. The perceived utility loss describing the degree to which each agent perceives the negative utility from the knowledge sharing activity due to the transfer of monopolistic knowledge, is denoted by -LA, which is A as a sender's perceived loss when sharing knowledge with B as a receiver; or denoted by -LB, which is sender perceived loss when sharing knowledge with receiver A and LA, LB≥0;

Assume that A and B are players who gain or lose in a knowledge sharing game. Table 2.3 shows the situation of each player when they share their knowledge or decide to not share and keep it to themselves.

<table>
<tr><td colspan="2"></td><td colspan="2">Player A</td></tr>
<tr><td colspan="2"></td><td>Sharing knowledge</td><td>Not sharing knowledge</td></tr>
<tr><td rowspan="4">Player B</td><td rowspan="2">Sharing knowledge</td><td>$R + S\text{-}L_A$</td><td>R</td></tr>
<tr><td>$R + S\text{-}L_B$</td><td>$-L_B$</td></tr>
<tr><td rowspan="2">Not sharing knowledge</td><td>$-L_A$</td><td>0</td></tr>
<tr><td>R</td><td>0</td></tr>
<tr><td colspan="4">Legend

R: basic value of knowledge from the opponent, where $R \geqq 0$.</td></tr>
</table>

S: synergetic value gaining from mutual sharing knowledge, where $S \geqq 0$. *I*: added utility gaining from organizational incentive, where $I \geqq 0$. $-L_A$: perceived loss of Player A's utility because monopolistic knowledge was transferred, where $0 \leqq L_A \leqq R$. $-L_B$: perceived loss of Player B's utility because monopolistic knowledge was transferred, where $0 \leqq L_B \leqq R$.

Table2.3: Payoff matrix for players A and B (Yang and Wu, 2007)

Based on this model, management supports and incentives can improve knowledge sharing in an organization. If the value of incentives is I, the knowledge sharing table would be like Table 2.4.

		Player A	
		Sharing knowledge	Not sharing knowledge
Player B	Sharing knowledge	$R + S - L_A + I$	R
		$R + S - L_B + I$	$-L_B + I$
	Not sharing knowledge	$-L_A + I$	0
		R	0
I: organizational incentives $I \geq 0$.			

Table 2.4: Payoff matrix for players A and B in a management-supported environment (Yang and Wu, 2007)

On the other hand, each individual's competency to share or absorb knowledge is different from that of others and this capability has to be considered in the formulas. The capabilities of knowledge sharing (Cs) and absorption (Ca) indicate the imperfect aspects of delivering and receiving knowledge, respectively. Table 2.5 shows the equations for when personal capabilities of sharing and absorption knowledge are different.

This is based on the idea that someone might be eager to obtain new knowledge; however he/she may not be good at knowledge absorption and therefore, knowledge sharing fails.

<table>
<tr><td colspan="2"></td><td colspan="2">Player A</td></tr>
<tr><td colspan="2"></td><td>Sharing knowledge</td><td>Not sharing knowledge</td></tr>
<tr><td rowspan="4">Player B</td><td rowspan="2">Sharing knowledge</td><td>$R \ast Cs_B \ast Ca_A + S - L_A \ast Cs_A \ast Ca_B + I$</td><td>$R \ast Cs_B \ast Ca_A$</td></tr>
<tr><td>$R \ast Cs_A \ast Ca_B + S - L_B \ast Cs_B \ast Ca_A + I$</td><td>$-L_B \ast Cs_B \ast Ca_A + I$</td></tr>
<tr><td rowspan="2">Not sharing knowledge</td><td>$-L_A \ast Cs_A \ast Ca_B + I$</td><td>0</td></tr>
<tr><td>$R \ast Cs_A \ast Ca_B$</td><td>0</td></tr>
<tr><td colspan="4">Cs_A, Cs_B: the player A's or player B's capability of sharing knowledge out, where $0 \leqq Cs_A, Cs_B \leqq 1$.

Ca_A, Ca_B: the player A's or player B's capability of absorbing others' knowledge, where $0 \leqq Ca_A, Ca_B \leqq 1$.</td></tr>
</table>

Table2.5: Pay-off matrix of knowledge sharing if agents' capabilities are different (Yang and Wu, 2007)

There are also some other models similar to the discussed ones. As was explored in this section, there are varieties of models that use different tools such as fuzzy logic, neural network, economic exchange theory, social variables and etc. to measure knowledge sharing in a community.

2.5.3 Critical review of knowledge sharing measurement models (integrated review)

Proposed models for knowledge sharing measurement are more concerned with determining the relationship between different subjective variables and knowledge sharing. However, there are also a few numeric models based on economic exchange theory in the literature.

The theory of reasoned action is more related to detecting attitude and norms in knowledge sharing. However, some disadvantages that are associated with this model are listed below.

1. The most important social variables such as trust are not mentioned in this theory.
2. The theory is more focused on willingness and intentions to share knowledge. However, the ability or competence to share knowledge is not covered in this theory.
3. The theory does not propose measurable variables to discover knowledge itself and role of knowledge in knowledge sharing.
4. Common understanding of the shared knowledge and transferability of the shared knowledge is not discussed in the model.

5. The model does not propose numeric variables to measure knowledge sharing level. Therefore, knowledge sharing cannot be reported by a numeric value in this model.

The abovementioned problems also apply to the theory of planned behavior and the revised version of this theory. Other theories that were explored in this research focused on trust and different dimensions of trust. However, knowledge itself and the complexity of a particular knowledge or transferability of the shared knowledge are not addressed in the literature. Table 2.6 shows the problems inherent in different theories.

Category	model	Issues
Subjective frameworks	Reasoned action theory Theory of planned behavior Revised version of Theory of planned behavior	Most important social variables such as trust are not addressed in this theory. Ability or competences to share knowledge are not addressed in this theory. Role of knowledge itself in knowledge sharing is not detected. Knowledge complexity and transferability of the shared knowledge are not addressed. Lack of numeric variables to measure knowledge sharing

		level.
	Chow et al. model	Relations of trust dimensions with knowledge sharing are not formulated properly. Role of knowledge itself in knowledge sharing is not detected. Knowledge complexity and transferability of the shared knowledge are not addressed. Lack of numeric variables to measure knowledge sharing level.
	Lin model	
	Wang et al. model	
	Riding model	
Metric models	Lin model	Role of knowledge itself in knowledge sharing is not detected. Knowledge complexity and transferability of the shared knowledge are not addressed. It is hard to put value for all the variables that are discussed in the models.
	Yang et al. model	

Table 2.6: Critical review of the knowledge sharing measurement models

As seen in Table 2.6, metric variables also have not dealt with the role of knowledge itself in knowledge sharing.

However, as the importance of knowledge sharing in business is increasing, another main issue in knowledge sharing is how the measured knowledge sharing level can be reported to decision makers and in order to help managers or decision makers to manage knowledge sharing within their organization. In the following sections, this main issue is explored and related works in the literature are examined.

2.6 Knowledge sharing reporting

Knowledge sharing level and some most important variables in knowledge sharing such as trust level should be reported to decision makers to help them in their decision-making process. Most of the business firms use available business solutions that are mostly based on process improvement such as supply chain process management (SCM). Also, business intelligence systems are developed to provide and report required information and knowledge for the managers to help them in making a decision based on current business solutions. It is important to understand the definition of business intelligence before investigating knowledge sharing-based business intelligence systems.

2.6.1 Business intelligence

The business world is moving rapidly and becoming more complicated. As a result, the supporting technology is more complex. Also, a huge amount of data is available in the business world and effective applications are required to manage the clutter of data and to respond to the needs of decision makers. Business Intelligence (BI) plays an increasingly important role in business operational analysis and decision support (Inmon, 2002). Business intelligence turns data into meaningful information. Business intelligence (BI) is a business management term, which refers to applications and technologies that are used to gather, provide access to, and analyze data and information about company operations and performance. BI systems refer to an important class of systems for data analysis and reporting that provide managers at various levels of the organization with timely, relevant, and easy to use information, which enable them to make better decisions (Hannula, 2003). BI systems help companies to acquire a more comprehensive knowledge of the factors affecting their business, such as metrics on sales, production, internal operations, and they can help companies to make better business decisions. If a business intelligence system can be successfully implemented, it can play its due role in four areas: business status understanding, measuring organization performance, improving stakeholder relationship and creating profitable opportunities (Wang, 2005). BI covers a wide range of tools and has three main components: reporting, data mining, and predictive analytics. Overall, BI delivers the right information to the right person at the right time (Eckerson Wayne, 2005).

2.6.2 Evolution of business intelligence

Business Intelligence (BI) has shifted from the traditional concentration by businesses on using data purely for repetitive calculations, monitoring and control to obtaining knowledge in a form that is suitable for supporting and enabling business decisions from marketing, sales, relationship formation, and fraud detection through to major strategic decisions. Figure 2.12 shows the evolution of business intelligence in the last 40 years.

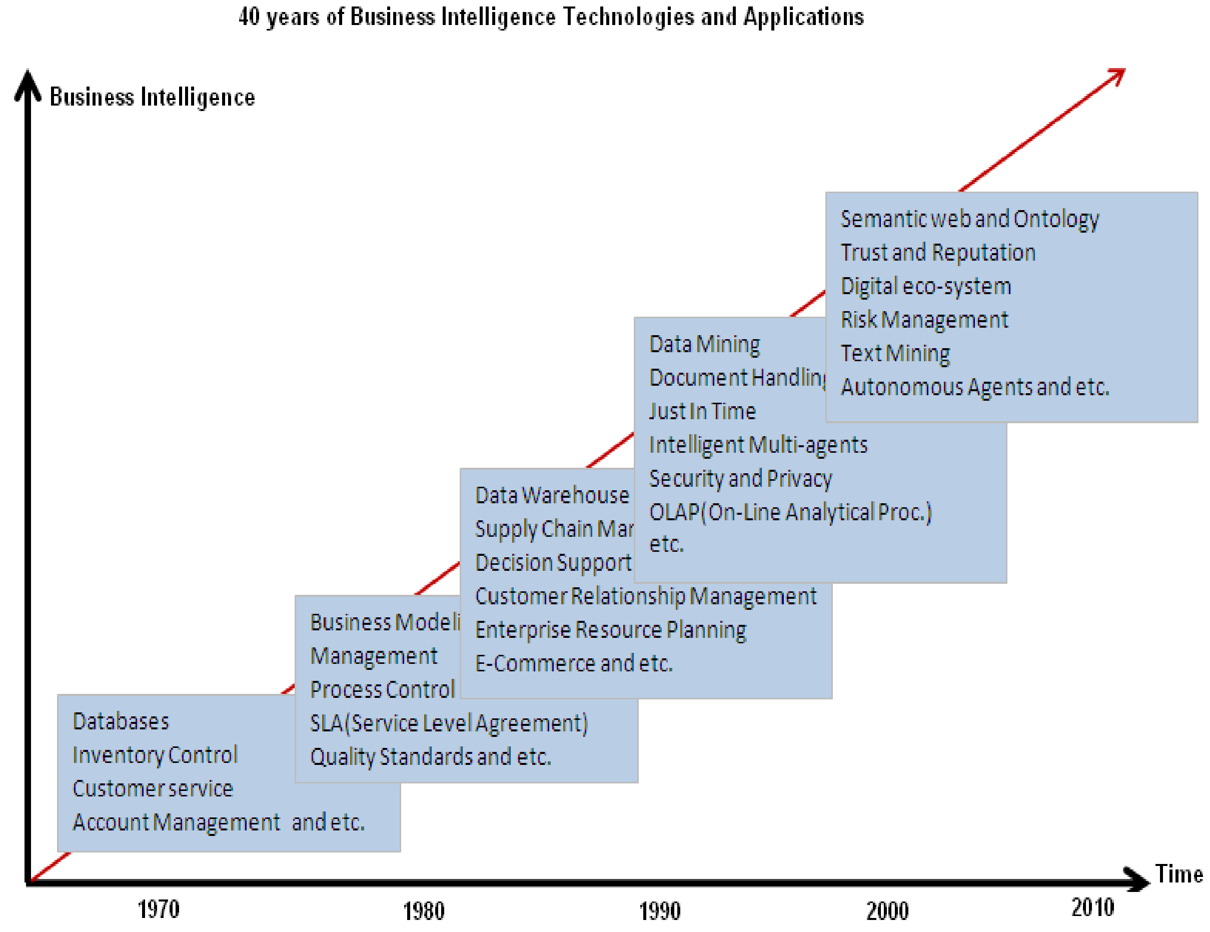

Figure 2.12: Evolution of business intelligence in the last 40 years (Chang et al., 2006)

As shown in Figure 2.12, a new generation of business intelligence is moving from traditional applications such as CRM, SCM, ERP and etc (Figure 2.13) to new concepts such as trust and knowledge transfer.

As seen in Figure 2.12, business intelligence applications were started by business modeling and quality standards in 1980s and moved to CRM, ERP (more process based) in 1990s.

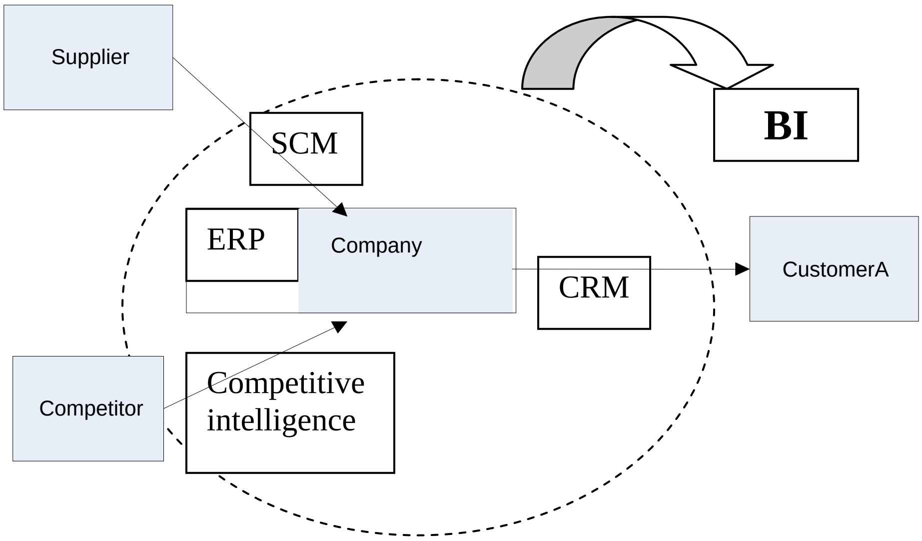

Figure 2.13: Traditional Business Intelligence components (BI)

However, new dimensions of interactions based more on information and knowledge analysis are going to replace the traditional aspects that were more focused on data analysis. Business Intelligence (BI) in the future will include, amongst other things, trust and reputation systems, knowledge sharing, ontologies and ontology-based search engines and internal and external holistic risk management. Figure 2.14 shows the new dimensions of future Business Intelligence.

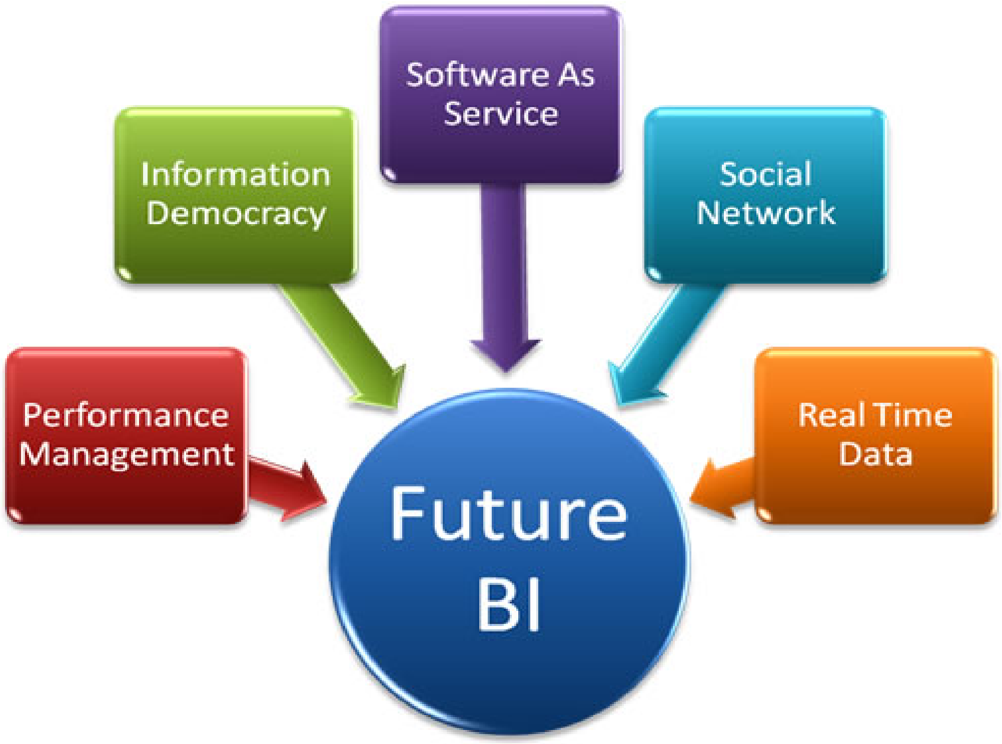

Figure 2.14: Future BI(Dave, 2009)

Figure 2.14 demonstrates that information democracy and social network are the most important parts of future business intelligence. Hence, more investigation is needed to design and propose trust-based business intelligence systems or the role of knowledge sharing in the future of business intelligence.

Most researches concerned with the role of trust and knowledge sharing in business intelligence, focus on the role of these factors in BI applications implementation and organization's need to improve trust and knowledge sharing between employees to decrease risk of failure in implementation. In this approach, managers need to develop strong employee commitment to enhance the effectiveness of their BI systems (Seah et al., 2010). As shown seen in Figure 2.15, managers need to consider socio-cultural variables such as knowledge sharing between business components like suppliers, customers and etc. and also need their collaboration and commitment to implement business intelligence systems.

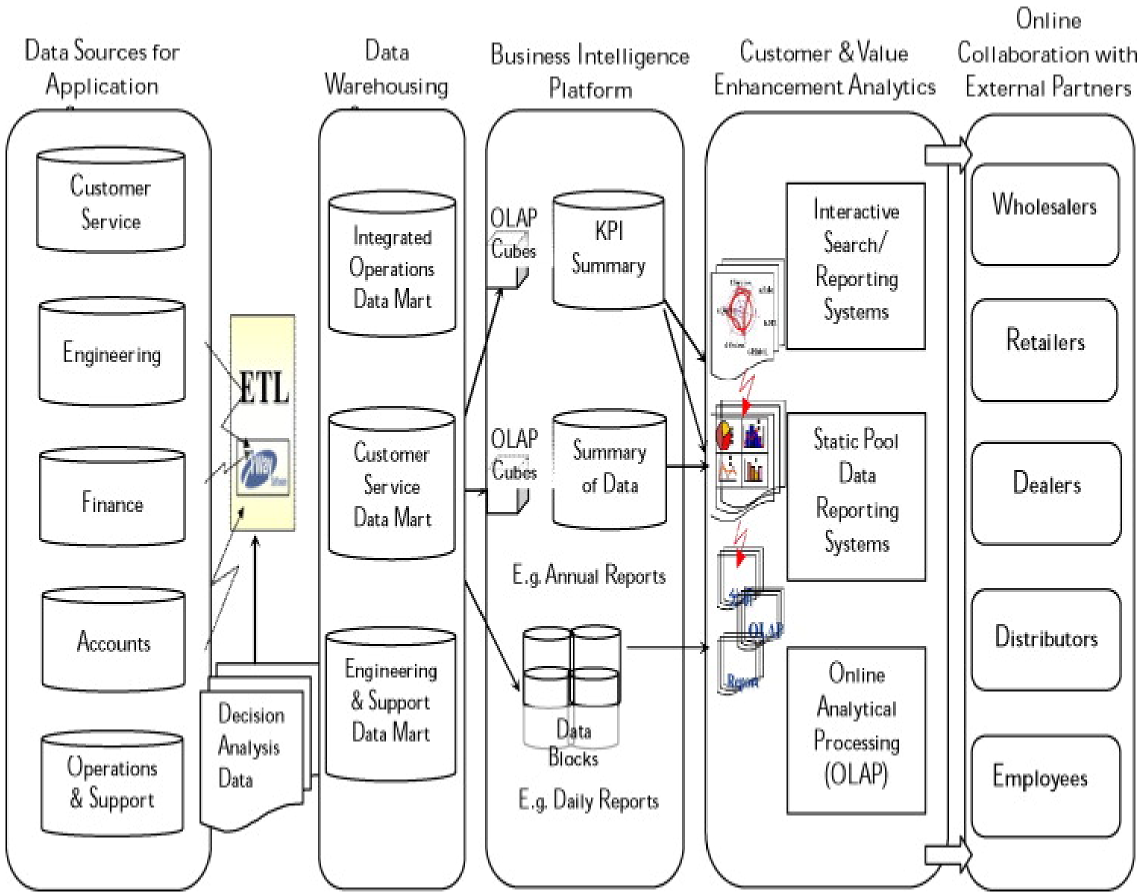

Figure 2.15: Collaboration and commitment in BI implementation(Seah et al., 2010)

Also, ontologies are developed in BI systems where users with different backgrounds collaborate to establish an agreed version that is accepted by all users. Ontologies can facilitate this process of collaboration between different parties. As the knowledge bases of BI systems increases in size and diversity, the need for a larger and more diverse base of ontology authors increases and a number of essential tasks for collaborative ontology management should be undertaken (Bao et al., 2006).

2.6.3 Critical review of knowledge sharing reporting

The proposed approaches in current reporting systems are more process-based. However, there is a lack of knowledge sharing and trust-based reporting systems in the literature. Some of the new approaches in business intelligence (BI) frameworks consider knowledge sharing and trust as key issues in BI. Dave has considered information democracy as a key issue in future BI. (Dave, 2009) However, the proposed model by Dave does not consider the relationship between information democracy and knowledge sharing, and there are no proposed measurement techniques in this model to measure the level of knowledge sharing. Some other models such as Seah's model (Seah et al., 2010) mentions only employee commitment and trust as issues in current BI implementation. It is totally different approach when a BI system is developed to show knowledge sharing and trust level in an organization with the approach that uses employee trust and commitment to implement current BI systems. In the first approach, a BI system is developed based on trust and knowledge sharing, and outcomes are related to the levels of these two variables. In the second approach, trust is used to successfully implement the current BI systems that are based more on process and outcomes, but are not exactly related to knowledge sharing. It is essential to develop a trust and knowledge sharing based BI system to provide reliable and useful data for decision makers in a knowledge-based economy where variables such as trust and knowledge sharing are key issues. The creation of a dashboard for managers to follow up the results of key variables such as knowledge sharing and trust is not addressed in the literature and needs further research.

The final section of this chapter discusses the measurement of capital that can be produced by knowledge sharing. Some of the models that have been developed to measure knowledge-based capital in an organization are discussed in this section.

2.7 Measurement of knowledge capital in knowledge sharing

Knowledge creates value and in a knowledge-based economy the measuring of the created capital is crucial. It is assumed as intangible asset in an organization and it cannot be calculated by traditional formulas that are used to measure tangible and physical assets. The main related domain that was explored in the literature to measure intangible assets is the intellectual capital domain. Intellectual capital is defined in this section in detail. In this research, intellectual capital techniques are used to calculate capital that can be generated by knowledge sharing.

2.7.1 Definition of intellectual capital

Intellectual capital is defined as "the group of knowledge assets that are attributed to an organization and most significantly contribute to an improved competitive position of this organization by adding value to defined stakeholders" (Sudarsanam et al., 2003). The aim of IC is to explain the difference between the book value and the market value of a firm. By one estimate, intellectual assets accounted for about 70 percent of the firm's market value in 2002, up from about 40% in 1982 (Kaplan and Norton, 2004). Although measuring IC (70% of firm's capital) is very important to manage business and maximize growth, these kinds of assets remain outside mainstream discussion in business, economy, and policy and are rarely reported in financial statements. Intellectual capital has emerged as a key concept for analyzing and evaluating the knowledge dimensions of organizations (Nonaka and Takeuchi, 1995). It is necessary to improve the quality of information on intellectual capital measurement to contribute to the decision-making process of corporate managers, investors, and policy makers. There are different types of intellectual capital classification due to research subjects and background. Roos and Bontis have proposed human capital, structural capital, and relational capital as the three basic dimensions of intellectual capital (Bontis et al., 2000; Roos et al., 1998). Even though marketing people may not include intellectual capital in their common terminology, they do constantly talk about and manage intellectual capital resources such as brands. A number of other marketing resources and capabilities fall within the category of intellectual capital resources, however, such as customer relationships and their management, creative skills, and negotiation skills of the sales force (Fernström et al., 2004). Intellectual capital in this research comprises Social capital, Human capital, and Market capital. Human capital is related to individuals, social capital is related to employees' relations within an organization and market capital is related to external customers.

2.7.1.1 Social Capital

The idea of social capital and its role in economic development has been increasingly growing. Social capital is one of the main factors in an organization’s success. A lot of work researches to find suitable tools to measure the level of social capital. Fukuyama describes social capital as the ability of people to work together for common purposes in groups and organizations (Fukuyama, 1995). Putnam indicates that “the norms and networks of civil society enable groups of individuals to co-operate for mutual benefit (and perhaps for broader social benefit) and may allow social institutions to perform more productively. Social capital is embodied in such forms as civic and religious groups, bonds of family, informal community networks, kinship and friendship, and norms of reciprocity, volunteerism, altruism and trust” (Putnam, 1995).

Deardorff's Glossary of International Economics (Glossary of International Economics) identifies social capital as the networks of relationships among persons, firms, and institutions in a society, together with associated norms of behavior, trust, cooperation, etc., that enables a society to function effectively. In recent years with several new kinds of communication tools, especially virtual communication tools, effects of social capital on economic, politic and society has increased. In brief, social capital has a meaning in a group or society (for individuals it is not meaningful) and starts to increase when members in the group or society start to communicate to each other (visual or virtual) depending on norms, trust, willingness of people to communicate, information and knowledge, and other factors. Also, the type of social network shall be considered.

It is a challenge to find suitable tools to measure the level of social capital. The social capital is related to people's willingness to make connection and the density of the information that is transmitted in those connections. Transmitted information has different influences and it depends on the trust between sender and received agents. Overall, social capital can be calculated by the numbers of connections, trust between agents, and information density within a given particular time slot.

2.7.1.2 Human Capital

Human capital in a knowledge-based economy is the most important part of economy that gives a competitive advantage to organizations. Bontis defines human capital as the summary of individual knowledge stock of organizations' employees (Bontis, 2001). Roos claims that human capital can be generated by employees' competence including skills and education, attitude such as employee's behavior, and intellectual agility such as innovation (Roos, 1997). Hudson defines human capital as a combination of genetic inheritance, education, experience, and attitude about life and business (Hudson, 1993). The human capital theory is grounded in the notion that individuals are investors and they invest similar to physical or financial assets in education in order to achieve higher incomes or obtain promotion in the years to come. People go to school, university, and invest in themselves to learn. They also spend time to study and test their knowledge in workplaces to increase their skills rather than doing other things and acquiring wealth. Thus, their time has value and also their opportunity cost is crucial because they could be acquiring wealth rather than studying or learning. Additionally, when a company employs people, the latter bring their embedded knowledge to the business and the company creates value with their knowledge. As a result, an employee's knowledge can be regarded as a capital for business and should be considered when determining the total capital. Human capital measurement is suitable for formal education and learning but, most significantly, innovation is more important than formal education and casual learning. Innovation, which involves a mind challenge, is more effective than formal learning. Although it is still possible to measure casual learning and innovation by the investment cost method where time is a key factor in calculating the level of investment, and in this way return of the investment is very high. Some other methods like the value-added method and market-based value are used to measure human capital.

In order to measure human capital, the knowledge value of education, innovation and skills, should be measured. Knowledge value of education can be measured by calculating the cost incurred when acquiring knowledge. The main costs here pertain to:

1. Investment – Investment in a formal education system such as cost of education in school, university, and some short term courses or any tuition fee one pays to acquire formal knowledge.
2. Time – Time that one spends in the classes including studying time and time related to education.

3. Opportunity cost – Opportunity cost is related to the cost of losing opportunities due to spending time on education. For example, one continues his/her master study and does not work. S/he cannot earn money and loses some opportunities.

The second category in human capital is knowledge value of skills. Basically, the skills arise from the experience. Here, the main costs are as follows:

1. Cost of training – This kind of cost is related to job training, mentoring training and all the costs business firms incur to improve their employee's knowledge.
2. Cost of experience – Practice can improve people's productivity and business firms spend a huge of money on their employees to increase their experience. This experience is a valuable asset and most of the business firms try to recruit experienced people from their competitors.
3. Time and opportunity cost – Business firms should invest in a new employee, who has just been appointed to the position, to improve their knowledge up to the required level. Business firms also lose opportunities in a labour market.

The third category in human capital is knowledge value of innovation. This is related to people's competency in innovation and creativity. Although basic knowledge is important, the major parameter in this category is environment. The total value of human capital is the sum of these three categories.

2.7.1.3 Market Capital

Market value is related to the external image of organizations among market components as shown in Figure 2.16, such as suppliers, customers, non-customers (i.e. society) and other related parts. The image can affect market components' expectations to buy or sell products and services. Market capital affects market share, promotion cost, and the introduction of new products to the market. Overall, market capital directly affects income and net profit. As seen in Figure 2.16, the market components have different relationships.

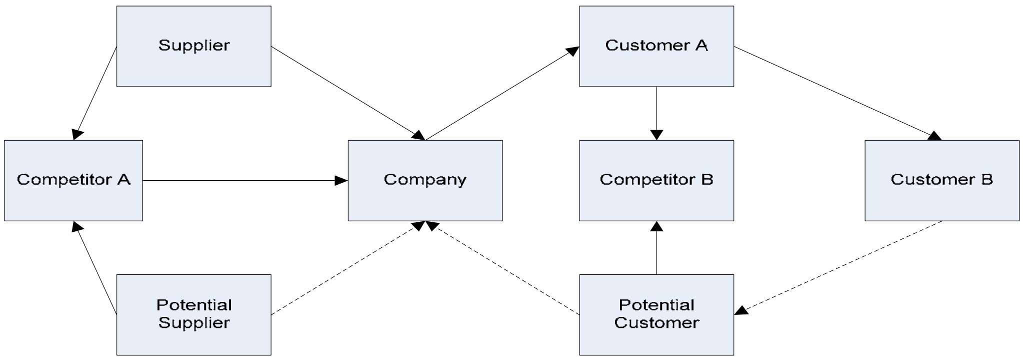

Figure2.16: Relations between market components

Bontis states that customer capital is the knowledge embedded in the marketing channels and customer relationships (Bontis, 1999). Market capital is the summary of value that can be created by knowledge sharing between market components. It depends on the density of knowledge sharing and trust level between the market components. The main factor in this kind of investment is trust. Trust then appears as a capital. As can be seen in Figure 2.16, there exist different relationships between market components. Although these relationships are for benefits, trust can play a main role in increasing the benefits and equates to a market value for all organizations in the market.

Moreover, trust, knowledge and knowledge sharing are key issues in intellectual capital. Trust is the most important issue in social capital, knowledge in human capital and both trust and knowledge sharing in market capital. These key variables should be measured and addressed in intellectual capital measurement. Some of the related works in intellectual capital measurement and related models are discussed in this research.

2.7.2 Intellectual capital measurement

The characteristics of a knowledge society are that they are part of a knowledge economy and should afford to facilitate knowledge flow and sharing. If these characteristics can be embraced by the community at large, then conventional public policy holds that a competitive economy and a higher quality of life is the outcome (Sharma et al., 2008). Different studies show that there is a strong relationship between countries' economic situations and their intellectual capital achievement. Intellectual capital can help to address poverty as well as being the key to wealth creation and national outcome. Hence, measurement should cover intellectual assets as well. Intellectual capital is also a key to success for private sectors in a dynamic and competitive environment. An increasing number of firms have started to report more of the intangible aspects of their business, even without the force of regulations. At the same time, accounting guidelines are being amended and standards are being questioned and reviewed to reflect the increasing importance of intangible elements (Marr, 2007). The measurement of the value of intellectual capital is now a significant issue in new financial management. Organizations should be clearly aware of the importance of measuring what is perhaps their most valuable asset. Due to the fuzzy entity of intellectual capital, many firms provide inadequate solutions, addressing only particular isolated aspects of a firm's intellectual capital such as implementing accounting for some intangibles, guidance on building customer or stakeholder relationships and improved stakeholder dialogue, human capital or capabilities assessments and solutions for valuing brands (Marr and Adams, 2004).

During the last few years several methods have emerged that specifically focus on the measurement of intellectual capital. In this section, the different methodologies used for measuring the intellectual capital of a firm, are investigated.

2.7.2.1 Balance Score Card (BSC)

The Balance Score Card (BSC) model was one of the business performance measurement methods presented to change the traditional approach to business performance. The BSC was proposed in the early 1990s in a performance management framework by Kaplan and Norton (Kaplan, 1992, 1996). The BSC considers four areas: (1) learning and growth, (2) internal business process, (3) customers as the major stakeholders in a business, and (4) value creation in the financial sector. The BSC extends traditional measurable tangibles from a traditional financial perspective of an organization with clients (customer capital), internal business process (structural capital), and learning and growth (human capital) (Kaplan and Norton, 2004; Kaplan, 2006). This method is one of the methods measuring the knowledge assets of organizations and considers intangible assets in the business performance. Also, BSC relates to organization strategies with core competencies that are very important to the business' success.

The four addressed areas are used to capture the essence of the organization's strategy materials and to reflect the achievement of strategic objectives. New generations of the BSC have more strategic relevance and relate to target setting as well as validation of strategic objectives.

There are several disadvantages of using the BSC as a model to measure intellectual capital in a firm. Macadam and Roan indicate that the BSC does a great job in strengthening the link between customer improvement initiatives and the organization's strategy. However, the BSC does not indicate how new customers and markets can be identified (McAdam and O'Neill, 1999). Malina and Selto indicate that the BSC approach to effective strategic management is often seen as subjective and difficult to implement. The BSC can cause disagreement and tension between top and middle management regarding the appropriateness of specific aspects of the BSC as a communication, control and evaluation mechanism (Malina and Selto, 2001). Overall, the BSC is more useful for a static environment, but in a dynamic environment it cannot measure the fluctuation of intellectual capital. Also, most of the variables in the BSC are subjective and therefore inappropriate for financial management.

2.7.2.2 Skandia Navigator Model

Skandia is the first company that included intellectual capital in its traditional financial report to its shareholders in 1994 (Bontis, 1998, 1999; Bontis et al., 1999; Bontis et al., 2000). This model, like the BSC, focuses on intellectual capital and has a new accounting taxonomy including financial, customer, process, renewal and development, and human capital. This model highlights the importance of human capital and defines knowledge as a core competitive advantage in a knowledge-based economy. The model proposes some indices to measure and assess knowledge, skill, and innovativeness. Another part of this model is structural capital that includes organizational processes, procedures, technologies and information sources. Customer capital includes value of relationship with customers, suppliers and market, and organizational capital.

In the Skandia Navigator model, a suitable taxonomy is created to measure intangible assets. It is significant for recognizing customer capital and human capital. A unique understanding of intangible assets is necessary for the organization to choose appropriate and valid metrics. Roos claims that generic standards for measuring intellectual capital across industries are increasing (Roos, 1997). The model measures the indices only at a given snapshot in time and cannot present the dynamic entities of an organization. Also, the model cannot measure the impacts of the different parts of intellectual capital (Roos, 1998).

2.7.2.3 Intellectual Capital(IC) Audit Model

This model focuses on intellectual capital including market assets, human assets, intellectual property assets, and infrastructure assets. Brooking defines intellectual capital as the combined amalgamation of these four assets (Brooking and Motta, 1996). Market assets include brands, customers, and distribution channels. Human assets include employees' knowledge, problem solving capability and skills. Intellectual property assets include the assets that can be calculated in financial terms such as copyright, design rights, etc. Infrastructure assets include technologies, process and methodologies. In this model the implementation starts with a questionnaire of 20 items (these items are defined in the model) to check whether or not the organization needs to develop a new area of intellectual capital. The aim of this model is to calculate the dollar value of the intellectual capital by using the following methods:

1. Cost-based approach takes into account the replacement cost
2. Market-based approach takes into account the market value
3. Income-based approach takes into account the income produced by the asset.

The model uses a monetary approach to measure intellectual capital and this approach is more sensible for managers. However, the checklist in this model does not have a consensus across different industries. The model tries to change the qualitative results of the questionnaire to an actual dollar value which is the main weakness. The value of assets cannot be measured by the model. There are many subjective questions while the model aims to measure objective indices. Also, the dynamic entity of the intellectual capital is not mentioned in the model.

2.7.2.4 Intangible Asset Monitor

Sveiby proposed a conceptual framework based on the following three intellectual capital categories shown in Table 2.7 (Sveiby, 1997).

1. Competence of employees (education, experience).
2. Intangible assets related to internal structure (management, structure, systems, and software).
3. Intangible assets related to external structure (brand, suppliers, and customers relations).

This model claims that people are the only true agents in business and all aspects of internal and external assets are embedded in human actions. Sveiby explains that the internal structure is part of traditional accounting measurement and external structure assets are not included in the traditional financial systems (Sveiby, 1997).

Intangible Assets (Stock Price Premium).		
External Structure (e.g. brands, customer and supplier Relations).	Internal Structure (e.g. management, legal structure, manual systems, R&D, software).	Individual Competence (E.g. education, experience).

Table2.7: Intangible asset monitor model (Bontis et al.,2000)

External components include customers, stakeholders, suppliers and creditors. They are usually interested in a company's position in the market versus changes in the company. Internal components are more related to information systems management, trend changes and control figures. Additionally, internal components are being used as a technique by managers. Sveiby identifies three measurement indicators: (i) growth and renewal, (ii) efficiency, and (iii) stability for each of the three intellectual capital categories (Sveiby, 2001).

However, the implementation of this model needs to be specific to the organizational culture. Also, the model does not support financial feedback systems. Lynn argues that for many organizations, making a business case means creating financial results; thus, this model needs to specify the culture of organization and needs a highly successful reporting system on intellectual capital (Lynn, 1998).

2.7.2.5 EVA

EVA was introduced by Stern Stewart as a comprehensive performance measurement that uses traditional accounting variables such as budgeting, financial planning, goal setting, performance measurement and incentive compensation to account for all the value that can be added or lost (Bontis et al., 1999; Stewart, 2002). The model is founded on a basic rule that economic value added is the net result of all managerial activities (Strassman, 1999). The model compares the cash that a firm's investors initially put into the company with the present value of the cash. EVA depends on the cost of capital and increases when the average cost of capital is less than the return on net assets. In general, EVA can be calculated by the following formula:

EVA = Net sales – Operating Expenses – Taxes – Capital Charges

Although the model is based on financial theories, it cannot measure intellectual capital specifically. Moreover, managers cannot understand exactly what the company's intangible resources are, what the exact definition of intellectual capital is, and how to improve it.

Although, some proposed models such as Balanced Score Card model (BSC), Skandia Navigator Model, IC Audit Model, Intangible Asset Monitor model, Value Add Model (EVA) etc. proposed some tools to measure intellectual capital in an organization, role of trust and knowledge sharing is these models are not properly being examined. These models are considered in detail in Chapter 7 with a discussion of how trust and knowledge sharing can create value and asset in an organization and how it can be measured.

2.7.3 Critical review of measurement of knowledge capital

In the current intellectual based business performance methods, such as BSC model, Skandia model, the measuring indicators are not standard and are not widely used in organizations (the measurement of intangible assets and associated reporting practices, 2003). Although some of them present some metric formula to measure intangible assets, the real asset values of different types of intellectual assets are not clearly determined. Additionally and importantly, knowledge itself cannot lead to success due to lack of knowledge sharing and flow within an organization. Table 2.8 shows a comparison between different models.

Model	Approach	Standard metric tools used	Sensibility	Categories
BSC	Strategy	No	Middle	Customer Finance Training Process
Skandia	Human	No	Middle	Process Human Technology Finance

				Customer
IC Audit	Market and Human	Yes	High	Market Human Intellectual Property Infrastructure
Intangible Asset Monitor	Internal and External Structure	No	Low	Employees Internal data (management, structure, systems, software). External data (brand, suppliers, customer's relations).
MVA and EVA	Add Value	Yes	High	Value add for capital budgeting Financial planning Goal setting Performance management Shareholder communication
Intellectual capitals	Knowledge Sharing and	Yes	High	Market capital Social capital

based model	Trust			Human capital Physical capital

Table 2.8: Comparison of different business performance models

As depicted in Table 2.8, key issues in a knowledge-based economy, knowledge and knowledge sharing and trust, have not been addressed significantly in the current intellectual capital measurement models and due to the dynamic entity of trust and knowledge sharing, the dynamic nature of intellectual capital cannot be addressed by current models.

2.8 Conclusion

The knowledge lifecycle is very short. It is claimed by different researchers that knowledge doubles every two years and it is forecasted that knowledge will be doubled every 35 days by 2015 (Cornall, 2008). Knowledge is created and but also diminishes very fast and organizations need to accelerate the knowledge flow in their organizations and update their employees as quickly as possible. Also, customers have access to numerous tools that can gather data from different sources, and customers use this knowledge in their decision to buy or sell the products or service. It is a crucial issue for a business to share reliable knowledge with their customers in order to establish customer loyalty. As the importance of knowledge sharing is increasing, managers need to understand key issues in knowledge sharing and be aware of the tools available to control and improve knowledge sharing between their employees, customers and other business components and stakeholders.

In this chapter, knowledge sharing was discussed thoroughly in relation to the communication process, and the different obstacles to knowledge sharing and the variables that affect knowledge sharing were discussed in detail. The components of the communication process are: knowledge sender or receiver, encoding or decoding a specific knowledge and communication channel that is used by individuals to share knowledge. Of great importance in the knowledge sharing process is the willingness of the sender or receiver to share or to receive a particular knowledge that was discussed in detail from the social, economic, individual, organizational, and other perspectives. Trust is fundamental to the communication process, and trust willingness to share knowledge and trust competence to absorb knowledge were identified as two key variables of trust. In Chapter 5, trust is discussed in detail and different dimensions of trust are investigated. Also, the relationship between trust and knowledge sharing and measurement tools to measure trust between individuals are explored. The next part of the communication process is the encoding or decoding of a particular knowledge. This, together with a common understanding of shared knowledge based on individuals background, professionals, cultures and languages, were discussed in detail. Individuals need to use effective tools to understand knowledge shared with others from different cultures. Ontologies as a technique to establish common understanding of shared knowledge is discussed in Chapter 6. The ability of individuals to understand the shared knowledge, given their different backgrounds and ontologies, is discussed in detail and measured. In this thesis, it is assumed that appropriate technology is available to everyone who wants to share or receive knowledge; hence, technology is not discussed in this thesis.

This chapter is followed by exploring the value of knowledge sharing in an organization and the role of knowledge sharing in managers' decision-making processes. As worldwide competition intensifies, traditional decision-making applications cannot satisfy the requirements of new business environments for effective decisions and more productivity. Most of the available business intelligence applications are more process-oriented and improve the speed and effectiveness of business operations by providing process-driven decision support system. On the other hand, in a knowledge-based economy new generations of business agents have emerged, including virtual organizations and electronic firms. In a new business environment, process-based business intelligence applications may not be productive. Therefore, updated business intelligence systems are needed to support decision makers. These updated business intelligence systems should take into consideration new variables such as trust and knowledge sharing which are important in a knowledge-based society. This issue is discussed in detail in Chapter 9.

The last part of this chapter focuses on the development of reliable and sensible tools to measure the value of new variables in a knowledge-based economy. Intellectual capital is the main asset for modern organizations in the digital world and measurement of this capital is a hot topic in knowledge-based organizations. In this thesis, a new method is proposed for measuring intellectual capital in an organization and equates this with the value that can be generated by trust and knowledge sharing.

To conclude, this thesis addresses four main issues. First, what are the key variables in knowledge sharing measurement? Second, how can these variables be measured? Third, how can these variables be reported and used in new generations of business intelligence to provide reliable and on time data for managers in their decision making? And lastly, how can these variables create value and how can this value be measured and documented?

The literature reviewed in this chapter leads us to problem definitions and an initial model to address these problems. In the next chapter, this model is proposed and a research methodology is selected to develop it.

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Chapter 3: Problem Definition

3.1 Overview

Knowledge sharing was identified as a key issue in a knowledge-based society as well as a knowledge-based economy. The need for a formalized model to measure the effectiveness of knowledge sharing and improve the level of knowledge sharing within and between communities was discussed. From the business viewpoint, organizations spend billions of dollars to encourage knowledge sharing between their employees, promote their brand between customers, share updated knowledge with their customers, on-the-job training programs, and train their employees to increase productivity or move to another technology. As mentioned previously, it has been estimated that at least $31.5 billion are lost per year by fortune 500 companies as a result of failing to share knowledge(Babcock, 2004) Every year, at least $300 billion are spent on on-the-job training programs and $100 billion of this is in the USA alone (Glakas, 2003). It was also estimated that the global Internet advertising market will hit $45 billion and is estimated to exceed $21 billion in the USA alone (Price waterhouse Coopers, 2008). From the social perspective, knowledge sharing and trust improve the connections and relationships between individuals within a society and encourage them to collaborate to solve the social problems. For example, non-government organizations (NGO) are based on trust between members, and knowledge sharing between them is the most critical issue in their community's achievement. In the literature reviewed in Chapter 2, the knowledge sharing process and several variables affecting knowledge sharing were investigated. Several theories and models related to the measurement of knowledge sharing were presented. In this chapter, the problems and the gaps in current research studies are discussed.

It is important that managers understand changes in the environment quickly and be prepared to adapt their organization to cope with the changes. It can help decision makers to link strategies with real and on-time data from customers, employees and other business entities. Then, managers need to access efficient tools to obtain reliable information about these variables and tools to measure and transfer the related data to decision makers. In this chapter, the shortcomings of current business intelligence tools in creating a framework to be used by decision makers to measure and control these key variables, are investigated. Various problems are also addressed in this chapter and solutions are proposed to design and develop techniques to help managers calculate their knowledge-based capital and create a balance between their physical and knowledge-based capital.

3.2 Preliminary concepts

In order to introduce problems associated with knowledge sharing measurement, in this section, a clear definition of the key concepts are presented. These key concepts include:

1. Knowledge sender
2. Knowledge receiver
3. Knowledge sharing
4. Knowledge Encoding
5. Knowledge Decoding
6. Capital

3.2.1 Knowledge sender

Definition: Knowledge sender in the context of knowledge sharing refers to the source from which knowledge starts to be shared for any reason such as establishing a relationship, business purposes, awareness, transfer innovation and any other purposes. The knowledge sender can be an individual, or an agent like a computer or whatever/whoever is used to send useful knowledge to others.

3.2.2 Knowledge receiver

Definition: Knowledge receiver in the context of knowledge sharing refers to the entity where shared knowledge starts to be absorbed for different purposes such as establishing a relationship, business purposes, be made aware of new events, acquire innovative ideas and any other purposes.

The knowledge receiver can be an individual, or an agent like a computer or whatever/whoever receives useful knowledge from others.

3.2.3 Knowledge sharing

Definition: Knowledge sharing is defined as the process of exchanging ideas and knowledge in different formats such as text, voice and can be any type of knowledge such as explicit or tacit, between knowledge sender and receiver based on their skills, experiences, education and understanding.

3.2.4 Knowledge encoding

Definition: Encoding of knowledge in the context of knowledge sharing refers to the process of translating knowledge into symbols to be communicated. Knowledge can be converted into symbols by knowledge sender source to be shared between members.

3.2.5 Knowledge decoding

Definition: Decoding of knowledge in the context of knowledge sharing refers to the process of converting the symbols transmitted in the knowledge encoding process back into knowledge that is understandable by the entity that is acquiring the shared knowledge.

3.2.6 Capital

Definition: Capital in the context of knowledge sharing refers to the benefits that knowledge sharing creates in a community. Benefits include tangible benefits such as monetary income that is generated by *knowledge sharing or intangible benefits such as motivation, incentives and non-monetary benefits.*

3.3 Problems in knowledge sharing

The problems in knowledge sharing are caused by a number of scientific issues such as different meanings of a particular knowledge in different sciences and social issues such as lack of trust between the parties that share or gain knowledge. The key problems related to knowledge sharing are categorized based on communication process as follows:

1. Knowledge sharing variables.
2. knowledge sharing measurement
3. knowledge sharing report
4. knowledge capital measurement

In the following sections, details about the definition of the problems are presented.

3.3.1 Knowledge sharing variables

To determine the related problems in defining of variables in knowledge sharing, it is important to indentify communication problems and problems in different components of the communication process. Communication problems in the context of knowledge sharing refer to failure in sharing knowledge through learning, discussions, etc. The key components of communication that were presented in Chapter 2 were: knowledge sender and receiver, knowledge encoding and decoding, and the channel that parties uses to communicate. Problems related to the knowledge sender or receiver are identified and discussed in this section. The problems are classified as follows:

1. willingness to share knowledge
2. competency to share knowledge

Also, problems related to knowledge encoding or decoding are defined and discussed in this section. These problems are:

1. Complexity of the shared knowledge
2. Transferability of the shared knowledge

These four problems are defined below.

3.3.1.1 Willingness to share knowledge

Definition: Willingness, in the context knowledge sharing, refers to the state of being motivated to share or exchange knowledge. Motivation can be related to monetary incentives such as negotiation in business or can be related to social incentives such as knowledge sharing when establishing a social relationship.

Willingness is the individuals' willingness to create connections, relations and networking. Variables such as culture, management support, trust, fear of losing knowledge and several other related variables are the most important variables that affect motivation to share or acquire knowledge.

3.3.1.2 Competency to share knowledge

Definition: Competency, in the context of knowledge sharing, refers to the basic ability to exchange information in any required form at the right *time with explicit details in the communication process between the parties involved (sender and receiver). Competency can be related to the knowledge sender's communication skills or knowledge receiver's learning competency to absorb the shared knowledge.*

This can range from ability to collaborate in basic discussions to the ability to present a lecture or even make decisions about the shared knowledge. The knowledge can be shared by face-to-face communication or by using virtual tools for sharing knowledge. Individuals' skills and confidence are the most important variables that affect their competence to share knowledge.

3.3.1.3 Complexity of shared knowledge

Definition: Complexity, in the context of knowledge sharing, refers to common understanding of the shared knowledge indicating how easy the shared knowledge is to understand. In knowledge sharing between individuals, understanding difficulty is the most important issue that is related to the structure of the shared knowledge. Individuals change their tacit knowledge to explicit knowledge in the knowledge sharing process and according to their backgrounds, use different symbols. These symbols are easily understood by parties from similar backgrounds but difficult to be understood by parties from different backgrounds. When it comes to communicating, it may cause a rift in communication, a misunderstanding, or sometimes, neither party understands the other at all. These issues are caused by the complexity of knowledge that refers to common understanding of the shared knowledge between all parties. To sum up, the complexity of a particular knowledge is one of the problems in knowledge sharing that should be addressed by a knowledge sharing framework.

3.3.1.4 Transferability of shared knowledge

Definition: Transferability, in the context of knowledge sharing, refers to the similarity of knowledge parties' domain knowledge in knowledge sharing process. Based on culture, education, experience and member's background, each party has a repository of knowledge and data and uses this repository in communication. The similarity of these repositories has a direct affect on the transferability of a particular knowledge. The greater the similarity between repositories, the better is the transferability of knowledge. When a particular knowledge that is shared between parties is not available in one party's repository, the shared knowledge cannot be transferred and this issue is also a problem in knowledge sharing. In this research it is assumed that each party uses a repository of knowledge that is unique to each. For example, a team member from a financial background wants to share knowledge with another member from a social science background. There are two repositories, one for the financial member repository and another one for the social science repository. The degree of similarity of their repositories can be calculated to measure the transferability of knowledge between these two parties. To sum up, transferability of a particular knowledge is one of the problems in knowledge sharing that should be addressed by the proposed model.

3.3.2 Knowledge sharing measurement

Definition: knowledge sharing measurement refers to measuring and expressing the related variables in knowledge sharing numerically. Numeric measurement in the context of knowledge sharing requires the design of a model that uses numeric variables to measure knowledge sharing levels and produce a numeric result.

Most variables that affect knowledge sharing are subjective and the problem is how to change these subjective variables to variables with a clear value that can be used in a knowledge sharing measurement framework. Numeric values can provide a most useful understanding of knowledge sharing effectiveness and can define clear ways to improve it. A measurement model should be convenient to the end users especially for the managers or decision makers who want to use the model. The current models are based on subjective values and cannot be used by managers to measure and report the current level of knowledge sharing.

3.3.3 Knowledge sharing reporting

Definition: Knowledge sharing reporting in the context of knowledge sharing refers to providing documentation to describe the findings of the measurement model in knowledge sharing.

The results of any designed model need to be evaluated by decision makers and be used by them to make decisions or for future strategic planning. However, the current literature exposes several problems in relation to the availability of reliable tools to provide required information in a decision-making process.

3.3.3.1 Awareness

Definition: Awareness, in the context of knowledge sharing, refers to providing information about the knowledge sharing level, progress achieved to improve knowledge sharing level, and the decisions being made by managers based on the provided information so that they are aware of what is going on at current stages and at the current time. It is important for managers to discover the knowledge that has been misunderstood and try to clarify the shared knowledge.

The problems related to awareness of knowledge in a community should be clarified and managers need to access developed models in order to create an effective awareness system.

3.3.3.2 Track and Trace

Definition: Track and trace, in the context of knowledge sharing, refers to an attempt to pursue a particular knowledge sharing recorded in an environment where knowledge can be shared or exchanged freely without any external pressure in the process of knowledge sharing. Track and trace can follow the knowledge from the initial source that begins to share it to the last receiver that obtains that particular knowledge. This can help decision makers to create an environment where information flows smoothly and remotely. Track and trace provides tools to track information that is exchanged or discussed or shared at any point in time.

3.3.3.3 Just-in-time

Definition: Just-in-time, in the context of knowledge sharing, refers to sending and responding to a particular knowledge within a specific time *slot.* Budget and time is limited in knowledge sharing and lack of enough capacity to share knowledge at the right time may affect the reliability and trustworthiness of the knowledge. Hence, knowledge should be shared and reported at the right time.

3.3.4 Knowledge capital measurement

Definition: Knowledge capital measurement in the context of knowledge sharing refers to the measurement of different kinds of assets that can be created by sharing knowledge. Knowledge can improve employees' knowledge and increase productivity, and can produce innovative ideas and new products.

Knowledge creates asset for a business and knowledge sharing can be assumed as a technique to increase this asset as well as maintain it. There is no related model which directly discusses the capital created by knowledge sharing.

3.4 Underlying Research Issues

Based on the problems identified in the previous section, the research issues are defined in this section. Four research issues are identified as being:

1. Identifying knowledge sharing variables
2. Developing a knowledge sharing measurement model
3. Developing a knowledge sharing reporting mechanism
4. Validation and verification of knowledge sharing framework
5. Developing a model to measure knowledge capital

In the next sections, the five research issues are defined and given in detail.

3.4.1 Identifying knowledge sharing variables

Definition: Identifying knowledge sharing variables is defined as factors that affect the knowledge sharing level between knowledge sender and knowledge receiver.

The research issue is to identify the most important variables in knowledge sharing. Variables in improving knowledge sharing levels between individuals with different backgrounds such as culture, education, age and skills, are examined. Variables in this research include complexity and transferability of knowledge as well as willingness and competence to share knowledge. Complexity is more related to measuring the difficulty of arriving at a common understanding of knowledge between knowledge sender and receiver. Transferability relates to the similarity of knowledge between domains that are used by knowledge sender or receiver.

Also, willingness to share knowledge and competence to share knowledge are key issues in knowledge sharing. Willingness is defined as individuals' willing to create a relation to share or exchange their knowledge. Also, competence is defined as skills that individuals need in order to be able to start communicating their knowledge to others

3.4.2 Developing a knowledge sharing measurement model

Definition: Developing a knowledge sharing measurement model is defined as a numeric model that is able to measure the knowledge sharing level between knowledge sender and receiver based on numeric variables.

Knowledge needs to be changed and shared in explicit format and explicit type of knowledge is used to measure knowledge sharing level.

3.4.3 Developing a knowledge sharing reporting mechanism

Definition: Knowledge sharing reporting, in the context of knowledge sharing, refers to providing business intelligence tools for managers and decision makers to be able to track and trace knowledge sharing levels at any time within and between communities.

3.4.4 Validation and verification of knowledge sharing framework

Definition: Validation and verification, in the context of knowledge sharing measurement, refers to building a system to demonstrate its feasibility allowing proof of claims in a knowledge sharing measurement framework. The solutions proposed for research issues 2, 3 and 4 must be validated. It creates confidence in the framework that is used to measure and report knowledge sharing level. To validate the solutions, an approximation of a prototyping system that is based on the knowledge sharing framework is developed. This system is used to verify the soundness of the framework. The solution overview is presented for the research issues in Chapter 4, and in Chapter 9 the prototype used for validation of the framework is explained. Also, a simulation model is used to validate knowledge sharing reporting framework in Chapter 9 and experimental studies are used to validate knowledge capital measurement framework in Chapter 10.

3.4.5 Developing a framework to measure knowledge capital

Definition: Developing a framework to measure capital of knowledge sharing refers to the competitive advantages and benefits that knowledge sharing can provide for a business or a community by increasing knowledge sharing level between members. The assets can be monetary benefits such as the effect of knowledge sharing between customers on their decision to buy a firm's product or can be benefits related to improvement of their business process such as training in new concepts by using knowledge sharing techniques.

3.4 Underlying solution requirement

Four key research issues were identified in the last section and any new solutions for knowledge sharing measurement should address and provide a solution for these four key issues. Therefore, in this section, four fundamental requirements for any proposed methodologies are presented as:

- ✓ identification of knowledge sharing variables
- ✓ development of Knowledge sharing measurement
- ✓ development of Knowledge sharing reporting system
- ✓ development of knowledge capital in Knowledge sharing

3.4.1 Requirement of knowledge sharing variables identification

Knowledge sharing is fundamentally related to willingness and competence of individuals to share knowledge. Also, knowledge should be understandable and transferable by all parties. The first requirement for any proposed framework is the underlying willingness to share knowledge. As a party has enough willingness to share knowledge, skills and ability to share knowledge is becoming more important. Another requirement is related to measuring the ability of knowledge sharing parties to share knowledge. In any knowledge sharing process, there are knowledge sender and knowledge receiver components, and the willingness and competence to acquire the shared knowledge should also be considered in knowledge sharing requirements. On the other hand, knowledge itself is important, and complexity as well as transferability of the shared knowledge should be covered by any knowledge sharing measurement framework. All these variables should be measured by numeric variables to numerically determine the final knowledge sharing level. Willingness and competence and complexity and transferability of knowledge are dynamic variables and can be changed in different kinds of knowledge domains. Then, the proposed framework should be able to measure the dynamic nature of these variables and also its effect on knowledge sharing measurement.

3.4.2 Requirement of developing of knowledge sharing measurement

Most of the related variables in knowledge sharing measurement are subjective and have a fuzzy entity. The proposed knowledge sharing measurement framework should be able to cover all these variables and should also be able to use fuzzy variables and show the result numerically. Any proposed framework should be able to link with input variables data repositories and matrices to use the related data in measurement processes. And also, the result should be easy to understand and convenient to report to the decision makers and managers.

3.4.3 Requirement of developing of knowledge sharing reporting system

Any report system in knowledge sharing should be able to report knowledge sharing level at any time due to the dynamic nature of knowledge sharing. It should also clarify the details and the problems in knowledge sharing to help decision makers to find the root problems in knowledge sharing and their decision to solve these problems. The result of the report should be easy to use by managers to explain the current situation to all stakeholders.

3.4.4 Requirement of developing of knowledge capital in knowledge sharing

In a business environment, benefits are more related to monetary benefits and add value that any new method can create for a business. Similarly, the proposed model should be able to explain the monetary benefits that the model can create for a business. For example, in on- the-job training programs, the value adds can be created by the proposed model. Another requirement is related to considering different viewpoints in measurement and reports the benefits. Stakeholders have different viewpoints and a report system should provide required information catering for different viewpoints.

3.5 Choice of Research Approaches

The thesis's objectives are to develop a method of knowledge sharing that defines measures and report variables in knowledge sharing. In order to carry out this development, it is necessary to follow a systematic, scientific approach to ensure the model development is of quality and is scientifically-based. Therefore, in this section, an overview of existing scientific research methods is explained and choice of a particular scientific-based research method for this thesis is outlined.

3.5.1 Research methodologies

Research method outlines the strategies to answer the research questions (Pinsonneault and Kramer, 1993). These strategies should be chosen according to the research question, research objectives, literature review and limitations. Some paradigms are proposed to classify research methods. Chua has classified research method into 3 categories: positivist, interpretive and critical (Chua, 1986).

The scientific or positivist research method category explains that there are quantifiable measures of variables, hypothesis testing, and the drawing of inference about a phenomenon from a representative sample to a stated population. Positivist researchers think that patterns observed in the past will repeat in the future.

In the interpretive research method category, it is assumed that human knowledge of reality is gained only through social constructions such as language, shared meaning, documents and tools. The philosophical base of interpretive research is hermeneutics and phenomenology. It does not predefine dependent and independent variables, but focuses on the complexity of human sense making as the situation emerges.

In the critical research method category, social critique is the main task. This theory assumes that people can consciously act to change their social and economic conditions. Human have the ability to improve their conditions by various forms of social, cultural and political domination as well as natural laws and resource limitations.

3.5.2 Choice of Science and Engineering Based Research Method

Information systems in organizations are complex, artificial, and purposefully designed. They are composed of people, structures, technologies, and work systems (Bunge, 1985). The science and engineering research is a new paradigm in information systems research and this paradigm may lead to the development of new techniques, architecture, methodologies, devices or a set of concepts which can be combined together to form a new theoretical framework. Better understanding of the science and engineering-based research approach as an information system research paradigm requires an important dichotomy in both a process (set of activities) and a product (artifact) – a verb and a noun (Walls et al., 1992). This research approach commonly identifies problems and proposes solutions to these problems. March and Smith have provided a concise conceptual framework for design-science research and state that design-science research deals with understanding the problem domain and designing a solution by building application or some design artifacts (March, 1995). Particularly in the science and engineering paradigm ‘making something work’ is essential (Nunamaker et al., 1991).

The different levels for science and engineering research according to (Galliers, 1991)are:

Conceptual Level. In this level, new ideas and concepts are created through analysis.

1. Perceptual Level. New methods and new approaches are formulated in this level through building tools or environment or system through implementation.
2. Practical level. Testing and validation is carried out in this level through experimentation with real world examples, using laboratory or field testing.

This research justifies the adoption of a science and engineering paradigm. The primary objective of this research is to discover the impact of variables on knowledge sharing. To achieve this objective, a framework is developed to understand, estimate and measure the variables' impact on knowledge sharing based on the literature review. In the next chapter, the conceptual level of the research method is discussed and an initial framework is proposed. This framework is developed in the perceptual level in Chapter 7 and the developed model is validated in Chapter 8 as the practical level in the science and engineering research method. The proposed framework should cover all the four issues that are examined as research questions including variables affect knowledge sharing, knowledge sharing measurement, knowledge sharing based business intelligence, and intellectual capital that is produced by knowledge sharing within an organization.

3.6 Conclusions

In this chapter, the related problems were discussed and key research issues defined as: underlining knowledge presentation by investigating the complexity and transferability of a particular knowledge, discussing willingness and competence to share ideas and knowledge, underlining a report system to provide related information about knowledge sharing measurement and presenting the benefits of knowledge sharing. Based on research problems and research issues, the requirements of each research issue were investigated and initial ideas for addressing the problems were presented. A summary of choice of research approaches was also given and the science and engineering based research method was selected as the most suitable research method for the development of the proposed solution.

In the next chapter, a conceptual solution to address the issues is proposed and solutions are discussed in detail.

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Chapter 4: Solution overview and conceptual framework

4.1 Overview

Sharing individual's embedded knowledge with others and increasing the flow of knowledge in a knowledge-based society are crucial issues in a modern society and knowledge-based economy. Knowledge sharing definition, barriers in knowledge sharing, variables' effects on knowledge sharing and proposed methods for knowledge sharing measurement were discussed in the previous chapter. Based on the literature review, some gaps in the current literature were indentified and research questions were examined based on the current shortcomings. It is necessary to choose a suitable research methodology to follow up the problems, and make research work understandable to other researchers. The science and engineering research method was selected as the suitable research method in this research. Different levels of the selected research methodology are discussed in this chapter and initial framework based on literature review in the last chapter is proposed to explore research questions. In Chapters 5 and 6, the variables of this proposed framework are discussed in detail and the proposed framework is developed in Chapter 7 and validated in Chapter 8.

4.2 Solutions overview

As was pointed out in Chapter 2, the existing research does not propose a complete framework for knowledge sharing measurement or a knowledge sharing reporting system and capital that can be created by developing an effective knowledge sharing model. In this section, an overview of the solution for knowledge sharing modeling is presented.

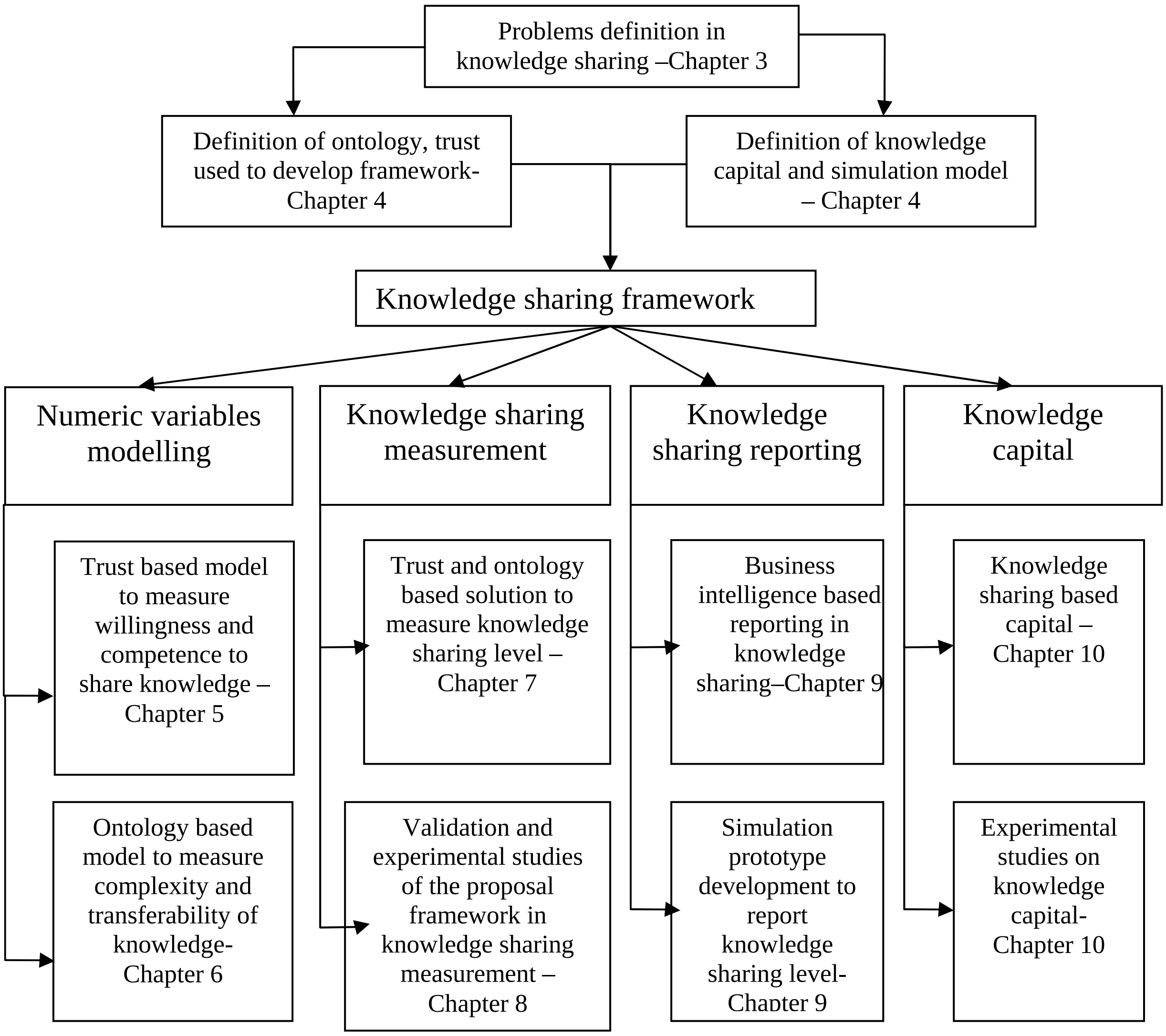


Figure4.1: Overview of the whole solution for knowledge sharing modeling

The overall solution proposed for knowledge sharing modeling comprises:

1. Solution for numeric variables modeling: The solution for numeric variables modeling includes:
    a. A solution for measuring willingness and competence to share knowledge in a given context and during the specific time slot based on trust and trust dimensions methodologies. The proposed solution seeks numeric values of willingness and competence to share knowledge and in Section 4.3, an overview of the solution is presented. Also, Chapter 5 discusses the solution in detail.
    b. A solution for measuring complexity and transferability of knowledge in a given context and during the specific time slot based on ontology methodologies. The proposed solution seeks numeric values of complexity and transferability of knowledge to be shared between knowledge sender and knowledge receiver. In Section 4.3, an overview of the solution is presented. Also, Chapter 6 discusses the solution in detail.
2. Solution for knowledge sharing measurement

In order to measure knowledge sharing level, a trust- and ontology-based framework is designed to numerically measure the value of knowledge sharing in the Section 4.4. The proposed framework is developed and discussed in detail in Chapter 7.

3. Solution for knowledge sharing reporting

In order to design a knowledge sharing reporting system, a simulation model is developed to report trust and knowledge sharing level to decision makers by taking into account the context of the shared knowledge as well as the dynamic nature of knowledge sharing and trust. Business intelligence techniques are used to develop the proposed simulation model and are discussed in Section 4.5. This solution is developed and discussed in detail in the Chapter 9.

4. Solution for knowledge capital improvement

In order to measure improvement in a community's or an organization's capital that results from knowledge sharing within that community or organization, intellectual capital techniques are used to develop a model to measure the value that can be created by knowledge sharing. The overview of the solution is examined in Section 4.6 and is discussed in detail in Chapter 10.

From Section 4.3 - Section 4.8, an overview of the solutions to each of the research issues identified in the previous chapter is presented.

4.3 Solutions for knowledge sharing variables identification

As discussed in Chapter 2, some variables affect on knowledge sharing. Some of these variables were discussed in Chapter 2 and were investigated based on different stages of knowledge communication including knowledge receiver or sender, knowledge channels and knowledge decoding or encoding. Knowledge channels are more related to technology level in knowledge sharing between individuals. This research assumes that technology is available to all the individuals within a community and everyone has access to the tools and technologies that are required for effective communication. Therefore, this research focuses on only two stages of knowledge communication: knowledge sender or receiver and encoding or decoding of knowledge. The proposed framework should be able to cover the related variables two stages. In this part of the research, variables in each stage are discussed in detail based on the literature review in the Chapter 2.

4.3.1 Variables in sending or receiving knowledge

Based on the literature in Chapter 2, individual's willing to share knowledge is related to monetary benefits (for example increase knowledge sender's salary, different kinds of monetary bonuses, rewards and etc.) or social credits (such as high respect, high trust and etc.) that they earn by sharing their knowledge. As soon as they feel there is no benefit in sharing their particular knowledge, they stop to share it. The main important variable in this part is the willingness of the knowledge sender to share knowledge. It is the most important variable to start a knowledge sharing processes between individuals. As a result, the first variable is defined as follows:

$$\mathrm{Ks} \cong f(Sw) + \mathrm{E}$$

Ks= knowledge sharing, Sw= Sender's willingness, E= other variables affect on knowledge sharing

(Equation4.1)

On the other hand, the other party's willingness to absorb the sender's shared knowledge is also important. Some times this requires enough time and budget (for example register in a short term courses) and another variable in knowledge sharing is the willingness of the knowledge receiver to catch the shared knowledge. It is also important that the shared knowledge be fully understood by the receiver and becomes a tacit knowledge because the shared knowledge is mostly explicit knowledge and the receiver needs to fully understand the shared knowledge to use it in the future. This part of the research is focused on the receiver's willingness to obtain a particular knowledge that is shared by a defined sender (If the sender is anonymous, the receiver's willingness will be different). As a result, the simplest formula, where sender and receiver know each other and have enough willingness to share a particular knowledge within a particular time slot can be formulated as follows:

$$\mathrm{Ks} \cong f(Sw(t1), Rw(t1)) + \mathrm{E}$$

(Equation4.2)

Ks=knowledge sharing for a specific knowledge, Sw= Knowledge sender's willingness to share knowledge in a specific time slot (t1), Rw= Knowledge receiver's willingness to gain knowledge in a specific time slot (t1), E= other variables affect knowledge sharing between sender and receiver.

Figure 4.2 shows two parties' willingness to share a particular knowledge in a particular time slot:

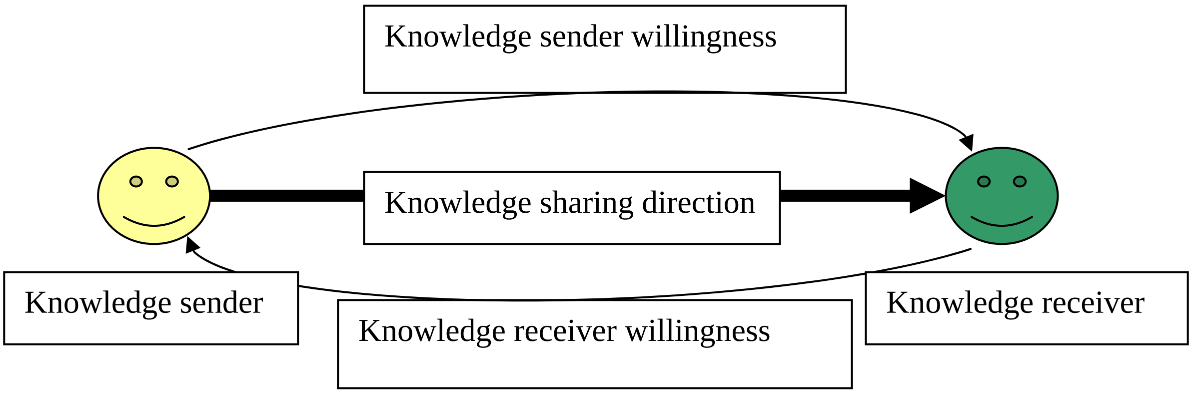


Figure 4.2: Knowledge sharing willingness between two parties

Willingness to share knowledge is a dependent variable and is more related to the variables such as the individual's culture, management support and organizational incentive systems, personal attitude and expectations and some other related variables that were discussed in the last chapter (barriers in knowledge sharing). Based on the literature, related equations can be defined as below:

A) Willingness to share/receive knowledge depends on culture $\cong$

$variables\ related\ to\ culture\ of\ the\ community + O1\ \cong f(C_V) + O1$

$C_V = Culture\ related\ variables$, O1=other variables affect on willingness to share knowledge

(Equation4.3)

B) Willingness to share/receive knowledge depends on management supports and incentive support system.

$\cong variables\ related\ to\ management\ sopports\ or\ organizational\ incentve\ systems + O2$

$\cong f(M_S\ ,\ I_S) + O2$

$M_s = variables\ related\ to\ management\ sopport$, $I_s = variables\ related\ to\ incentive\ systems$

O2=other variables affect on willingness to share knowledge

(Equation4.4)

C) Willingness to share knowledge depends on personal attitude and expectations.

$\cong variables\ related\ to\ personal\ attitude\ and\ expectations + O3$

$\cong f(P_a\ ,\ P_e) + O2$

$P_a = variables\ related\ to\ personal\ attitude$, $P_e = variables\ related\ to\ personal\ expectations$

O3=other variables affect on willingness to share knowledge

(Equation4.5)

Overall, these equations can be accumulated as below:

$KS_w = f(C_v, M_S, I_S, P_a\ , P_e\ ) + O$ $\quad$ KS_w = Knowledge sharing willingness

(Equation4.6)

These formulas are verified by different researches. Cheng et al. (2008) have proposed an equation to measure knowledge sharing willingness as follows:

$$KSi = \alpha + \beta 1ISi + \beta 2MSi + \beta 3OCi + \beta 4IAi + \beta 5PEi + \beta 6ITi + \mu i$$

(Equation4.7)

Where

KSi = Knowledge Sharing willingness; IS = Incentive System; MS = Management System; OC = Organizational Culture; IA = Individual Attitude; PE = Personal Expectation; IT = IT Application; $\alpha, \beta 1, \beta 2, \beta 3, \beta 4, \beta 5, \beta 6$=Regression coefficients; μi= Standard error; i=1, 2, 3... n n=number of the members.

To sum up, willingness to share knowledge is the most key issue in knowledge sharing management and both sender and receiver parties have to be motivated to share or gain knowledge. This issue should be considered in the proposed model and as seen in Chapter 7, willingness to share knowledge is one of the key issues in the developed model in knowledge sharing measurement. However, as mentioned in Chapter 3, sometimes both parties have enough motivation to share knowledge, but knowledge is shared with difficulty. As was discussed in the literature, knowledge sharing needs resources such as time and budget and these resources are limited. Individuals need to learn skills to share their knowledge effectively in the limited time and budget. This is more related to individual's competency. To achieve a high level of competency, individuals need to update their knowledge and learn continuously. As was discussed in Chapter 1, they have to increase their tacit knowledge and learn explicit knowledge as much as they can (Nonaka's spiral of knowledge). Learning updated knowledge can increase knowledge self-efficiency between individuals and encourage them to share their knowledge. Knowledge self-efficacy refers to individual's belief that the knowledge that they have would be helpful to co-workers were they to receive it (Cabrera and Cabrera, 2002). Self-efficacy can increase one's ability to engage in the particular action or behavior required to share particular knowledge and improve an individual's capability to share or receive knowledge. Based on this theory, people examine others' knowledge levels to ascertain the importance of their own knowledge. This can also happen when a new employee starts to work with his or her co-workers and in first stage he or she is more interested in evaluating other's knowledge, and then starts to discuss or share knowledge. One way to increase self-efficacy between individuals is to establish mechanisms by which employees receive feedback whenever others use their contributions. It should be noted that negative feedback might reduce an employee's knowledge self-efficacy and, consequently, reduce the likelihood that the employee will choose to contribute to knowledge sharing processes in the future (Cabrera and Cabrera, 2002). However, this may not be a negative consequence of the use of feedback and could actually help control the quality of contributions for any possible negative effects of selective incentives, encouraging quantity rather than quality (Cabrera and Cabrera, 2002). To sum up, some people are more competent when absorbing new ideas and they are able to change explicit knowledge to tacit knowledge faster than others. These people have high levels of self-efficacy and are trustworthy resources to share updated knowledge within a community. This issue can be formulated as:

$$\mathrm{Ks} \cong f(Sc) + E'$$

Ks=Knowledge sharing Sc= Sender competency E'= other variables

(Equation4.8)

This equation is the most simple equation to show the role of sender's competency to learn and share a particular knowledge. However, competency and self-efficacy requirement are key issues for a receiver as well. The receiver should make sure that the shared knowledge is useful and can provide advantages in the future. Also, receivers should be able to understand the shared knowledge and have enough competencies to absorb it and change explicit knowledge to tacit knowledge to use in the future. Equation 4.9 shows the relationship between receiver's competency and knowledge sharing:

$$\mathrm{Ks} \cong f(Rc) + E'$$

Ks=Knowledge sharing Rc= Receiver competency   E'= other variables

(Equation4.9)

As a result, both parties in a knowledge sharing process should be able to share/absorb a particular knowledge within a specific time slot and both parties' competency, skills and self-efficacies are important in a successful knowledge sharing process. This issue has been shown in Figure 4.3:

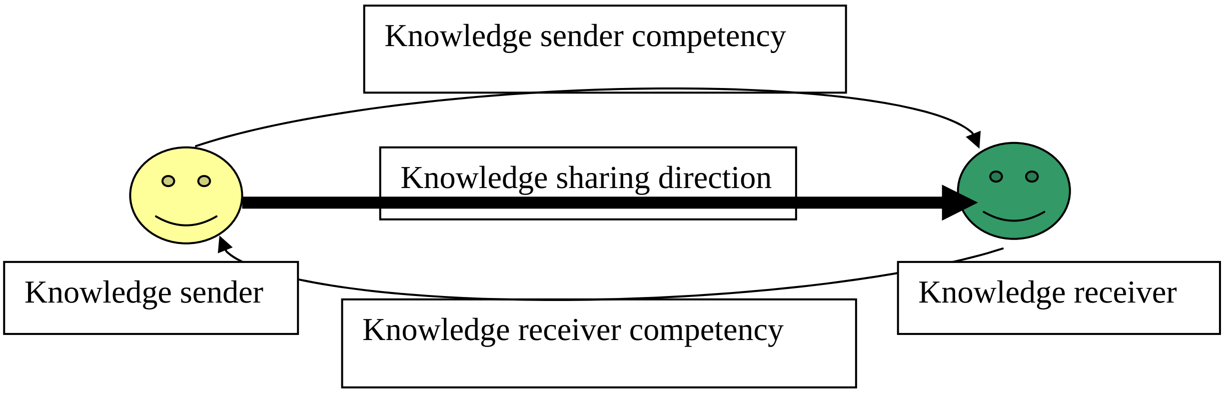


Figure 4.3: Knowledge sharing competency between two parties

Based on the variables in Figure 4.3, the simplest formula to show the roles of senders and receivers' competencies in knowledge sharing processes to share a particular knowledge in a particular time slot can be formulated as:

$$\text{Ks} \cong f(Sc(t1), Rc(t1)) + \text{E'}$$

Ks=knowledge sharing for a specific knowledge, Sw= Knowledge sender's competencies to share knowledge in a specific time slot (t1), Rw= Knowledge receiver's competencies to gain knowledge in a specific time slot (t1), E' = other variables affect on knowledge sharing between sender and receiver

(Equation4.10)

Senders' or receivers' knowledge sharing competencies are dependent variables and based on the literature, they depend on the ability to learn new ideas and new knowledge, ability to know others' knowledge in a particular domain where they want to share knowledge (this produces self- efficacy to share knowledge) and special communication skills such as presentation skills, writing and listening skills. Some of these skills depend on people's personalities and intelligence such as ability to learn and some of these skills can be improved by training and special courses such as presentation skills or writing skills. Equations related to individuals' knowledge sharing competency are discussed below:

A) Ability to share/receive knowledge depends on learning competency

$\cong variables\ related\ to\ learning\ competency + C1\ \ \cong f(L_c) + C1$

$L_c = Learning\ competency\ variables$,

C1=other variables affect on ability to share knowledge

(Equation4.11)

B) Ability to share/receive knowledge depends on competencies to define knowledge requirement of others to share related knowledge and produce self- efficacy.

$\cong variables\ related\ to\ Knolwedge\ requirement\ definition + C2$

$\cong f(K_{rd}\ ,\ S_e) + C2$

$K_{rd} = variables\ related\ to\ knowledge\ requirement\ definition$,

$S_e = variables\ related\ to\ self\ efficiency$,

C2=other variables affect on competency to share knowledge

(Equation4.12)

C) Ability to share knowledge depends on personal communication skills

$\cong variables\ related\ to\ personal\ Communication\ skills + C3$

$\cong \mathrm{f}(\mathrm{P_n}\ ,\ \mathrm{P_p}) + \mathrm{C3}$

$P_n = variables\ related\ to\ personal\ skills(intelligence\ based)$,

$P_e = variables\ related\ to\ personal\ skills(practice - based)$.

C3=other variables affect on willingness to share knowledge

(Equation4.13)

Overall, these equations can be combined as follows:

$KS_c\ = f(L_c, K_{rd}, S_e, P_n\ , P_p\ ) + C$ KS_c = Knowledge sharing competency

(Equation4.14)

Figure 4.4 summarizes the discussion about willingness and competency of both parties in the knowledge sharing process. As seen in Figure 4.4, knowledge sharing depends on willingness and ability to share knowledge by the sender as well as the willingness and ability to absorb the shared knowledge by the receiver. The most important issue is that willingness and ability to share or absorb the particular knowledge are dynamic and can be changed in different time slots. Also, it can be changed to different kinds of knowledge. Then, the specific knowledge and time slot should be defined in any research in knowledge sharing measurement.

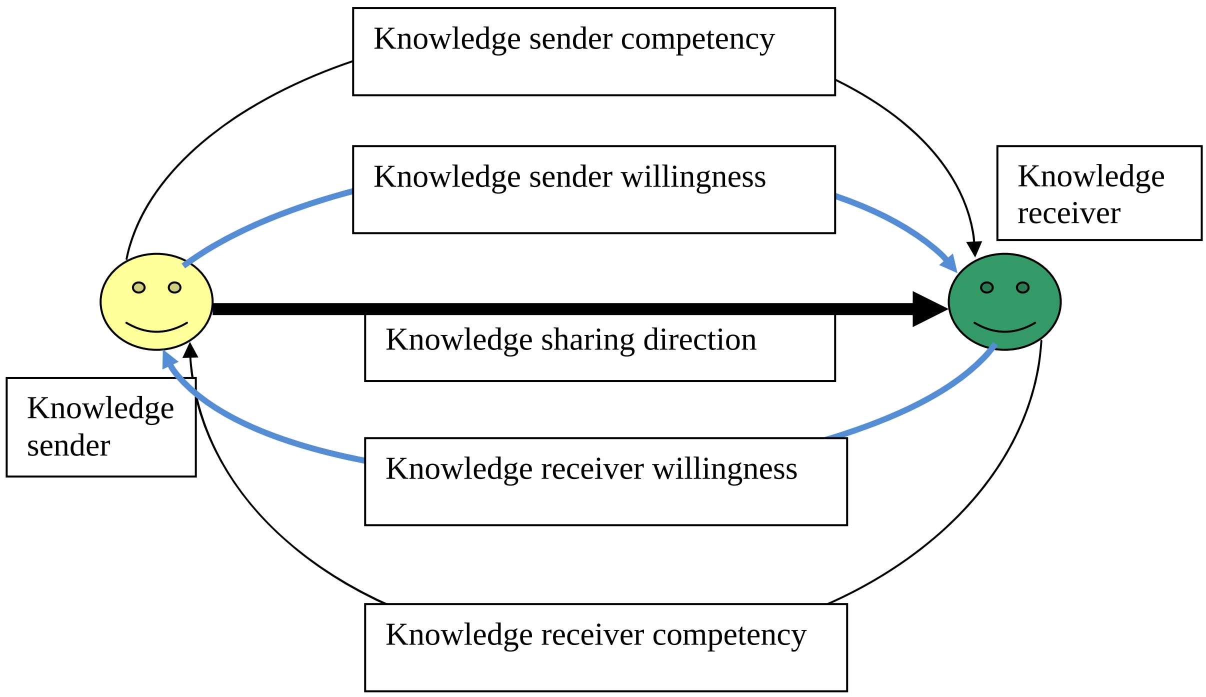


Figure 4.4: Variables related to sender and receiver that affect on knowledge sharing

Based on Figure 4.4, knowledge sharing is a function of four variables including sender's willingness to share knowledge, sender's competency to share knowledge, receiver's willingness to share knowledge and receiver's competency to share knowledge. Equation 4.15 shows the relation between these four variables with knowledge sharing.

$$KS = f(S_{ksw}, S_{ksc}, R_{ksw}, R_{ksc}) + o_v$$

Where,

S_{ksw} = sender's willingness to share knowledge

S_{ksc}= sender's competency to share knowledge

R_{ksw}= receiver's willingness to share knowledge

R_{ksc}= receiver's competency to share knowledge

(Equation4.15)

Figure 4.5 shows that all these four variables are dependent variables and all are related to variables that are mentioned in Figure 4.5.

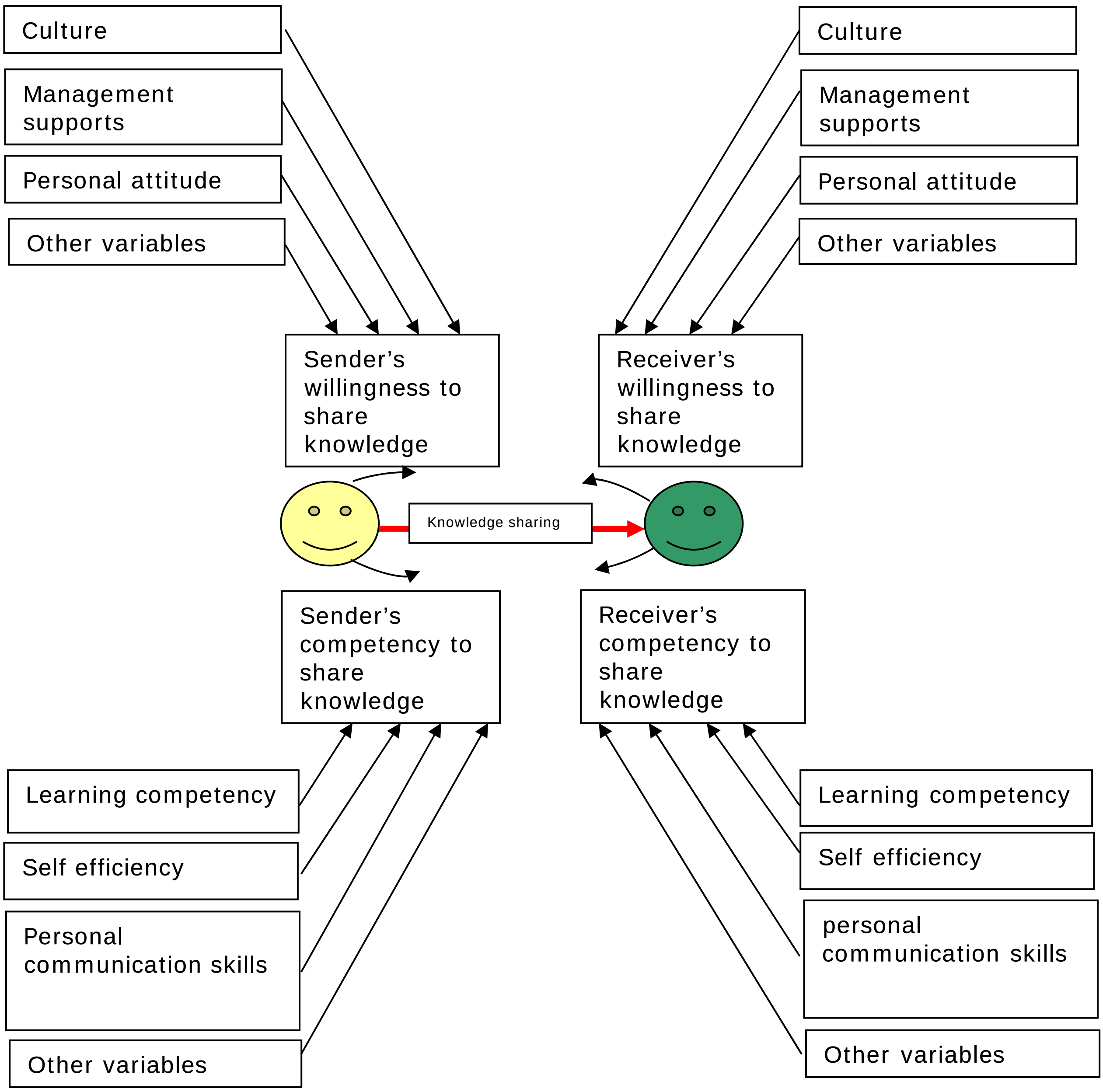


Figure4.5: Dependent variables in knowledge sharing

The variables that were discussed were all related to sender or receiver. However, as discussed in Chapter 2, some knowledge sharing variables are related to encoding/decoding the shared knowledge and in the next section, these variables are discussed in detail.

4.3.2 Variables in encoding or decoding knowledge

In Chapter 2, variables in knowledge sharing were classified into three categories including variables related to sender or receiver, variables related to encoding or decoding the shared knowledge and variables related to technology availability. The proposed framework in knowledge sharing measurement should cover all these issues and this part of the chapter is more focused on encoding or decoding of the shared knowledge. As discussed in the literature, language difference and same understating of a particular knowledge by all senders and receivers are key issues in encoding or decoding of a particular knowledge. To have a better view about the problem, a case study is used to explain the problem precisely. There is an international women's movie festival and all countries are invited to send their best young movie director to this festival. The girls are located in the three-bedroom apartments and each of these three girls live together in one apartment. The girls who are living at Unit 5 are Lee, Sevda and Alice. Lee is from China, Sevda is from Turkey and Alice is from Australia. Figure 4.6 shows a brief glimpse of their backgrounds.

Figure 4.6: Unit 5 members

First, it is assumed that all three girls just know their own language and they are not able to talk in other languages. The problem is, knowledge cannot be transferred between them. For example, Alice wants to know Sevda's favorite season and asks her: Sevda, What is your favorite season? (Figure4.7).

Figure4.7: Message from Alice to Sevda

It is clear that the message is not transferred from Alice to Sevda and this is not related to willingness or competency of both parties to share their knowledge. If knowledge sharing level is supposed to be shown from 0 to 1, the knowledge sharing level between Alice and Sevda will be close to 0 but not zero, because they may transfer a little knowledge by using body language or show related equipments and tools related to their topic. Again, it is very important to note that transformability of knowledge between the parties is related to time and it is dynamic. However, Sevda may learn some English during the festival time and start to share her knowledge with Alice by using very simple words. Overall, transformability depends on the number of the words that are common to both parties' language. This can be measured by comparing language similarities and to do this, a words repository can be defined for each party and by comparing repositories, the level of transformability can be calculated. Figure 4.8 shows the similarity between sender and receiver repositories.

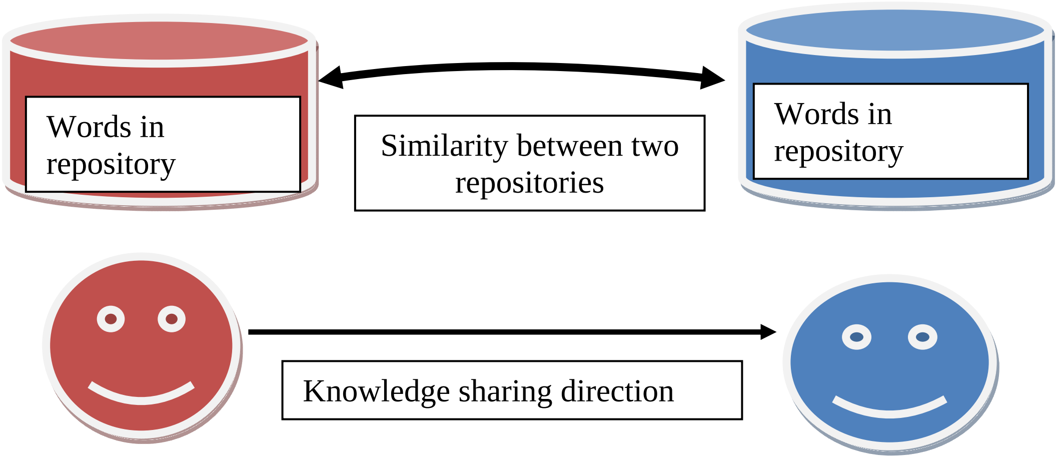


Figure 4.8: Similarity of the repositories to measure the shared knowledge transformability

Based on Figure 4.8:, related equations to show the relations between sender's and receiver's repositories can be defined as follows:

$S_d \cong f(t)$ Sender's repository (Dynamic nature of repository)

(Equation4.16)

$R_d \cong f(t)$ Receiver's repository (Dynamic nature of repository)

(Equation4.17)

$K_T = f(Sim(S_d, R_d)) + K_0$ K_T=Knowledge transformability Sim(S_d, R_d)=Similarity between two repositories (sender and receiver's repositories)

(Equation4.18)

Now, suppose Lee moves to another unit and Diana from Canada joins the girls from Turkey and Australia at Unit 5. Then, Diana and Alice are from English-speaking countries and they can start to share their knowledge easily. By this way, knowledge transformability between Diana and Alice is high but, still there are some words with different meanings due to cultural differences and they may have different education backgrounds, and some words in different domains have different meanings. For example, 'windows' or 'folder' in the computer engineering context have particular meanings but in public, people may use the normal meaning of these words. This may cause confusion in knowledge sharing between a person with a computer engineering background and another person with a social science background. This also should be considered in knowledge sharing between individuals and homonyms as well as different words with different meanings should be considered in word repositories of both parties. This helps both parties to know about these words and have a similar understanding of their shared knowledge. Hence, knowledge transformability between sender and receiver is another key issue in knowledge sharing.

The last key issue in knowledge sharing is complexity of a particular knowledge in a specific time slot. Suppose all the members come from a business background and therefore are all familiar with business terminology and all use almost the same business words in a repository. Figure 4.9 shows knowledge sharing between Alice and Erika where both are from a business background.

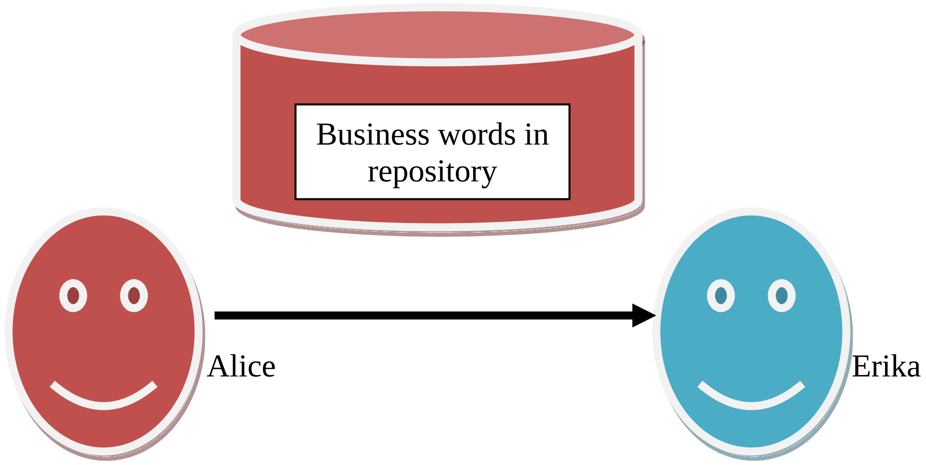


Figure 4.9: Knowledge sharing between two parties with the same language

Although both parties use the same repository, the complexity of the shared knowledge is different for different persons with different backgrounds. As discussed in Chapter 1, there are various types of knowledge. Commonsense knowledge is general knowledge that every member of a society is expected to know versus expert knowledge that is understood by a limited numbers of experts. Also, explicit knowledge includes numbers, tables, graphs and etc. that make it easy to understand but, tacit knowledge is based on personal experience and not easily understood by others. As a result, a particular knowledge may be understood by one person whereas, it can be understood only with difficulty by another one. It is very important in knowledge sharing research to study the difficulty of a particular knowledge for the sender or receiver in a specific time slot. This can be shown with Equation 4.19 as follows:

$K_c \cong f(t)$ K_c =Knowledge complexity

(Equation4.19)

In this research, in order to measure knowledge transformability and knowledge complexity, ontologies techniques are applied and discussed in detail in Chapter 6.

To sum up, knowledge sharing in this research is evaluated by four variables that are shown in Figure 4.10.

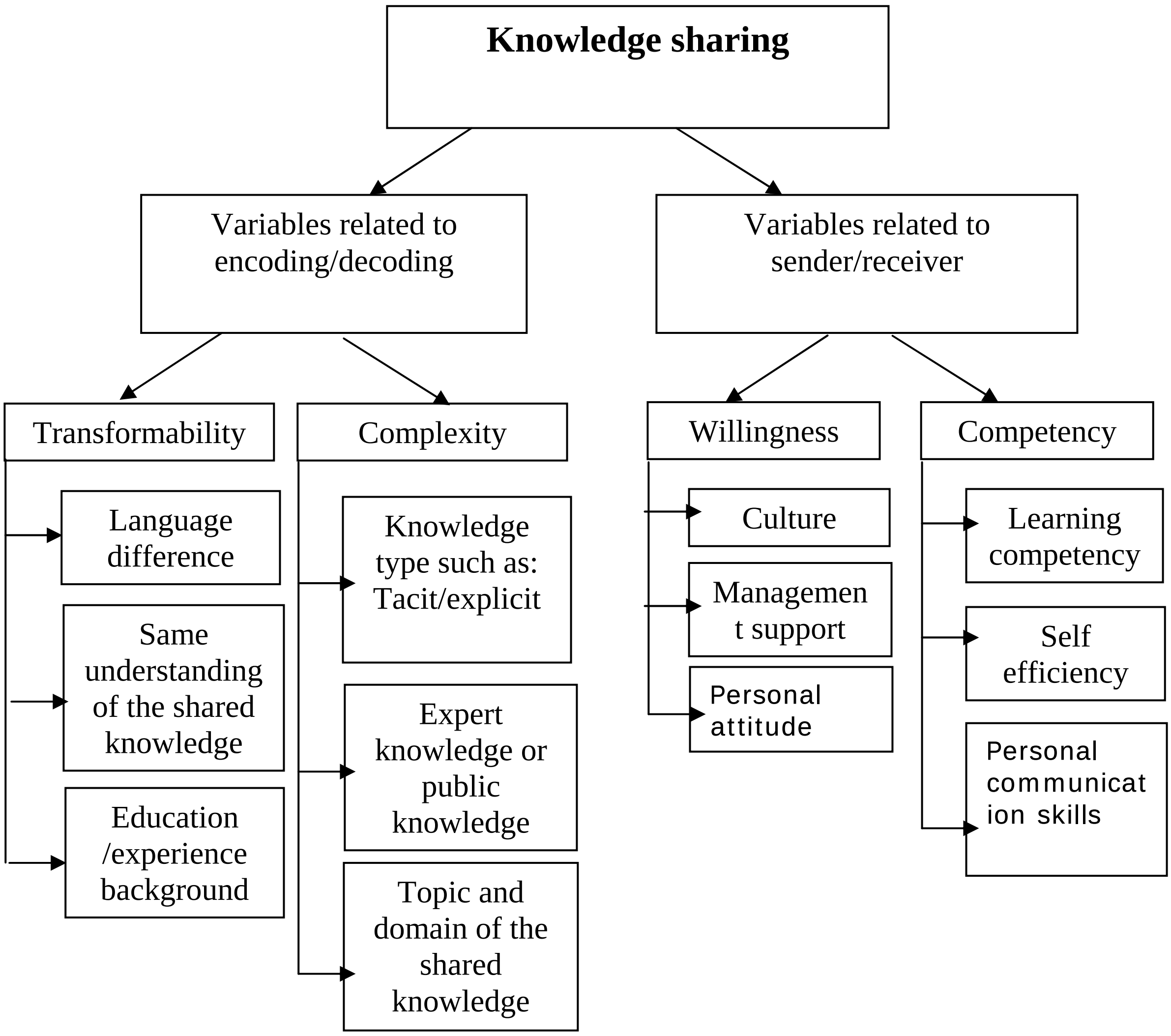


Figure 4.10: Main variables in knowledge sharing measurement

As shown in Figure 4.10, in this research variables, that affect knowledge sharing are divided into two main categories including the variables that affect the sender's or receiver's willingness or competency to share a particular knowledge and the variables that affect encoding or decoding a particular knowledge and make the knowledge either easily transferable or complex to share. Measurement of the variables that are defined in the initial prototype is another key issue in knowledge sharing and the next section focuses on measurement of the stated variables.

4.4 Solutions for measurement of knowledge sharing

Based on the previous discussion, variables are classified into two main categories including variables related to sender or receiver of a particular knowledge, and variables related to encoding or decoding of knowledge. In this section, willingness and competency as major variables that are related to sender or receiver are discussed in detail.

4.4.1 Measuring willingness and competence to share knowledge

It was mentioned that willingness and competency are two key variables related to the sender and receiver in knowledge sharing measurement. Also, it was discussed that these two variables are dependent variables and depend on several other variables. On the other hand, the literature indicates that trust plays a main role in knowledge sharing and is one of the most important issues in knowledge sharing measurement. Trust has been recognized as being "at the heart of knowledge exchange" (Davenport and Prusak, 1998) and "the gateway to successful relationships" (Wilson and Jantrania, 1993). In this section, the relationship between different dimensions of trust and knowledge sharing is more focused and trust techniques are developed to measure the willingness and competency of individuals to share knowledge.

4.4.1.1 Trust definition

The concept of trust is related to different and various fields including philosophy, sociology, business, computing. The notion of trust involves having confidence in the other parties; hence, having an expectation without risks will not result in loss. In business contexts, individuals are dealing with a business enterprise that has advantages over them, in the forms of scale, resources, information and expertise. Trust plays an important role in determining the success of business. Trust affects both internal and external data where, in the external data resources trust improves the business performance in different ways and in all parts such as suppliers, customers, between customers and branding. In a relationship between suppliers and mother organizations, trust is the basis of the just-in-time (JIT) method to decrease inventory cost. Also, trust affects the way that payments are made (such as credit card payment), price mitigation and many other issues. Trust between customer and organizations can decrease promotional and customer replacement costs and increase income. In the same way, trust between organization and customer can transfer between customer-to-customer and the level of trust between customers is a key factor in this issue. The new methods of promotion are now using this section to improve promotion effectiveness. With the internal resource data, trust also plays a very important role. Vertically, trust is important to leadership and horizontally, trust is important for knowledge sharing and team working. As a result, the level of trust in different parts of business should be included in business performance methods as it plays a key role. In the case of corporations, it has been institutionalized through the legal requirement that directors and employees must make decisions based on the best interests of the organization, not of the parties it deals with. As a result, trust in the context of business is not grounded in culture, but is merely what a party has to depend on when no other form of risk amelioration strategy is available.

In sociology, trust is a key ingredient in forming and maintaining collaborative social relationships (Newell et al., 2007) Moreover, trust is an essential ingredient of any successful society (Alesina and La Ferrara, 2002) Also, in the political context, trust is a key issue to build and sustain a mutual level of trust for a party to win in an election. As digital environments are increasing in the world, the role of trust in computing is going to be a key issue in computing. For example, trust is a key variable in virtual teams (Lipnack and Stamps, 1997) and most IT companies such as IBM, Sun, Microsystems and others suggest that the success and failure of virtual teams is primarily contingent upon trust (Kanawattanachai and Yoo, 2002). Some researchers have investigated trust from the health perspective and found that it is crucial for health and harmony (Kramer, 1998). In this research, trust is explored more from the social, computing and business perspectives.

Put simply, trust is defined as “one party’s confident belief in another party’s specified action” (Gefen, 2000). Mayer defines trust as “the willingness of a party [trusting agent] to be vulnerable to the actions of another party [trusted agent] based on the expectation that other [trusted] will perform a particular action important to the trusting, irrespective of the ability to monitor or control that other party” (Mayer et al., 1995). Williams defines trust one’s willingness to rely on another’s actions in a situation involving the risk of opportunism (Williams, 2001). Trust can be viewed as an attitude (derived from trustor’s perceptions, beliefs, and attributions about the trustee based upon trustee’s behavior) held by one individual toward another (Whitener et al., 1998). Trust is necessary to exchange knowledge, goods and services and any organization/team or community has to build and sustain a mutual level of trust in the other party’s actions (Kugler et al., 2007).

Based on these different definitions of trust, the important elements of the trust concept can be expressed as follows:

4.3.1.1.1 Trusting agent and trusted agent

There are two different parties in a trust relationship. The one party is a trusting agent who has faith or belief in another party in a given context and within a specific time slot and the other party is the trusted agent as an entity in whom faith or belief has been placed by another entity in that given context and specific time slot (Chang et al., 2006). Trust by a trusting agent in a trusted agent leads to establishing a trust relationship.

4.3.1.1.2 Beliefs

It is postulated that only a cognitive agent who has goals and beliefs can trust another agent (Castelfranchi, 2001) and the beliefs that the trusting agent has in the trusted agent makes the trust that the trusting agent has in the trusted agent (Chang et al., 2006) Trust is a set of beliefs about another person or agent and includes beliefs about knowledge, abilities, desires and commitments (Jarvis et al., 2005).

4.3.1.1.3 Context

Context can be defined as an object or an entity or a situation or a scenario (Chang et al., 2006). Trust is dependent on context, for example, trust to lend money to someone or trust to share an innovative idea. Trusting in a context does not mean trusting agent trust on trusted agent in every context. For example, an agent may have trust to share normal ideas with another one but, does not have to lend money to the same person. Also, if the trusting agent has trust in a specific context to trusted agent, it does not mean the trusted agent has the same trust level in the trusting agent in that context.

4.3.1.1.4 Willingness

Willingness to trust is based on expectancies. Some individuals have more positive expectancies and are more willing to trust; however, some have negative generalized expectancies and are less willing to trust (Rotter, 1967). It also refers to optimistic or pessimistic characteristics of individuals. Optimistic individuals are more willing to trust and pessimistic individuals are less willing to trust.

4.3.1.1.5 Capability

Capability refers to skills, competence, attitude and ability of the trusted agent in delivering the mutual agreed behavior (Chang et al., 2006). This should be delivered in the time slot with the agreed quality between trusting and trusted agents. If the trusted agent unable to deliver the mutually agreed service, it may affect the capability trust of trusting agent in trusted agent.

The willingness and capability trust are the two characteristics from which the trusting agent can make a qualitative inference using the actual behavior of the trusted agent in its interaction (Chang et al., 2006).

4.3.1.1.6 Time

The level of trust is dynamic due to the time and the inter-operation between two entities (Zhuo et al., 2006). Trust can be changed by different factors and trust level should be discussed in a specific time slot in a specific context. Individuals need to maintain a high degree of trust until the end of a relation and trust maintenance is a key concept in trust management due to the dynamic nature of trust.

4.3.1.1.7 Delivery

In trust management, it is very important that a service or product that is delivered by a trusted agent satisfy the trusting agent and the trusted agent deliver the mutually agreed services or products. This affects the trust level and increases or decreases trust level.

4.3.1.1.8 Mutually agreed service

Terms and conditions of a service or product should be clearly defined between trusting and trusted agents. Trusted agent should exactly understand the responsibilities of a trust relationship and states the perceptions for the trusting agent. On the other hand, trusting agent should understand what service in what quality will be delivered by trusted agent and the trusted agent is committed to providing the service that is clearly defined in their agreement.

4.4.1.2 Trust value

The trust value is assigned in two directions. The first direction is trust value of trusting agent in trusted agent. And the second direction is the trust value of trusted agent in trusting agent. The trust value has fuzzy entity and can be defined by a numerical value such as trust value in the range of 1-7 (Using a Likert scale as a trust value) or can be defined as fuzzy values such as high trust, distrust, low trust and etc.

Overall, trust has different elements and as seen in Figure 4.11, trusting agent, trusted agent and the trust relationship between them in a specific context and specific time slot are key issues in trust management and trust value measurement can be used to analyse trust relations and improve the trust level between agents in a community.

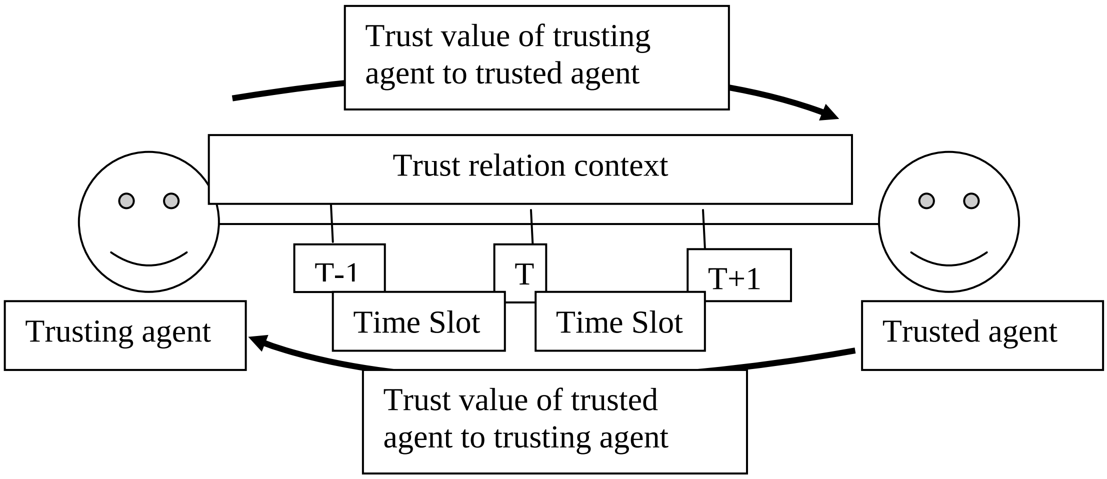


Figure4.11: Trust relationship elements

Trust can be established in different ways. The most common way is a direct relationship. Some other ways such as direct experience (like a prior transaction), referred trust (trust provided by someone else), signifiers or images of trustworthiness (like brand effect) affect the trust level. This thesis focuses on data transaction between trusting and trusted agents and the role of trust level is considered in making intellectual capital in data transaction between agents (increasing market capital, social capital and human capital with increasing trust level in data transaction).

In the next section, trust dimensions are investigated in detail and then different variables that may affect trust and different dimensions of trust are discussed.

4.4.1.3 Trust Dimensions

Trust consists of different components and dimensions. McKnight defines trust components as trusting intention and trusting beliefs. Trusting intention is one's willingness to depend on the other person in a given situation and trusting beliefs are defined as one's belief that the other person is benevolent, honest, or predictable in a situation (McKnight et al.,1998). Gefen has defined three dimensions of trust: ability, benevolence, and integrity (Gefen, 2002). Three dimensions of trust also are identified as ability (expertise, information, competence, expertness, dynamism), integrity (fairness in transaction, fairness in data usage, fairness in service, morality, credibility, reliability, dependability), and benevolence (empathy, resolving concerns, goodwill, responsiveness) (Bhattacherjee, 2002). Similarly, Mayer suggested that trust evaluations are composed of perceptions of the ability, benevolence and integrity of the target (Mayer et al., 1995). Ability is a group of skills, competencies, and characteristics that enable a party to have influence within some specific domain; benevolence is the extent to which a trustee is believed to want to do good to the trustor, aside from an egocentric profit motive, and integrity involves the trustor's perception that the trustee adheres to a set of principles that the trustor finds acceptable (Ammeter et al., 2004). The concept of competence trust refers to "reliability" and "integrity" as two important dimensions of trust (Caniels and Gelderman, 2004). Reliability refers to the extent to which an exchange partner has the required expertise to perform the job successfully (Ganesam, 1994). Integrity refers to the expectancy that the partner's word or statement can be relied on (Doney and Cannon, 1997). Benevolence trust reduces perceived relational risk by increasing confidence in a partner's willingness to fulfill their responsibilities (Das and Teng, 2001). Due to a partner's good intention increasing, a closer cooperation can be created and partners will be encouraged to more openly information exchange and make a deeper commitment (Fryxell et al., 2002). This can also help to maintain trust between partners in cooperation due to the high level of commitment to do the task on time and complete the agreement in the due date. Also, goodwill trust can reduce monitoring cost and the trusting agent does not need to spend many resources to control and monitor activities to make sure that the trusted agent is doing well based on the agreement. Goodwill trust also can be called benevolence trust. Benevolence trust might be described as “the extent to which the client believes that the financial planner has intentions and motives beneficial to the client when new conditions arise, conditions for which a commitment was not made” (Ganesan, 1994). Benevolence focuses on the motives and intentions of the financial planner and could be described as an inclination or tendency towards goodwill (Mayer et al., 1995). Personal characteristics are more important in this kind of trust. Some of these personal characteristics such as caring, being kind, sympathetic, altruistic, and selfless, form the foundation of benevolence trust (Kirchmajer and Patterson, 2003). Benevolence also “depicts the extent to which a partner is genuinely interested in the other’s welfare” (Garbarino and Olivia, 2003). It involves one party caring about another party’s interests and needs and intending to promote the other’s best interests. Competence trust is another important dimension of trust. This kind of trust is related to concerns about the expectation that a trading partner will perform its role competently (Green, 2003). Competence Trust, build ups in relation to the dependability connected with the expertise, know-how, ability, and the actual performance of partners in meeting targets and obligations as distinct from their stated intention to perform (Sako, 1997). In this trust dimension, the trusting agent is confident of the other partner's ability to perform as expected and based on their mutual agreed service. The ability of the trusted agent can be updated and valuable knowledge, high skills, competence and so on. Competence-based trust as well as benevolence-based trust focus more on immediate trust of the trusting agent in the trusted agent. However, another dimension of trust concerns the building of more resilient trust over time and focuses more on trusting agent's loyalty, integrity and honesty in long term cooperation. Integrity trust answers the question, "will trusted agent consistently care about trusting agent interests and needs?" These three dimensions of trust are discussed further in the literature related to trust dimensions. However, several other dimensions are recognized and discussed in the literature. Some of these dimensions are closely linked in meaning with these three types of trust. Table 4.1 shows several other dimensions of trust.

	Trust dimension	**References**	**Description**
1	Credibility	(Schlenker et al., 1973) (Rotter, 1971) (Kirchmajer and Patterson, 2003) (Ganesan, 1994) (Doney and	Credibility trust can create the communication of intentions. An individual is believed to be credible if they do as they say they will or convey information accurately. Therefore their future behaviors are possible to anticipate thus, trust them.

		Cannon, 1997)	
2	Confidence	(Aulakh et al., 1996)	Confidence trust is the belief that trusting agent can count on the trusted agent to do the right thing or act in positive, ethical ways.
3	Reliability	(Aulakh et al., 1996) (Chow and Holden 1997) (Smith and Barclay, 1997) (Zaheer et al., 1998) (Coote et al., 2003)	Reliability trust is the level of expectation or degree of certainty in the truth/honesty of a person or thing.
4	Contract	(Sako and Helper, 1998)	Contract trust is defined as" an expectation held by an agent that its trading partner will behave in a mutually acceptable manner''.
5	Dependability	(Young-Ybarra and Wiersema, 1999)	Dependability trust is defined as "expectation that the trusted agent will act in the alliance's best interests".
6	Cognitive	(Mo¨ llering, 2002) (Moorman et al., 1992) (Rempel et al., 1985) (Johnson and	Cognitive trust is trusting agent's confidence or willingness to rely on trusted agent's competence and reliability. It arises from an accumulated knowledge that allows one to make predictions, with some level of confidence, regarding the likelihood that a focal partner

		Graysonb, 2005)	will live up to his/her obligations.
7	Affect	(Mo¨ llering, 2002) (Rempel et al., 1985) (Johnson and Graysonb, 2005) (Johnson-George and Swap, 1982)	Affective trust is the confidence one places in a partner on the basis of feelings generated by the level of care and concern the partner demonstrates. It is characterized by feelings of security and perceived strength of the relationship.

Table4.1: Trust dimensions

As seen in Table 4.1, trust has been defined in different dimensions. In this thesis, benevolence trust and competence-based trust are focused upon as the two key dimensions in knowledge sharing between individuals. The role of these trust dimensions in knowledge sharing is discussed in detail in the next sections of this chapter. The key issues in trust management are trust building and trust maintenance. How trust can be built and maintained are the most important issues that are being addressed in this section.

4.4.1.4 Trust building

Many mechanisms and tools are proposed for the building of trust. However, trust within the business context exists at three levels (Shapiro et al., 1992). The initial and lowest level of trust stages is deterrence based trust. The primary motivation in this kind of trust is keeping the current relationship because of a fear of punishment (for example, cancelation of a contract or discontinuing of a relationship). The further step of this stage is calculus trust and it develops deterrence-based trust to the preserving trust by positive factors such as reward. This stage of trust can be influenced by negative factors such as different punishment or can be influenced by positive factors such as reward and management support. Deterrence-based trust exists where the trusting and trusted agents are aware of sanctions that will be brought to bear on the trusted if there is a breach of trust (Shapiro et al., 1992). Institutional trust is a form of deterrence-based trust, where the trust is in the institution providing laws and rules to protect the trusting agent, where the trusted is subject to those rules (Zucker, 1986). As a result, trust in this stage can be created by formal rules and laws. For example, a new employee in a new workplace has formal relationships with subordinates, peer co-workers or managers. Or a new business in the initial stage of its establishment has formal relationships with other business agencies based on business rules in the market.

The second level of trust is knowledge based trust. This trust is based on the predictability of the trusted agent's behavior. This kind of trust is based more on knowledge rather than fear of punishment or incentives. Knowledge-based trust exists where the trusting agent has knowledge of the trusted agent such that he/she is able to predict their likely behavior, and trust accordingly (Shapiro et al., 1992). As individuals become more and more familiar with each other, they know more about their behaviors and can predict this behavior. Ability to predict others' behavior make individuals more confident and increases their trust level. The key factor at this level of trust is the information derived from a relationship over time that allows the trusting agent to predict the behavior of the trusted agent (Shapiro et al., 1992). The final and highest order of trust is identification-based trust. This level of trust is developed when one party has “fully internalized the other’s preferences” (Shapiro et al., 1992). Identification-based trust happens when the trusted agent understands and endorses the trusting agent and can act for each other in interpersonal transactions; thus, this requires parties to fully internalize and harmonize with each other's desires and intentions.

These three stages of trust are linked together in a sequential iteration and the first level enables the development of trust at the next higher level (Lewicki and Bunker, 1996). The decline of trust is also related to these stages and it starts to decline from the higher level to the lower level.

Based on these three stages of trust, different methods are proposed to build trust in each stage. In the first stage, initial interactions are key issues to build calculus trust. In initial interaction, some methods are proposed such as using reputation, knowing stakeholders and business rules between them, using early team building efforts etc. (Nooteboom et al., 1997). Trust level is largely determined during the initial interaction and this is the critical time period for building trust between individuals (Xiao and Benbasat, 2003). Repeated interactions between individuals increase trust level among them because familiarity with a trusted agent increases over repeated interactions and familiarity increases trust (Kanagaretnama et al., 2010). However, there is an argument in the literature of initial and repeated interactions affecting trust level. Some researchers support this idea that initial impression is the most important interaction that builds trust between individuals and trust level remains consistent in the repeated interactions. Some researchers support the idea that repeated interactions increase trust level. Further studies have suggested that trust in competence and integrity builds up during the initial interaction, while trust in benevolence requires repeated interactions to develop. Whether trust is being created in the initial interaction or by repeated interactions, it is one of the key issues in trust building in the calculus-based trust. After interactions, individuals start to evaluate the personality and behavior of the other parties and try to predict their behaviors. During the interactions, some factors influence the trust level such as telling the truth, fulfilling promises, not exaggerating and etc. Predictability of the trusted agent's behavior is the next step to increase trust level from calculus-based trust to knowledge based trust. In this stage, trusting agent starts to gather information about trusted agent and tries to predict trusted agent's behavior and this prediction make the trusting agent more confident. Trust is related to confidence and predictability and predictability is defined as the other's behavior in terms of what is ”normally“ expected of a person "acting in good faith” (Mayer et al., 1995). If the trusted agent is predictable, the trusting agent will start to share knowledge and appropriate information, creating common language and shared vision as well as offering explanations for decisions (Lander et al., 2004).

The next and important stage in trust building is creating identification-based trust. This level of trust is the highest trust level and creates value and assets for individuals. In building this level of trust, different factors are important and should be discussed. Table 4.2 shows some of the main factors that influence the identification trust level:

Category	Factors	References
Sharing control	Delegating obligations	(Costigan et al., 1998) (Korsgaard et al., 1995) (Nelson and Cooprider, 1996) (Whitener et al., 1998)
	Sharing and delegating control	
Concerns for others	Fairness	(Costigan et al., 1998) (Korsgaard et al., 1995) (Nelson and Cooprider, 1996) (Whitener et al., 1998)
	Respecting others	
	Apologizing for unpleasant consequences	
	Showing concern for various stakeholders' interests	
Joint identification	Using co-location	(Korsgaard et al., 1995) (Nelson and Cooprider, 1996) (Whitener et al., 1998)
	Availability	
	Involving in meaningful participation	
	Attachment to group	
	Interactions/cooperation	

Commitment	Loyalty	(Costigan et al., 1998)
	Stressing the long-term interests of participants	(Korsgaard et al., 1995)
	Job satisfaction	(Tsai and Ghoshal, 1998)
Potential for success	Achieving early successes	(Costigan et al., 1998) (Nelson and Cooprider, 1996)
	Competence	(McKnight et al., 1998)
Managerial	Providing training and personal growth opportunities	(Lander et al., 2004)
Decisions	Selection of vendor/negotiation of contract	(Costigan et al., 1998) (Bigley and Pearce, 1998)
	Commitment of appropriate resources (people).	
	Change management	

Table 4.2 Factors that influence identification-based trust (Lander et al., 2004)

Based on different stages of trust building, various stakeholders play different roles in trust building and their importance for different factors are different. For example, managers can improve the number of interactions between employees and encourage them to interact with themselves more. This can be done by various rewards or punishments that a manager can apply to increase trust, especially face-to-face interactions such as meetings, team working, workshops or speeches. This is more related to calculus-based trust and managers can encourage this kind of trust within their organization. Some of the factors are more personal and depend on an individual's personality and characteristics. For example, dependability of a person or responsibility is more related to their personal behaviors. Also, team members and co-workers (environment) can affect different trust stages. For example, job satisfaction and commitment to the team are the factors that are greatly influenced by the other people in the community or team. Similarly, trust building in business relationships needs to initiate interactions and repeated interactions establish reputation for a business. In second stage, as interactions have been established, business partners share their goals and visions and move to knowledge-based trust and act predictably. Finally, in the third stage, all stakeholders concern about their success in business and because of their high level of dependency on benefits, they are more committed to help each other to establish a win-win relationship.

It is very important and a key issue that in all of the trust stages, trusted and trusting agents should care about trust elements and try to be clear about their mutually agreed service and improve their ability to deliver.

In this section, trust building stages and factors that influence trust are discussed and explored in detail. However, some factors have a negative impact on trust and decrease the trust level between individuals as well as business partners. It is very important that negative factors are identified to avoid trust decline and protect the current trust level. In the next section, trust maintenance is discussed in detail.

4.4.1.5 Trust maintenance

Trust develops and changes over time and it is easier to destroy than to build. The trusting agent will trust as long as the trusted agent is not cheated or betrayed but, once the trusted agent has that experience, the trusting agent's attitude will quickly shift to distrust (Pearce, 2004). Distrusters avoid cooperative activities (because they expect exploitation) and have fewer opportunities to make discoveries (Hardin, 1993). As a result, individuals as well as organizations need to maintain the current level of trust and improve it for further cooperation. Several strategies have been proposed by researchers to maintain trust levels, some of which are explored in this chapter. One of the key issues in trust maintenance is frequent communication. Trust building and trust maintenance are closely related and trust building is a slow process that needs effective and frequent communication between the trusting and trusted agents as well as trust maintaining (Ali Babar et al., 2007). Frequent communication can prevent misunderstanding and improves cultural understanding which is considered a major issue in maintaining trust. However, the most important issue in maintaining trust is related to the trusted agent's performance and delivery of the agreed service or product on time and with the expected quality as mutually agreed. As a result, trusted and trusting agents should define all these components clearly and one of the theories proposed in this domain is trust ontology. Trust ontology has been defined as the conceptualization of the trust that the trusting agent has in a given trusted agent in a given context and in a given timeslot (Chang et al., 2007) Figure 4.12 shows the concept of trust ontology that includes two key issues: trust relationships and trust value.

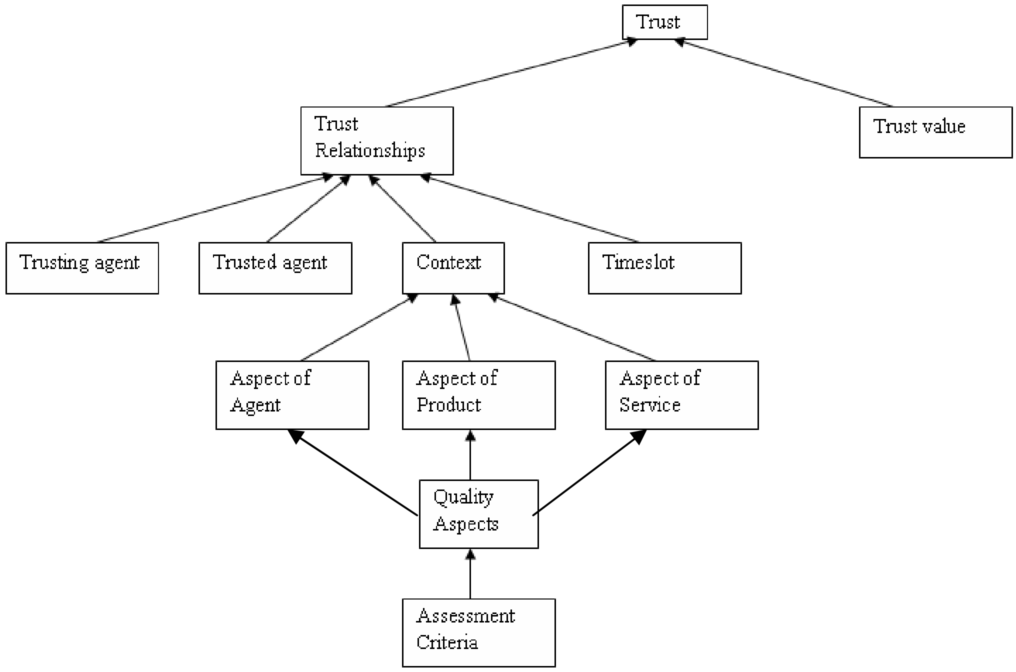


Figure 4.12: Trust ontology concept (Chang et al., 2007)

To improve trust level and maintain trust, the trusted agent must satisfy the trusting agent in terms of quality of service. Figure 4.13 shows details of the features of a service that should be delivered by the trusted agent.

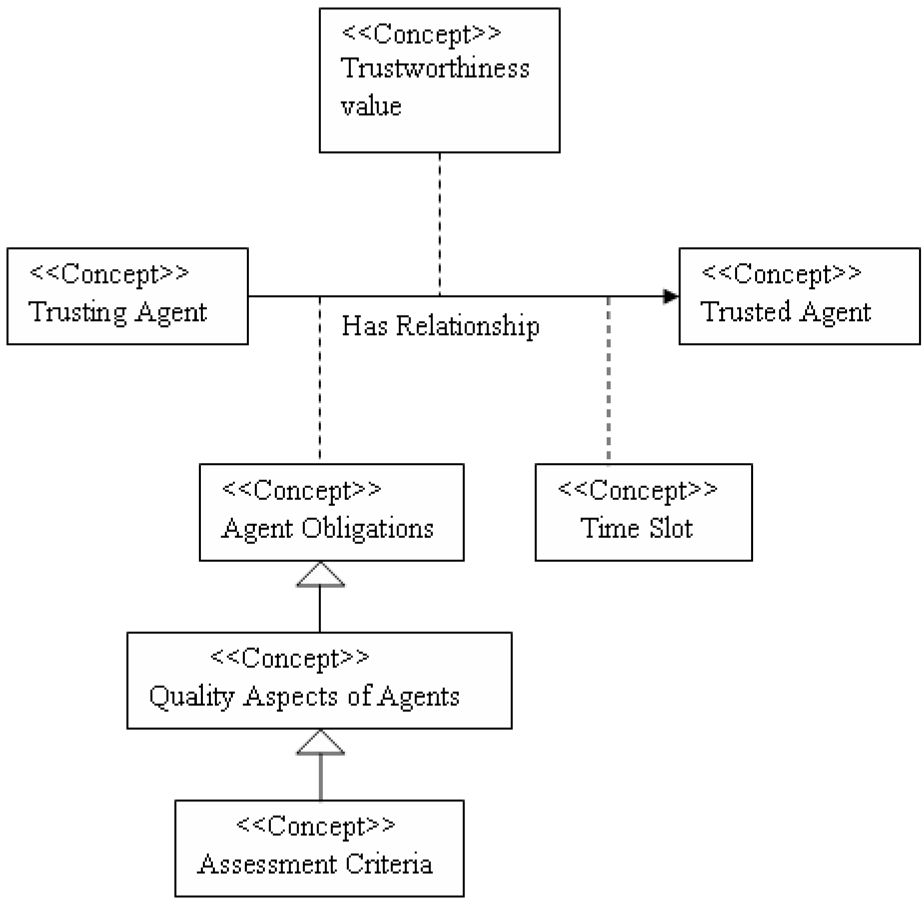


Figure 4.13: Trust maintaining in trust ontology (Chang et al., 2007)

As seen in Figure 4.13, the trusting agent uses assessment criteria based on his or her perceptions to evaluate the quality of the delivered service or product. A clear agreement and clear understanding of the agreement by two parties can help to maintain trust levels. The trusted agent knows exactly what the trusting agent wants and, based on capability and resources, decides whether to accept the agreement and deliver the requested service or product, or reject the agreement. On the other hand, the trusting agent knows exactly what the trusted agent is going to deliver and can create suitable assessment criteria to evaluate the delivered service or product. This can also reduce the possibility of misunderstandings between two parties.

Moreover, trust has a dynamic nature and changes based on communications, relationships, service or product delivery, environmental factors etc. Also, trust can be affected by some personal issues and in maintaining trust, these variables should be considered as well.

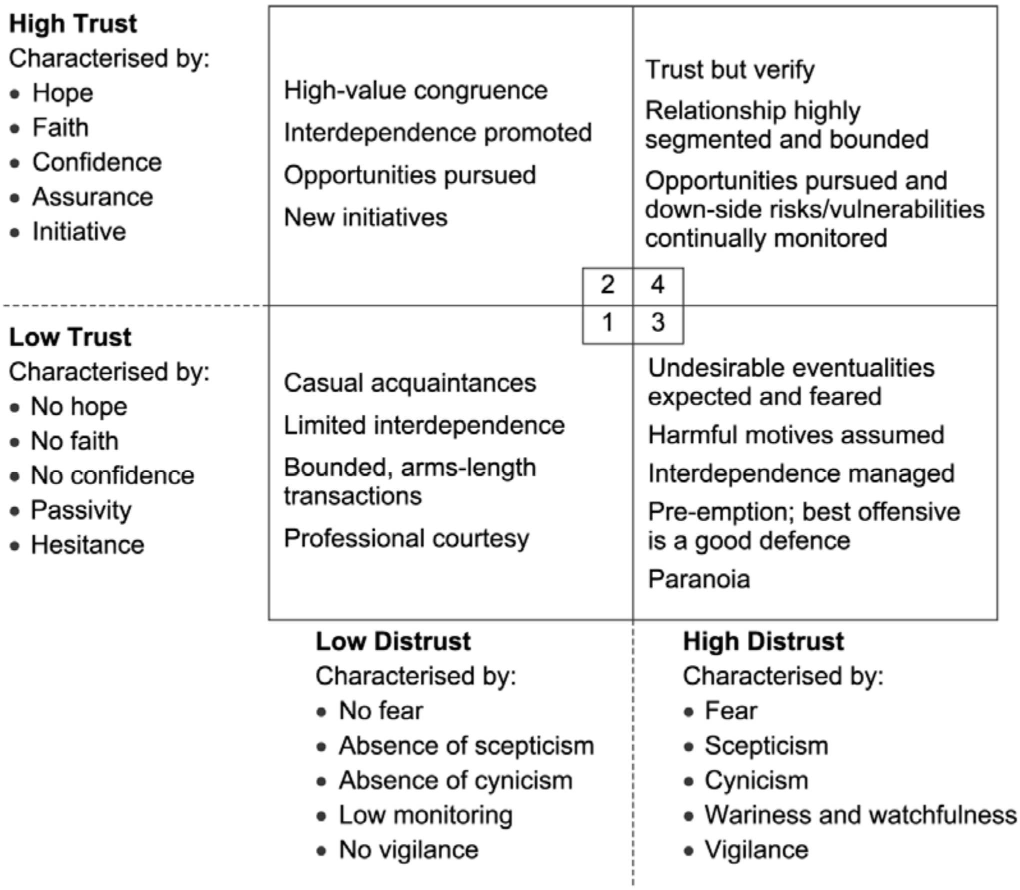


Figure4.14: Factors that cause distrust (Lewicki et al., 1998)

As shown in Figure 4.14, a low trust and high distrust relationship may develop as challenges are encountered so that relationship become poorly managed with numerous “withdrawals” from the “loyalty bank” (Walker and Hampson, 2003). Although in this situation the relationship may still exist, both parties are not motivated to share information or knowledge and the quality of information is likely to be poor. Both parties apply a high level of control and this can be wasted energy being expended on negative relational behaviors. The best situation in a trust relationship is one where both parities apply low monitoring and use their energy and resources to improve the quality of service or product.

As discussed in the last section, trust is built in the three stages: calculus trust, knowledge-based trust and identification-based trust. As shown in Figure 4.15, after a long term of trust building, the trusting parties' perceptions and expectations increase and this leads to a decline in the trust level.

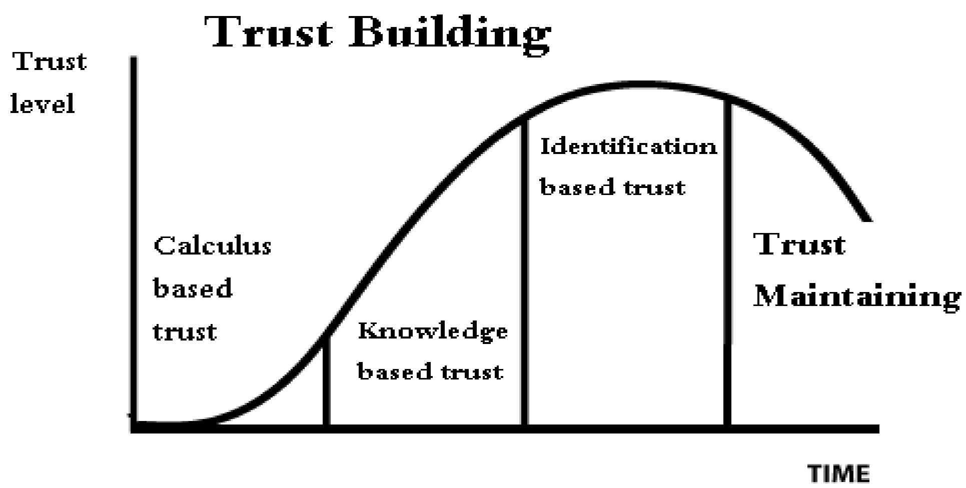


Figure4.15: Trust lifecycle

Trust maintenance is more meaningful in the stage of the trust level where it has started to decrease. Managers and decision-makers should plan different strategies to react to trust level decline. For this reason, trust level should be measured frequently to ensure that it is at an acceptable level. However, as soon as managers understand that trust level is going to decrease, they should use different techniques and tools for trust maintenance to prevent trust decline in their business domain. For example, when the trust level of customers is about to decrease, managers need to understand this trust reduction and try to stop it. This is why trust should be measured and reported to decision makers in business. In individual relationships this can also be useful where the trusted parties know about the trust level of trusting parties and they can prevent trust reduction in their relationships. In the next section, trust measurement tools are discussed and trust value is explored in detail.

4.4.2 Trust based model to measure willingness and competency to share knowledge

In the long term, others' willingness trust in an individual's willingness to share knowledge is equal to the level of that individual's willingness that is measured by the variables that were discussed in the previous section. This can be shown in the Equation 4.20.

$$KS_w = T_w = f(C_v, M_S, I_S, P_a, P_e) + O \qquad T_w = \text{Trust willingness}$$

(Equation4.20)

Another dimension of trust that was explored in detail is competence-based trust. Competence-based trust provides cues as to how to process, interpret and act upon the information (Parayitam, 2010). Although first interaction has the most impact on benevolence trust, competence based trust is more based on several interactions in the past. Past interactions provide significant clues about the competence of the members and context considerations specify the members upon whom competence-based trust is bestowed (Zucker, 1986). Competence-based trust enables the members to use diverse skills and become more innovative (Dutton, 1987). It is also helpful in understanding and explaining how the information is inferred and interpreted by members and increases members' commitment to share their information.

The same as willingness trust, in the long term, people's competence-based trust in an individual shows his/her ability to share knowledge within a community and based on Equation 4.21 competence- based trust can be shown as:

$$KS_c = T_c = f(L_c, K_{rd}, S_e, P_n, P_p) + C \qquad T_c = \text{Trust competency}$$

(Equation4.21)

In this research, trust measurement techniques are applied to measure individuals' willingness and competency to share knowledge and in Chapter 5, this issue is discussed thoroughly. Figure 4.16 shows the role of trust dimensions in knowledge sharing.

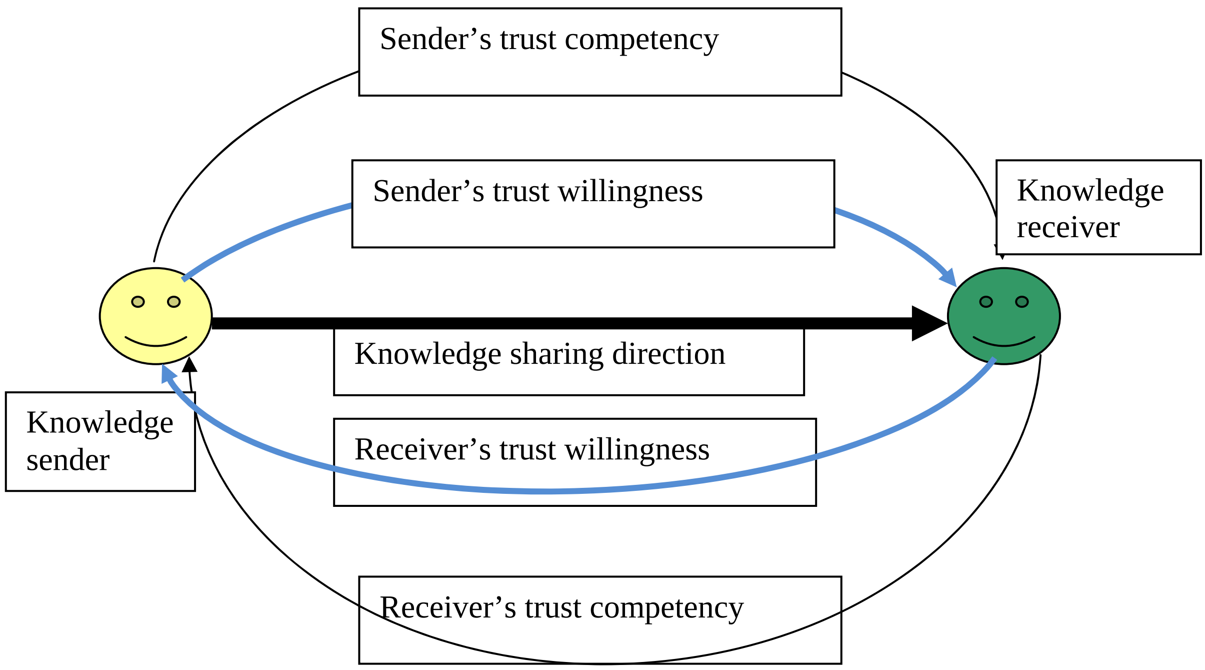


Figure 4.16: Trust dimensions role in knowledge sharing

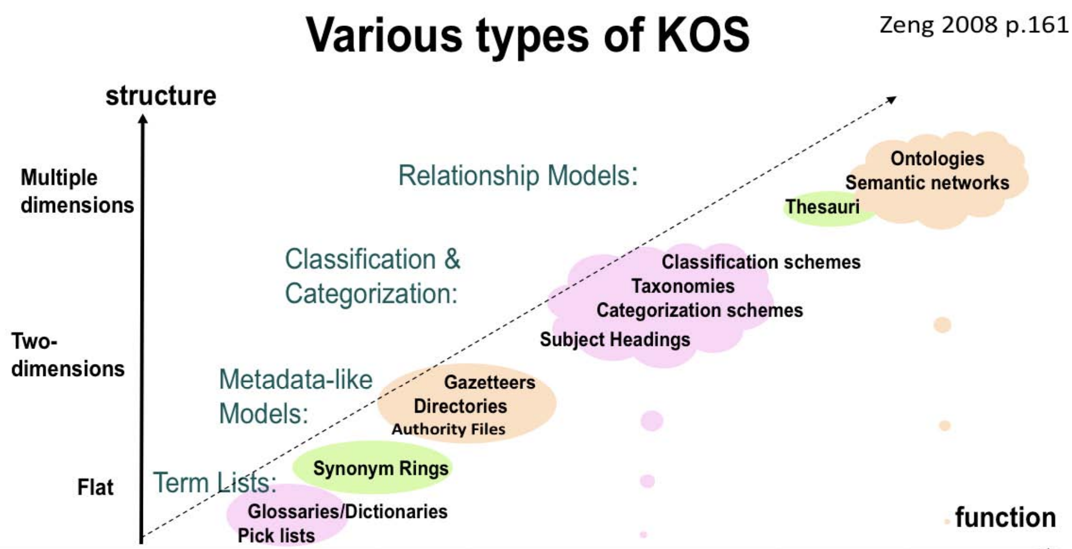
Another key issue in knowledge sharing measurement is related to measuring knowledge transferability as well as knowledge complexity. In this section, these two variables are discussed in detail.

4.4.3 Complexity and transferability of the shared knowledge

This research aims to propose metrics to measure the complexity of knowledge by using ontology, and choosing personal ontology. Ontologies have to be created explicitly by hand and require a process of explicit community negotiation for achieving a consensus about the shared understanding that is to be expressed (Novak and Wurst, 2004). Also, this research proposes to develop a model to measure the transferability of knowledge by comparing the two ontologies [sender and receiver of the knowledge] and ascertaining whether or not there are similarities. Definition of ontologies and the techniques for using ontologies to measure transferability and complexity of a particular knowledge are discussed in this section.

4.4.3.1 Ontology concept

Ontology concept has recently gained popularity within the knowledge engineering community. However, it meaning and the contexts in which the term is used vary such as philosophical discipline, semantic domain etc. (Guarino and Giaretta, 1995). The sharing of a common understanding of the structure of information among people or software agents is one of the more common goals in developing ontologies (Gruber, 1995). The term “ontology” is derived from its usage in philosophy where it means the study of being or existence as well as the basic categories (Witmer, 2004). Ontologies are a “formal description and explicit specifications of conceptualization” (Tao and Embley, 2009). 'Formal' refers to machine-processable semantics of information sources and the fact that in communication between different agents, ontology should be machine readable (Zhong and Hayazaki, 2002). Ontologies provide a common understanding of topics for communication between systems and users (Zhong and Hayazaki, 2002). In overall an ontology provides a faithful specification of a knowledge unit and represents a consistent view of that knowledge unit. Ontologies permit categorization and classification to organize a particular knowledge. Figure 4.17 shows different categories of knowledge organization systems.



Major functions						
eliminating ambiguity	xxx		xxx	xx	xxxx	xx
controlling synonyms		xxxx	xxx	xx	xxxx	xx
establishing relationships: hierarchical			x	xxxx	xxx	xxx
establishing relationships: associative					xxxx	xxxxx
presenting properties						xxxxx

Figure 4.17: Knowledge organization systems (Zeng, 2008)

The part of the world that is conceptualized or classified is called the knowledge domain and ontology for each domain represents knowledge of that domain. For different knowledge domains, ontologies definition can be different. Here are some definitions of an ontology in different domains.

In computer science, an ontology is the product of an attempt to formulate an exhaustive and rigorous conceptual schema within a given domain (Xu et al., 2008).

In the study of artificial intelligence, an ontology is an explicit specification of a conceptualization (Gruber, 1995) describing what the concepts mean, and formal axioms that constrain the interpretation and well-formed used of the terms (Beuster, 2002).

Ontology provides a unified vocabulary for capturing declarative knowledge in different knowledge domains and classifies that knowledge clearly to allow reasoning in explicit format and also, provides a vocabulary that describes a domain of interest and a specification of the meaning of terms used in the vocabulary (Wongthongtham, 2007).

As seen in Figur17, ontology is different from data catalogues of glossaries, data dictionaries, thesauri and taxonomies. Ontology is more than a glossary or data dictionary and the terms in ontology are chosen thoughtfully, ensuring that the abstract foundational concepts and distinctions are defined and specified (Fensel et al., 2001). Also, an ontology defines all the relationships between the selected terms by using formal techniques and based on these, formal "defined relationships provide the semantic basis for the terminology chosen" (Wongthongtham, 2007). To sum up, ontologies explore deeper relations between terms and centralize knowledge. They explore the related rules about how concepts relate to each other. Ontologies help to facilitate structuring of knowledge to represent a particular knowledge and make a unique understanding of the terms. As a result, ontology is considered to be a knowledge model rather than a data / information / instance model and is an important tool for managing the knowledge base (Osman and EI-Diraby, 2006).

In this research, ontologies are used to examine knowledge complexity and knowledge transferability. In this part of the chapter, ontology structure is discussed and ontology techniques are explored in knowledge representation.

4.4.3.2 Ontology structure

Before investigating ontology structure, it is important to examine how an ontology can be created and the steps needed in ontology development. There are different ways to model a domain and develop an ontology for that domain. In this section, seven steps for developing an ontology for a domain are explored and discussed.

4.3.3.2.1 Step1. Determine the domain and scope of the ontology

The first step in ontology development is definition of domain and scope. Although the defined domain can be dynamic and may change over time, it is very important to have a clear understanding of an ontology domain and focus on the items in the related domain. To clarify an ontology domain, there are some questions that may help developers to determine the scope of an ontology. Some of these questions are listed below (Noy and McGuinnes, 2001):

1. What is the domain that the ontology will cover?
2. What is the aim of using the ontology?
3. What information is required to be addressed by the ontology?
4. Who will use and maintain the ontology?

For example, consider the ontology of pizza that is used in this chapter as a sample to explain the above questions clearly. Representation of meat pizza and vegetarian pizzas is the domain of the ontology. Depending on who will use the pizza ontology, the design and definition of the ontology can be changed. If the ontology is used by customers to decide which pizza to order, some information such as price, ingredients and flavor would be required. If the people who use the ontology speak different languages, the mapping between the languages will be necessary.

Answers to the questions above are key issues when determining the scope of an ontology and the completed ontology should be able to answer competency questions (Gruninger and Fox, 1995). In the sample ontology (pizza ontology) the competency questions can be listed as (Gruninger and Fox, 1995):

1. Which pizza characteristics should be considered in a pizza selection?
2. Is Soho a meat pizza or vegetable pizza?
3. What types of ingredients are used on pizza topping for meat pizza or vegetarian pizza?
4. Which kinds of cheese are suitable to be used in American pizza?

4.3.3.2.2 Step2. Consider reusing existing ontologies

It is normally a good idea to reuse or develop the current ontologies and check if there are any existing ontologies close to the new requirements? There are libraries of reusable ontologies on the Web. For example, there are different open source ontologies in the food domain, software development and many other domains.

4.3.3.2.3 Step3. Enumerate important terms in the ontology

It is useful to write down a list of all terms and the properties of the terms that should be explained to a user (Noy and McGuinnes, 2001).

4.3.3.2.4 Step4. Define the classes and the class hierarchy

There are different approaches in the classes and sub-classes definition of an ontology. Some of the approaches are listed below (Gruninger and Fox, 1995).

1. · "A top-down development process starts with the definition of the most general concepts in the domain and subsequent specialization of the concepts" (Noy and McGuinnes, 2001). For example, in Figure 4.18, pizza is classified into two sub-classes including meat pizza class and vegetable pizza class. Then each sub-class also can be classified into further sub-classes such as American meat pizza etc.
2. · "A bottom-up development process starts with the definition of the most specific classes, the leaves of the hierarchy, with subsequent grouping of these classes into more general concepts" (Noy and McGuinnes, 2001). For example, Italian pizza can be defined as a class. Or Pepperoni pizza can be defined as a class and then super class can be created for these classes.
3. · Another approach is a combination of the top-down and bottom-up approaches. In this approach, class definition can be defined with a few top levels such as meat pizza or vegetable pizza or middle level such as American or Italian pizza. Then relationships

between these pizza can be investigated and sub-classes or a super class of all defined classes can be created.

Figure 4.18 shows the relationship hierarchy of different sub-classes in the pizza ontology.

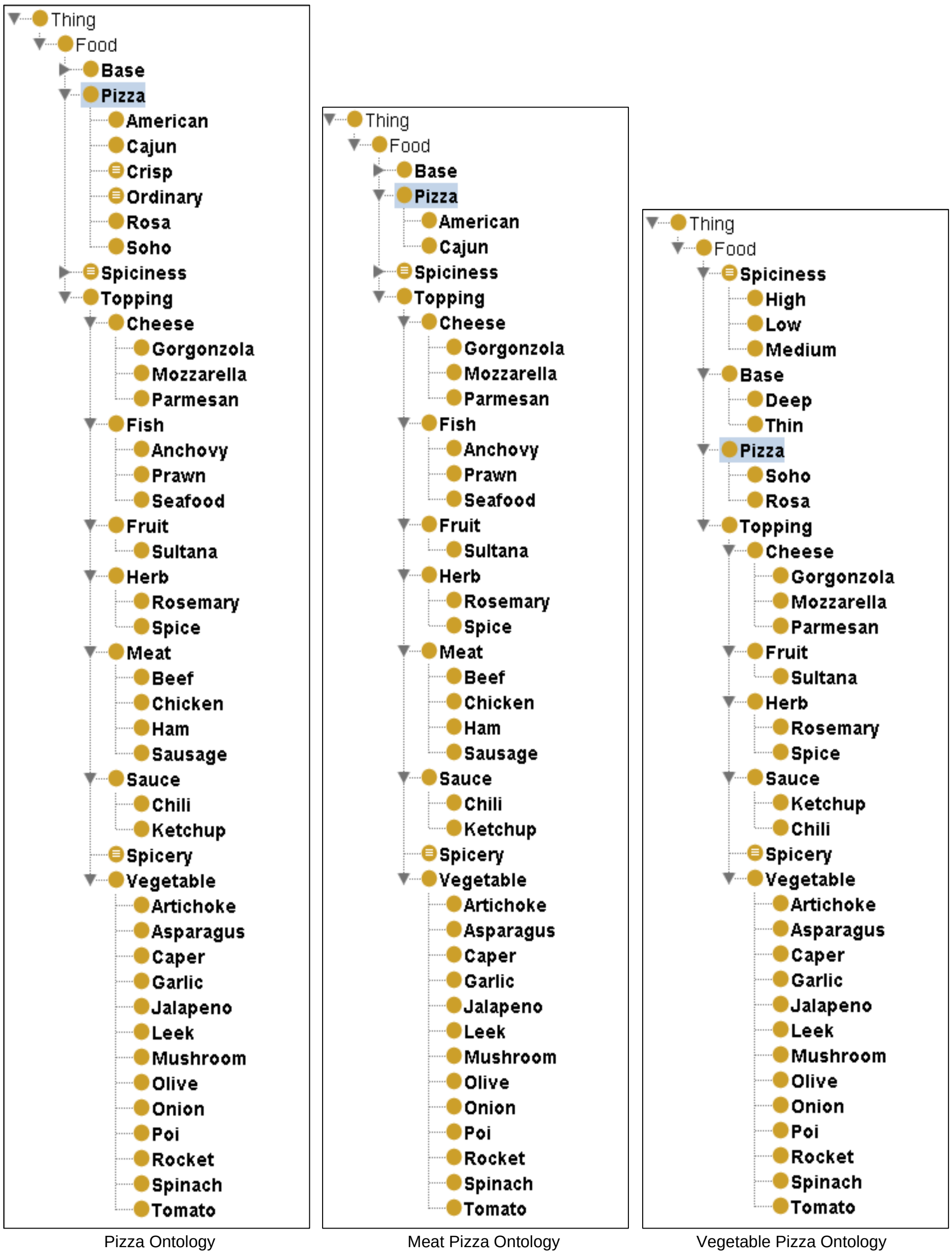


Figure4.18: Relationship hierarchy of different sub classes in the pizza ontology, meat pizza ontology and vegetable pizza ontology

4.3.3.2.5 Step5. Define the properties of classes—slots

Each class has different kinds of properties including intrinsic (such as the taste of a pizza), extrinsic (such as a pizza's name) and relationships between class members (such as relationship between a pizza and meat or chicken that the pizza is made from).

4.3.3.2.6 Step6. Define the facets of the slots

Slots can have different facets describing the value type, allowed values, the number of the values (cardinality), and other features of the values the slot can take (Noy and McGuinnes, 2001). For example, a pizza name is a string value type but pizza price is number value type. Slot cardinally defines how many value types that each slot can have. Some kinds of value types are discussed below (Noy and McGuinnes, 2001):

1. String; it the simplest value type which is used for slots such as pizza name.
2. Number; (In both type's integer and float) describes slots with numeric values. For example, a pizza price
3. Boolean; (yes–no flags).
4. Enumerated slots specify a list of specific allowed values for the slot. For example, spiciness can be hot, medium, or mild.
5. Instance-type slots allow definition of relationships between individuals. Slots with value type Instance must also define a list of allowed classes from which the instances can come (Noy and McGuinnes, 2001).

4.3.3.2.7 Step7. Create instances

“The last step is creating individual instances of classes in the hierarchy. Defining an individual instance of a class requires (1) choosing a class, (2) creating an individual instance of that class, and (3) filling in the slot values” (Noy and McGuinnes, 2001).

These steps were the brief of an ontology building for a particular domain. Based on these steps, ontology structure can be defined. The most important parts of the ontology structure are class/sub class definition, properties and relationship between members of that ontology. It is very important to distinguish between name and class. Class represents concept in the domain but, the class name is an extrinsic property than can be changed in different terminologies (Noy and McGuinnes, 2001). Also, it is important that all sub-classes be assigned to the correct classes and that the number of classes be minimized as much as it is possible. Adding a new class is often one of the hardest decisions when designing an ontology and creates new issues as a new class or properties of the current classes are critical. Another key issue in ontology design is property definition. Default values for slots and relations between them are key issues in an ontology property definition. If a particular slot value is the same for most instances of a class, the value can be defined to be a default value for the slot, and for each new instance of a class containing this slot, the system fills in the default value automatically (Noy and McGuinnes, 2001).

Generally, ontologies consist of a set of concepts (classes), hierarchies (sub-classes), a set of vocabularies (instances), semantic relations and several logic rules for a general purpose or a particular domain (Antoniou, 2004; Davies, 2006). Semantic relations as discussed can be hierarchical relations between sub-classes and super classes and some kinds of the relations are not hierarchical. The non-hierarchical relationships can be associative (cause –effect) or equivalence (synonymy or related to) relationships (Jiang and Conrath, 1997).

An ontology structure is used to measure complexity and transferability of a particular knowledge in knowledge representation. Before discussing the role of ontology to represent knowledge and measure the complexity of a particular knowledge, it is important to understand that ontology is dynamic and can change over time. This part of the research examines ontology evolution and the dynamic nature of an ontology.

4.4.3.3 Ontology evolution

"Change" is a key feature of a knowledge-based ecosystem and this is true also for ontologies and semantic knowledge representation. Ontology evolution refers to the process of modifying an ontology in response to a certain change in the domain or its conceptualization (Flouris et al., 2008). It is defined also as "the process of adaptation of an ontology to arisen changes in the corresponding domain while maintaining both the consistency of the ontology itself as well as the consistency of depending artifacts" (Plessers and De Troyer, 2006). Different phases of ontology evolution are listed below (Konstantinidis et al., 2007).

1. *Change capturing phase;* Determination of the changes
2. *Change representation*
3. *Semantics of change phase;* determine the effect of the changes to the ontology itself.
4. *Change implementation phase follows,* "where the changes are physically applied to the ontology, the ontology engineer is informed of the changes and the performed changes are logged".
5. *Change propagation phase;* propagate the changes to the dependent elements.
6. *Change validation phase;* allows the ontology engineer to review the changes and possibly undo them, if desired.

It is very important to understand and capture the changes that have been made and take appropriate actions with regard to their own dependent artifacts. The most critical phases in ontology evolution are the second and third phases. The change representation phase is more concerned with determining the requested change (i.e., what should be changed), whereas the semantics of change phases is more focused on determining the actual change (i.e., how the change should be performed) (Konstantinidis et al., 2007).

There are many procedures for providing suitable tools to capture, represent and implement the changes in an ontology that are not within the scope of this research. The purpose of this section was to show that an ontology is not static and can be changed. As a result, complexity of a particular knowledge in a specific knowledge domain can be change over time based on ontology evolution.

Ontology structure, ontology domain and ontology evolution that were discussed in this chapter are used to measure the complexity of a particular knowledge in a specific knowledge domain and time slot. However, transferability of a particular knowledge is important as complexity and in knowledge transformability measurement, similarity of the ontologies that are used by sender and receiver are most important issues. In this section, similarity of ontologies is studied in detail.

4.4.3.4 Ontology similarities

An increasing number of ontologies are going to be constructed and used especially on the web to represent knowledge in different domains. Due to the web applications that have become so popular, it is necessary to provide a technique to efficiently measure the similarity of ontologies to make query decisions based on the ontology similarity or difference of the semantic web services(Wang and Ali, 2005). "For the task of detecting and retrieving relevant ontologies, one needs means for measuring the similarity between ontologies on a canonical scale (e.g., the reals in [0, 1])" (Maedche and Zacharias, 2002). There are many studies in semantic web applications emphasizing on measuring ontology similarity. A number of approaches have been proposed to deal with the heterogeneity of ontologies. One approach integrates different ontologies and creates a more generic ontology by mapping the ontologies (Weinstein and Birmingham, 1999) or by vocabulary heterogeneity resolution of various ontologies (Mena et al., 2000). Building a shared and integrated ontology is more complicated, especially for the online ontologies this is very difficult. Also, these approaches are more focused on comparing the classes between two ontologies rather that comparing similarity of the ontologies. Another approach in ontology similarity is “to develop a merged ontology by sharing ideas from all available ontologies and mapping the entries of merged ontologies with WordNet entries” (Pease et al., 2002). This approach reduces the complexity of concept mapping, yet it does not address the requirement of comparing two different ontologies (Wang and Ali, 2005). In order to measure similarity between two ontologies the two levels that are mostly focused on include: first, the lexical level that investigates how terms are used to convey meanings; second, the conceptual level that investigates the conceptual relationships that exist between the terms (Agirre and Rigau, 1996).

Another similarity measurement model is based on set theory so that difference in characteristics between objects can be evaluated by set operations (Tversky, 1977). In this research, Tverskey’s model is applied to define a numeric measurement of ontologies similarity. “A senses set for an entity class is a set of synonym words denoting the concept of the entity class. A senses set for an ontology is obtained by extracting synonyms related to the ontology semantics from the senses sets of all concepts in the ontology” (Wang and Ali, 2005). This model is discussed in knowledge transferability in detail.

Definition of an ontology, an ontology structure, an ontology evolution and similarity between different ontologies were discussed in this chapter. The next section relates to the role of an ontology in a particular knowledge representation and using ontologies techniques to measure complexity and transferability of a particular knowledge within a specific time slot as two important variables in knowledge sharing.

4.4.3.5 **Knowledge and ontology**

Ontologies have been used by many scholars to specify user background knowledge and to explicitly specificy a conceptualization to be used in knowledge representation. When the knowledge of a domain is represented in a declarative formalism, the set of concepts, relations among them and constraints are reflected in the representational vocabulary which represents knowledge (Gruber, 1995). There is a commitment between users of an ontology and the meaning of the terms that are exchanged between users are based on an agreement. The issue of ontological commitment is described as being an agreement about concepts and relationships between those concepts within ontology (Gruber, 1995). Therefore, knowledge sharing between users of an ontology occurs in a coherent and consistent manner. However, recently, ontologies have become widely used in many expert system applications "not only to support the representation of knowledge but also complex inferences and retrieval" (McGuinness, 2000). The extensive applications of ontologies now are ranged from "light-weight ontologies that is taxonomies of non-faceted concepts to more sophisticated ones where not only concepts but also their properties and relationships are represented" (Tamma, 2001). The level of sophistication of an ontology and the number of classes, sub-classes (hierarchy) and properties are used to measure the complexity of a particular knowledge in this research.

Ontology structure is used to measure the complexity of knowledge and the similarity between two ontologies is used to measure transferability of knowledge in this research.

4.4.4 Knowledge sharing measurement

Knowledge sharing measurement variables is summerised and shown in Figure 4.19.

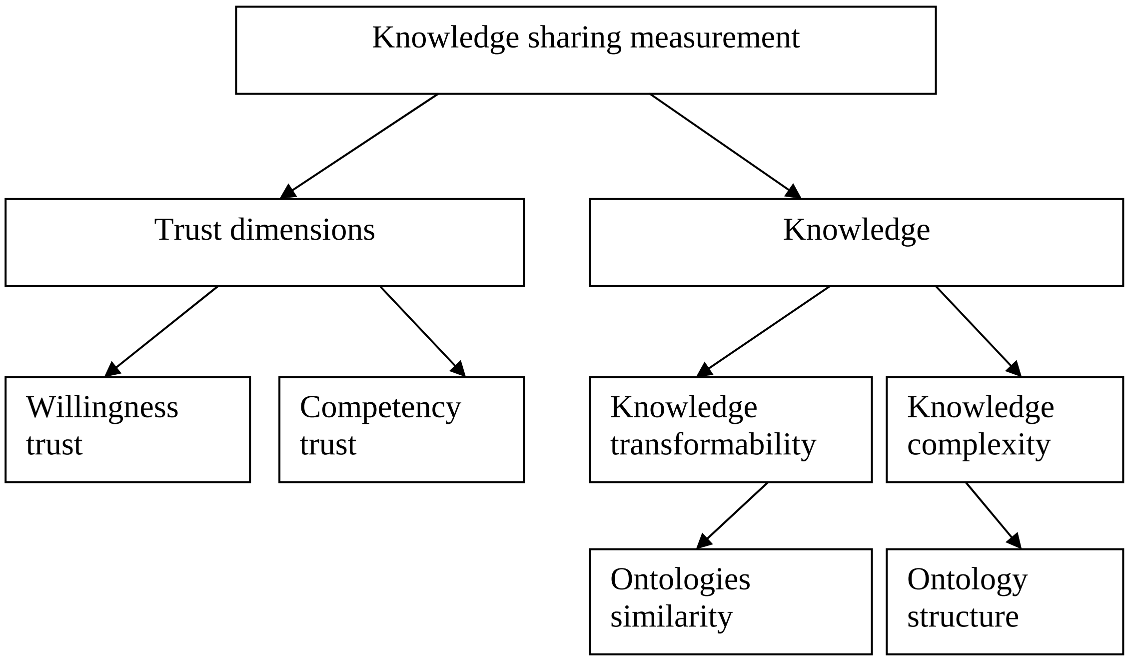


Figure 4.19: Summary of knowledge sharing measurement variables

Trust measurement is discussed in Chapter 5 and knowledge complexity as well as knowledge transformability measurement is discussed in the chapter6. Developed version of the proposed prototype is discussed in

Chapter 7 and Chapter 9 shows the results for validation of the developed prototype.

As discussed in Chapter 3, the results from knowledge sharing and trust measurement should be available to decision makers as an effective business intelligence system to be evaluated. Decisions in a digital business ecosystem should be decided based on the knowledge sharing and trust situation provided by this business intelligence system. In this section, the initial idea for a trust and knowledge sharing based business intelligence system is proposed.

4.5 Solutions for knowledge sharing reporting

Based on the literature in Chapter 3, new generations of business intelligence applications are related to digital business ecosystems and some key issues such as trust, information democracy, text mining, semantic web and ontologies, are the most important variables in the new business intelligence applications. Also, as stated, the knowledge lifecycle in a knowledge-based society is very short. Knowledge is created and loses its value very fast and organizations need to transfer the created knowledge to all employees as much as they can in a short period of time. This should also be done with the lowest budget and resources. The best way to share the created knowledge within a community or an organization is to use employees or community members as knowledge senders and create a total knowledge sharing system (such as total quality management (TQM)) where all individuals contribute to the knowledge sharing processes. Creating a total knowledge sharing system needs a high level of trust between individuals in a community or an organization. Also, external knowledge resources such as customer knowledge are key issue in modern businesses. To sum up, in a knowledge-based economy "Communication, Collaboration, and Contribution" are key variables in business success and these variables are related to trust and knowledge sharing within and between communities in a digital business environment. Decision makers should have access to reliable data about the knowledge flow between employees, internal trust level, customer's trust level and knowledge sharing flow between customers. To access the reliable data, an effective business intelligence system based on the new variables is needed and this part of the chapter is proposed the initial idea to design a new business intelligence system. Figure 4.20 demonstrates the fundamental requirements when designing business intelligence applications.

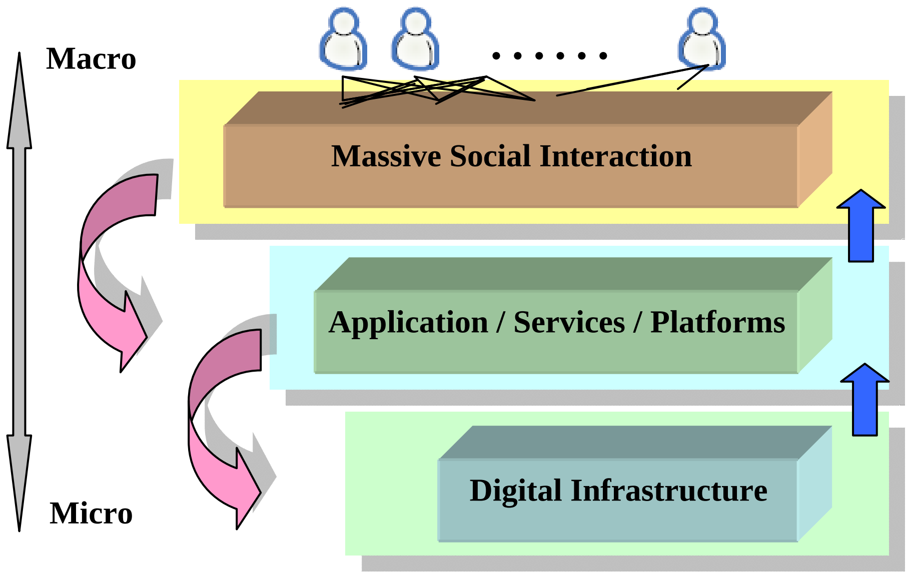


Figure 4.20: Fundamental requirement in digital ecosystem applications

As shown in Figure 4.20, interactions between individuals (agents) are the most important issues in a digital ecosystem.

In this research, simulation techniques are used to create a management dashboard for decision makers and show trust and knowledge sharing levels between employees and customers. A Business Intelligence Simulation Model (BISIM) is designed and developed for use as a business intelligence system to show the situation based on trust and knowledge sharing. The BISIM is a developed version of Digital Ecosystem Simulator (DES) that is developed on top of this simulator to incorporate knowledge sharing in a digital ecosystem and cover knowledge sharing framework variables such as trust dimensions and knowledge complexity as well as knowledge transferability. DES simulator has been developed to indicate individual's behavior in a digital business ecosystem and has been designed and developed by Dr Chen Wu (Wu and Chang, 2007). Figures 4.21, 4.22 and 4.23 show some examples of individuals' behavior simulated by the DES simulator.

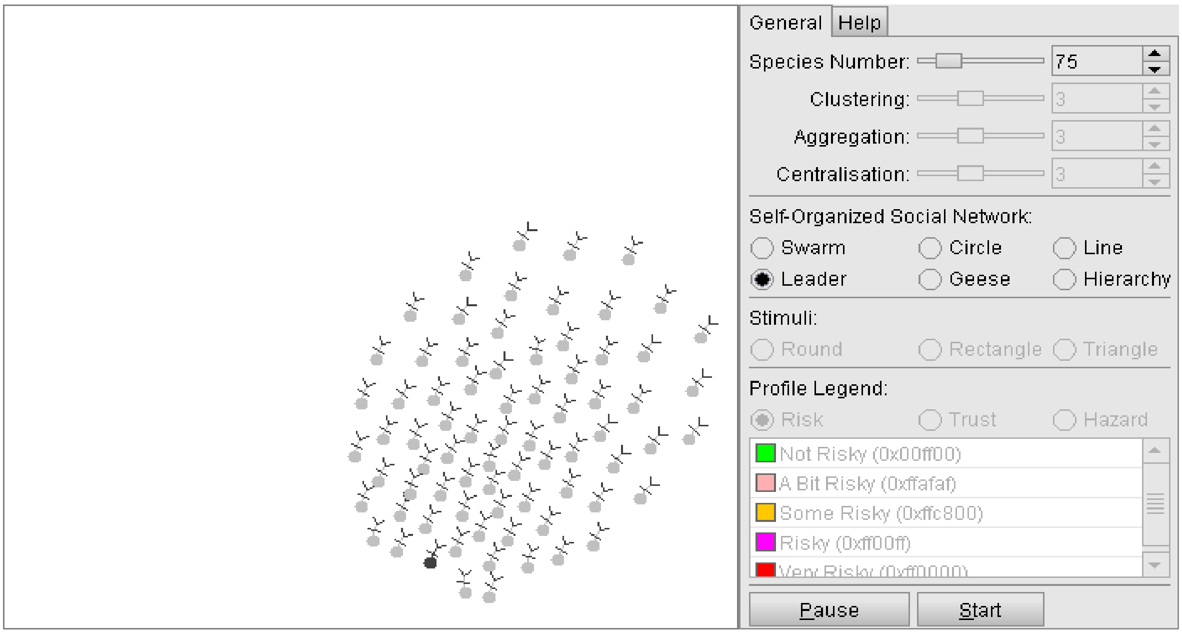


Figure 4.21: Digital ecosystem simulation in "Leader"-based social network (Wu and Chang, 2007)

As seen in Figure 4.21, a community can be created from a leader-based social network. In this kind of social network, most of the members within the community trust their leader. Trust between members and leader should be very high. Knowledge is mostly shared by leader with the members. Trust willingness and competency both are high and the leader uses a simple and understandable means of communication to share the related knowledge. As a result, knowledge is more transferable and less complex.

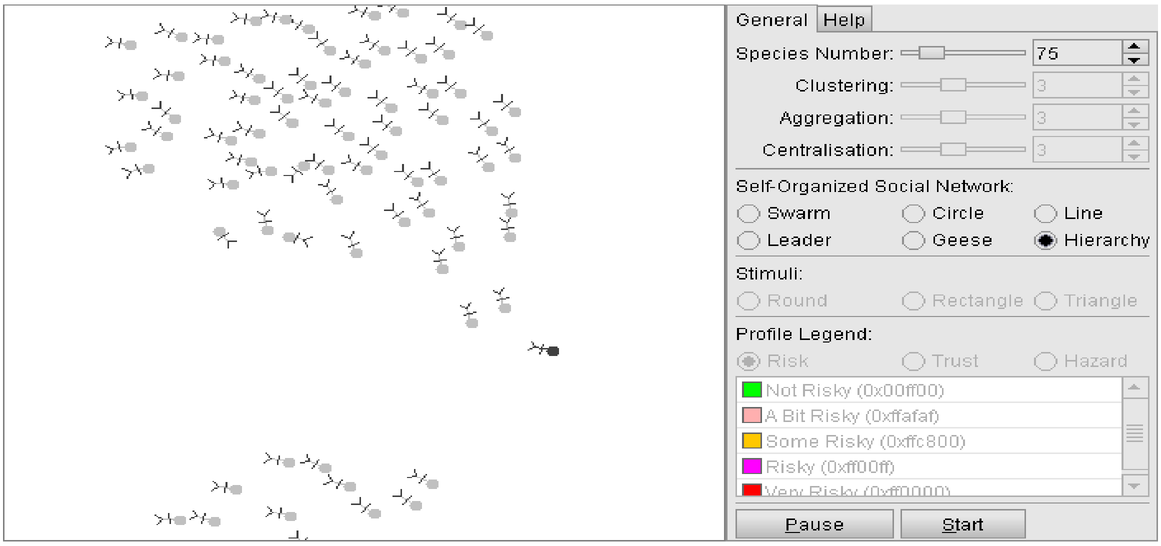


Figure 4.22: Digital ecosystem simulation in "Hierarchy"-based social network (Wu and Chang, 2007)

In this kind of social network, there are some hierarchies and knowledge transfers from upper hierarchies to lower hierarchies. There are also two dimensions of trust and knowledge sharing including vertical and horizontal dimensions. Horizontal knowledge sharing occurs between members of a community who are located at the same level of hierarchy and trust between these members is also a key issue. Vertical knowledge sharing occurs between members from two different hierarchies and normally knowledge as a command flows from upper level to lower level and as a suggestion, flows from lower level to upper level. Although knowledge sharing from upper level to lower level is like a command and must be accepted by the lower level members, low level members' trust in the upper level members noticeably increases organizational performance and also the upper level members' trust in low level members provides them with the right information for their decision-making.

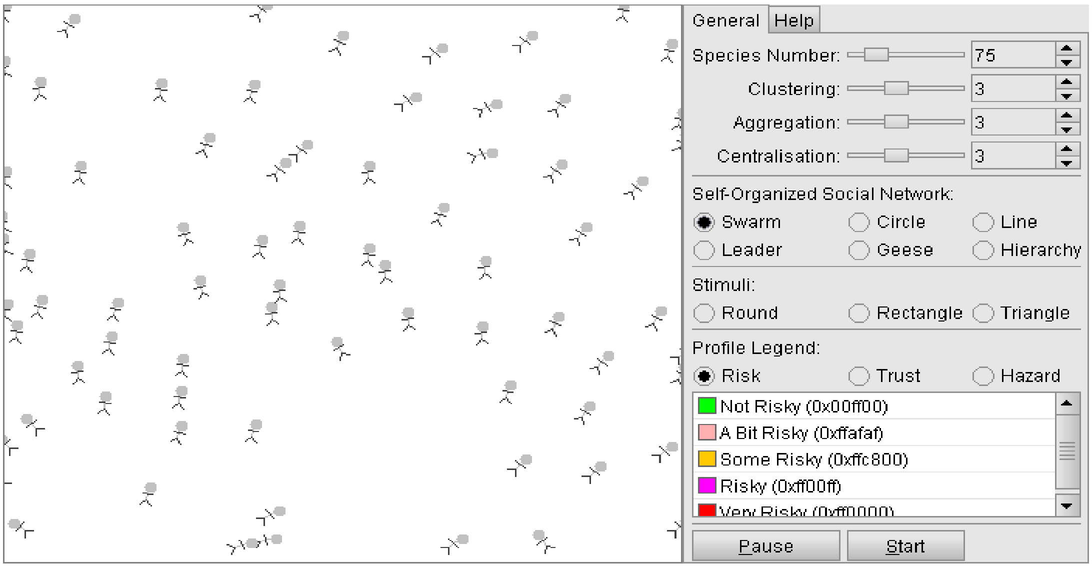


Figure 4.23: Digital ecosystem simulation in "Swarm"-based social network (Wu and Chang, 2007)

In this kind of social network, individuals are more intelligent and free to make a decision and communicate with others. This society is an ideal society based on a knowledge sharing democracy. The proposed prototype to measure knowledge sharing measurement in this research is more based on this kind of social network where all the individuals are free to share their knowledge or not, and they are from different backgrounds with different languages, experiences, educations etc.

In Chapter 9, the BISIM simulator is developed based on the DES simulator which is more focused on trust and knowledge sharing between members.

4.6 Solutions for knowledge capital measurement

In the literature, knowledge capital was defined as capital that can be created by trust and knowledge sharing and intellectual capital techniques were defined to measure this capital. Three main dimensions of intellectual capital are: human capital, social capital and market capital. Based on these three dimensions' definition, knowledge sharing and trust play a main role in intellectual capital measurement. Knowledge embedded in humans is a key variable in human capital measurement and knowledge sharing helps to increase individuals' embedded knowledge. Also, competence-based trust increases individuals' self-efficacy to share more knowledge and makes more connections. As a result, human capital is a function of knowledge sharing and trust which is shown as:

$$H_c = f(KS, T_{c,w}) + H_{c0} \qquad H_c = Human\ capital \quad KS = Knowledge\ sharing$$

$T_{c,w}$ =*Trust (competence based and willingness based)* H_{c0} =*other factors affect on human capital*

(Equation4.22)

Social capital is also based on individual's relationships and trust is a core variable that creates connections between and within communities. Knowledge sharing can make relationships stronger and social capital can be assumed as a function of trust and knowledge sharing.

$$S_c = f(KS, T_{c,w}) + S_{c0} \qquad S_c = Social\ capital \quad KS = Knowledge\ sharing$$

$T_{c,w}$ =*Trust (competence based and willingness based)* S_{c0} =*other factors affect on Social capital*

(Equation4.23)

And in market capital, trust between customers and an organization creates a high level of knowledge sharing and encourages them to maintain and improve their connection with the business and creates loyal customers. Also, trust between customers makes knowledge sharing more effective and in a short time, knowledge can be shared between customers. This is a new strategy in marketing and is based on word of mouth. Equation 4.24 shows the relationship between market capital and trust and knowledge sharing:

$$M_c = f(KS, T_{c,w}) + M_{c0} \qquad M_c = Market\ capital \quad KS = Knowledge\ sharing$$

$T_{c,w}$ =Trust (competence based and willingness based) M_{c0} =other factors affect on Market capital

(Equation4.24)

Based on the equations, the initial idea is shown in Figure 4.24.

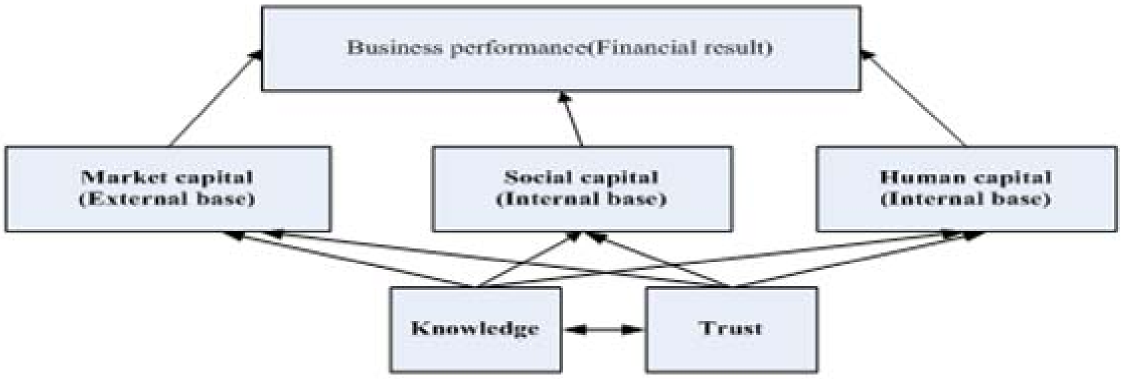


Figure 4.24: Conceptual model in intellectual capital measurement

As proposed in the initial model, intellectual capital within a specific community is based on knowledge and trust.

In Chapter 10, the proposed model is developed and discussed in detail and for each dimension of intellectual capital, a mathematical formula is proposed to measure trust and knowledge sharing.

4.7 Conceptual framework in knowledge sharing measurement

As discussed earlier, variables from different viewpoints such as social, economical and technological viewpoints affect on knowledge sharing. As it is seen in Figure 4.25, competence-based trust, willingness-based trust, complexity of knowledge as well as transferability of a particular knowledge in a specific time slot were defined as the key variables in knowledge sharing measurement.

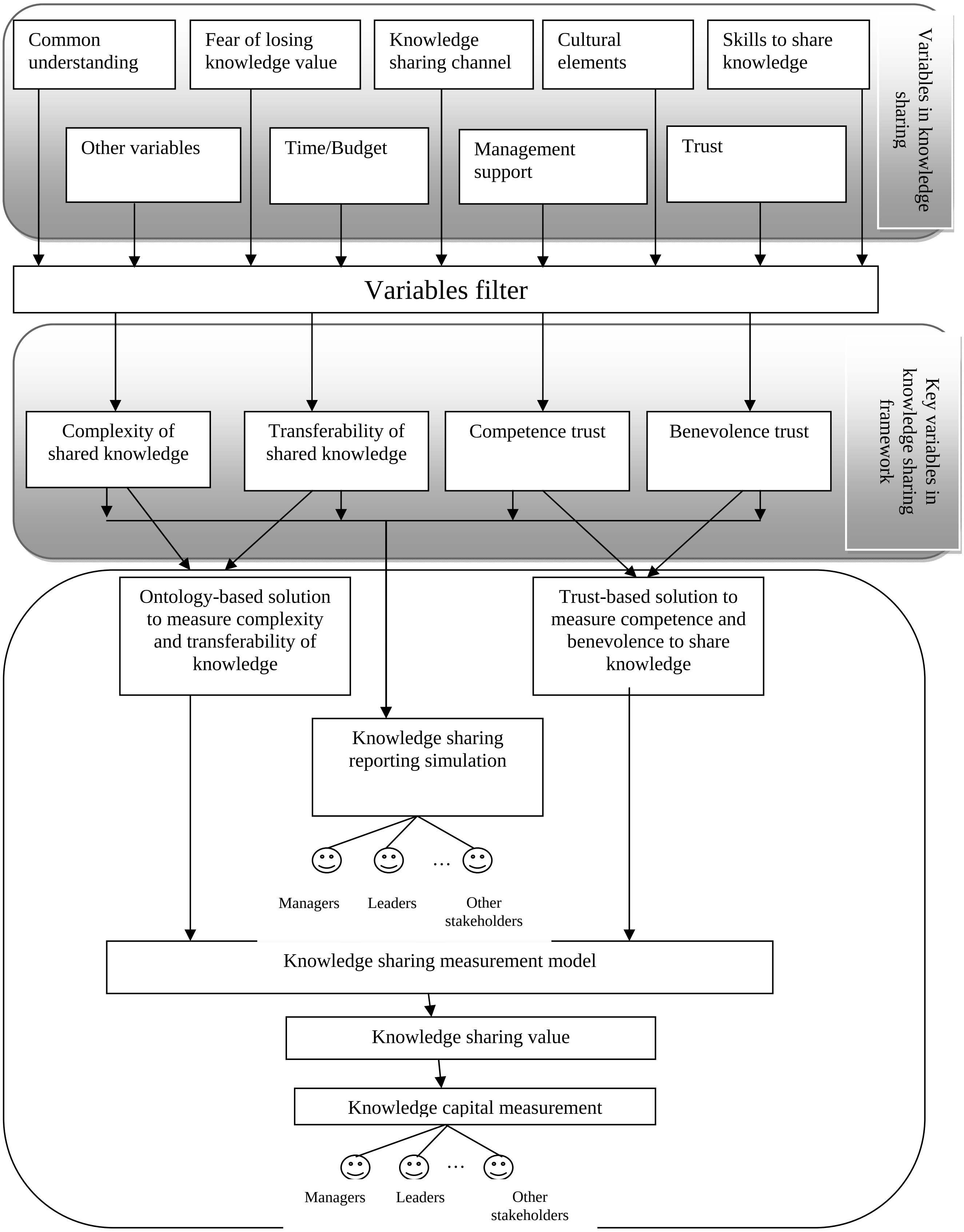


Figure 4.25: Knowledge sharing measurement conceptual framework

Figure 4.25 shows the conceptual framework that is proposed to measure knowledge sharing level and report it. As seen in Figure 4.25, an ontology-based solution is proposed to measure complexity and transferability of knolwedge. Ontology structure is used as a technique to measure Knowledge complexity, and the similarity between knowledge sender and knowledge receiver's ontologies is used to measure transferability of knowledge between knowledge sharing parties. It is shown in Figure 4.25 that trust techniques are used to measure competency and willingness to share knowledge. An ontology-based solution as well as a trust-based solution are used to develop a knowledge sharing framework and measure knowledge sharing value. Also, key variables in knowledge sharing are used to simulate a knowledge sharing reporting mechanism. Simulation results provide useful knowledge for decision makers such as managers, leaders and stakeholders to be used in their decision making process. As can be seen in Figure 4.25, a knowledge sharing framework is able to measure capital that can be created by knowledge sharing. This capital is based on knowledge and is called knowledge capital in this thesis. Measurement of Knowledge capital also provides useful knowledge for decision makers such as managers, leaders and stakeholders and helps them in their decision-making process.

4.8 Validation and verification of framework

Validation and verification involve checking that the results that have been drawn by the proposed framework are reliable as well as is the method of data is collection. Also, the results can be generalized for wider communities. This is to ensure that all techniques and methods in the framework do really work for knowledge sharing measurement. In this thesis, simulation experiments as well as experimental studies are used in order to validate the model for determining the knowledge sharing value of a particular knowledge in a given context during the specific time slot. Specifically, in this research the three following prototypes are validated.

1. Knowledge sharing measurement prototype: The objective of this prototype is to determine the knowledge sharing level of a particular knowledge in a specific time slot. Experimental studies are discussed in Chapter 9, along with the results obtained.

2. Knowledge sharing reporting Simulation: The BISIM (Business Intelligence Simulation Model) Simulation is developed to report knowledge sharing level and experimental studies are conducted to validate the prototype.

3. Knowledge sharing capital simulation: Experimental studies are conducted to validate the formulas that are used to measure knowledge capital that can be created by knowledge sharing and are presented in Chapter 10.

4.9 Conclusion

Based on the problems that were investigated in Chapter 3 and research issues, the initial conceptual framework is proposed in this chapter. The conceptual framework explains the initial ideas to measure and report knowledge sharing levels and also measures knowledge capital of the shared knowledge. Trust techniques are proposed to measure the benevolence and competence of the knowledge sender or knowledge receiver to send or gain knowledge. Also, ontology techniques are proposed to measure complexity and transferability of a particular knowledge. In the next chapter, trust measurement and related techniques are discussed thoroughly and different methods for measuring trust levels numerically are presented.

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Chapter 5: Trust-based solution in knowledge sharing measurement

5.1 Overview

In the previous chapters, the importance of knowledge and trust as key variables in knowledge sharing were discussed in detail. Different theories and models were discussed to investigate and measure knowledge sharing via trust measurement. Based on these examined models from the social viewpoint, a conceptual framework was proposed in Chapter 4 and knowledge sharing was proposed as a function of trust and knowledge. Two dimensions of trust including competence-based trust and benevolence-based trust were used to measure the willingness and competency of knowledge sender or knowledge receiver to share or acquire knowledge. Trust is a dynamic entity and it is not fixed over a time period and different factors can influenced the trust level over time. The most important part of this chapter is trust measurement. As trust was introduced as a key variable in knowledge sharing measurement, it is necessary that this variable be measured accurately. This chapter discusses different techniques and tools for measuring trust level between individuals so that the result can be used in knowledge sharing measurement. Trust has a fuzzy value and measurement tools should be capable of measuring fuzzy nature of trust. Fuzzy-based techniques such as fuzzy logic, fuzzy AHP (Analytic Hierarchy Process), fuzzy neural network and other measurement techniques can be applied to measure trust level and some of these techniques are investigated in this chapter. This chapter leads the research to develop the developed model in knowledge sharing measurement as iis proposed in Chapter 7.

5.2 Trust measurement

As stated previously, trust between individuals and business components, is a dynamic phenomena; it builds, declines and re-emerges over time and trust must be measured in specific time slot. Before investigating trust measurement methods, it is important to know about the trust principles which are discussed next.

5.2.1 Trust measurement principles

A trust network is important in creating relationship between communities' members. In a trust network, individuals share their knowledge and derive beliefs collaboratively (Figure 5.1).

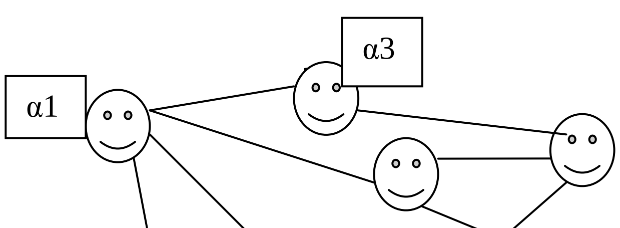


Figure5.1: Trust network

Two important variables in the trust network for a specific knowledge domain are: 1- number of members in the network, 2- Number of objects for each member. The system is defined by having N members T=($\alpha 1, \alpha 2, \alpha 3, \ldots, \alpha n$), n= 1,2,3,...,N and three objectives O=(Distrust(-1), unknown(0), high trust(1)). Then, a member may have three statuses within a specific context in a specific time slot to another member in community.

Some basic rules are defined to create a trust matrix in a community for a specific knowledge domain. The most important rules are:

1. **Trust is subjective**; it is based on observations and evidence made available to the node in a specific situation.
2. **Trust is reflexive;** Every trustee agent trust itself.
3. **Trust is not symmetric**; two agents do not need to have similar trust in each other.
4. **Trust is not transitive;** if $\alpha 1$ trusts $\alpha 2$ and $\alpha 2$ trusts $\alpha 2$; this does not necessarily imply $\alpha 1$ trusts $\alpha 3$.

This rule attempts to prove that if ɑ1 trust ɑ2 in a specific context and specific time slot and $\alpha 2$ trust $\alpha 3$ in the same context and at the same time ɑ1 may not trust $\alpha 3$ in that specific context and in the same time slot.

These rules are applied in all trust dimensions such as competence trust and benevolence trust. Another thing that should be explored and investigated in detail is trust measurement domain. This trust domain can be numeric such as trust between [-1, 1] or subjective such as high trust or low trust. This research is more focused on the two most important dimensions of trust by considering benevolence and competency as the two dimensions of trust. Competence trust refers to trust that is created by ability, contracts, laws, governance mechanisms, and structural assurances, while benevolence refers to trust due to goodwill intention (Pavlou and Dimoka, 2006). Competence and willingness trust are viewed as independent constructs, and empirically showed that they are distinct variables that usually have different relationships with other variables (Pavlou and Dimoka, 2006). The proposed distinction between competence and benevolence trust is consistent with the economic literature and benevolent sellers are committed to acting in a goodwill fashion while, competent sellers are committed to fulfillment (Dellarocas, 2003).

Benevolence is related to willingness within a community and is based on the idea that individuals will not intentionally harm another when given the opportunity to do so. This kind of trust can be positive or negative where agents within a community may believe in others' willingness to share knowledge and the trust level can be at the highest level. On the other hand, they may refuse to accept others' willingness and trust can be negative. This research assigns 1 for the highest level of trust within community and -1 for the lowest level of trust within community. All the values for willingness trust are located in a closed interval [-1, 1] (Figure 5.2). Trust is a relationship between A and B; witch may be described as trusted, distrusted or undecided.

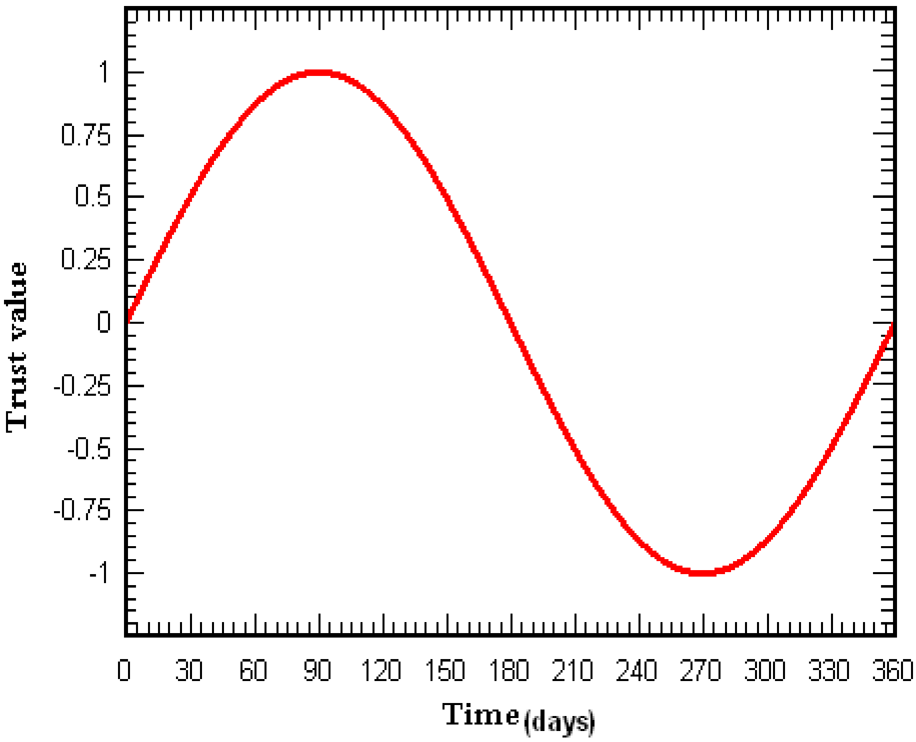


Figure 5.2: Benevolence Trust Value (during a year)

The second dimension of trust is competency. This kind of trust refers to the trusting agent's belief in the trusted agent's competency. It describes a relationship in which an individual believes that another person is knowledgeable about a given subject area. Competence-based trust can be either negative or positive and agents can believe in another's ability or may completely not accept another's ability in a given subject area. Again 1 is assigned for the highest level of competence-based trust within community and -1 for the lowest level of competence-based trust within the community. All the values for competence trust are located in a closed interval [-1, 1] (Figure 5.3).

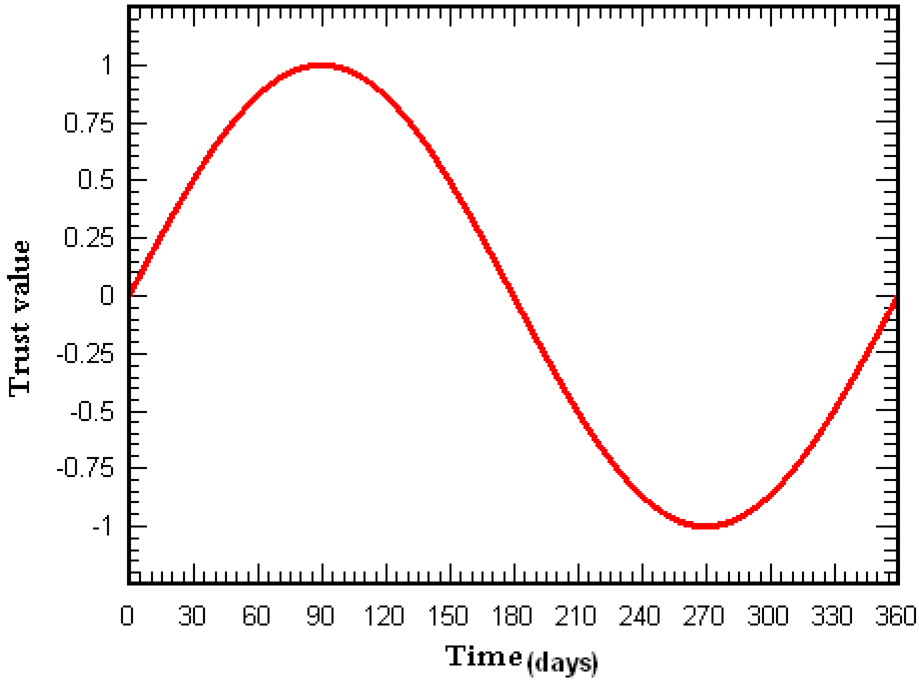


Figure 5.3: Competence Trust Value (during a year)

Binary ratings are considered insufficient to capture various degrees of judgment; therefore, a measurement model should give more than one choice for positive/negative ratings besides a neutral rating. As a consequence, ratings can be easily assigned and understood by human users and therefore a more accurate judgment can be obtained (Ries, 2006). For example, trust value= (-2,-1, 0, +1, +2). can be translated into discrete form as very bad, bad, average, good, and very good, respectively (Bharadwaja and Al-Shamri, 2009).

In this research, as shown in Figures 5.2 and 5.3, trust value is between -1 and 1 and all the values and results for trust must be between -1 and 1.

5.2.2Trust measurement Matrix:

Based on the trust rules, a trust matrix for a social network in Figure 5.1 is developed as:

Trust benevolence=Tb=

	α1	α2	α3	…..	αn
α1	1	$tb12$	$tb13$	….	$tb1n$
α2	$tb21$	1	$tb23$	….	$tb2n$
α3	$tb31$	$tb32$	1	….	$tb3n$
….	….	…..	…..	1	…..
αn	$tbn1$	$tbn2$	$tbn3$	….	1

Figure 5.4: Benevolence trust

As seen in Figure 5.4, every one trust himself/herself and trust value is 1. It is the reflexive rule of trust principles. Also as seen in the matrix 1, α1 trust on α2 is not equal with α2 trust on α1 and they have different values ($tb12$, $tb21$). All the values in this matrix are between -1 and 1.

This matrix can also apply to competence-based trust. Similarly, trust value in competence-based trust is between -1 and 1 and this dimension of trust also follows trust principles such as reflexive rule. Figure 5.5 shows competence trust value in a social network that is shown in Figure 5.1.

α1	α2	α3	…..	αn

$$\text{Trust competency} = Tc = \begin{array}{|c|}\hline \alpha 1 \\ \alpha 2 \\ \alpha 3 \\ \ldots \\ \alpha n \\ \hline \end{array} \begin{pmatrix} 1 & tc12 & tc13 & \ldots & tc1n \\ tc21 & 1 & tc23 & \ldots & tc2n \\ tc31 & tc32 & 1 & \ldots & tc3n \\ \ldots & \ldots & \ldots & 1 & \ldots \\ tcn1 & tcn2 & tcn3 & \ldots & 1 \end{pmatrix}$$

Figure 5.5: Competency-based trust

All variables in the two matrices are between -1 and1 and are identified in crisp and fuzzy logic systems. In a simple model, it is assumed that all members have the same weight and equal 1. However, in a developed model, each member can be assigned a different weight.

There is no need to normalize the matrices because all the variables are between -1 and 1. But, if there are different weights to the different members, it would be necessary to normalize the matrices.

Based on the matrices, the value of benevolence trust and competency trust for each member of the community can be calculated using the following formulas:

Benevolence trust of member n to other members in community= $\sum_{m=1}^{N} tbnm$

(Equation 5.1)

Competency trust of member n to other members in community= $\sum_{m=1}^{N} tcnm$

(Equation 5.2)

Benevolence trust of all members in community to member n = $\sum_{m=1}^{N} tbmn$

(Equation 5.3)

Competency trust of all members in community to member n = $\sum_{m=1}^{N} tcmn$

(Equation 5.4)

Average of benevolence trust within community= $\sum_{m,n=1}^{N} tbnm$ /N

(Equation 5.5)

Average of competency trust within community= $\sum_{m,n=1}^{N} tcnm$ /N

(Equation 5.6)

The most important issue in both matrices is defining the trust value between -1 and 1 for each element. The simplest way is to ask network members to assign a trust value to each other or create a questionnaire based on the variables that affect both competence-based trust and benevolence-based trust, and ask network members to assign a value to those variables and measure the trust values based on related variables. However, individuals judge others more according to subjective values such as good, bad, high trust, low trust and etc. It is necessary that the subjective values change to objective and measurable values and fuzzy logic is one of the tools that can be used for this.

5.2.3 Fuzzy logic techniques

Fuzzy logic represents a promising concept to close the gap between human reasoning and computational logic (Zadeh, 1994). Fuzzy logic is an easy-to-understand mathematical concept that incorporates fuzzy values and uncertainty into the decision-making process. It accepts fuzzy numbers that are normally used by the individuals to explain their trust value to others to express the membership to a context. Fuzzy rules are based on natural language which removes implementation complexity and enhances understanding and readability (Schmidta et al., 2007). More recent contributions to the evaluation of trust and reputation use fuzzy logic concepts (De Acebo and de la Rosa, 2002). With the fuzzy logic concept, it is necessary to define the fuzzy membership functions. These determine the degree of membership of each input parameter in the context of the model. To simplify the model, three fuzzy sets of triangular shape are used as membership functions for both fuzzy variables (competence based trust and benevolence based trust). Figures 5.6 and 5.7 show the membership functions for each variable and as shown in the figure, three fuzzy sets including distrust, unknown and trust are used to show the trust value between individuals.

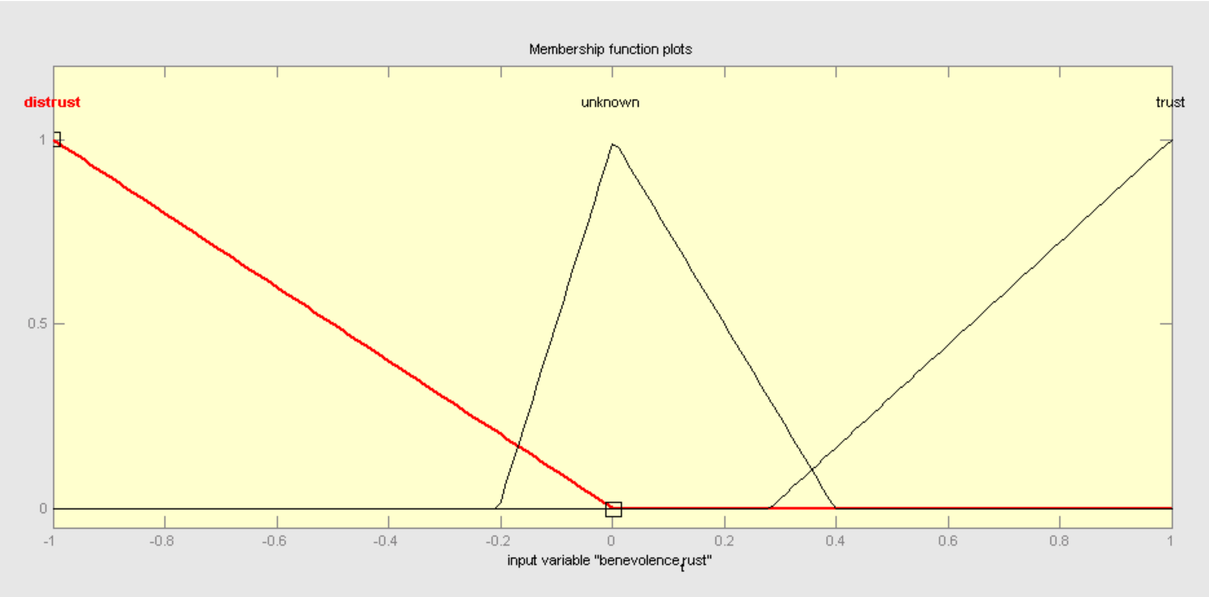


Figure 5.6: Benevolence trust membership

Similarly, Figure5.7 shows competence-based trust membership.

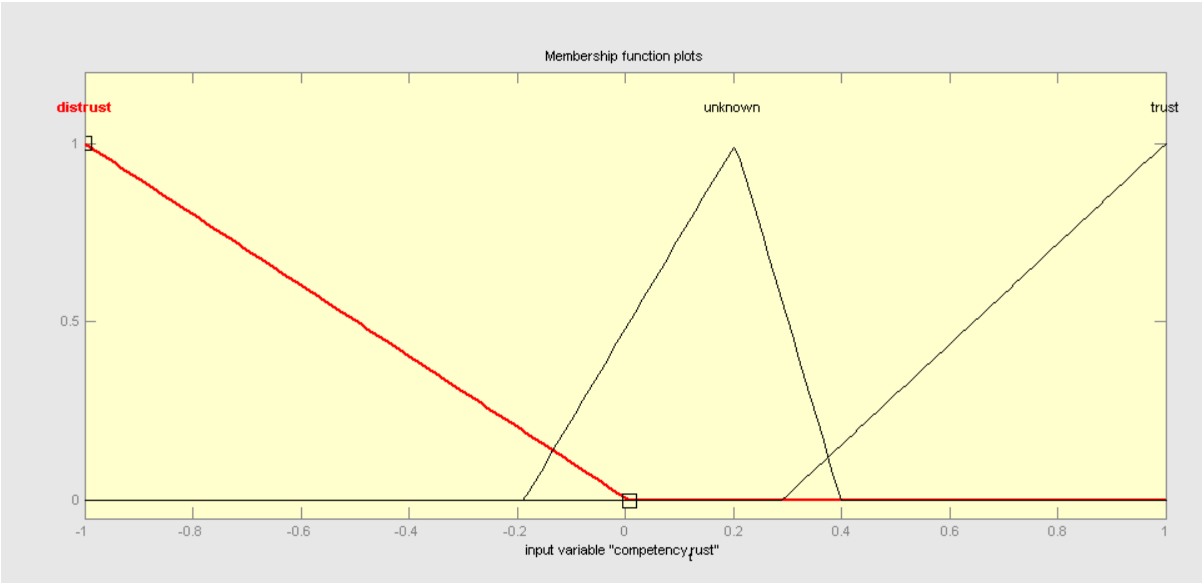


Figure 5.7: Competence trust membership

These variables are used in a knowledge sharing measurement model as input variables. This method has been used in this thesis and is discussed in detail in Chapter 7 to measure the trust level in knowledge sharing measurement.

5.2.4 CCCI method

Another method of trust measurement is CCCI (Correlation, Commitment, Clarity, and Influence) method. CCCI is based on determining the correlation between the originally committed services and the services actually delivered by a Trusted Agent in a business interaction over the service-oriented networks to determine the trustworthiness of the Trusted Agent (Chang et al., 2005). This method uses a scale system as a measurement system which can be used to determine the level of trust. The scale system can have either numeric measures or non-numeric measures. Trustworthiness is a measure that determines the amount of trust that the Trusting Agent has in the Trusted Agent. One of the most popular scale systems in this method is a 7-level trustworthiness scale system. Trustworthiness helps in the rating of trust by numerically quantifying the trust values and qualifying the trust levels none numerically. Table 5.1 shows the seven levels of trustworthiness determined by this method:

Trust-worthiness Level	**Semantics** (Linguistic Definitions)	**Trustworthiness Value** (User defined).	**Visual Representation** (Star Rating System)
Level -1	Unknown Agent	x = -1	Not displayed
Level 0	Very Untrustworthy	x = 0	Not displayed
Level 1	Untrustworthy	$0 < x \leq 1$	From ☆ to ★
Level 2	Partially Trustworthy	$1 < x \leq 2$	From ★ to ★★
Level 3	Largely Trustworthy	$2 < x \leq 3$	From ★★ to ★★★

Level 4	Partially Trustworthy	3 <x ≤ 4	From ★★★ to ★★★★
Level 5	Very Partially Trustworthy	4 < x ≤ 5	From ★★★★ to ★★★★★

Table5.1: Seven levels of trustworthiness (Chang et al., 2005)

This method is used by different websites such as eBay, YouTube and most customer-to-customer buying and selling websites to measure the trust level of buyers and sellers, and helps other members to decide whether or not to enter into a transaction with trusted or trusting agents.

Some other techniques such as neural networks can also be applied to measure trust between trusted and trusting agents.

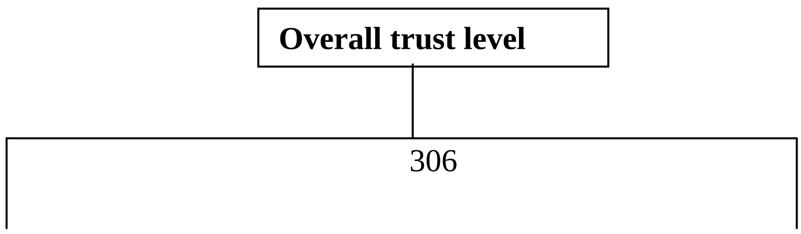
In some cases, it is necessary to define a trust value for an agent on the basis of integrating different values from different resources. For example, an organization wants to define trust value of a person who intends to occupy a position at management level. In this case, they need to ask experts, peer co-workers, subordinates and higher level managers to assign a trust value to this person (360 degree trust evaluation). Suitable tools are required to integrate different values and help decision makers to evaluate the trust level of the said person. AHP (Analytical Hierarchy Process) is one of the techniques that can be used to integrate experts' ideas. AHP is a technique for considering data about a decision in a systematic manner (Saaty and Vargas, 2001). AHP is a highly flexible decision methodology that is used to combine different alternatives from several candidates on the basis of multiple decision criteria of a competing or conflicting nature. Particularly important for the trust factor selection situation, the decision criteria may hold a different perceived degree of preference or level of importance to the decision in the eyes of the decision makers (Radcliffe and Schniederjans, 2003).

5.2.5 AHP methodology

AHP helps to bring consistency to selection problems whose decision criteria are expressed in subjective measures based on managerial experience (Bryson, 1996). Expert choice is software that uses the AHP technique in the decision-making process. AHP has four important steps and these four steps are customized to be used in trust concept as follows:

5.2.5.1 Step 1- Construction of the hierarchy layer structure

The top level of the hierarchy is the overall goal of the problem and, in trust level measurement, the overall goal is to measure the level of trust for a group member within a specific time slot and in a particular context. The following lower levels are the indicators (these indicators can be subjective or objective) and sub-indicators that contribute to achieving the goal. The bottom level is formed by the alternatives that are used by the experts to evaluate indicators. For example, the hierarchy layer structure of trust level evaluation in knowledge sharing has been shown in Figure 5.8:



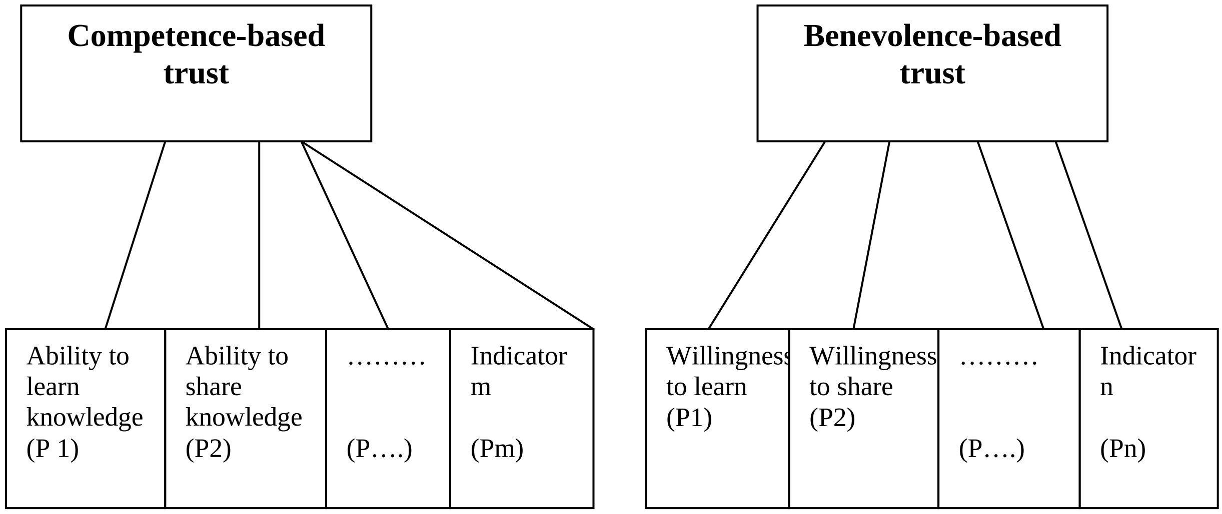


Figure 5.8: Hierarchy layer structure in using AHP for trust measurement

5.2.5.2 Step 2- Establishment of matrix P

It is supposed there are k decision makers that determine the trust level based on m indicators for n members in a group. Decision makers' ideas can be equal in weight or they may be different. For example, people who are in the same department may know each other better than do people who work in different departments; or a direct supervisor may have a better idea than indirect supervisors or managers and their idea's weight can be higher in comparison with those of others. In this case, they can be allocated different weights to highlight this issue. In this chapter, it is supposed that all the decision makers have equal importance in assigning trust levels to individuals in a specific time slot and in the defined domains. AHP uses pair-wise comparison to allocate weights to the elements of trust dimensions, measuring indicators level by using 1–9 scale, and finally calculates global weights for assessment at the bottom level. If the numbers of indicators is assumed to be m, the numbers of the matrix are m. For example, in Figure 5.8, one matrix is for trust ability to learn updated knowledge and another matrix is for trust ability to share the obtained knowledge. Pair comparison of a matrix's elements can be defined with pij being the judgment matrix element where i, j = 1, 2... k(k is the number of the group members). If pij=1, then member Pi and Pj are assigned by a same trust level; if pij=3, then Pi in comparing with Pj is more trustworthy for that indicator and it can be increased up to pij=9.

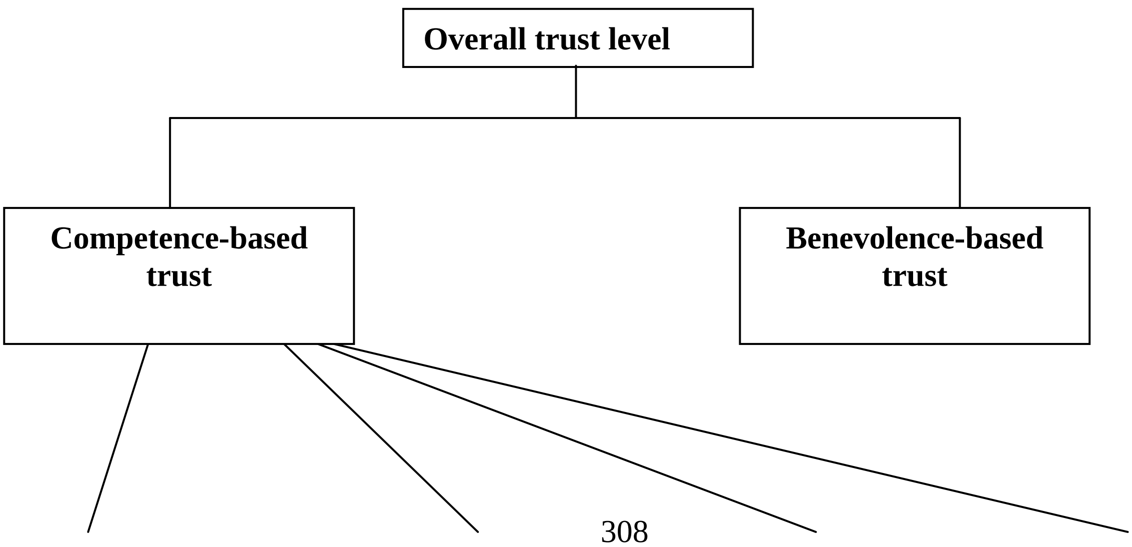
	p1	p2	p3	…..	pi
p1	1	$p12$	$p13$	....	$p1i$
p2	$p21$	1	$p23$	.....	$p2i$
p3	$p31$	$p32$	1	......	$p3i$
.	....	.....	.....	1	.....
pj	$p1j$	$p2j$	$p3j$	.....	1

i and j = 1,2,3,...,n

Figure 5.9: Pair comparison of trust level between group members

As can be seen in Figure 5.9, trust comparisons of each member with themselves are equal to 1. As a result p11=p22=p33=...=pij=1 (when i=j).

Each matrix shows trust comparison in one indicator. As a result, the numbers of matrices are "m" due to the number of indicators that are m.



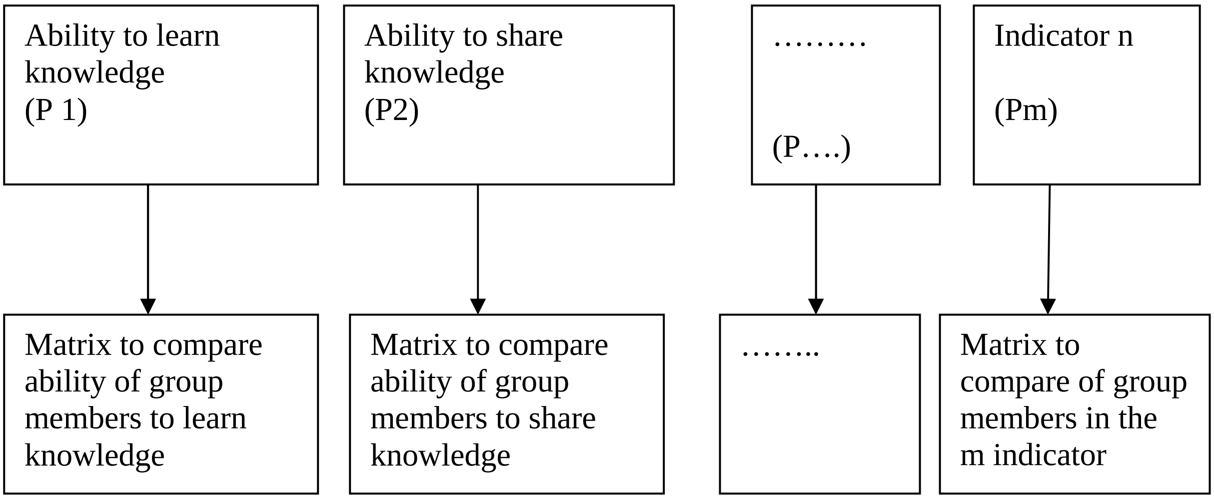
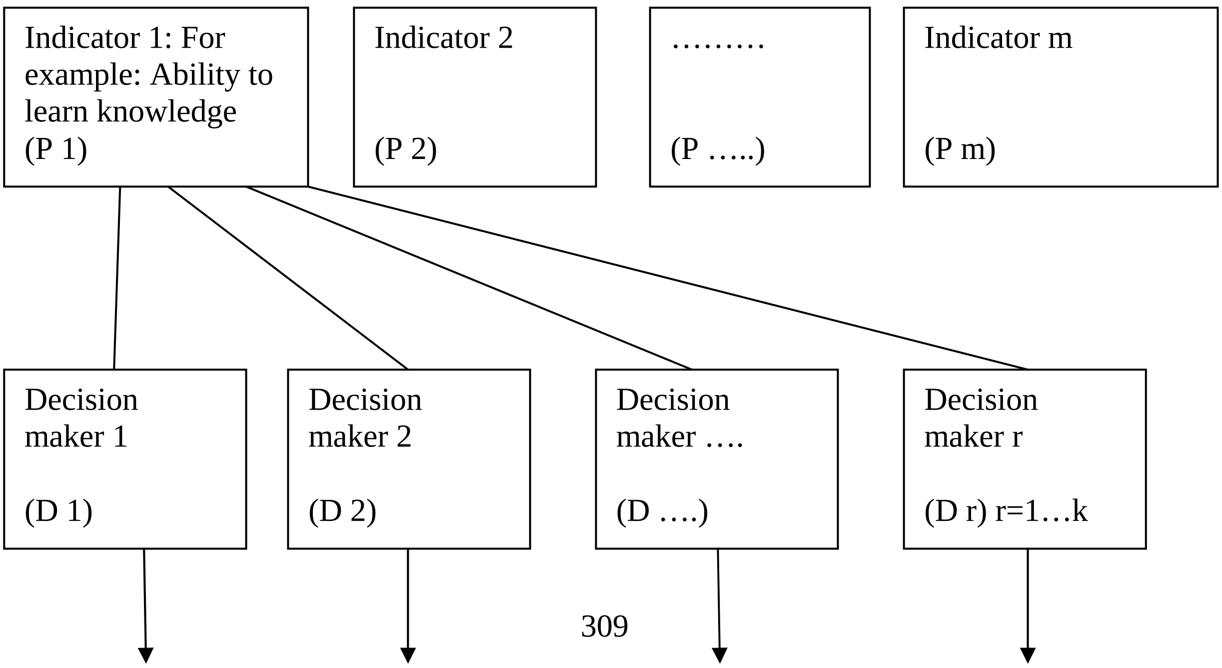


Figure5.10: Comparison matrices

Decision makers set can be defined as, D = (D1… Dr). where r=> 2. r is the number of decision makers expressing reciprocal judgment matrices corresponding to pair-wise comparisons of trust level indicators (m indicator) with regard to the criterion considered for a set of n members in the group (A1, …, An), where there is a positive square matrix (n × n) which validates for i, j = l, …, n. Figure 5.11 shows the role of AHP in combining different decision makers' ideas about the trust level of members of a group.



Matrix to compare indicator 1 between members by decision maker1	Matrix to compare indicator 1 between members by decision maker2	Matrix to compare indicator 1 between members by decision maker….	Matrix to compare indicator 1 between members by decision maker r

Figure 5.11 Combining different ideas of decision makers

The judgments represent the relative importance to the decision maker Dr(r=1…k) of individual i compared to individual j, (I,j=1…n) in the different indicators (1…m) according to the basic scale (1…9).

5.2.5.3 Step3. Combining the matrices to find the trust value based on decision makers ideas

The next step is to combine the different matrices to build a final decision-making matrix and find the trust value based on different ideas.

With AHP methodology, the best way to combine the different ideas of different decision makers is to calculate the geometric mean for each pij. In this way, the geometric mean of each pij can be calculated with this formula:

Geometric mean of $\overline{Pij} = (\prod_{r=1}^{k}((p_{ij})^{r}))^{1/k}$

(Equation 5.7)

As mentioned in the figure5.11, i and j are the individual's (agents) that are compared and Pij is trust value of individual i in comparing with individual j by decision maker r and k is the numbers of decision makers.

Therefore, all the matrices can be combined and in the final stage, there is one matrix available. For example, if there are three decision makers, the matrix is shown with:

$$\begin{bmatrix} 1 & \sqrt[3]{p12^{(1)} * p12^{(2)} * p12^{(3)}} & \sqrt[3]{p1i^{(1)} * p1i^{(2)} * p1i^{(3)}} \\ \sqrt[3]{p21^{(1)} * p21^{(2)} * p21^{(3)}} & 1 & \ldots.. \\ \sqrt[3]{pj1^{(1)} * pj1^{(2)} * pj1^{(3)}} & \ldots\ldots.. & 1 \end{bmatrix}$$

Figure5.12: AHP Matrix for three decision makers

The next step is normalization of the matrix and placing all the elements between 0 and 1. This can help to change trust level between 0 and 1 for use in any scales. The normalization can be done by this formula: (r_{ij} shows ~~t~~he elements of normalized matrix).

$$r_{ij} = \frac{\text{Pij}}{\sum_{i=1}^{n} \overline{\text{Pij}}} \qquad \text{Pij} = \text{geometric mean} \qquad \text{i} = \text{j} = 1,2,\ldots,\text{n}$$

$$\text{n} = \text{number of the members in the network}$$

(Equation 5.8)

In this formula, all the elements are between 0 and 1.

The trust level for each member of the group can be calculated by this formula:

Trust level for i= $\left(\sum_{j=1}^{n} r_{ij}\right) \Big/ j$ $\qquad r_{ij} = elements\ of\ normalized\ matrix$, i,j=1,2,..,n

n= number of the members in the network

(Equation 5.9)

Using this methodology, it is also possible to measure the consistency of the result.

5.2.5.4 Step4. Consistency test

AHP calculates a consistency ratio to verify the coherence of the judgments and includes standards as guides for accepting or rejecting the test result

5.3 Discussion

This chapter focuses on trust measurement. Two main dimensions of trust that are used in the proposed model are benevolence- and competence-based trust. Some of the main principles related to trust were discussed in detail and trust value in this research is defined to be between 0 and1 ([0, 1]). Trust should be calculated between each pair, and trust matrices are developed in this chapter to indicate the trust value between each pair. Willingness trust (benevolence) and competence-based trust between community members can be calculated by different methods that are discussed in this chapter. The main methods for measuring trust value that are discussed in this chapter are AHP and CCCI. AHP is based on expert's ideas and measures the trust level based on trust value between pairs that are assigned by the experts. AHP is able to mix all the ideas and find the best value of trust. CCCI is also a method of measuring trust levels and it is more commonly used in websites to measure the trust level of customers and reputation of sellers. Trust value can be fuzzy value such as distrust, high trust and etc. or can be an integer value. In this research, both types of values are considered in trust measurement.

5.4 Conclusion

The chapter explores trust measurement and proposes several methods for measure the trust level between two members. This chapter is focused on willingness and competence-based trust as a solution to measure individuals' motivation and ability to share knowledge. In the next chapter, ontologies are used as a solution to measure the complexity and transferability of a particular knowledge.

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Chapter 6: Ontology-based solution for knowledge sharing measurement

6.1 Overview

As stated earlier, an individual's sharing of embedded knowledge with others and increasing the flow of knowledge, is crucial major challenge in a knowledge-based society. The challenges arise when people from different educational backgrounds, different experiences and skills, different cultures end ecosystems, and different expectations that exist among team members with different levels of trust between them, attempt to share knowledge. In the previous chapter, a trust-based solution was discussed to measure willingness and competence to share a particular knowledge. In this chapter, an ontology-based solution is discussed to measure the complexity of a particular knowledge when encoding or decoding as well as transferability of that knowledge. Knowledge representation needs to be shared among community members formally, semantically, and explicitly. The process of making the knowledge formal, semantic, explicit is the main challenge of knowledge sharing.

Shared knowledge between sender and receiver should be changed from tacit to explicit knowledge and be accessible to team members. Since exchange requires conversion of tacit knowledge into explicit communicative actions, each team member needs normative frames of reference to interpret the shared knowledge. Frames of reference depend on educational or cultural backgrounds as well as other related variables such as skills etc. Team members who have different experiences and educational backgrounds use basic communication frameworks for describing and clarifying. The key issue is to have an agreed, explicitly interpreted knowledge accepted by the parties involved in knowledge sharing processes. An ontology enables shared conceptualizations and terminology as well as agreement among teams distributed across the sites by making the assumptions explicit. Ontology is an explicit specification of a conceptualization and allows knowledge to be shared by team members through their focus on making meaning explicit and their intention to share agreements.

In this research, ontology tools are used to propose metric measurement formulas to measure complexity of knowledge.

Ontology provides a semantically shared domain knowledge in a declarative formalism. However, the meaning and understanding of concepts in ontologies vary in different communities. Determining the similarity or difference of two ontologies is vital to knowledge transferability. Similarity of different concepts between two ontologies is fundamental to knowledge sharing. Sharing of knowledge would be efficient and effective if knowledge senders and knowledge receivers have a similar understanding of concepts in ontologies and/or the new knowledge is not complicated. The ontologies similarity concept is applied to measure transferability of a particular knowledge in a specific time slot.

Overall, this chapter presents two key variables of knowledge representation in knowledge sharing measurement and explores how these variables are related to the efficiency of knowledge sharing. A numeric measurement of the transferability between two ontologies and a numeric measurement of the complexity of the ontology difference are proposed. Several experiments are conducted using sample ontologies to measure the complexity and transferability of a particular knowledge between knowledge sender and receiver.

6.2 Knowledge complexity

As already discussed, knowledge complexity refers to a common understanding of the shared knowledge between knowledge sender and knowledge receiver. It means that the knowledge sender and knowledge receiver use unique symbols to transmit knowledge and the meanings of the used symbols should be understood by both parties. Ontology complexity is used in this thesis as a solution to measure knowledge complexity and is discussed in this section.

6.2.1 Ontology complexity

There is no unified metric so far that indicates the complexity of ontology. Ontology complexity is related to the complexity of conceptualization of the domain of interest. It is measured to indicate how easy any ontology is to understand. Based on the ontology structure that was discussed in the Chapter 4 (section 4.4.3.2), nine metrics are used to measure the complexity of a particular knowledge in a particular ontology and in a specific knowledge domain.

The final formula for measuring the complexity of a particular knowledge is shown in Equation6.1:

$$\text{Complex(O)} = \left(\frac{\sum(NoDP+NoOP+NoC+NoHP)}{Max(NoDP)+Max(NoOP)+Max(NoC)+Max(NoHP)}\right)/NoOC$$

(Equation 6.1)

Two ontologies including software engineering ontology and pizza ontology are used to justify equation 6.1 and proof of concept is discussed in the section 6.4. The variables that are used in Equation 6.1 are listed below.

1. Number of Data type Properties (NoDP)
2. Maximum Number of Data type Properties (Max (NoDP))
3. Number of Object Properties (NoOP)
4. Maximum Number of Object Properties (Max (NoOP))
5. Number of Constraints (NoC)
6. Maximum Number of Constraints (Max (NoC))
7. Number of Hierarchical Paths (NoHP)
8. Maximum Number of Hierarchical Paths (Max (NoHP))
9. Number of Classes (NoOC)

The metrics give an indication of how well and how finely the concepts are being defined. High value of metrics shows that it is assumed as complex knowledge. It is assumed that the ontology being evaluated for complexity is written in Web Ontology Language (OWL).

6.2.2 Number of datatype properties

The Metric of Number of Data type Properties (NoDP) presents how well concepts are being defined. NoDP is the sum of the number of data type properties (dp) in an ontology. In OWL, the data type property is indicated as owl:dataTypeProperty.

$$NoDP = \sum_{i=1}^{n} dp_i$$

(Equation 6.2)

n: number of data type properties

dp: data type property

6.2.3 Maximum Number of Data type Properties

The Maximum Number of Data type Properties (Max (NoDP)) indicates the maximum value of data type properties in the ontology.

6.2.4 Number of object properties

The metric of Number of Object Properties (NoOP) shows how well spread of concepts within the ontology. NoOP is the sum of the number of object properties of each class in an ontology. In OWL, the object property is indicated as owl:objectProperty.

$$NoOP = \sum_{i=1}^{n} op_i$$

(Equation 6.3)

n: number of object properties

op: object property

6.2.5 Maximum Number of Object Properties

The Maximum Number of Object Properties (Max (NoOP)) indicates the maximum value of object properties within the ontology.

6.2.6 Number of constraints

The metric of Number of Constraints (NoC) illustrates the degree to which relationships between classes are restricted. NoC is the sum of the number of constraints in an ontology. In OWL, constraints are indicated as owl:allValuesFrom, owl:someValueFrom, owl:hasValue, owl:cardinality, owl:minCardinality, and owl:maxCardinality.

$$NoC = \sum_{i=1}^{n} const_i$$

(Equation 6.4)

n: number of constraints

const: constraint

6.2.7 Maximum Number of Constraints

The Maximum Number of Constraints (Max (NoC) presents the highest number of constraints in the ontology.

6.2.8 Number of hierarchical paths

The Metric of Number of Hierarchical Paths (NoHP) indicates how finely the concepts are being presented. Hierarchical paths is also known as inheritance of concepts reflecting hierarchy of concepts (relations 'is-a', 'part-of', and 'compose-of'). NoHP is the sum of the number of paths of each concept starting from the root node to the leaf node. In OWL, the hierarchical path is represented as owl:subClassOf.

$$\text{NoHP} = \sum_{i=1}^{n} p_i$$

(Equation 6.5)

n: number of hierarchical paths

p: hierarchical path

6.2.9 Maximum Number of Hierarchical Paths

The Maximum Number of Hierarchical Paths per Class (Max (NoHP)) presents the highest hierarchical path in the ontology.

6.2.10 Number of ontology class

The number of ontology classes presents the sum of classes in the ontology in order to arrive at a value of complexity between 0 and 1.

The complexity value ranges between 0 and 1 where 0 indicates that the ontology is not very complicated, while 1 means the ontology is very complicated.

6.3 Knowledge transferability

Knowledge is a combination of the data and information being produced by human thought processes. Knowledge can be distinguished into general knowledge and specific knowledge. General knowledge is explicit and is easily understood by locals and neighbors since both their ontologies are similar. Specific knowledge is more technical and difficult to understand and depends on an individual's background and knowledge level (ontologies are different). It is necessary to understand the nature of knowledge in order to analyze the process of knowledge sharing between and within organizations or individuals. The characteristics of knowledge influence the outcome of knowledge sharing (Nonaka, 1995). The impact of the nature of knowledge on knowledge sharing is part of this research's objective. The nature of the knowledge also affects the importance of trust in knowledge sharing. When the knowledge seems simple, competence-based trust is not necessarily important and in this case, people care more about benevolence-based trust. On the other hand, when the knowledge is complex and professional, people care more about competency-based trust.

Knowledge types are classified into easy or difficult transferable knowledge (transferability). Metrics to measure the complexity of knowledge by using ontology are presented and a proposed model is proposed to measure the transferability of knowledge by comparing the two ontologies (sender and receiver of the knowledge) and ascertaining whether or not there are similarities.

Transferability of the knowledge is more related to the members' backgrounds and their domain ontology. The similarity between ontologies is used to measure the level of transferability between two members. Transferability of the knowledge for both transmitter and receiver is given a value between 0 and 1.

6.3.1 Ontology similarity as a solution to measuring knowledge transferability

To measure the transferability of two knowledge backgrounds, ontology similarity is considered and calculated. By means of obtaining the senses and hyponyms of each concept in the ontologies, and based on the structure of the ontologies, the level of similarity between two ontologies can be calculated. More precisely, knowledge transferability is indicated by ontology similarity. Nevertheless, there may be more than one sense for each concept. The senses of subclasses of ontology can be determined by their ancestors to which sense from the root of the ontology it is determined by users.

In this chapter, the formulas give a numeric measurement of ontology transferability.

6.3.2 Formula to measure transformability

Assume that transferability of two ontologies can be calculated by using ontology similarity formulas. Wang and Ali(Wang and Ali, 2005) determined the difference of set of concepts, S1, captured in ontology 1, O1, from set of concepts, S2, captured in ontology 2, O2 as :

$$S1 - S2 = \{x | x \in S1 \wedge x \notin S2\}$$

The semantic difference between O1 and O2 can be defined by function Dif(S1, S2) in the following formula(Wang and Ali, 2005)

$$Dif\ (S1, S2) = \frac{|S1 - S2|}{|S1|}$$

(Equation 6.6)

Based on the above formula, if the two ontologies are totally different, the difference value is given 1 or the similarity value is given 0. On the contrary, if the two ontologies are the same, the difference value is given 0 or the similarity value is given 1. Therefore, the similarity of set S1 from set S2 is defined as

The similarity between S1 and S2 = $\{x | x \in S1 \wedge x \in S2\}$

The semantic similarity between O1 and O2 or the transferability can be defined by function Trans(S1, S2) in following formula

$$Trans(S1, S2) = 1 - \frac{|S1 - S2|}{|S1|}$$

(Equation 6.7)

Both directions are compared i.e. Trans(S1, S2) and Trans(S2, S1) which may be given a different value.

In domain ontology where two individuals (receiver and sender) are sharing their knowledge (a class in ontology), they first need to agree on a sense of shared knowledge. Sense sets are provided to summarize the semantics of the shared knowledge (the class in ontology). Basically, the sense set is a set of synonyms denoting the concept of the class in ontology. A sense set is extracted from the electronic lexical database

WordNet which is available online as Java WordNet Library (JWNL). JWNL is used to obtain the semantic meanings of concepts contained in ontologies.

Proposed simple ontology transferability procedure is shown below.

```
OntologySenseSet(O).

begin

R = resultSet;

for all the node n in Ontology O

p = parent node of n;

senseSetP = all the senses of p;

senseSet = all the senses of n from WordNet;

if n = root

user selects a related sense to use in this Ontology O;

    else

relateFlag = false;

    for each sense S in senseSet

hyperSet = hyponyms of each sense S of n;

      for each h in hyperSet

        if h is in senseSetP
```

```
          relateFlag = true;
          for each s in S
          if s == n
            R.add(s + "_is-a_" + p).;
          else
            R.add(s).;
          endif
          endfor
        endif
      endfor
    endfor
    if relateFlag == false
      R.add(n).;
    endif
    endif
endfor
return R;
end
```

```
OntologyTransferability(O1, O2).

begin

  difference = 0;

  for each r1 in OntoSenseSet(O1).

        if r1 is not in OntoSenseSet(O2).

           difference ++;

        endif

  endfor

  Trans = 1- difference/size of OntoSenseSet(O1).;

  return Trans;

end
```

Figure 6.1: Ontology transferability procedure

Quantifying the transferability of knowledge is the intersection between two different ontologies and for this purpose it is important to assess the semantic similarity of difference between two ontologies. To demonstrate the procedure, simple ontologies are used to show transferability between them. Assume there are two ontologies i.e. Furniture Ontology and Position Ontology as shown in Figure 6.2.

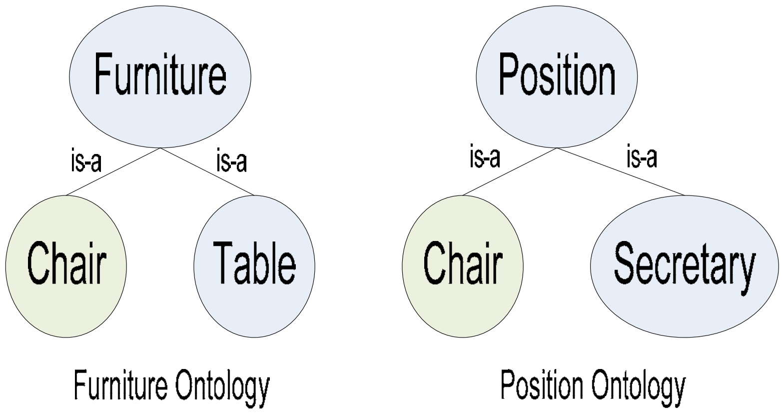


Figure 6.2: Chair concept in two different ontologies

Furniture Ontology represents concepts of chair and table as furniture while Position Ontology represents concepts of secretary and chair as position. Transferability between these two ontologies is assessed. To assess transferability from Furniture Ontology to Position Ontology, it is needed to get the sense set of the two ontologies. In other words, the concepts and their senses with hyponyms for both Furniture Ontology and Position Ontology are obtained. In the process of obtaining a sense set, a user initially choose which sense s/he means at the root concept if there is more than one sense. Senses and its hyponyms are obtained from WordNet. Among those retrieve from WordNet, it is also included is-a relationship to differentiate concept from others if there is more than one senses in that particular concept.

The tables below show senses and hyponyms from WordNet for Furniture Ontology and Position Ontology. The highlighted senses are the ones in the sense set or the ones that have meaning within the intended content.

Concept	Senses	Hyponyms
Furniture	furniture, piece of furniture, article of furniture	Furnishing
Chair	Chair	Seat
	Professorship, chair	position, post, berth, office, spot, billet, place, situation
	president, chairman, chairwoman, chair, chairperson	presiding officer
	electric chair, chair, death chair, hot seat	instrument of execution
Table	table, tabular array	Array
	table	furniture, piece of furniture, article of furniture
	table	furniture, piece of furniture, article of furniture
	mesa, table	tableland, plateau
	table	gathering, assemblage
	board, table	fare

Table 6.1: Senses and hyponyms retrieved from WordNet for Furniture Ontology

Concept	Senses	Hyponyms
Position	position, place	point
	military position, position	point
	position, view, perspective	orientation
	position, posture, attitude	bodily property
	status, position	State
	position, post, berth, office, spot, billet, place, situation	occupation, business, job, line of work, line
	position, spatial relation	Relation
	Position	Point
	Position	Role
	placement, location, locating, position, positioning, emplacement	Activity
	situation, position	condition, status
	place, position	Item, point
	stance, posture	attitude, mental attitude
	side, position	opinion, view
	stead, position, place, lieu	function, office, part, role
	Position	assumption

Secretary	Secretary	head, chief, top dog
	secretary, secretarial assistant	assistant, helper, help, supporter
	repository, secretary	confidant, intimate
	secretary, writing table, escritoire, secretaire	desk
Chair	Chair	Seat
	professorship, chair	position, post, berth, office, spot, billet, place, situation
	president, chairman, chairwoman, chair, chairperson	presiding officer
	electric chair, chair, death chair, hot seat	instrument of execution

Table 6.2: Senses and hyponyms retrieved from WordNet for Position Ontology

As can be seen in Table 6.2, there are 16 senses for the Position concept. Since the Position concept is the root concept, the user needs to initially select which sense(s) s/he means. In this example, sixth sense (position, post, berth, office, spot, billet, place, situation) is what the user has chosen and is what s/he means by Position concept. The sixth sense will be included in the sense set for the Position Ontology. There are 4 senses for the Chair concept in Position Ontology, shown in Table 6.2, the second sense (professorship, chair) are selected and to be included in the sense set because its hyponyms are matched with selected root sense. The concept 'chair' needs to be differentiated from other 'chair' in other senses by incorporating is-a relationship. '_is-a_' is used to identify the is-a relationship, followed by parent concept to 'chair' becoming 'chair_is-a_position'. For the Secretary concept, there is no matched sense with parent (root) sense, it is simply included in the sense set.

From Table 6.1, the senses set for Furniture Ontology is {furniture, piece of furniture, article of furniture, chair, table_is-a_furniture, table_is-a_furniture}. From Table 6.2, the senses set for Position Ontology is {position, post, berth, office, spot, billet, place, situation, secretary, professorship, chair_is-a_position}. To find the transferability value from Furniture Ontology to Position Ontology, we need to find sense(s) that appear in the Furniture sense set but do not appear in the Position sense set as follows.

Furniture sense set – Position sense set = $\{x | x \in$ Furniture sense set $\wedge$ $x \notin$ Position sense set$\}$ = 6

The transferability can be defined by function Trans(Furniture Ontology, Position Ontology) as follow

Trans(Furniture Ontology, Position Ontology) = $1 - \frac{6}{6} = 0$

The value of transferability 0 means that knowledge is not transferable. Concept 'chair' is used in both ontologies but means something different.

6.4 Experiments

Two domains are used for experimental purposes: (i) Software Engineering and (ii) Pizza as examples. In the first experiment, parts of Software Engineering Ontology (SE Ontology) developed by (Wongthongtham et al., 2009) are used. In the SE Ontology Class Diagram, the Ontology and Classification Model Ontology is used for experiments. In the second experiment, Pizza Ontology developed by CO-ODE team at Manchester University (Drummond, Horridge, Stevens, Wroe, & Sampaio, 2007) is used. The Pizza Ontology is modified and 2 other different Pizza ontologies are created, namely Vegetable Pizza and Meat Pizza, for our experiments. The ontologies used in this thesis are available for the reader's reference online at www.debii.curtin.edu.au/~ponny/ontologies. The prototype is implemented using JAVA. OWL2.0 API is used to load and manipulate ontologies which are related to the domains of people who are going to share the knowledge. JWNL is the main API which is used to obtain the semantic meanings of each concept captured in ontologies.

6.4.1 Software Engineering Ontology

There are some communication problems in a multi-site distributed software development environment. Some of these problems are related to awareness of the tasks that are being carried out by others, overlap of the work of two groups, or other misinterpretation of the work. Consequently, these problems cause development delays or fail in a multi-site environment (Wongthongtham, 2007).

Software engineering ontology is developed to enable shared conceptualizations and terminology as well as agreement among teams distributed across the sites by making the assumptions explicit (Wongthongtham, 2007). This enables effective ways of sharing the knowledge for remote software engineers, reaching a consensus of understanding which is of benefit to team members in a distributed environment.

Assume that two remote software engineers want to share knowledge and how well both software engineers share the knowledge is the subject of this thesis. There are two key variables involved: i.e. transferability and complexity of knowledge sharing. For two software engineers from different information domains, firstly their background similarity is measured to find the differences in their knowledge. Then the complexity of the different parts of the knowledge is measured. If both have very similar backgrounds of knowledge, both will share the knowledge well. If both have similar backgrounds of knowledge and the new knowledge is not complicated, both can share the knowledge with some level of value. In a worst case scenario, if both come from totally different backgrounds of knowledge and the new knowledge is very complicated, then neither will be able to share knowledge.

Assuming a software engineer who has Class Diagram Ontology wants to share knowledge about the relationship between entities with another software engineer who has Classification Model Ontology. Figure 6.3 shows relation hierarchy of the two ontologies. One who has Class

Diagram Ontology has all sorts of idea about relationships, but one who has Classification Model Ontology has only a general idea. How well these two software engineers share the relationship knowledge can be measured. Firstly, the transferability indicated by ontology similarity is measured. By comparing both ontologies, the difference will then be calculated as its complexity. The transferability values are calculated in both directions.

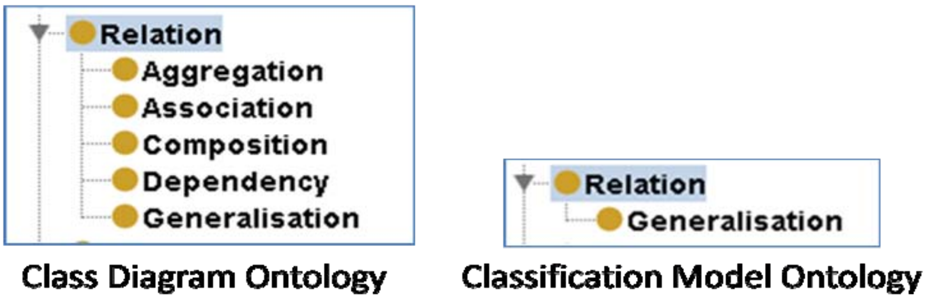


Figure 6.3: Relationship hierarchy of two different ontologies

Table 6.3 shows senses and hyponyms from WordNet 2.1for Class Diagram Ontology. The highlighted senses are ones in the sense set or are ones that have meaning within the intended content.

Concept	Senses	Hyponyms
relation	Relation	abstraction
	sexual intercourse, intercourse, sex act, copulation, coitus, coition, sexual congress, congress, sexual relation, relation, carnal knowledge	sexual activity, sexual practice, sex, sex activity
	relative, relation	person, individual, someone, somebody, mortal, soul
	relation, telling, recounting	narration, recital, yarn
	relation back, relation	legal principle, judicial principle, judicial doctrine
	Relation	dealings, traffic
dependency	dependence, dependance, dependency	State
	dependence, dependance, dependency	physiological state, physiological condition
	colony, dependency	geographical area, geographic area, geographical region,

		geographic region
generalisation	abstraction, generalization, generalisation	theorization, theorisation
	generalization, generalisation, induction, inductive reasoning	colligation
	generalization, generalisation, generality	idea, thought
	generalization, generalisation, stimulus generalization, stimulus generalisation	transfer, transfer of training, carry-over
aggregation	collection, aggregation, accumulation, assemblage	group, grouping
	collection, collecting, assembling, aggregation	grouping
association	Association	organization, organisation
	Association	social activity
	Association	union, unification
	affiliation, association, tie, tie-up	relationship
	association, connection, connexion	memory, remembering
	Association	Relation
	Association	chemical process, chemical change, chemical action
	Association	group, grouping
composition	Composition	Mixture
	constitution, composition, makeup	property
	composition, composing	Relation
	musical composition, opus, composition, piece, piece of music	Music
	composing, composition	creating by mental acts
	writing, authorship, composition, penning	verbal creation
	typography, composition	printing, printing process
	composition, paper, report, theme	Essay
	Composition	Creation

Table 6.3: Senses and hyponyms for Class Diagram Ontology

The number of senses (|S1|) found in Class Diagram Ontology is 7. The senses set for Class Diagram Ontology is {relation, dependency, generalization, aggregation, association_is-a_relation, composition_is-a_relation, composing}. The number of senses (|S2|) found in Classification Model Ontology is 2. The senses set for classification model ontology is {relation, generalization}. After comparing,

$$S1 - S2 = \{x | x \in S1 \wedge x \notin S2\} = 5$$

There are five distinct senses that appear in the Class Diagram sense set which do not appear in the Classification Model sense set. The five senses are “dependency, aggregation, association_is-a_relation, composition_is-a_relation, and composing”. The transferability between a set of concepts, S1, captured in class diagram ontology from a set of concepts, S2, captured in classification model ontology is as follows:

$$\text{Trans}(S1, S2) = 1 - \frac{5}{7} = 0.2857143$$

In the opposite direction, the transferability between a set of concepts, S2, captured in classification model ontology from a set of concepts, S1, captured in class diagram ontology is as follows:

$$\text{Trans}(S2, S1) = 1 - \frac{0}{2} = 1$$

There is no sense that appears in the Classification Model sense set and does not appear in the Class Diagram sense set. Trans(S2, S1) = 1 means the semantics existing in the classification model ontology are also in the class diagram ontology; thus, the knowledge is highly transferable. However, the software engineer who has knowledge about a class diagram does not necessarily have knowledge that is highly transferable to the other software engineer who has classification model knowledge.

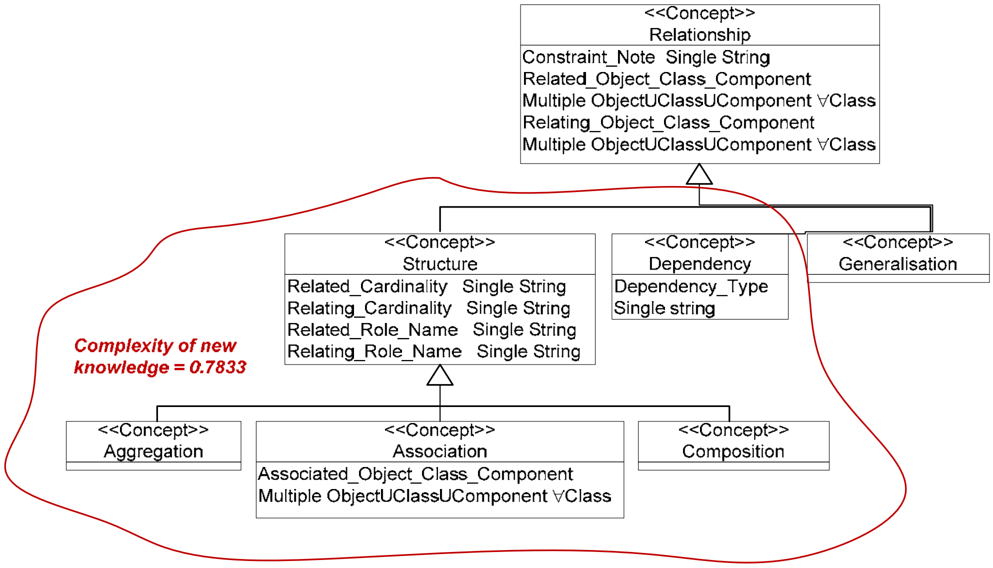


Figure 6.4: Different parts of ontology

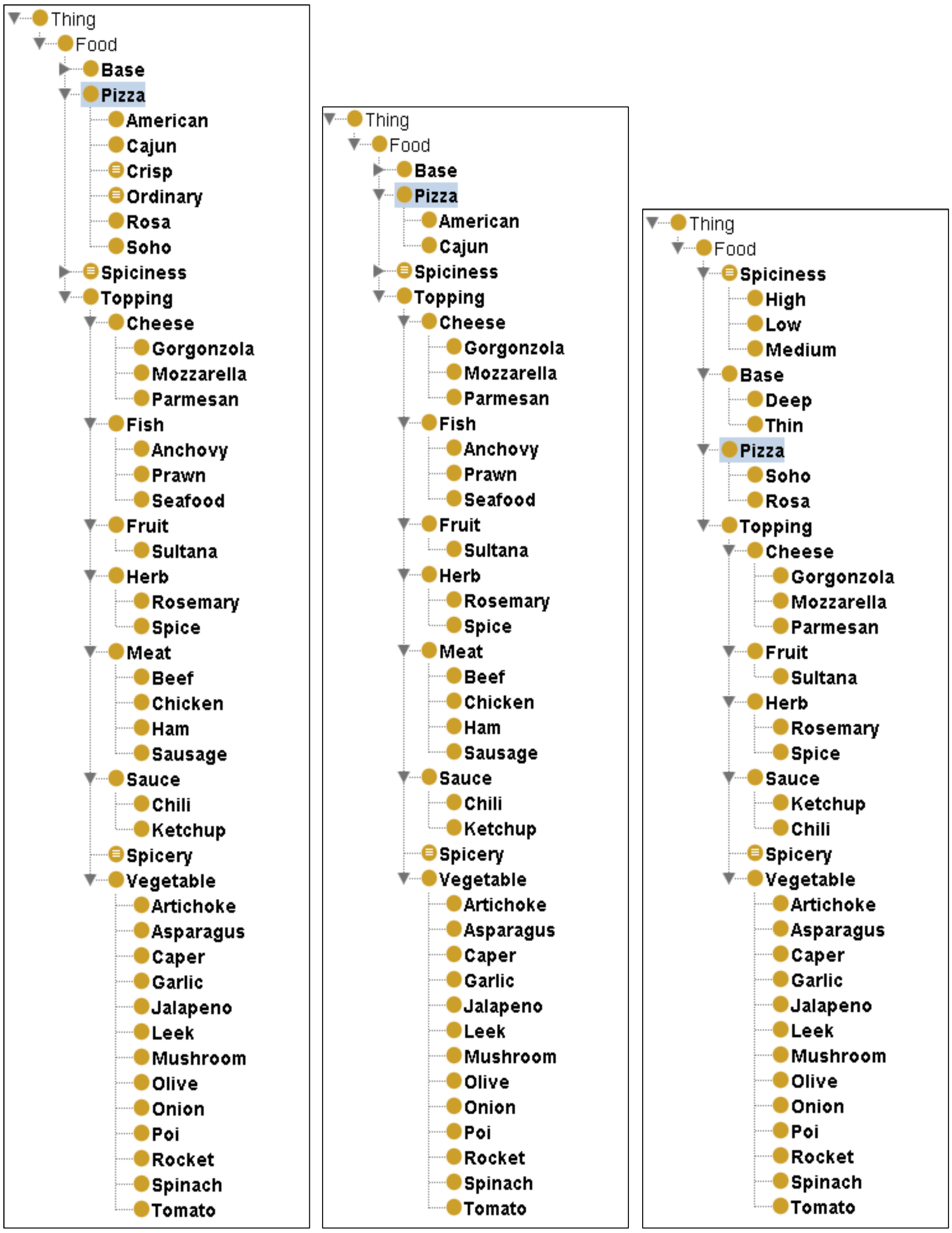
Next, the complexity of different parts of the class diagram ontology is calculated. Figure 6.4 shows the different parts of knowledge. These parts are comprised of 5 classes i.e. Structure, Dependency, Aggregation, Association, and Composition. Class Structure has 5 datatype properties and 2 object properties, 2 constraints, and no hierarchical path. Class Dependency has 2 datatype properties, 2 object properties, 2 constraints, and no hierarchical path. Class Aggregation has 5 datatype properties, 2 object properties which are all inherited properties, 2 constraints, and 1 hierarchical path. Class Association has 5 datatype properties and 3 object properties, 3 constraints, and 1 hierarchical path. Class Composition has 5 datatype properties, 2 object properties which are all inherited properties, 2 constraints, and 1 hierarchical path. Therefore, the complexity value of the different path in the class diagram ontology is as follows:

$$\text{Complex(O)} = \left(\frac{\sum(NoDP+NoOP+NoC+NoHP)}{Max(NoDP)+Max(NoOP)+Max(NoC)+Max(NoHP)}\right)/NoOC = \left(\frac{9+6+10+12+10}{5+3+3+1}\right)/5 = 0.7833$$

The result shows that one who has a classification model ontology will understand one who has a class diagram ontology to some degree. In contrast, one who has aclass diagram ontology will greatly understand one who has classification model ontology. How well both share their knowledge also depends on the complexity of their knowledge background difference.

6.4.2 Pizza Ontology

Assume that people want to share knowledge about pizza. Those who are vegetarian have an idea that vegetable pizza will be different from those who have an idea of meat pizza and from others who have ideas of pizza in general. In other words, when people start to share pizza knowledge, vegetarian people will be thinking of vegetable pizza, meat lovers will be thinking of meat pizza, and other people will be thinking of pizza in general. How well they share the pizza knowledge is assessed. Pizza Ontology is modified to create Vegetable Pizza Ontology and Meat Pizza Ontology. In experimental studies, firstly the transferability of pizza knowledge is measured in different ontologies. Figure 6.5 shows the relationship hierarchy of Pizza Ontology, Meat Pizza Ontology, and Vegetable Pizza Ontology.



Pizza Ontology — Meat Pizza Ontology — Vegetable Pizza Ontology

Figure 6.5: Relationship hierarchy of different ontologies

Table 6.4 shows senses and hyponyms from WordNet 2.1 for Pizza Ontology. The highlighted senses are ones in the sense set or are ones that have meaning within the meant content.

Concept	Senses	Hyponyms
Food	food, nutrient	substance, matter
	food, solid food	Solid
	food, food for thought, intellectual nourishment	content, cognitive content, mental object
Base	Alkali	compound, chemical compound

	base of operations	military installation
	Foundation	Support
	Bag	baseball equipment
	Radix	Number
	Base	part, piece
	Base	Bottom
	Floor	Control
	foundation, fundament, groundwork, cornerstone	assumption, supposition, supposal
	pedestal, stand	Support
	Base	Flank
	basis, base	part, portion, component part, component
	Home	Location
	root, root word, stem, theme, radical	form, word form, signifier, descriptor
	Infrastructure	store, stock, fund
	Base	Ingredient
	Base	side, face
	Base	Electrode
Deep	Deep	Middle
	trench, deep, oceanic abyss	natural depression, depression
	Deep	Ocean
Thin	Thin	Bladed
	Lean	anorexic, anorectic
	Slender	very narrow
	flimsy, slight, tenuous	Weak
	Sparse	Distributed
	Thin	rare, rarefied, rarified
	Thin	Pale
	Thin	Spiritless
Pizza	pizza, pizza pie	food, nutrient
American	American	inhabitant, habitant, dweller, denizen, indweller
	American English, American language, American	English, English language
	a native of a North American	inhabitant, habitant, dweller, denizen
Cajun	Cajun	Acadian
Crisp	chip, crisp, potato chip, Saratoga chip	food, nutrient
Ordinary	Ordinary	judge, justice, jurist, magistrate
	Ordinary	Condition
	Ordinary	clergyman, reverend, man of the cloth
	Ordinary , ordinary bicycle	bicycle, bike, wheel, cycle
	Ordinary	charge, bearing, heraldic bearing, armorial bearing
Rosa	Rosa, genus Rosa	rosid dicot genus
Soho	Soho	city district
	Soho	city district
Spiciness	spiciness, spice, spicery	taste property
	aminess, raciness, ribaldry, spiciness	Indelicacy
High	High	degree, grade, level
	high, high pressure	air mass
	High	Elation
	High	Elation
	high, heights	topographic point, place, spot

	senior high school, senior high, high, highschool, high school	secondary school, lyceum, lycee, Gymnasium, middle school
	high gear, high	gear, gear mechanism
Low	low, low pressure, depression	air mass
	Low, David Low, Sir David Low, Sir David Alexander Cecil Low	Cartoonist
	Low	degree, grade, level
	first gear, first, low gear, low	gear, gear mechanism
Medium	Medium	instrumentality, instrumentation
	Medium	environment, environs, surroundings, surround
	Medium	communication, communicating
	culture medium, medium	substance, matter
	Medium	substance, matter
	Medium	Liquid
	Medium	substance, matter
	Medium	State
	medium, spiritualist, sensitive	Psychic
	medium, mass medium	Transmission
	metier, medium	occupation, business, job, line of work, line
Topping	Topping	Garnish
Cheese	Cheese	food, nutrient
	tall mallow, high mallow, cheeseflower, malva sylvestris	mallow
Gorgonzola	Gorgonzola	food, nutrient
Mozzarella	Mozzarella	food, nutrient
Parmesan	Parmesan	food, nutrient
Fish	Fish	aquatic vertebrate
	Fish	food, solid food
	pisces, fish	person, individual, someone, somebody, mortal, soul
	pisces, pisces the fishes, fish	region, part
Anchovy	Anchovy	Fish
	Anchovy	Fish
Prawn	prawn, shrimp	food, solid food
	Prawn	decapod crustacean, decapod
Seafood	Seafood	food, solid food
Fruit	Fruit	reproductive structure
	Fruit	consequence, aftermath
	Yield, fruit	product, production
Sultana	Sultana	food, solid food
	dried seedless grape, sultana	food, solid food
Herb	herbaceous plant, herb	vascular plant, tracheophyte
	Herb	food, nutrient
Rosemary	rosmarinus officinalis, rosemary	herb, herbaceous plant
	Rosemary	Herb
Spice	Spice	Preservative
	Spice	food, nutrient
	spiciness, spice, spicery	taste property
Meat	Meat	food, solid food
	meat, kernel	plant part, plant structure
	kernel, substance, core, center, essence, gist, heart, heart and soul, inwardness, marrow	content, cognitive content, mental object

Beef	beef cattle	cattle, cows, kine, oxen, Bos taurus
	beef, boeuf	Meat
	gripe, kick, bitch, beef, squawk	Objecting
Chicken	chicken, poulet, volaille	Meat
	gallus gallus	domestic fowl, fowl, poultry
	wimp, crybaby	a person who lacks weakling, doormat, wuss
	Chicken	contest, competition
Ham	ham, jambon, gammon	Meat
	Ham	Instance of man, adult male
	Ham	radio operator
	ham actor, ham	actor, histrion, player, thespian, role player
Sausage	Sausage	Meat
	blimp, sausage balloon, Sausage	airship, dirigible
Sauce	Sauce	food, nutrient
Chilli	chili, chili pepper, chilli, chilly, chile	food, solid food
Ketchup	catsup, ketchup, cetchup, tomato ketchup	food, nutrient
Spicery	spiciness, spice, spicery	taste property
Vegetable	vegetable, veggie	food, solid food
	Vegetable	herb, herbaceous plant
Artichoke	artichoke, globe artichoke, artichoke plant, Cynara scolymus	Vegetable
	artichoke, globe artichoke	vegetable, veggie
Asparagus	edible asparagus, Asparagus officinales	herb, herbaceous plant
	Asparagus	vegetable, veggie
Caper	Caper	shrub, bush
	Caper	food, nutrient
	caper, job	Robbery
	capriole, caper	leap, leaping, spring, saltation, bound, bounce
	play, frolic, romp, gambol	diversion, recreation
	antic, joke, prank, trick	diversion, recreation
Garlic	Allium sativum	alliaceous plant
	garlic, Ail	food, nutrient
Jalapeno	cayenne, cayenne pepper, chili pepper, chilli pepper, long pepper	capsicum, pepper, capsicum pepper plant
	Jalapeno, jalapeno pepper	vegetable, veggie
Leek	scallion, Allium porrum	alliaceous plant
	Leek	vegetable, veggie
Mushroom	Mushroom	Agaric
	Mushroom	basidiomycete, basidiomycetous fungi
	mushroom cloud, mushroom-shaped cloud	Cloud
	Mushroom	vegetable, veggie
Olive	Olive	Fruit
	European olive tree, Olea europaea	olive tree
	Olive	Wood
	Olive	food, nutrient
	Olive	chromatic color, chromatic colour, spectral color, spectral colour
Onion	Onion	Bulb
	onion plant, Allium cepa	alliaceous plant
	Onion	vegetable, veggie

Poi	Poi	food, nutrient
Rocket	Projectile	Vehicle
	rocket engine	jet engine
	roquette, garden rocket, rocket salad, arugula, Eruca sativa	herb, herbaceous plant
	Skyrocket	visual signal
	skyrocket, rocket	firework, pyrotechnic
Spinach	spinach plant, prickly-seeded spinach, Spinacia oleracea	Vegetable
	Spinach	vegetable, veggie
Tomato	Tomato	vegetable, veggie
	love apple, tomato plant, Lycopersicon esculentum	herb, herbaceous plant

Table 6.4: Senses and hyponyms for Pizza Ontology

The transferability between Vegetable Pizza Ontology and Meat Pizza Ontology is explained as follows. From WordNet 2.1, the number of senses (|S1|) found in Vegetable Pizza Ontology is 56. The sense set for Vegetable Pizza Ontology is {food, nutrient, food, solid food, base, deep, thin, pizza_is-a_food, pizza pie, rosa, soho, spiciness, high, low, medium, topping, cheese_is-a_topping, gorgonzola_is-a_cheese, mozzarella_is-a_cheese, parmesan_is-a_cheese, fruit, sultana_is-a_fruit, dried seedless grape, sultana_is-a_fruit, herb_is-a_topping, rosemary_is-a_herb, spice_is-a_herb, sauce_is-a_topping, chili, chili pepper, chilli_is-a_sauce, chilly, chile, catsup, ketchup_is-a_sauce, ketchup, tomato ketchup, spicery, vegetable_is-a_topping, veggie, artichoke_is-a_vegetable, globe artichoke, asparagus_is-a_vegetable, caper_is-a_vegetable, garlic_is-a_vegetable, ail, jalapeno_is-a_vegetable, jalapeno pepper, leek_is-a_vegetable, mushroom_is-a_vegetable, olive_is-a_vegetable, onion_is-a_vegetable, poi_is-a_vegetable, rocket, spinach_is-a_vegetable, tomato_is-a_vegetable}. The number of senses (|S2|) for Meat Pizza Ontology is 72. The sense set for Meat Pizza Ontology is {food, nutrient, food, solid food, base, deep, thin, pizza_is-a_food, pizza pie, American, Cajun, spiciness, high, low, medium, topping, cheese_is-a_topping, gorgonzola_is-a_cheese, mozzarella_is-a_cheese, parmesan_is-a_cheese, fish_is-a_topping, anchovy_is-a_fish, anchovy_is-a_fish, prawn_is-a_fish, shrimp, seafood_is-a_fish, fruit, sultana_is-a_fruit, dried seedless grape, sultana_is-a_fruit, herb_is-a_topping, rosemary_is-a_herb, spice_is-a_herb, meat_is-a_topping, beef_is-a_meat, boeuf, chicken_is-a_meat, poulet, volaille, ham_is-a_meat, jambon, gammon, sausage_is-a_meat, sauce_is-a_topping, chili, chili pepper, chilli_is-a_sauce, chilly, chile, catsup, ketchup_is-a_sauce, ketchup, tomato ketchup, spicery, vegetable_is-a_topping, veggie, artichoke_is-a_vegetable, globe artichoke, asparagus_is-a_vegetable, caper_is-a_vegetable, garlic_is-a_vegetable, ail, jalapeno_is-a_vegetable, jalapeno pepper, leek_is-a_vegetable, mushroom_is-a_vegetable, olive_is-a_vegetable, onion_is-a_vegetable, poi_is-a_vegetable, rocket, spinach_is-a_vegetable, tomato_is-a_vegetable}. After comparing,

$$S1 - S2 = \{x | x \in S1 \wedge x \notin S2\} = 3$$

There are two distinct senses in the Vegetable Pizza sense set that are not in the Meat Pizza sense set. The two senses are “rosa” and “soho”. The transferability from Vegetable Pizza Ontology to Meat Pizza Ontology is as follows:

$$\text{Trans}(S1, S2) = 1 - \frac{|S1 - S2|}{|S1|} = 1 - \frac{2}{56} = 0.9642858$$

In the opposite direction, the transferability from Meat Pizza Ontology to Vegetable Pizza Ontology is as follows:

$$\text{Trans}(S2, S1) = 1 - \frac{|S2 - S1|}{|S2|} = 1 - \frac{18}{72} = 0.75$$

There are 18 distinct senses in the Meat Pizza sense set that are not in the Vegetable Pizza sense set. The eighteen senses are “american, cajun, fish_is-a_topping, anchovy_is-a_fish, anchovy_is-a_fish, prawn_is-a_fish, shrimp, seafood_is-a_fish, meat_is-a_topping, beef_is-a_meat, boeuf, chicken_is-a_meat, poulet, volaille, ham_is-a_meat, jambon, gammon, and sausage_is-a_meat”.

Table 5.6 shows results of different levels of transferability for different ontologies.

Ontology target	Ontology source	Transferability	Distinct senses
Pizza	**Meat Pizza**	$1 - \frac{7}{79} = 0.9113925$	**chip, crisp_is-a_food, potato chip, Saratoga chip, ordinary, rosa, soho**
Pizza	**Vegetable Pizza**	$1 - \frac{7}{79} = 0.9113925$	**American, Cajun, chip, crisp_is-a_food, potato chip, Saratoga chip, ordinary**
Meat Pizza	**Vegetable Pizza**	$1 - \frac{18}{72} = 0.75$	**american, cajun, fish_is-a_topping, anchovy_is-a_fish, anchovy_is-a_fish, prawn_is-a_fish, shrimp, seafood_is-a_fish, meat_is-a_topping, beef_is-a_meat, boeuf, chicken_is-a_meat, poulet, volaille, ham_is-a_meat, jambon, gammon, and sausage_is-a_meat**
Meat Pizza	**Pizza**	$1 - \frac{0}{72} = 1$	-
Vegetable Pizza	**Pizza**	$1 - \frac{0}{56} = 1$	-
Vegetable Pizza	**Meat Pizza**	$1 - \frac{2}{56} = 0.9642858$	**rosa and soho**

Table 6.5: Transferability of different ontologies

Next, the complexity of new knowledge or complexity of the different part of the ontology is calculated. If one who has Vegetable Pizza ontology shares his/her knowledge with one who has Meat Pizza ontology, the complexity of the new knowledge that one who has Vegetable Pizza has to give to one who has Meat Pizza ontology, is measured. Figure 6.6 shows the properties and restrictions of classes rosa and soho which are different parts of the Vegetable Pizza ontology.

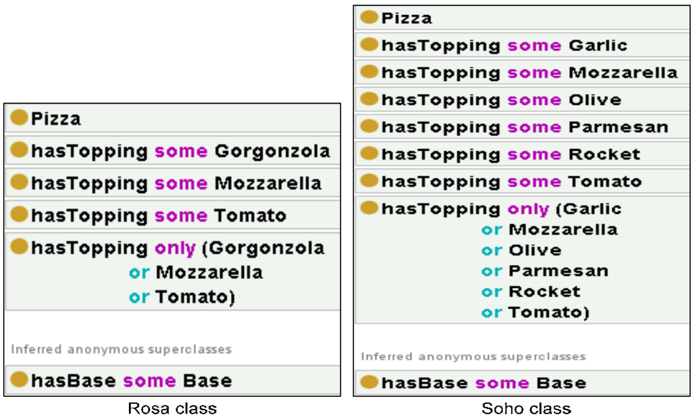


Figure 6.6: Properties and restrictions of Rosa class and Soho class in Vegetable Pizza ontology

In order to measure complexity value of different paths in the Vegetable Pizza ontology, we need to find the number of classes, datatype properties, object properties, constraints, and hierarchical paths that are in the Vegetable Pizza ontology but do not appear in the Meat Pizza ontology. There are 2 classes: Rosa and Soho. As in Figure 6.6, class Rosa has 2 object properties (i.e. hasTopping and hasBase) and has 5 constraints. As in Figure 6.6, class Soho has 2 object properties (i.e. hasTopping and hasBase) and has 8 constraints. There is no hierarchical path in classes Rosa and Soho. Therefore the complexity value of the different path in the class diagram ontology is as follows:

$$\text{Complex}(O) = \left(\frac{\sum(NoDP+NoOP+NoC+NoHP)}{Max(NoDP)+Max(NoOP)+Max(NoC)+Max(NoHP)}\right)/NoOC = \left(\frac{0+4+13+0}{0+2+8+0}\right)/2 = 0.85$$

Table 6.6 shows other results of different complexity in different ontologies.

Ontology target	Ontology source	Complexity	Different classes	Properties and restrictions of the different classes
Pizza	**Meat Pizza**	$(\frac{0+7+17+0}{0+2+8+0})/4 = 0.6$	**Crisp, Ordinary, Rosa, and Soho**	**Class Crisp has 1 object properties (i.e. hasBase) and has 2 constraints. Class Ordinary has 2 object properties (i.e. hasTopping and hasBase) and has 2 constraints. Class Rosa has 2 object properties (i.e. hasTopping and hasBase) and has 5 constraints. Class Soho has 2 object properties (i.e. hasTopping and hasBase) and has 8 constraints. There is no hierarchical path in Crisp, Ordinary, Rosa and Soho classes.**
Pizza	**Vegetable Pizza**	$(\frac{0+7+16+0}{0+2+6+0})/4 = 0.71875$	**American, Cajun, Crisp, Ordinary**	**Class American has 2 object properties (i.e. hasTopping and hasBase) and has 6 constraints. Class Cajun has 2 object properties (i.e. hasTopping and hasBase) and has 6 constraints. Class Crisp has 1 object properties (i.e. hasBase) and has 2 constraints. Class Ordinary has 2 object properties (i.e. hasTopping and hasBase) and has 2 constraints. There is no hierarchical path in American, Cajun, Crisp and Ordinary classes.**
Meat Pizza	**Vegetable Pizza**	$(\frac{0+11+19+2}{0+2+6+1})/11 = 0.3232323$	**American, Cajun, Fish, Anchovy, Prawn, Seafood, Meat, Beef, Chicken, Ham, Sausage**	**Class American has 2 object properties (i.e. hasTopping and hasBase) and has 6 constraints. Class Cajun has 2 object**

				properties (i.e. hasTopping and hasBase) and has 6 constraints. Class Fish has 1 object property (i.e. hasSpiciness) and has 1 constraint same as classes Anchovy, Prawn, and Seafood. Class Meat has none of object property and none of constraint same as Class Ham. Class Beef has 1 object property (i.e. hasSpiciness) and has 1 constraint same as classes Chicken and Sausage. Classes Fish and Meat have 1 hierarchical path each.
Meat Pizza	**Pizza**	**0**	**-**	**-**
Vegetable Pizza	**Pizza**	**0**	**-**	**-**
Vegetable Pizza	**Meat Pizza**	$(\frac{0+4+13+0}{0+2+8+0})/2 = 0.85$	**Rosa, Soho**	**Class Rosa has 2 object properties (i.e. hasTopping and hasBase) and has 5 constraints. Class Soho has 2 object properties (i.e. hasTopping and hasBase) and has 8 constraints. There is no hierarchical path in classes Rosa and Soho.**

Table 6.6: Complexity of different ontologies

The value of the new knowledge complexity is 1 which means the new knowledge is more complicated. Conversely, the value of the new knowledge complexity is 0 which means the new knowledge is less complicated. Meat Pizza and Vegetable Pizza are subsets of Pizza so there is no new knowledge to share between Meat Pizza to Pizza or Vegetable Pizza to Pizza. Therefore the complexity value is 0.

6.4.3 Discussion

In this study two key variables for knowledge sharing measurement have been identified: knowledge transferability and knowledge complexity. Since ontology is utilized as knowledge representation in this thesis, it is proposed procedure of measurement of ontology transferability and ontology complexity. In the experiment, the degree to which a particular knowledge is shared, given that the parties involved have different backgrounds or have different information domains, is numerically measured. The process simply involves measuring their knowledge background similarity and then finding the difference of knowledge background. The summarized results from several experiments are given below.

a. People have the same background knowledge resulting in best knowledge sharing, for example:
    i. One who has Classification Model Ontology shares relationship knowledge with one who has Class Diagram Ontology. The knowledge is highly transferable because knowledge exists in both Classification Model Ontology and Class Diagram Ontology. Thus, it results in a value of 1 in transferability and value of 0 in complexity of new knowledge.
    ii. Meat Pizza and Vegetable Pizza are subsets of Pizza, therefore transferability between Meat Pizza Ontology and Pizza Ontology or between Vegetable Pizza Ontology

and Pizza Ontology is high (value 1). There is no new knowledge to share between Meat Pizza to Pizza or Vegetable Pizza to Pizza, thus the complexity value is 0.

b. People have similar background knowledge and the new knowledge is not complicated resulting in some value of knowledge sharing, for example:

    i. Comparing Meat Pizza with Vegetable Pizza, transferability value is high (0.75) but complexity value is low (0.3232323).

c. People have similar background knowledge and the new knowledge is complicated, resulting in some value of knowledge sharing, for example:

    i. Comparing Vegetable Pizza with Meat Pizza, the transferability value (0.9642858) and complexity value (0.85) are both high.

d. People have different background knowledge and the new knowledge is very complicated resulting low value of knowledge sharing. This means that people will not be able to share knowledge.

    i. Comparing Class Diagram Ontology with Classification Model Ontology, transferability value is 0.2857143 in which it is poorly transferable. The new knowledge is complicated as well, resulting in a value of 0.7833 in complexity.

Figure 6.7 clarifies the measurement value of knowledge transferability and knowledge complexity. The value of knowledge transferability and knowledge complexity can be included in a fuzzy logic system to show high, medium, or low levels.

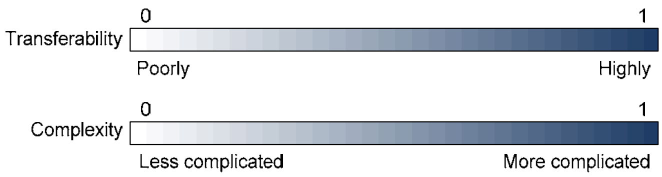


Figure 6.7 Measurement value of knowledge transferability and knowledge complexity

In the process of finding transferability and complexity value, the sense set which is extracted from the electronic lexical database WordNet available online is implemented. However, WordNet has some limitations; for example, for the ontology concept only one word can be defined which means it can only be a noun and cannot be an adjective, verb or adverb. In the process of transferability measurement in this thesis, only the is-a relationship is considered, omitting other ontology properties (object property and datatype property), constraints, and concept relations e.g. siblings. However, it is enough as a measurement of the level of transferability because the complexity of new knowledge is taken into consideration by the abovementioned ontology attributes.

6.5 Conclusion

In this chapter, the basic concept of an ontology and different definitions of ontologies were investigated. The structure of an ontology and process of ontology creation were discussed in detail and six steps for designing an ontology were explained. Also, it was mentioned that an ontology can be dynamic and changes over time and some techniques for controlling ontologies evolution were presented for updating an ontology. As the number of ontologies increases, it is necessary to integrate some of the ontologies and also measure the similarity or differences between ontologies. These issues were also discussed in this chapter. The next section explains the role of an ontology in a particular knowledge representation and uses ontologies techniques to measure transferability as well as complexity of a knowledge. It was indicated that ontology similarity can be used for determining whether the knowledge captured in the ontologies is transferable. Transfer of knowledge will be efficient and effective if knowledge transmitter agents and knowledge receiver agents having a similar understanding of ontological concepts. The approach provided a numeric measurement of the transferability between two ontologies whose value is given between 0 and 1. To ensure the accuracy and practicality of the procedure, the concepts captured in ontologies are weighed against words retrieved from the electronic lexical database WordNet which is available online as Java WordNet Library (JWNL). In the experimental studies, domain knowledge of modified pizza ontologies is used as a sample and the results were confirmed feasibility of the approach. However, the complexity of a particular knowledge was measured by the complicated structure of the ontology and the numbers of the classes, subclasses and properties and the same ontologies were used as samples to derive the formulas.

In Chapter 7, based on the results and formulas presented in Chapters 5 and 6, a developed framework with the four main variables of knowledge complexity, knowledge transferability, benevolence trust and competence trust, is presented to measure knowledge sharing levels.

6.6 References

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Chapter 7: Development of trust- and ontology-based framework for knowledge sharing measurement

7.1 Overview

As was discussed in Chapters 5 and 6, ontologies and trust concepts are proposed as solutions to measure knowledge sharing levels between individuals. Ontologies are proposed to measure the complexity and transferability of knowledge to address the related barriers in encoding or decoding a particular knowledge and common understanding of the shared knowledge. Knowledge representation and unique understanding of the shared knowledge between knowledge senders and receivers are the major issues in knowledge sharing, and ontology techniques are used in this research to solve these barriers in knowledge sharing. Also, willingness and ability to share knowledge are key issues in knowledge sharing and the trust concept was used to solve this problem in knowledge sharing between individuals. Trust includes different dimensions and willingness trust was used to measure the knowledge sender's willingness to share his/her knowledge to others and also willingness of receiver to receive that particular knowledge. As well as willingness trust, competence-based trust was also proposed to measure ability of the sender to share a particular knowledge, and the ability of the receiver to acquire that particular knowledge and change the explicit shared knowledge to tacit knowledge in order to reuse it in the future. In this chapter, a trust- and ontology-based framework is proposed. The relationship between trust dimensions and knowledge complexity and transferability,y and the final formula to measure knowledge sharing effectiveness between two knowledge sharing parties, is discussed and proposed in this chapter.

7.2 Knowledge sharing related variables

The related variables in knowledge sharing measurement were investigated and Figure 7.1 shows these variables:

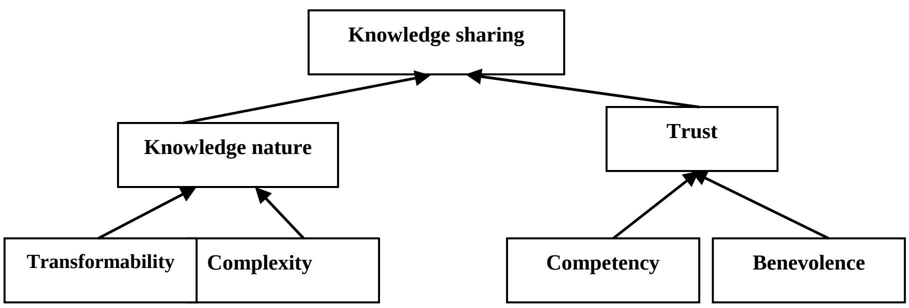


Figure 7.1: Knowledge sharing measurement variables

Based on Figure 7.1, the equations below are proposed to measure knowledge sharing:

$$\textbf{Knowledge sharing} = f(\text{knowledge nature, trust}) \qquad 0 \le \text{Knowledge sharing} \le 1$$

(Equation 7.1)

$$\textbf{Trust} = f(\text{competence, benevolence}) = f(\text{Tb [A, B], Tc [A, B]})$$

$$0 \le \text{Tb [A, B], Tc [A, B]} \le 1$$

Tb [A, B] = Trust benevolence between sender(A)and receiver(B).

Tc [A, B] = Trust competency between sender(A)and receiver(B).

(Equation 7.2)

$$\textbf{Knowledge nature} = f(\text{transferability, complexity})$$

$$0 \le \text{transferability, complexity} \le 1$$

(Equation 7.3)

On the other hand, knowledge sharing is not just from sender to receiver and both parties should be considered in any knowledge sharing measurement models. For example, in most cases a teacher has enough willingness and competency to share his/her knowledge with a student but, if the student does not have enough willingness or competency to acquire the shared knowledge, the knowledge sharing level will be low. As a result, knowledge sharing effectiveness from sender to receiver as well as knowledge sharing effectiveness from receiver to sender should both be evaluated at the same time. Figure 7.2 shows two different levels of knowledge sharing effectiveness between sender and receiver of the knowledge.

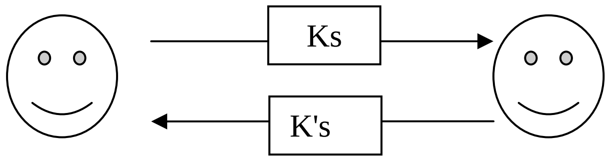


Figure 7.2: Knowledge sharing between two parties

As seen in Figure 7.2, if the knowledge sharing level from sender to receiver is assumed to be Ks and knowledge sharing effectiveness level from the perspective of the receiver is assumed to be K's, the final knowledge sharing level will be the minimum of Ks and K's.

$$\text{Knowledge sharing} = \min(Ks, K's) \quad 0 \leq \text{Knowledge sharing} \leq 1$$

(Equation 7.4)

In this section, the numeric measurement of Ks and K’s is presented. Due to the fuzzy nature of variables, firstly the proposed model in a fuzzy system is discussed and fuzzy logic is used to measure knowledge sharing. Then the developed model in Crisp is presented.

7.3 Knowledge Sharing Measurement in Fuzzy Logic Systems

In this research, the Mamdani fuzzy system is used to design the proposed model in knowledge sharing measurement. In Mamdani fuzzy systems, fuzzy rules should be defined to clarify the relations between input variables and output variables. These rules are designed based on the importance of each variable and relationships between variables. For example, if willingness trust between knowledge sender and receiver is high and knowledge is a simple knowledge, knowledge sharing will be at a high level. Designed rules are available in Appendix 2. Figure 7.3 shows a Fuzzy Inference System used to measure knowledge sharing levels for specific knowledge and trust levels.

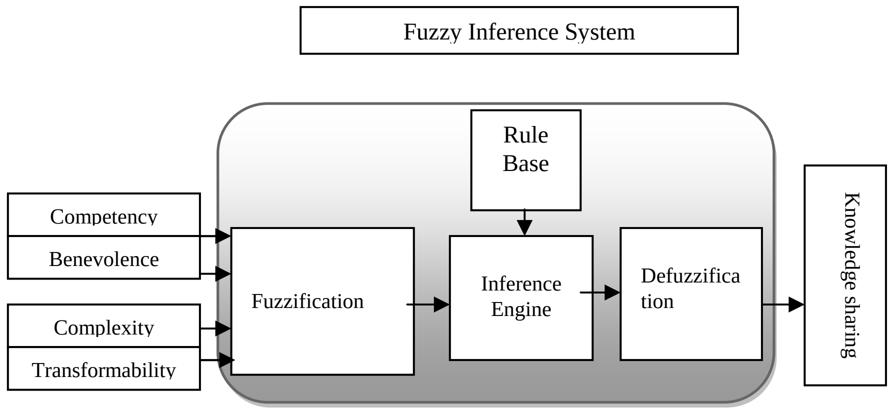


Figure 7.3: Fuzzy Inference system to measure knowledge sharing

Fuzzy Inference Systems [FIS] can efficiently handle the situations that cannot be characterized by a simple and well-defined deterministic mathematical model. This method utilizes simple rules and a number of simple membership functions to derive the correct result. The subjective and heuristic FIS is particularly efficient for various aspects of uncertain knowledge. The FIS structure is composed of three basic elements: fuzzification, fuzzy reasoning, and defuzzification.

7.3.1 Fuzzification

Crisp input variables are first transferred into fuzzy values based on input membership functions [MF]. These fuzzy variables will then be used to apply rules formulated by linguistic expressions of the fuzzy rule base. The membership function [MF] essentially embodies all fuzziness for a particular fuzzy set. The shape of the membership function (triangular, trapezoidal, Gaussian, etc.) is chosen based on the work that needs to be conducted. In this work, four crisp input variables are transferred into fuzzy sets as shown in Figure 7.3. It is clear from Figure 7.3 that for the first two input variables (competency and willingness), the crisp universe of discourse is considered to be between -1 and 1. The fuzzy membership functions include the linguistic fuzzy sets of Negative, Zero, and Positive. The other two crisp input variables [Complex and Structure] are laid in the universe of discourse [0 1], which are transferred to fuzzy linguistic variables of Low, Medium, and High. All fuzzy sets are a Generalized Bell curve.

7.3.2 Fuzzy Reasoning

As shown in Figure 7.3 information flows from four-input variables to a single-output. Though there are various ways to represent human knowledge using the fuzzy rule base, the most common way is to form it into natural language expressions of the if–then type. An expression in such a form is commonly called the if–then rule based form. It typically expresses an inference such that, if we know a fact [premise], then we can infer, or derive, another fact called a conclusion. This form of knowledge representation can express human empirical and heuristic knowledge in our language of communication. In the inference engine, the truth value for the premise [If part] of each fuzzy logic rule is computed and applied to compute the conclusion part of the rule [Then part]. The output fuzzy sets of all rules are then combined to form a single fuzzy set for the output variable.

7.3.3 Defuzzification

As shown in Figure 7.3, defuzzification is the last stage of a Fuzzy Inference System, which converts the conclusion made by the fuzzy inference into a crisp output value. The output linguistic variables are Absolutely Unsatisfactory, Unsatisfactory, Satisfactory, and Ideal. Of the different available methods of defuzzification, this chapter implements the most popular defuzzification method, centre of gravity, formulated as:

$$P = \frac{\int_p \mu_c(p) \times p dp}{\int_p \mu_c(p) dp}$$

(Equation 7.5)

Where p is the fuzzy output value of each rule and P is the crisp output value of the Fuzzy Inference System.

Based on the proposed model, MATLAB software is used to simulate the proposed model and a sample of the results are presented in Chapter 8. An important issue in knowledge sharing measurement is the dynamic nature of the knowledge sharing level. Trust can change over time and the complexity or transferability of knowledge is different in different knowledge domains. As a result, knowledge sharing is dynamic by nature. In the developed model, it is necessary to design intelligent tools to measure complexity and transferability of a particular knowledge and for this reason, a developed application is designed and programmed to analyze a particular knowledge based on personal ontologies and calculate knowledge complexity. Also, we compare the level of similarity of the ontologies of the knowledge sender and receiver, and measure transferability. The developed formulas are presented in this section.

7.4 Key factors in knowledge sharing measurement framework

The proposed framework is also developed in non-fuzzy systems and, in this section, the developed non-fuzzy system is discussed in detail. As stated earlier, the proposed model has four main variables: knowledge complexity, knowledge transferability, willingness trust and competence trust. These four main variables are reviewed again briefly before arriving at the final formula.

7.4.1 Knowledge complexity and transferability

Based on ontologies structure, eight indicators were proposed to measure knowledge complexity including:

1. Number of Data type Properties (NoDP)
2. Maximum Number of Data type Properties per Class(Max (NoDP))
3. Number of Object Properties (NoOP)
4. Maximum Number of Object Properties per Class $(Max$ (NoOP))
5. Number of Constraints (NoC)
6. Maximum Number of Constraints per Object Property $(Max$ (NoC))
7. Number of Hierarchical Paths (NoHP)
8. Maximum Number of Hierarchical Paths per Class $(Max$ (NoHP))

The final formula for measuring the complexity of a particular knowledge is:

$$\text{Complex(O)} = \left(\frac{\sum(\text{NoDP}+\text{NoOP}+\text{NoC}+\text{NoHP})}{\text{Max(NoDP)}+\text{Max(NoOP)}+\text{Max(NoC)}+\text{Max(NoHP)}}\right)/\text{NoOC}$$

(Equation 7.6)

And the complexity of knowledge is between 0 and 1 based on this formula.

Another key variable in knowledge sharing measurement is knowledge transferability. To measure the transferability of two knowledge backgrounds, ontology similarity is considered and calculated. Based on different methodologies that were discussed in Chapter 6, the similarity between different ontologies was calculated as follows.

$$\text{Trans (S1, S2)} = 1 - \frac{|S1 - S2|}{|S1|}$$

(Equation 7.7)

Where set of concepts, S1, captured in ontology 1, compared with set of concepts, S2, captured in ontology 2.

$S1 – S2 = \{x | x \in S1 \wedge x \notin S2\}$

The semantic difference between O1 and O2 can be defined by function Dif (S1, S2)

$$\text{Dif (S1, S2)} = \frac{|S1 - S2|}{|S1|}$$

(Equation 7.8)

Because the formula shows the differences of the two ontologies, the similarity level of these ontologies is 1- Dif (S1, S2) and this is calculated using Equation 7.8. Knowledge transferability is also between 0 and1.

7.4.2 Willingness and competence trust

Two matrices were proposed to measure competence and willingness based trusts as follows:

$$\text{Benevolence based trust} = \begin{pmatrix} 1 & tb12 & tb13 & .... & tb1n \\ tb21 & 1 & tb23 & ..... & tb2n \\ tb31 & tb32 & 1 & ...... & tb3n \\ .... & ..... & ..... & 1 & ..... \\ tbn1 & tbn2 & tbn3 & ..... & 1 \end{pmatrix}$$

$$\text{Competence based trust} = \begin{pmatrix} 1 & tc12 & tc13 & .... & tc1n \\ tc21 & 1 & tc23 & ..... & tc2n \\ tc31 & tc32 & 1 & ...... & tc3n \\ .... & ..... & ..... & 1 & ..... \\ tcn1 & tcn2 & tcn3 & ..... & 1 \end{pmatrix}$$

Moreover, different methods such as the CCCI method and AHP method were proposed to measure the trust level between paired parties in the matrices.

7.5 Trust and ontology based model in knowledge sharing measurement

Now, all the variables are defined by using different techniques and the most important issue is the relationship between these variables. As was discussed previously, trust dimensions and knowledge complexity are directly related to knowledge transferability. For example, simple knowledge needs higher willingness trust and less competence-based trust.

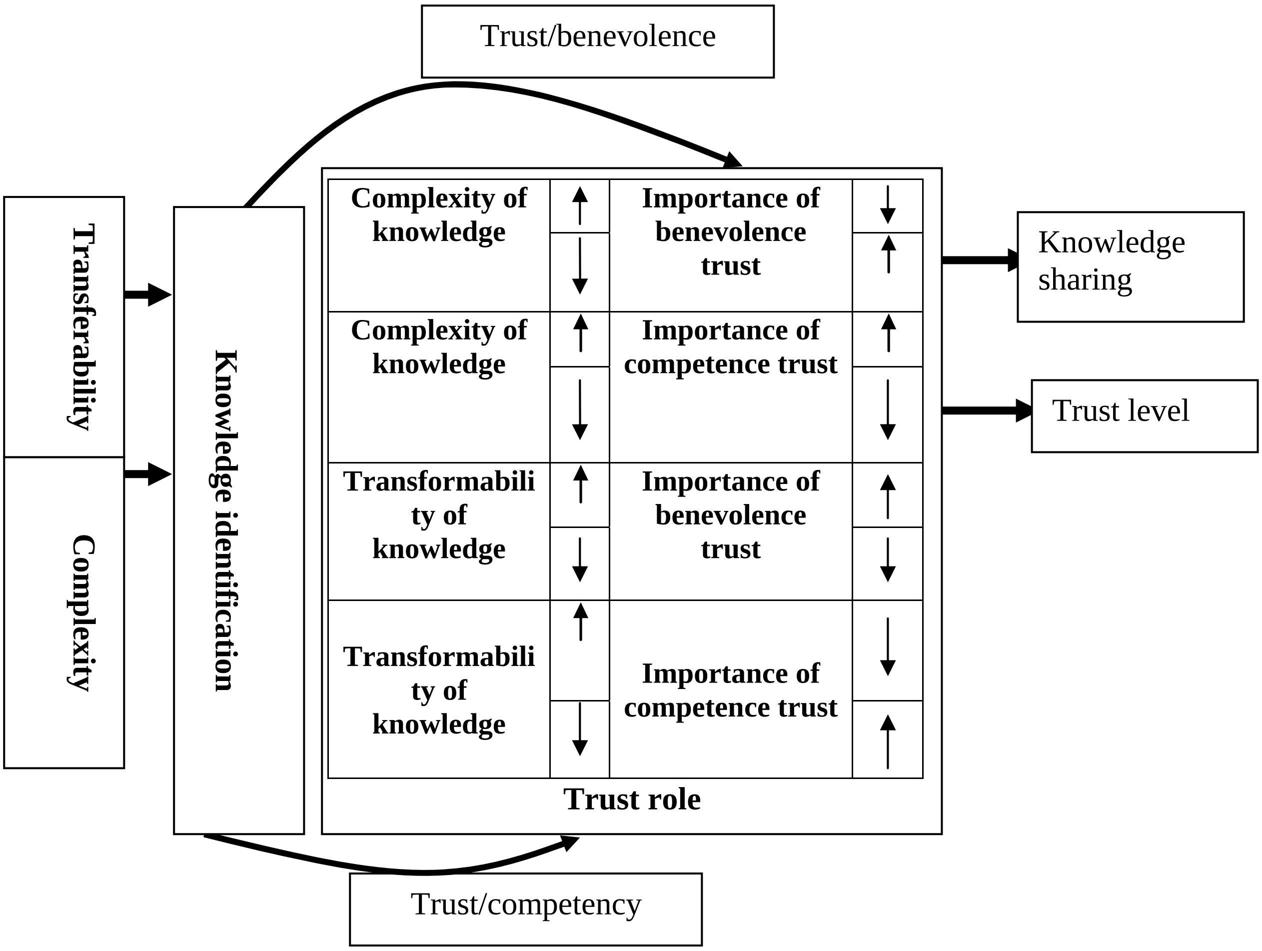


Figure 7.4: Effect of trust on different kinds of knowledge in knowledge sharing measurement

As seen in Figure 7.4, the sharing of complex knowledge is more dependent on competence-based trust, and transferable knowledge is more dependent on willingness trust. Therefore, it is necessary to define some auxiliary variables in knowledge sharing equations. Based on Figure 7.4, related equations can be expressed as:

Knowledge sharing= [$(complexity\ of\ knolwedge * benevolence\ trust * Importance\ of\ benevolence\ trust) + (complexity\ of\ knolwedge * competency\ trust * Importance\ of\ competency\ trust) + (transformability\ of\ knolwedge * benevolence\ trust * Importance\ of$

benevolence trust) + (*transformability of knolwedge* ∗ *competency trust* ∗ *Importance of competency trust)]/2*

$$Ks1=[((1-Kc)*|Tb|*K1)+((1-Kc)*|Tc|*K2)+(Kt*|Tb|*K3)+(Kt*|Tc|*K4)]/2$$

(Equation 7.9)

Kc= knowledge complexity (because knowledge sharing reduces by increasing complexity, 1-Kc is used in the formula so if 1-Kc increases, knowledge sharing level will be increased). Tb= trust benevolence K1= Importance of benevolence trust in different level of knowledge complexity Tc= trust competency Kt= knowledge transferability K2= Importance of competency trust in different level of knowledge complexity K3= Importance of benevolence trust in different level of knowledge transferability K4= Importance of competency trust in different level of knowledge transferability

Also, the willingness and competency of receiver to acquire knowledge can be calculated by Equation 7.10 below:

$$K's1= [((1-K'c)*|T'b|*K5) + ((1-K'c)*|T'c|*K6)+ (K't*|T'b|*K7) + (K't*|T'c|*K8)]/2$$

(Equation 7.10)

K's1=competence and ability of the receiver to gain the share knowledge K'c= knowledge complexity for the receiver (because knowledge sharing reduces by increasing complexity, 1-K'c is used in the formula so if 1- K'c increases, knowledge sharing level will be increased).

T'b= receiver's trust benevolence K5= Importance of receiver's benevolence trust in different level of knowledge complexity T'c= receiver's trust competency K't= receiver's knowledge transferability K6= Importance of receiver's competency trust in different level of knowledge complexity K7= Importance of receiver's benevolence trust in different level of knowledge transferability K8= Importance of receiver's competency trust in different level of knowledge transferability

And

$$Ks= min\ [(K's1, Ks1)]$$

(Equation 7.11)

It is important to know that the measured level of shared knowledge is for a specific time slot and that it is the first time that the measured knowledge is shared between sender and receiver. Knowledge sharing is a function of time and Equation 7.11 shows the knowledge sharing level at time $T0$. Also, if the same knowledge is repeated, it will become easier for the receiver to acquire the shared knowledge and it will change the receiver's competency and personal ontology.

7.6 Development of the proposed framework for knowledge sharing measurement

Figures 7.5, 7.6 and 7.7 show developed procedure that is proposed in this thesis to define and measure variables in knowledge sharing and report the result as well as calculate the capital that can be produced by knowledge sharing within a community. Figures 7.5 and 7.6 show the framework developed for measuring the knowledge sharing level. Figure 7.7 shows the framework developed for reporting the measured level of knowledge sharing to decision makers and managers. Also, Figure 7.7 shows the proposed means for measuring the capital that can be created by knowledge sharing within a community or an organization.

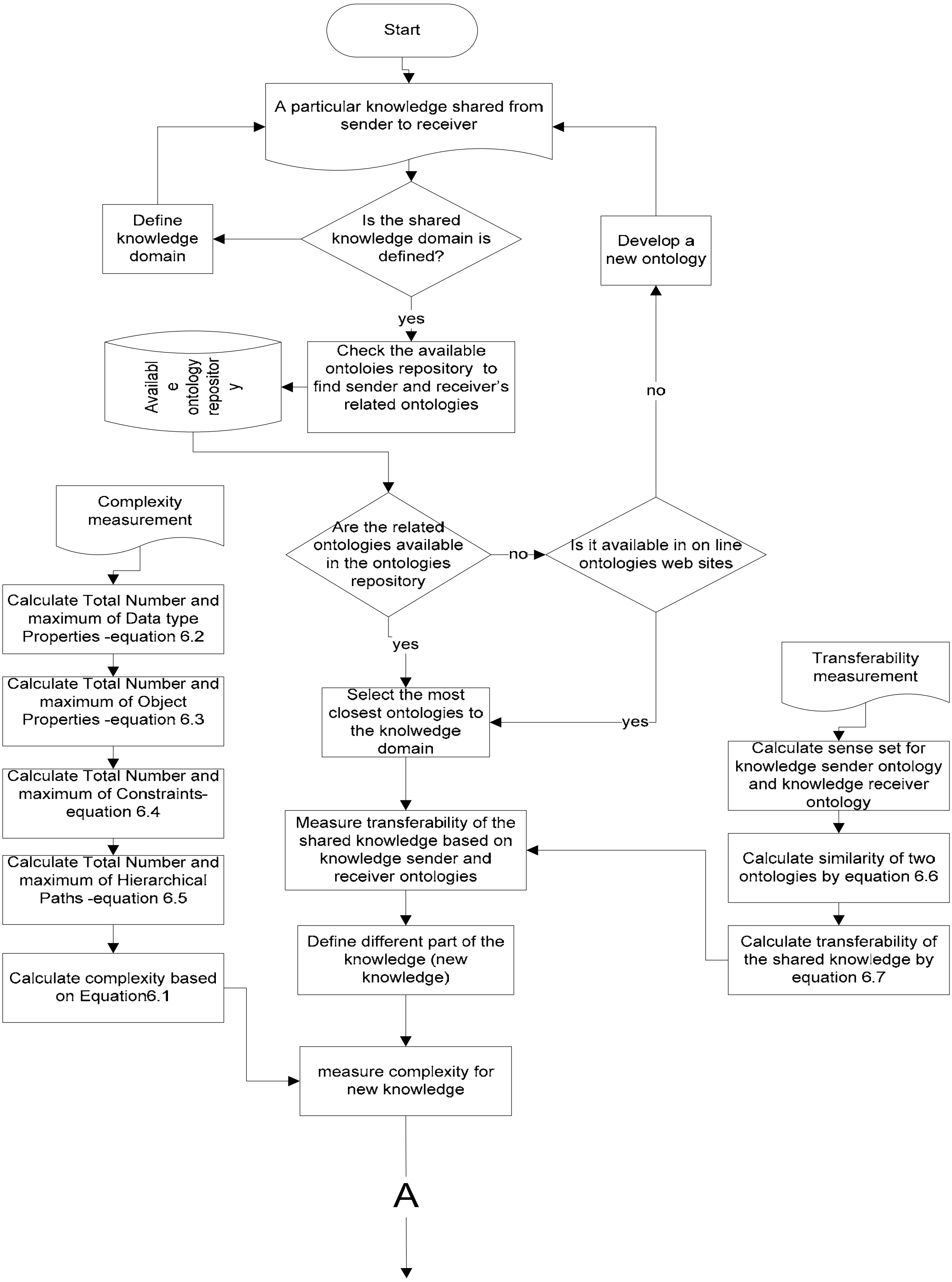


Figure 7.5: Knowledge complexity and knowledge transferability measurement

Figure 7.5 depicts the procedure that is developed to measure knowledge complexity and knowledge transferability between knowledge sender and knowledge receiver. The initial process of the developed model identifies the relevant ontology repository of the knowledge sender. It checks the availability of the ontologies repository and selects the relevant ontologies of the knowledge sender and knowledge receiver. If there is no ontology common to both of them, a new ontology will be developed for use in the flowchart. Then, the procedure starts to measure knowledge transferability based on the formulas that were discussed in Chapter 6 and reviewed in this chapter. It is followed by the process of measuring knowledge complexity for new knowledge and Equations 6.1 to 6.5 are used in Chapter 6 to measure knowledge complexity.

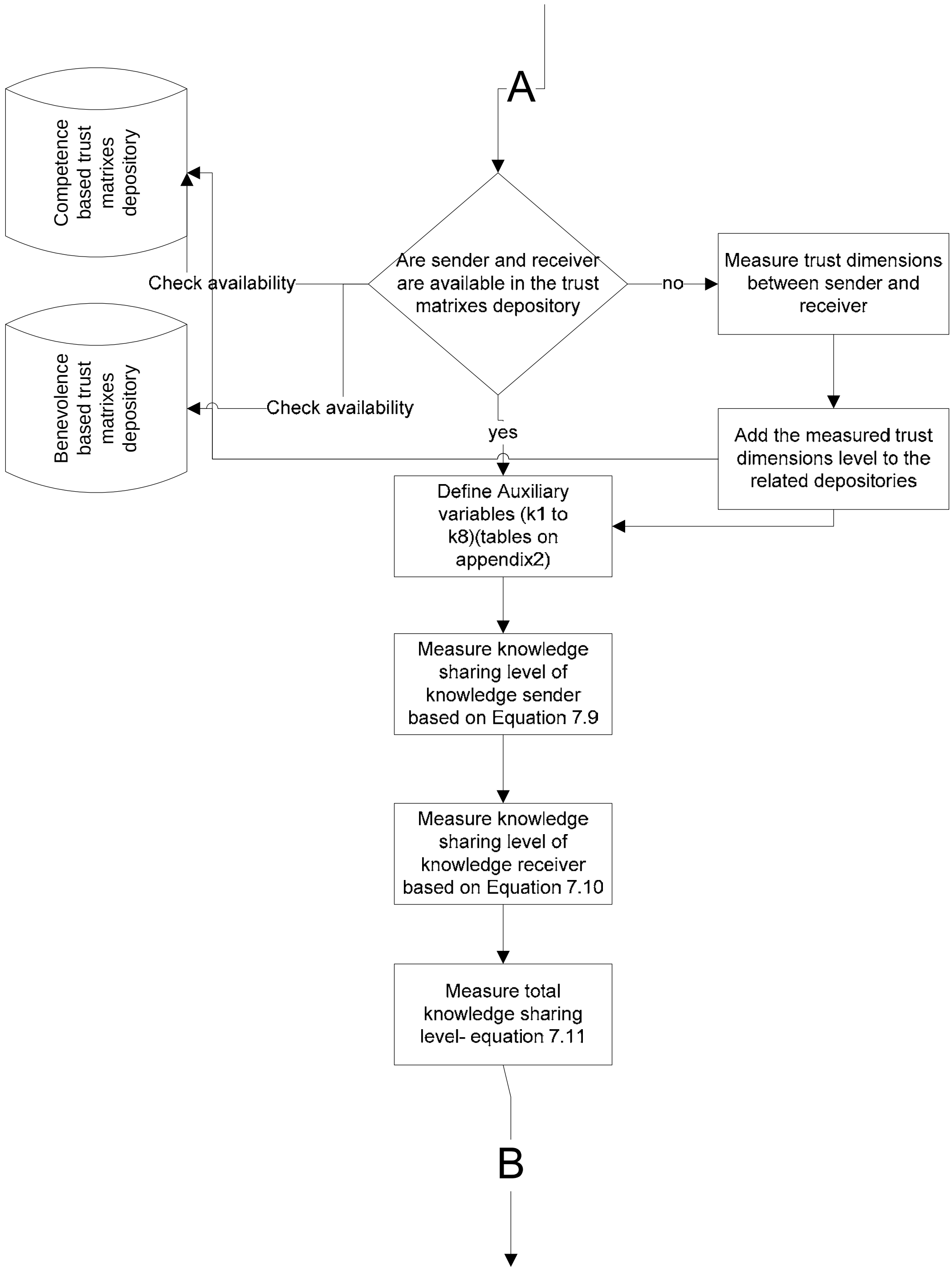


Figure 7.6: Knowledge sharing measurement

Figure 7.6 shows the measurement of the knowledge sharing level based on knowledge complexity, knowledge transferability, willingness trust and competence trust. The figure continues the process in Chapter 5 to measure the knowledge sharing level for both sides (from knowledge sender to knowledge receiver and from knowledge receiver to knowledge sender). Depending on the complexity and transferability level of the shared knowledge, the importance of trust willingness and trust competency can be determined by the model (based on the tables in Appendix 2) and the knowledge sharing level from knowledge sender to knowledge receiver can be calculated. Then, the same process is developed to measure the knowledge sharing level from knowledge receiver to knowledge sender. The figure's outline is the final knowledge sharing level between two parties that can be calculated by Equation 7.11 given in this chapter.

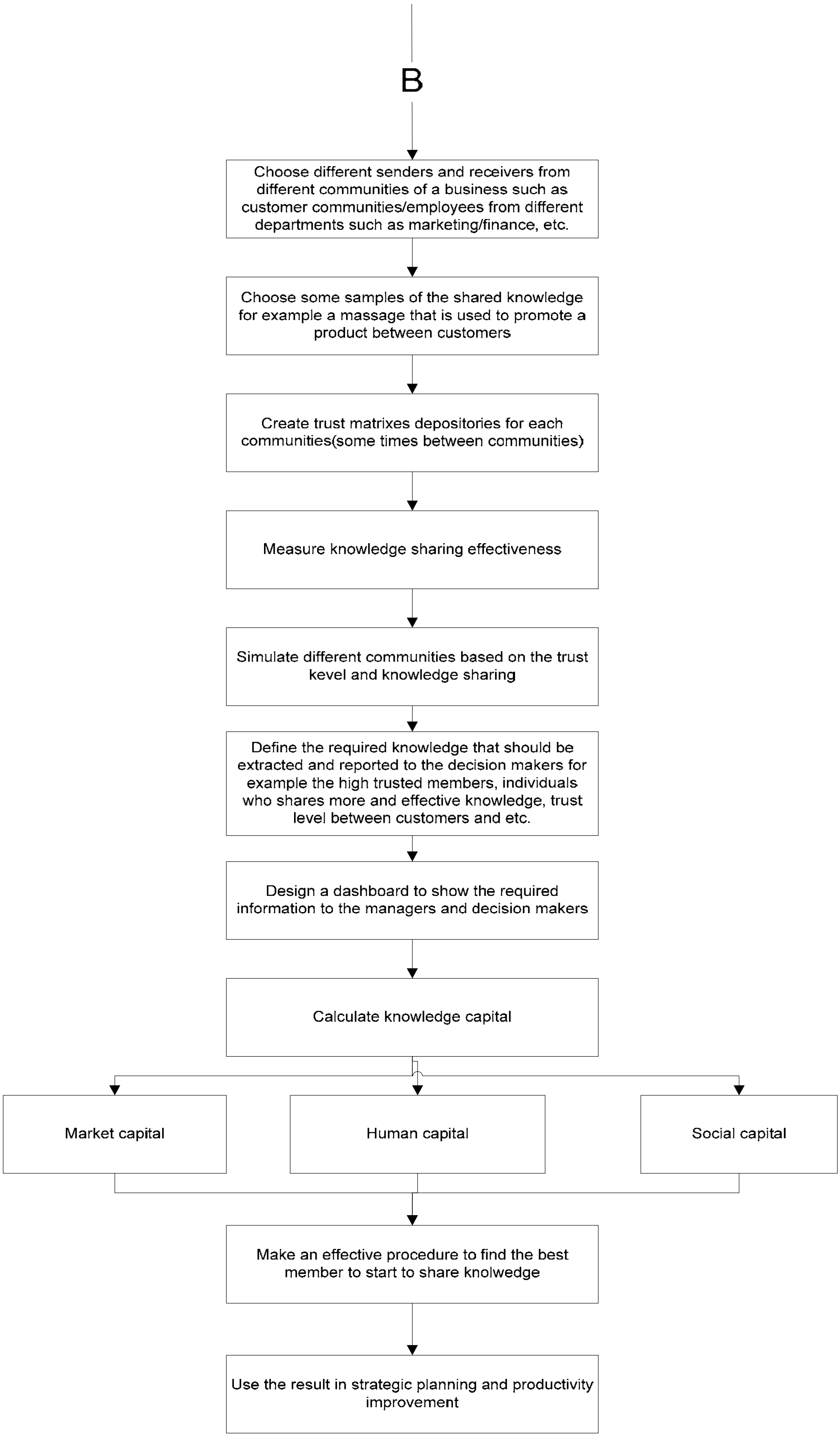


Figure 7.7: Some benefits of the research

Figure 7.7 follows Figures 7.5 and 7.6 to report the result of knowledge sharing levels between different members to decision makers and managers. This can help decision makers to follow knowledge sharing levels in different communities such as employees, customers, stakeholders and other related business components and creates a competitive advantage for businesses in a dynamic and competitive environment. For example, the loss of trust between a bank and its customers can create major problems for the bank (such as *bankruptcy* of some banks in the recent recession or a few years ago in South Asia). The monitoring of trust and knowledge sharing levels of customers can provide an opportunity for decision makers to predict critical situations before they occur. In political issues, it helps politicians to predict serious social dissatisfaction and change their policies or use effective knowledge sharing channels to increase citizens' satisfaction and prevent social or political collapse in the future. On the other hand, trust and knowledge sharing produces assets in a community or an organization, and so this research also develops an effective technique for measuring the capital that can be produced by knowledge sharing.

Figures 7.5 and 7.6 are used to develop a prototype for knowledge sharing measurement and for programming a related system in JAVA. This system and experimental results of the system are discussed in Chapter 8. A simulation model is developed to create an effective report system for knowledge sharing and the simulated model is presented in Chapter 9.

Also, Chapter 10 demonstrates and discusses the intellectual capital techniques for measuring the capital that is created by sharing knowledge.

7.7 Conclusion

This chapter focused on developing a conceptual framework for knowledge sharing measurement and creating business intelligence tools to report the measured variables as well as benefits of knowledge sharing in a community. Ontologies techniques and tools are used to solve part of the research problems that were related to knowledge representation and related issues in encoding or decoding a particular knowledge. On the other hand, the trust concept is a highly important research domain that has recently received more attention from researchers. In this research, trust measurement tools are used to measure the ability and benevolence of community members to share their knowledge with others. Based on these solutions, a conceptual framework is developed to measure the effectiveness of shared knowledge between sender and receiver within a specific time slot. Also, a simulation model is used to simulate a digital ecosystem based on different levels of trust values and knowledge domains. This helps decision makers in new digital environments to know more about any environmental changes, especially trust between customers and employees as well as knowledge sharing between them, and create a useful strategies based on the changes in these communities. The last aim of the research is to address the value of knowledge sharing for a community and is discussed in Chapter 10.

Chapter 8: Experimental simulation of a reporting system for knowledge sharing measurement

8.1 Overview

Based on research issues and research objectives, measured knowledge sharing levels should be reported to decision makers and a business intelligence system needs to provide valuable information to managers about knowledge sharing levels as well as trust levels within and between different communities. As worldwide competition is growing, traditional decision-making applications cannot satisfy the requirement of new business environments for effective decisions and more productivity. As explained in Chapter 2, most of the available business intelligence applications are more process-oriented and improve the speed and effectiveness of business operations by providing process-driven decision support system. On the other hand, in a knowledge-based economy, new generations of business agents have been born, such as virtual organizations and electronic firms in digital ecosystems. Digital Ecosystems (DES) transform the traditional, rigorously defined collaborative environments from centralized or distributed or hybrid models into an open, flexible, domain cluster, demand-driven interactive environment (Wu and Chang, 2007). Digital ecosystems are based on knowledge and all members in these ecosystems are intelligent and everyone is free to make relationship, connection and collaboration with other members and ecosystems are constructed by knowledge workers. New collaborations rely greatly on trust between collaborators and the knowledge that can be shared between them. Process-based business intelligence applications may not be able to cover all the requirements of knowledge-based collaborations and it is necessary to investigate new requirements and provide accurate information to decision makers in modern organizations that are mostly based on knowledge. As mentioned earlier, knowledge is rapidly created and just as rapidly loses its value, so decision makers need to ensure that their organizations have enough ability to absorb and share updated knowledge and use it in their business before their competitors do so. In this chapter, firstly digital ecosystems and the DES simulator to simulate digital ecosystems are discussed. Then, the roles of trust and knowledge sharing in digital ecosystems are presented. Then the BISIM (Business Intelligence Simulation Model) simulation prototype is developed as a business intelligence system to demonstrate measured levels of trust and knowledge sharing in a dashboard for decision makers. Business intelligence systems provide the ability to analyze business information in order to support and improve management decision making across a broad range of business activities (Elbashir et al., 2008).

8.2 Digital Ecosystem Simulator

A digital ecosystem is a collaborative environment in which all members feel free to initiate a relationship with other participants within a virtual community. Anyyone can join any community except for dangerous communities that damage ecosystems, and share his/her ideas and knowledge freely. This is opposite to the traditional ecosystems where individuals are more dependent on their family, their society, cultures, and religions, and usually the rules are pre-defined and community members have to follow the rules. In traditional ecosystems, individuals are not free enough to share all of their ideas. In this research, it is assumed that everyone is free to join groups and share his/her ideas without any external pressure, and community members are not ordered to collaborate or are not forced to follow the rules.

In a traditional ecosystem, an individual's behavior can be affected by the rules that each ecosystem has developed over a long period of time. Some of these ecosystems are shown in Figures 8.1 and 8.2.

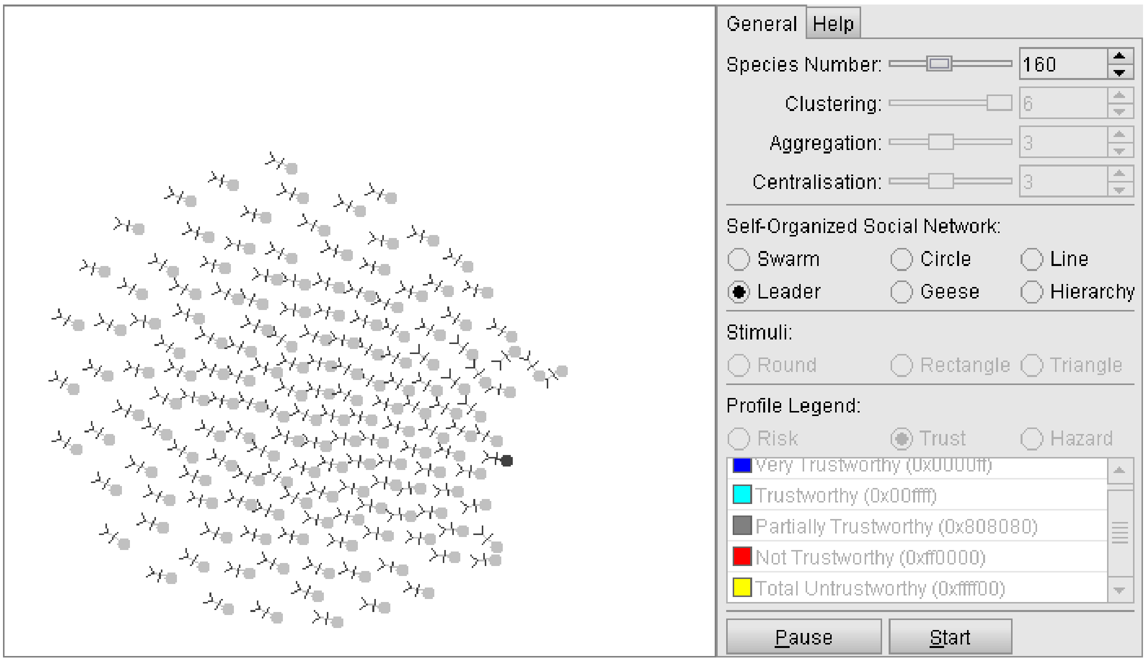


Figure 8.1: Leader-based ecosystem (Wu and Chang, 2007)

As shown in Figure 8.1, all the community members follow the leader. In traditional ecosystems, individuals are forced to follow the leader but, in a digital and free ecosystem, individuals might not trust the leader and follow the leader reluctantly. In a digital and free ecosystem, it is very important that if any community (business or organizations) wants to adopt a leadership management style, the trust and knowledge sharing levels between members have to be calculated regularly. This is also applicable to any business that wants to play a leadership role in a free ecosystem and in this case, customers' trust is a key factor in determining whether this business is accepted as a leader in the market. In a traditional ecosystem, members are forced to follow the leader and accept the knowledge that is shared by the leader even if they are not able to understand the shared knowledge. In a free ecosystem, leaders need innovative tools to ensure that the shared knowledge is transferable to the majority of the community members and sometimes to all of them. Also, the knowledge complexity should be based on a member's competency to be understood by most of the other members. One of our aims is to work on the current simulation model (DES) to extend and develop it to create a BISIM. Another type of ecosystem is hierarchical. Trust and knowledge sharing between members is both vertical and horizontal in these kinds of the communities. Figure 8.2 shows this type of ecosystem.

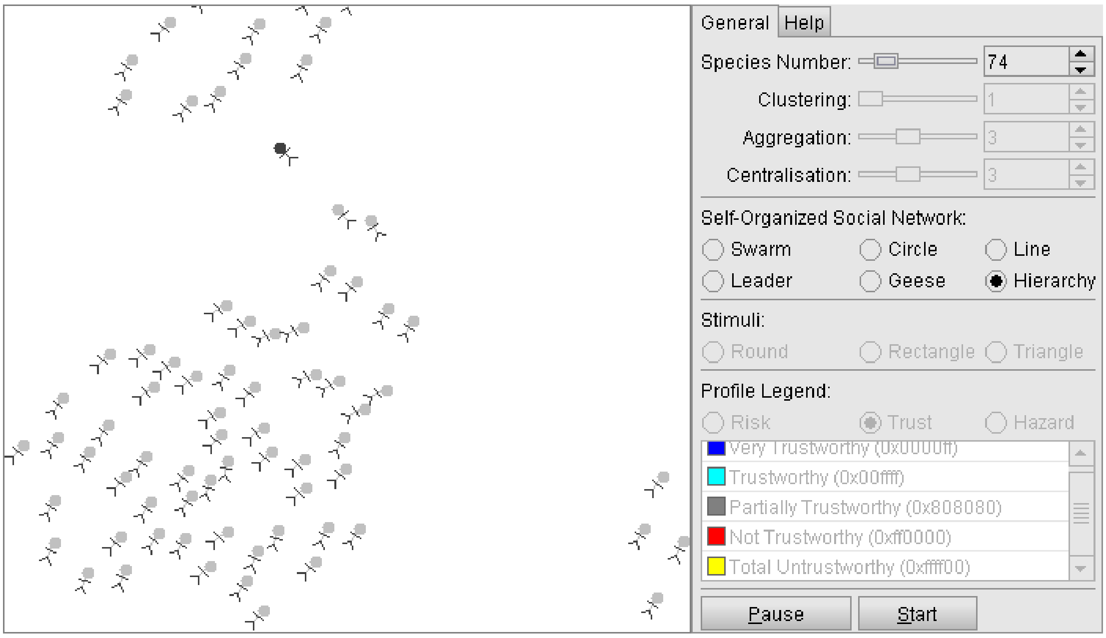


Figure 8.2 Hierarch- based ecosystem (Wu and Chang, 2007)

In traditional hierarchy ecosystems, knowledge sharing is like a command from top levels to bottom levels and members are forced to follow the commands. Although in developed free ecosystems members in hierarchical ecosystems are given the opportunity to explain their ideas and suggestions, they still need to follow the rules and commands of their higher level members. This is one of the major disadvantages of these kinds of ecosystems. However, in this kind of ecosystem, supporters believe that hierarchy creates motivation between members to increase their competency and progress towards higher levels.

Another key issue in an ecosystem is community clustering. Normally, ecosystems are divided into sub-communities and knowledge sharing occurs between the members of these sub-communities. For example, in traditional ecosystems, different religions have their own sub-communities and trust between the members of sub-communities is high. Figure 8.3 shows different sub-communities in an ecosystem.

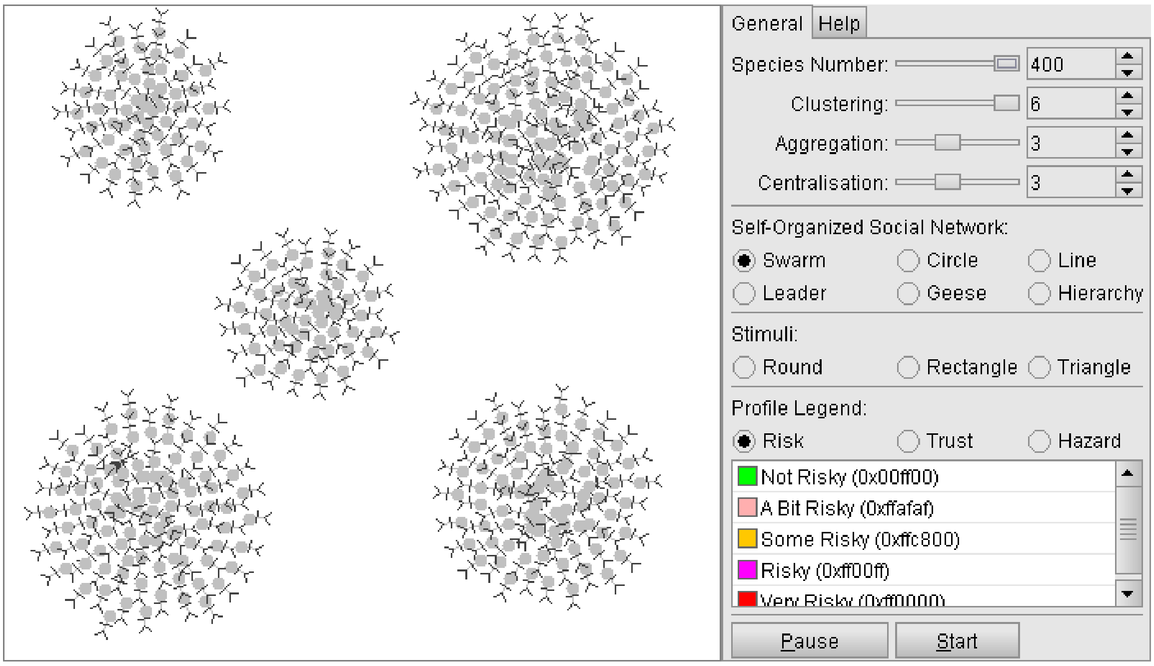


Figure 8.3: Sub-communities in an ecosystem (Wu and Chang, 2007)

As seen in the Figure 8.3, there are 5 sub-communities and knowledge sharing among members of one specific sub-community is much more than knowledge sharing between members of two different-sub communities. The rules are normally pre-defined in these communities by the community founders. However, in a free ecosystem there are also sub-communities although individuals are free to join or exit from these communities and they encourage rather than the following of rules. For example, sport communities encourage people to join them or music groups on the Internet encourage people to join them and support their community. There are also some other styles of ecosystems such as line and circle that are mentioned in the DES simulator. The ecosystem that is the focus of this research is a free ecosystem where everyone can join any legal communities, share any knowledge and refuse anything that they do not like such as an offer of membership of a community or forced sharing of knowledge. Figure 8.4 shows this type of ecosystem.

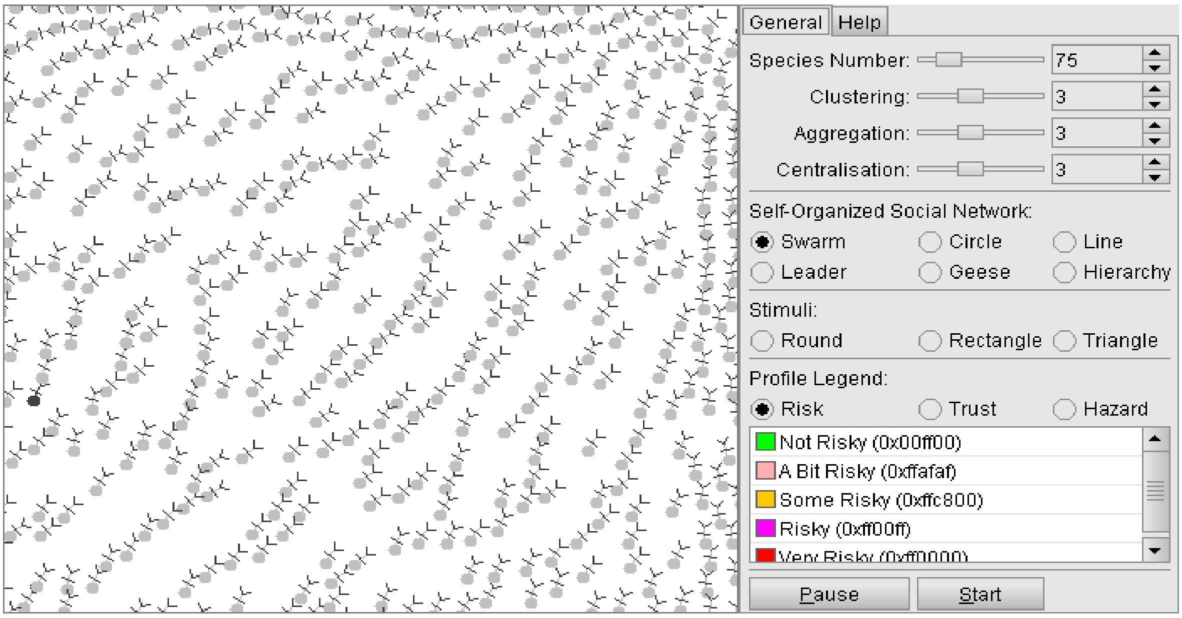


Figure 8.4: Ecosystem without pre rules and restrictions (Wu and Chang, 2007)

Traditional business ecosystems are going to change to digital business ecosystems and this will change the structure and business elements of the firms. In digital business ecosystems, decision makers need access to real and on-time data and they cannot limit themselves to analyzing previous data and forecasting the future based on past events. Hence, process-based business intelligence applications may not satisfy new requirements and some new variables have to be considered in decision-making models. One of the key elements in developing a business in a digital ecosystem is using new data resources to access on-time data and create reliable knowledge to use in the decision-making process. Knowledge is an organization's most important competitive advantage in digital ecosystems and pioneer organizations need to plan a strategy whose objective is to collect, manage and put knowledge in action, and develops knowledge continuously. Knowledge creation and knowledge sharing are crucial to organizations in a digital ecosystem. It is necessary for decision makers to develop and use knowledge-based business intelligence tools. In new businesses, intelligence tools and the level of knowledge sharing within communities and the trust level between members should be addressed. As was discussed in the literature, the success of Knowledge sharing depends on developing an effective relationship between transmitter and receiver of the knowledge. The key variable in establishing an effective relationship is trust. Competence- and benevolence-based trust are important variables in knowledge sharing and should be considered in the new applications. In this chapter, BISIM simulator based on the theory that proposed in the chapter7 is introduced. BISIM simulation model indicates trust and knowledge sharing as the main variables in free ecosystems and to success in a competitive and knowledge based business environment, new business intelligence simulation is developed based on these key variables.

8.3 Business Intelligence Simulator Model

In the area of digital economy, the most important challenges are those of producing and using data, information, and knowledge. As was discussed in the DES simulation description, there is a rise of ultra-large cooperative efforts to embrace Digital Ecosystems that transform the traditional rigorously defined collaborative environments from centralized or distributed or hybrid models to an open, flexible, domain cluster, demand-driven interactive cyber space.

Following the vision of 'creating value by making connections', in a digital ecosystem, each digital species acts for its own benefit and profit by choosing different strategies (i.e. business partners, human resources, intelligence models) for communicating, collaborating, socializing, contributing and even competing with each other. There are some key contributors to the success of the selected strategies in an open and flexible collaborative environment. Therefore, a central and pressing research question is related to maximizing the benefits to members in these ecosystems and forecasting the overall behavior of the DES in order to ensure that DES as a whole can achieve the desired goals (i.e. value creation and increase) beneficial for the entire community and all stakeholders. Based on the conceptual framework that was proposed in this thesis to improve knowledge sharing and developing a strong relationship between community members, this research has been designed and implemented the BISIM simulator using a Business Intelligence concept.

The main aim of this simulation is to represent the development of knowledge sharing in different as areas of an organization including its strategic planning, where “Knowledge Creation” and “Knowledge Sharing” are vital to organization’s knowledge management process. To encourage people to share their knowledge and contribute to decisions, the BISIM simulator projects the level of Knowledge Sharing within communities and addresses the trust level between members. According to the Knowledge Sharing principle, members rely on an effective relationship between one another to exchange knowledge, and the key factor in making an effective relationship is Trust. Two of the most regularly cited forms of trust - Competence and Benevolence - are used in this simulation for knowledge sharing measurement. While Competence-based trust represents the essential capability to share a particular knowledge within a specific time slot, and benevolence-based trust represents the willingness to share that particular knowledge within the same time slot. The basic model captured in this DES simulator is shown in Figure 8.5.

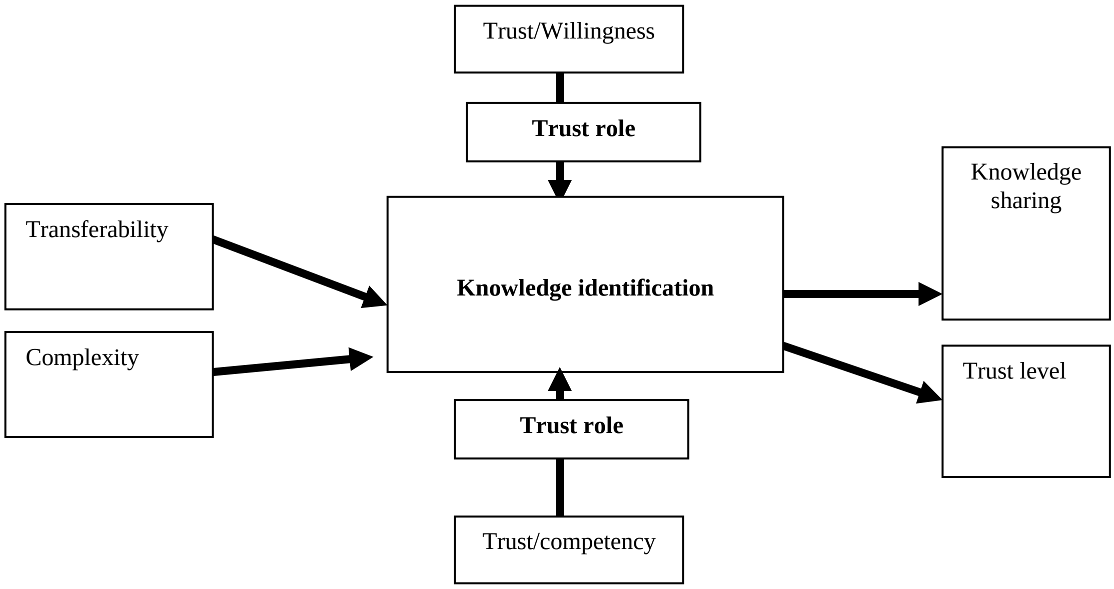


Figure 8.5: BISIM simulation model

The significance of this simulation is twofold. Firstly, it is one of the few simulators in the world that provides a visualized and dynamic demonstration of trust and knowledge sharing in a complex system such as a digital ecosystem. Secondly, it is an attempt to create Swarm Intelligence by creating an ideal knowledge sharing environment to capture and simulate the knowledge sharing behavior of species in the digital world. The result of this simulation can be applied to different domains such as customer-to-customer marketing, e-commerce, and social networking.

8.4 Business Intelligence Simulator Features

As discussed previously, this Simulator represents Knowledge sharing in an organization. It shows how Knowledge Sharing depends on the levels of Trust and personal ontologies. Trust is represented by Competency and Benevolence. Knowledge is represented by Complexity and Transferability. In the first version, the simulator is designed for the user to decide the levels of Trust and Knowledge of the individual within the community. In the developed version, the simulator is connected to the developed trust dimensions and knowledge complexity and transferability measurement application that was discussed in Chapter 7. The levels of the variables are calculated automatically by the simulator based on ontologies and the knowledge that members want to share. In the first version that is presented in this chapter, the Simulation started with the default values of Species number, trust, knowledge and result. This means that the simulator had random face expression, number of faces, colors, and connection lines displayed on screen. These reflect the species' different levels of Benevolence and Transferability within the same communities and inter-community.

The simulation consists of two main features: a Drawing canvas (left hand side) and Control panel (right hand side) as shown in Figure 8.6.

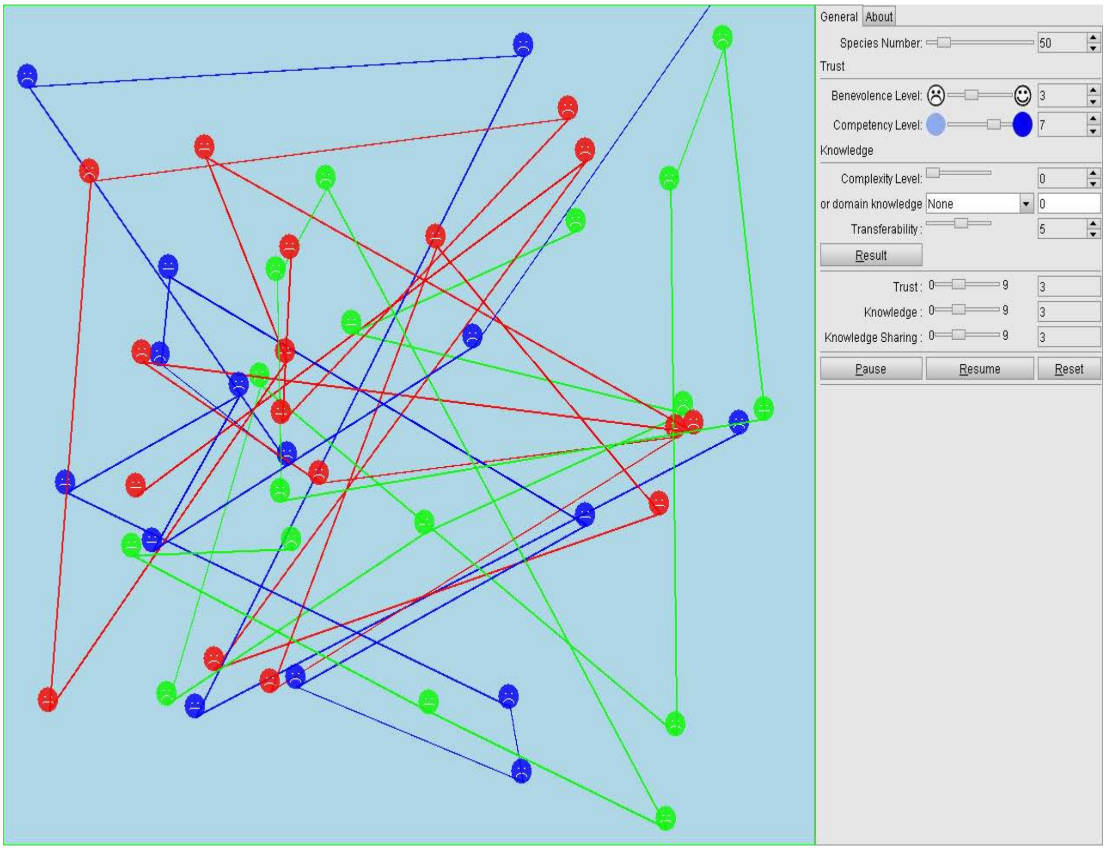


Figure 8.6: Business Intelligence Simulator Screen shot

The user uses the control panel to vary the species number (from 1 to 400) and the levels of Competency, Benevolence, Complexity and Transferability on a scale of 0 to 9. Also, the user can see the result in the drawing canvas. These two main parts of the BISIM are discussed in this chapter.

8.4.1 Control Panel

The control Panel is designed for the user to enter values for calculation by the slider bar and spin box button. The Control Panel is composed of five sections: “Species number”, “Trust”, “Knowledge”, “Result”. These four sections and animated graphical images control buttons are shown in Figure8.7.

8.4.1.1 Species

The Species number identifies the number of faces of faces displayed on the Drawing Canvas. The default value is set for 50 faces. The simulator has set the number of faces to be displayed from a minimum of 1 face to a maximum of 400 faces. To adjust the number of faces displayed on the drawing canvas, the user slides on the slider bar or changes the value on the spin box. The extreme left of the slider bar indicates the minimum value. On the other hand, the right-most side of the slider bar indicates the maximum value. The spin box shows the value of the slider bar in numbers. It also allows users to change the value by clicking the 'up' and 'down' buttons on the right hand side of the spin box. The value increased by the spin box would affect that on the slider bar. As the value goes up or down, the slider bar moves to the left or right according to the value.

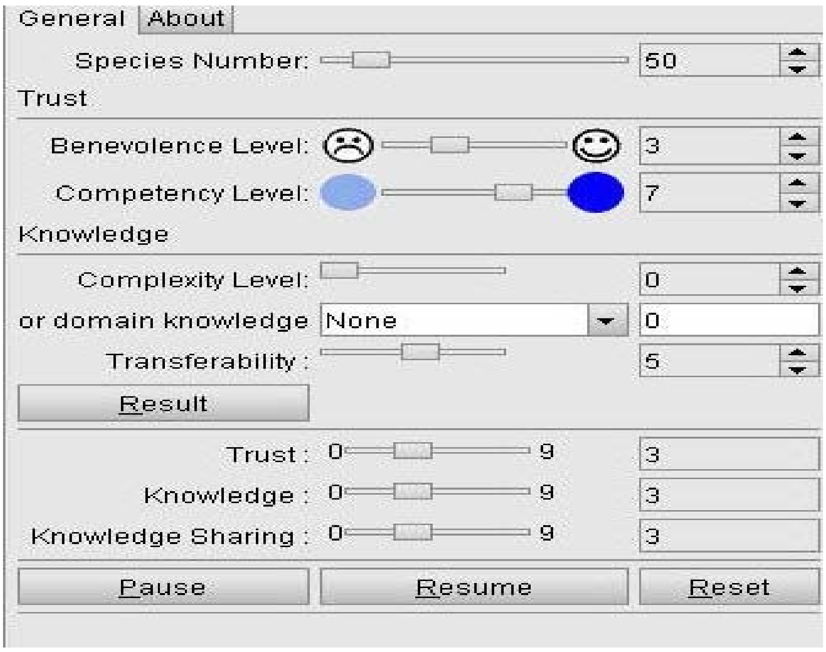


Figure 8.7: Business Intelligent Simulator Control Panel

8.4.1.2 Trust

According to Knowledge Sharing principles, individuals in the community rely on an effective relationship between one another to exchange knowledge. Based on the proposed model in Chapter 7, one of the important key factors in creating effective knowledge sharing is Trust. This simulator demonstrates the level of trust between members in the community in relation to sharing knowledge. Two of the most regularly cited forms of trust that are presented in the prototype are: (1) Competence; (2) Benevolence. The simulator calculates the values of both Benevolence and Competency levels for the total rate of Trust and rate of Knowledge Sharing.

8.4.1.2.1 Benevolence

The Benevolence level or the willingness level is represented by the smiley face in the Drawing canvas. The faces change according to the level of individuals' benevolence. A very happy smiley face indicates a high Benevolence level. The very sad faces on the other hand, indicate a low Benevolence level. The higher the Benevolence level, the better is the capability of individuals to learn new Knowledge. The Benevolence level contains ten levels from minimum value of 0 to the maximum value of 9. The value of levels can be change by sliding the slider bar or by spin box. The value is displayed in numbers on the spin box. The user can edit the value on the spin box by clicking the 'up' and 'down' buttons on the right hand side of the box. The value that is edited by the spin box would show on the slider bar on the bar indicator.

8.4.1.2.2 Competency

The Competency Level of Trust is represented by shading the faces from faint shading to a bright shade. The faint shading indicates a low level of competency. The bright shading indicates a high level of competency. As If Competency level is high, the capability of individuals to learn new Knowledge increases. The Competency Level contains ten levels from minimum value of 0 to the maximum value of 9. The value of levels can be changed by sliding the slider bar or by the spin box. The value is displayed in numbers on the spin box. The user can edit the value on the spin box by clicking the 'up' and 'dow'n buttons on the right hand side of the box. The value that is edited by the spin box would show on the slider bar and can be found on the bar indicator.

8.4.1.3 Knowledge

Knowledge is another important key issue in Knowledge sharing beside Trust. In Knowledge sharing, it is vital to measure the complexity and transferability of the knowledge. The Complexity and transferability of knowledge has a direct influence on Knowledge Sharing. The high value of knowledge complexity is limiting the capacity of community members to share their knowledge. The high value of knowledge transferability would increase the capacity of each individual to transfer the knowledge to others in the community or across the community. The simulator calculates the value of Complexity and Transferability for the total Knowledge and the rate of Knowledge Sharing.

8.4.1.3.1 Complexity

The Complexity level of Knowledge depends on the knowledge ontology that applies to the community. As Complexity increases, it is more difficult for individuals to acquire new Knowledge. The simulator uses this complexity value to calculate the transferability rate. The Complexity level is represented by the straight line that connects each face. The simulator allows the user to enter the Complexity Level in three ways: (1) Users can to click on the "Import Ontology" dropdown list to select the domain of knowledge and its complexity value. The complexity value of the selected domain knowledge would display in number on the text box next to the dropdown list. The value of the complexity can be altered by (2) sliding the slider bar or on the (3) spin box. The value in numbers is displayed on the spin box. The user can edit the value on the spin box by clicking the 'up' and 'down' buttons on the right hand side of the box. The value that is edited by the spin box would show on the slider bar by checking the location of the indicator on the bar. The Complexity Level contains ten levels from minimum value of 0 to the maximum value of 9.

8.4.1.3.2 Transferability

Knowledge Transferability is represented as the connection line between the faces. The thickness of lines depends on the value of transferability. The greater the value of transferability, the thicker is the line. This means that individuals can share new knowledge more effectively. The value of transferability can be entered by sliding the slider bar or clicking on the spin box. The value in numbers is displayed on the spin box. The user can edit the value on the spin box by clicking the 'up' and 'down' buttons on the right hand side of the box. The value that is edited by the spin box would show on the slider bar by looking at the location of the indicator on the bar. The Transferability Level contains ten levels from minimum value of 0 to the maximum of 9. This Transferability level also depends on the Benevolence, Competency and Knowledge complexity Level of each individual as well.

8.4.2 Drawing Canvas

As mentioned, BISIM consists of two parts: Drawing canvas, and Control panel.

Drawing canvas as Figure 8.8 is the area where the animated graphical images display. The animated graphical images such as smiley faces show their reaction according to the input value from the Control Panel. In the drawing canvas, face animation that demonstrate the relationship of the simulation consist of smiley faces, sad faces, colors of faces, faces' colors alpha and connection lines.

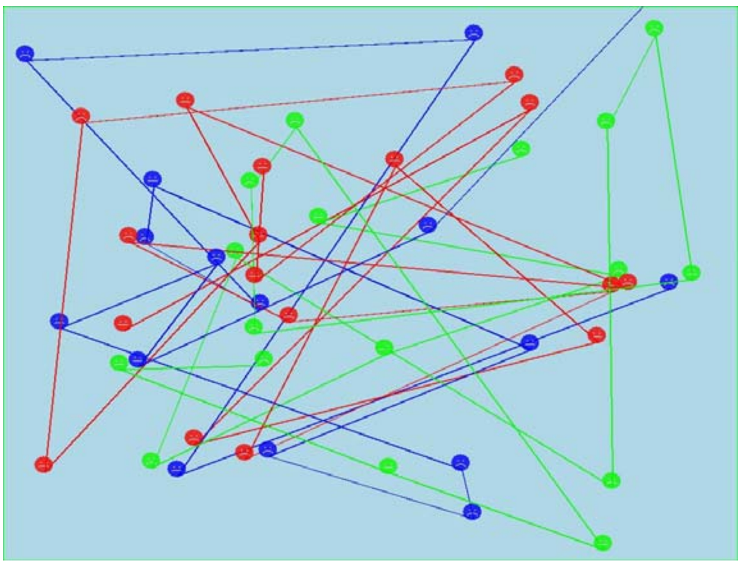


Figure 8.8: Business Intelligent Simulator Drawing Canvas

8.4.2.1 Connection Line

Connection Lines are the lines that connect species. The thickness of these lines represent the Knowledge Transferability rate at which each species is able to exchange its knowledge. The Transferability also depends on the Benevolence value (Smiley face) as well. If each species has a very high Benevolence value, the chance of Knowledge Transferability is high. Thus, the thickness of the line will also change in relation to the Benevolence value.

8.4.2.2 Smiley face status

The smiley face with different face background colors represent species that belong to a different domain knowledge expertise community (they belong to different ontologies). For example: Green faces indicate the individuals are experts in the Market domain. Blue faces indicate the individuals who have expertise in the Finance domain. Red faces indicate the individuals who are experts in the Management domain etc.

The outcome of the simulation presents numerically the Trust, Knowledge and Knowledge sharing Levels via animated graphical images as partially explained above. The Knowledge Sharing outcome is indicated by the thickness of the connection line: if the line is thick, this means the Knowledge sharing rate is high, but if the line is thin, the sharing rate is low. The calculation of outcome values involves the values of Benevolence, Competency, Complexity and Transferability levels. The calculation is triggered by a click of “Result” button. The button also has a mechanism to pause and update the animated graphical images and outcome values to provide the user with a better view of the changes.

8.4.3 Control buttons

Animated graphical images control buttons designed to control the movement of the animated graphical images. These buttons consist of Pause button, Resume button, and Reset button. The purpose of these buttons is to provide a better view of the animated graphics images.

8.4.3.1 Pause

The Pause button provide the motionless movement of the animated graphical images. Once the button is click, the Text on the button is change to “Next”. This would allow user to view the next movement of the animation. The text on the button changes to “Pause” again if the “resume” button has been click.

8.4.3.2 Resume

The Resume button provides full motion movement to the animated graphical images. It is active when the pause button or the result button has been clicked.

8.4.3.3 Reset

The Reset button provides the function for setting all values in Trust, Knowledge, and Result section to 0. The value of zero allows the user to restart the animation and enter values again.

8.4.4 Graphical images

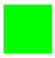
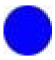
Symbol Name	Symbols	Remarks
Smiley face	☺	High benevolence level of the individuals.
Sad face	☹	Low benevolence level of individuals.
Red face background color		Community who expert in Management domain.
Blue face background color		Community who expert in Finance domain.
Green face background color		Community who expert in Marketing.
Fade shading face background color		Low competency level of individuals.
Bright shading faces background color		High competency level of individuals.
Thin connection line		Low transferability level of individuals.
Thick connection line		High transferability level of individuals.

Table 8.1: Summary of animated graphical images

8.4.5 Assumptions

This simulator application makes two assumptions that affect the design and implementation process. Two assumption emerge during the development process. Firstly, the simulator assumes that the users have basic knowledge of computer and familiar with a computer Graphic User Interface. This is because the simulator requires input values from users in the first version, and navigates through the simulator's control panel. Another assumption occurring during the process is the simulator purposely created to be displayed in an exhibition or a workshop for industry or executive managers. Therefore, to prevent the users from accidentally closing the simulator, no "Exit" button is present on the simulator application. Thus, Section 9.4.3 provides instructions on how to terminate the simulator application.

8.4.6 Requirement and Specification

The simulator application program provides an interactive graphic user interface input pane where users need to enter a value on the pane for calculation. Thus, the output values are displayed in the diagram on the drawing pane on the left hand side and the numeric values are displayed at the bottom of the input pane on the right hand side.

8.5 The use of BISIM development features

In the developed simulation model, input variables are calculated automatically and are integrated with the application that is discussed in Chapter 9. For each member in the community, a trust record folder is created to save results of measured trust levels. Over a long period of time, the reputation of each member is an essential knowledge that forecasts the knowledge sharing level of a new knowledge. Figure 8.9 shows the trust level repository of community members.

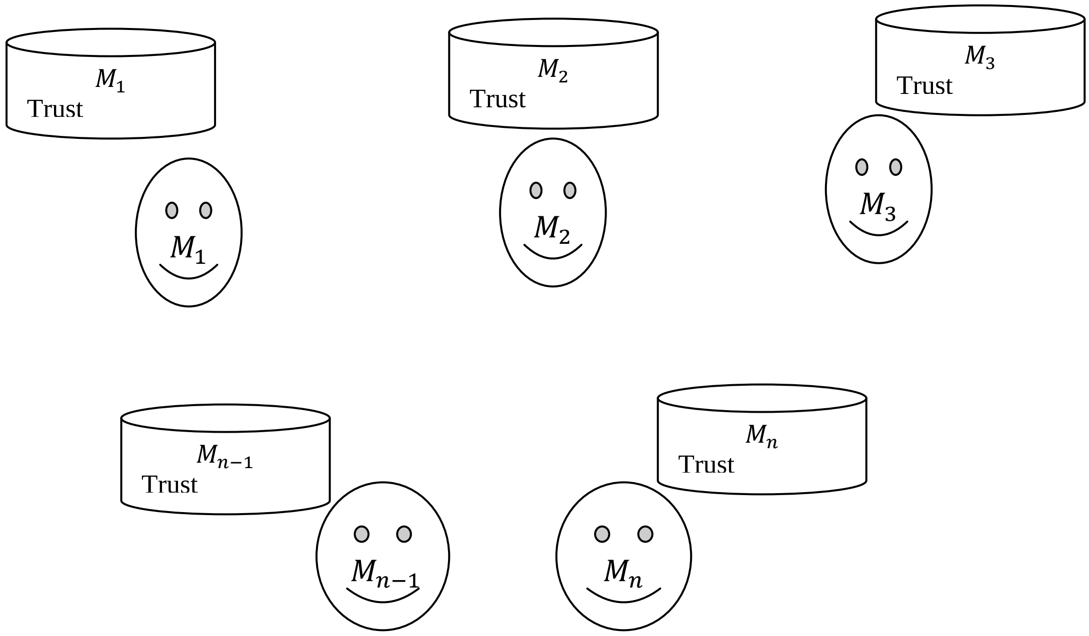


Figure 8.9: Trust repository in a community

Trust level can be regularly checked and updated in different knowledge domains and in the long term an individual's trust level in each knowledge domain can be found in the trust level repositories. Also, by using the formulas that were discussed in detail in Chapters 6 and 7, the complexity and transferability of a particular knowledge within a specific time slot can be calculated. Another key issue that can be developed in the simulator is the role of knowledge repetition in decreasing the complexity of knowledge. Normally, if information (knowledge) is repeated several times, its complexity decreases due to the intelligence of the community members. For example, when learning a language if a new word is repeated several times, the receiver eventually learns the meaning of the word. Figure 8.10 shows the relationship between knowledge repetitions and complexity.

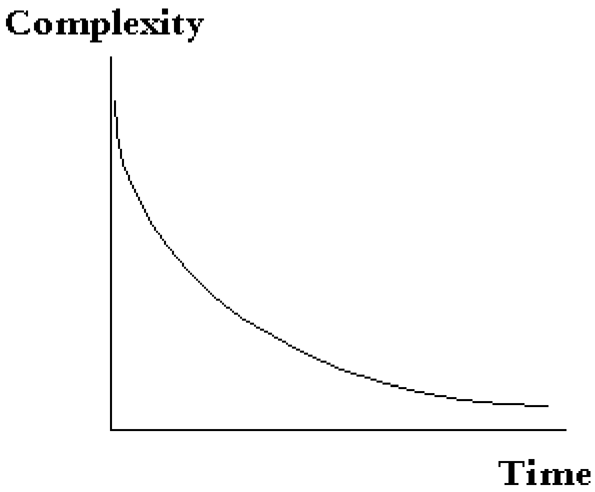


Figure 8.10: Relationship between time and complexity

Figure 8.10 demonstrates that complexity of knowledge reduces over time and the overall complexity is a function of time (Equation 8.1).

$$K_c \cong f(t)$$

(Equation 8.1)

This figure is based on Wright's learning model where the function is defined as:

$$Y = aX^b$$

(Equation 8.2)

Where Y shows the average time needed to learn X number of units (knowledge), and learning rate is b (S. S. Liao, 1988). It is clear that learning rates differ from person to person.

One more issue that is important in business intelligence applications is making a dashboard for managers to follow real-time situations in different communities. For example, managers need to know their customers' level of trust in their business or the trust level between their employees and between their marketing staff. The simulator can be developed to provide these kinds of data and show them a management dashboard in real time. Figure 8.11 shows a sample of a dashboard that can be developed by the simulator.

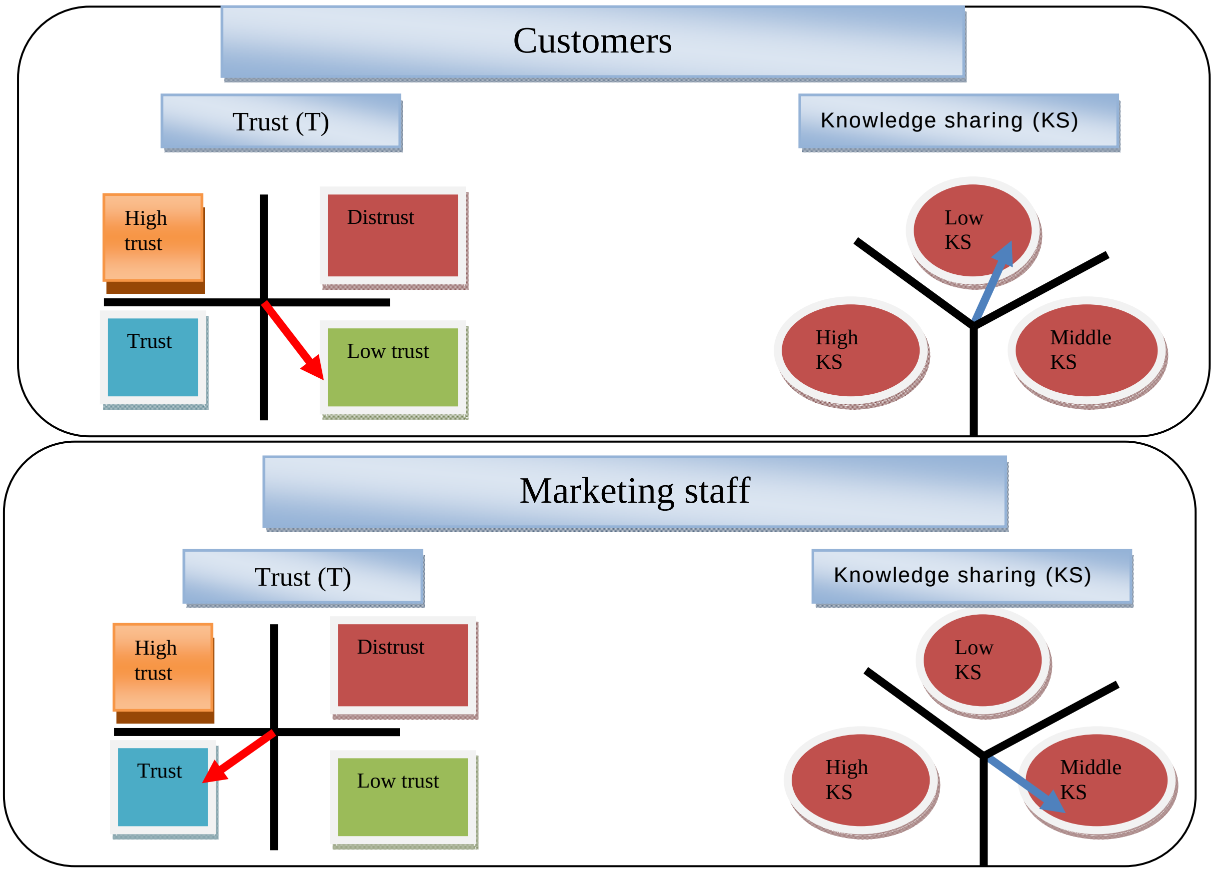


Figure 8.11: BISIM, BI management dashboard

As shown in Figure 8.11, decision makers can control the trust and knowledge sharing level between employees from different departments as well as customers, and as trust level reduction is a negative effect that can reduce business revenue, they can change business strategy or determine the causes of the trust level reduction. Similar to customers, reduction in trust level between employees can reduce business performance and decision makers should follow the trust level between employees.

8.6 BISIM outcomes support proposed knowledge sharing prototype

BISIM conducted experimental tests to simulate knowledge dissemination in a simulated network. The tests examined the role of the variables that are defined in the knowledge sharing prototype as the main variables in knowledge dissemination. Outcomes support proof of concept and correctness of the proposed equations in the proposed knowledge sharing measurement prototype. To prove the importance of the variables of willingness and benevolence trust in knowledge sharing measurement, members of a simulated network were divided into three groups based on the level of trust in each other. These three groups are blue group, red group and green group. Blue group members have a high level of benevolence and competence trust in each other, but their level of trust in other group members is low. Similar to the blue group, red group members and green group members have a high level of trust in their own group members and a low level of trust in members from other groups. Figure 8.12 shows the knowledge sharing levels in the simulated network.

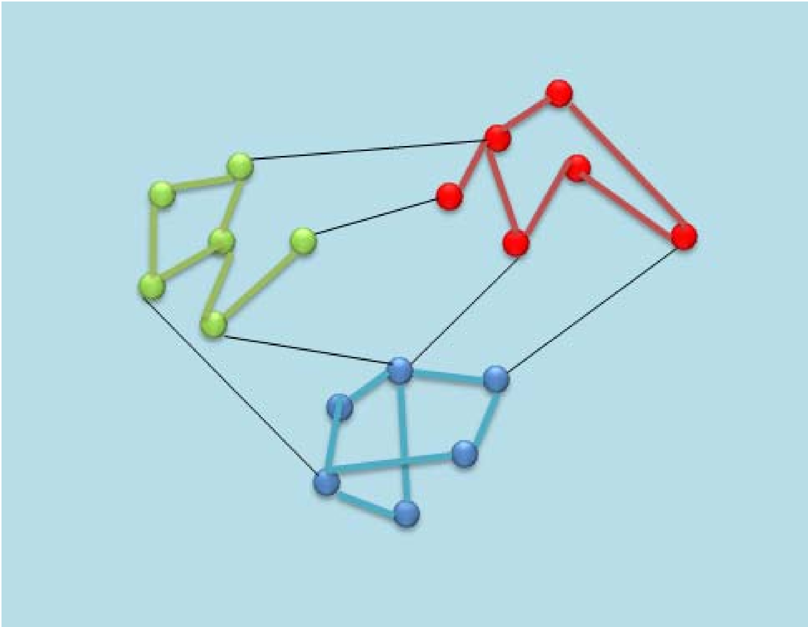


Figure 8.12: Knowledge sharing level in the simulated network based on trust between members

As seen in Figure 8.12, the thickness of the lines between members of a group is greater than the thickness of the lines between members from different groups. Line thickness indicates the level of knowledge sharing between members and it is clear that a high level of trust leads to a high level of knowledge sharing in a network. The result supports the concept that trust is a key issue in knowledge sharing measurement.

To prove the importance of the complexity and transformability of knowledge in knowledge sharing measurement, members from engineering (pink color), management (white color) and medical (black color) backgrounds are simulated in BISIM. Figure 8.13 shows the simulation outcomes:

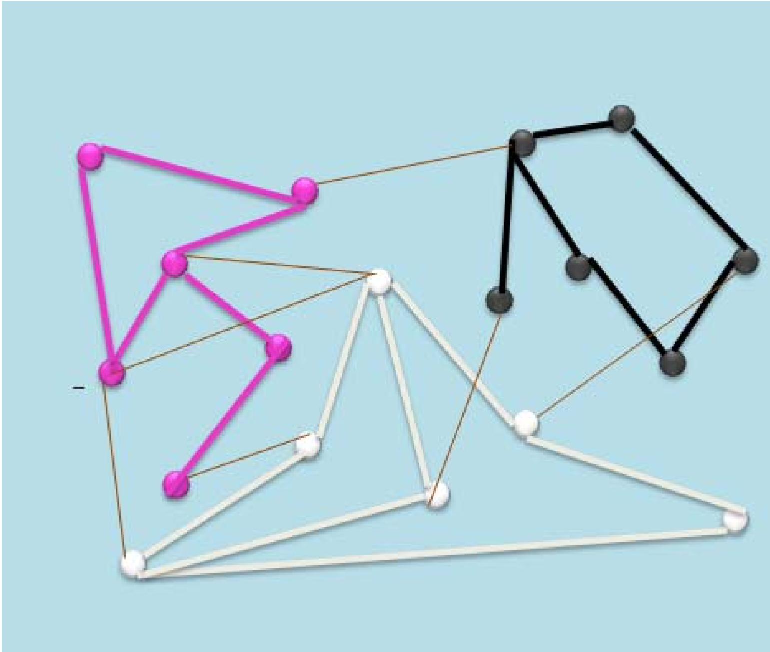


Figure 8.13: Knowledge sharing level in the simulated network based on ontology repository of the members

As can be seen in Figure 8.13, the thickness of the lines between members with the same ontology background is greater while the level of knowledge sharing between members from different backgrounds is low. The result supports the proposed framework for knowledge sharing measurement and is proof of the correctness of the knowledge sharing variables.

Overall, BISIM support the research concept and verify the effectiveness and correctness of the proposed knowledge sharing prototype in this thesis.

8.7 Conclusion

In this chapter, the BISIM simulator was introduced to simulate knowledge sharing between individuals from different ontologies with different trust levels. This simulation model is based on a simulator that was developed by Dr. Chen Wu to simulate a digital ecosystem versus traditional ecosystem. In a digital ecosystem, there are collaborative environments and traditional ecosystems from centralized or distributed or hybrid models that have been transformed into an open, flexible, domain cluster, demand-driven interactive cyber space. It was discussed that in a free and open environment, contribution, relationships and connections are the most important issues and trust as well as knowledge sharing are the most important variables in these kinds of ecosystems. In order for new ecosystems to be successful, it is necessary to control and improve the variables such as trust and knowledge sharing, and decision makers need tools with which to measure and control these variables. The BISIM Simulator seeks to create new business intelligence tools that provide useful knowledge to decision makers in a digital and competitive environment. Managers can follow up these variables and define or change their strategies based on the fluctuation of these variables. The simulator can be a suitable platform for future business intelligence applications to provide on time and reliable data for decision makers.

8.8 References

Elbashir, M. Z., Collier, P.A, Davern. M.J. (2008). Measuring the effect of business intelligence systems: The relationship between business process and organizational performance. International Journal of Accounting Information Systems, 9, 135-153.

Liao, S. S. (1988). The learning curve: Wright's model vs. Crawford's model. Issues in Accounting Education, Fall, 302-315.

Wu, C., Chang,E. (2007). Exploring a Digital Ecosystem Conceptual Model and Its Simulation Prototype. Proceedings of 2007 IEEE international symposium on industrial electronics, 2933-2938, Vigo, Spain, June 4-7.

Chapter 9: Experimental studies in knowledge sharing measurement

9.1 Overview

The major contributions of this dissertation are firstly, the variables that affect knowledge sharing including willingness-based trust, competence-based trust, knowledge complexity and knowledge transferability; secondly, the measurement of these variables and how these results are made available to decision makers. Finally, the value that can be created by these variables is measured. As was discussed in the previous chapters, competence-based trust and willingness-based trust have fuzzy entity and fuzzy logic systems can be applied to measure these variables. This chapter shows the result outcomes of the fuzzy logic system that is designed based on the theory in Chapter 7. In this proposed fuzzy logic system, both dimensions of trust are input variables. Knowledge complexity and knowledge transferability are another two variables that are used in the fuzzy logic systems as input variables. The outcome of the system is the level of knowledge sharing between individuals. Also presented in this chapter, are experimental studies to measure the complexity and transferability of a particular knowledge within a specific time slot and to measure knowledge sharing level at different levels of benevolence- and competence-based trust.

9.2 Variables in Fuzzy Logic systems

Two dimensions of trust including competence-based and benevolence-based trust were defined as input variables in knowledge sharing measurement. Base on discussion on fuzzy variables' membership function in chapter 5 (section 5.2.3), figures 9.1 and 9.2 show membership functions of competence-based and benevolence-based trust in fuzzy logic systems.

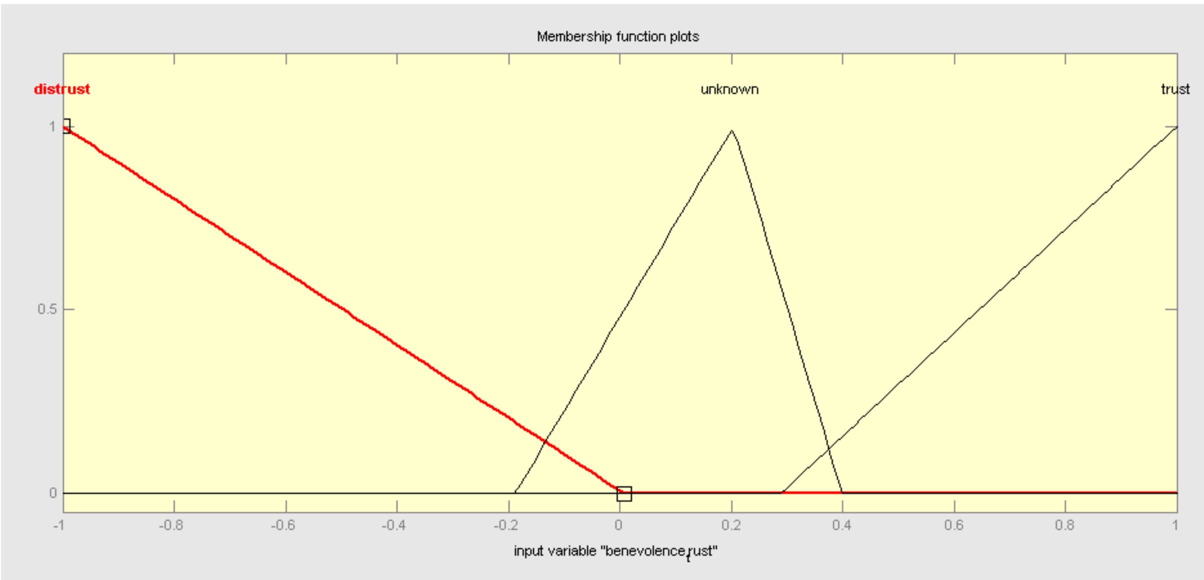


Figure 9.1: Membership function of benevolence trust

As shown in Figure 9.1, benevolence based of an individual to others can be distrust, unknown (when an individual do not familiar with another one and they want to just start a relationship) or trust. These objectives can be modified to 5 or more such as high trust, trust, low trust, unknown, distrust. Similar to benevolence trust, the function membership for competence-based trust has been shown in Figure 9.2 below.

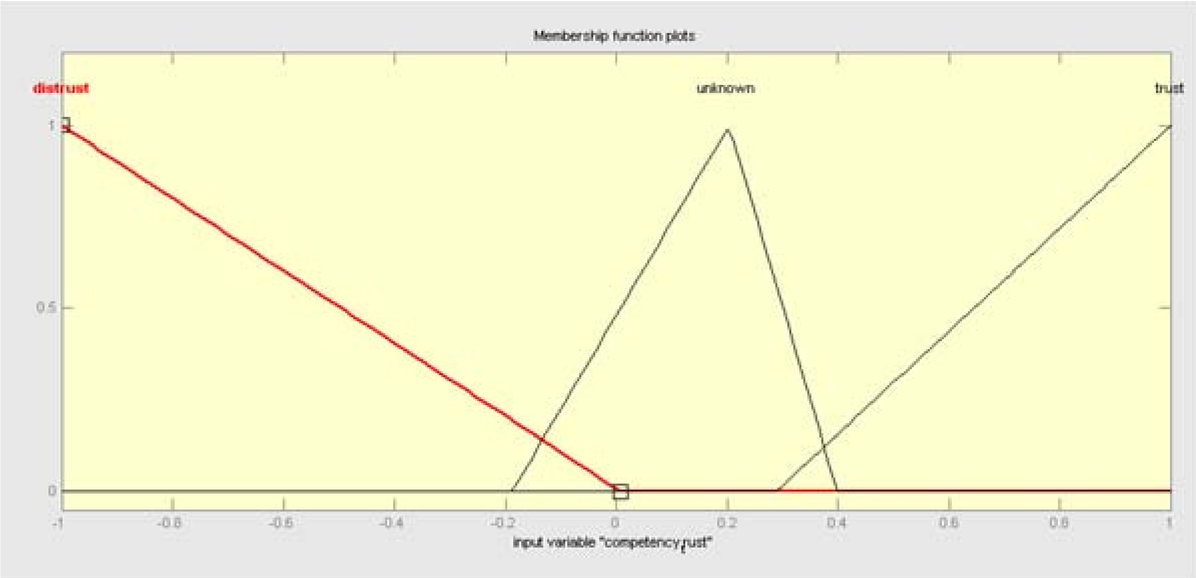


Figure 9.2: Membership function of competence trust

In the developed model, there are four input variables in the designed fuzzy logic system (Figure 9.3).

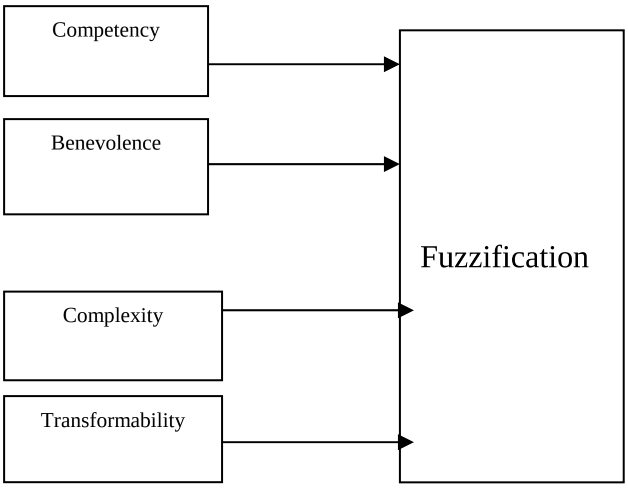


Figure 9.3: Input variables (benevolence & competence trust, complexity & transferability of knowledge) in fuzzy logic system

Figures 9.4 and 9.5 show the complexity and transferability function of members in the designed fuzzy logic system.

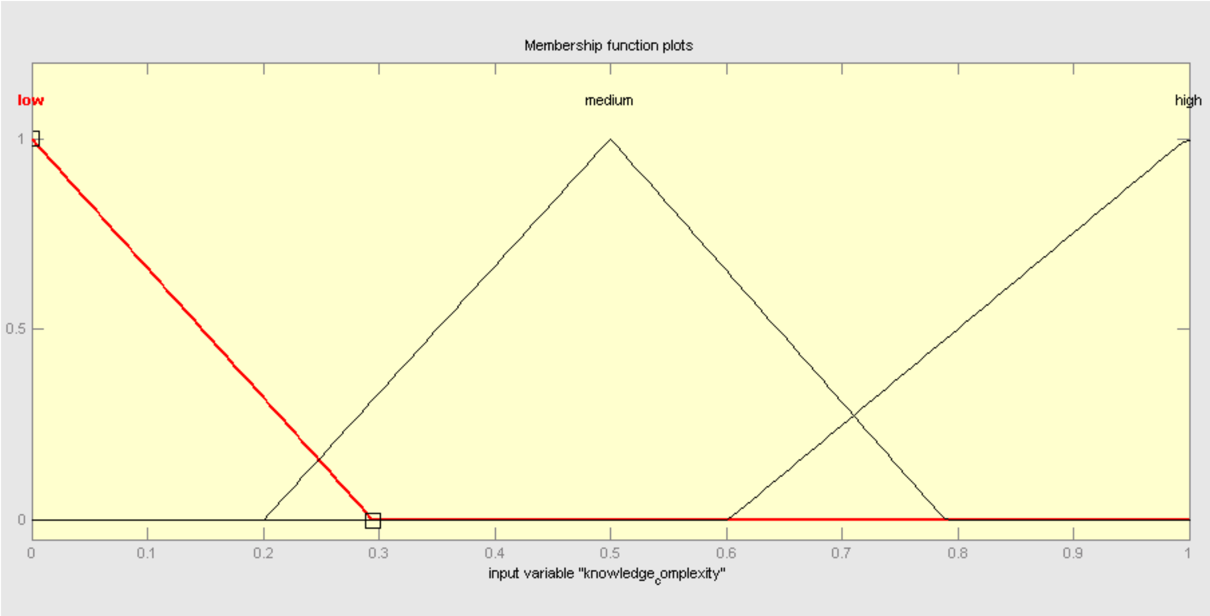


Figure 9.4: Knowledge complexity function membership

As clearly seen from Figure 9.4, knowledge complexity can be low, medium or high. These objectives can also be modified to very low, low, medium, high and extreme high. Figure 9.5 shows knowledge transferability function membership.

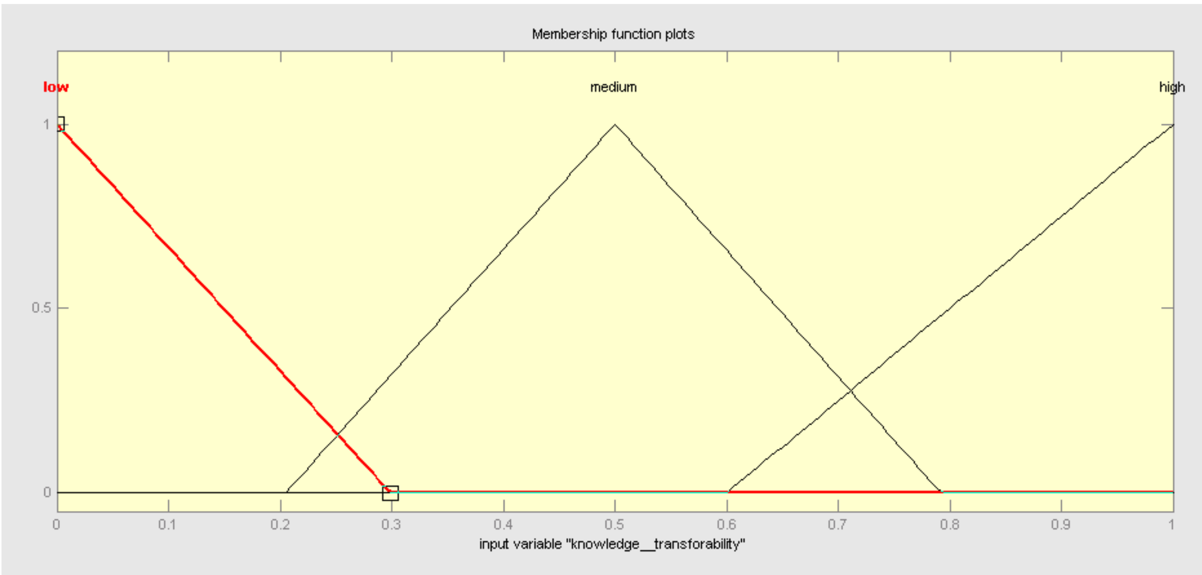


Figure 9.5: Knowledge transferability function membership

The output variable of this fuzzy logic system is the knowledge sharing value. Figure 9.6 shows the connection between input variables and the output variable.

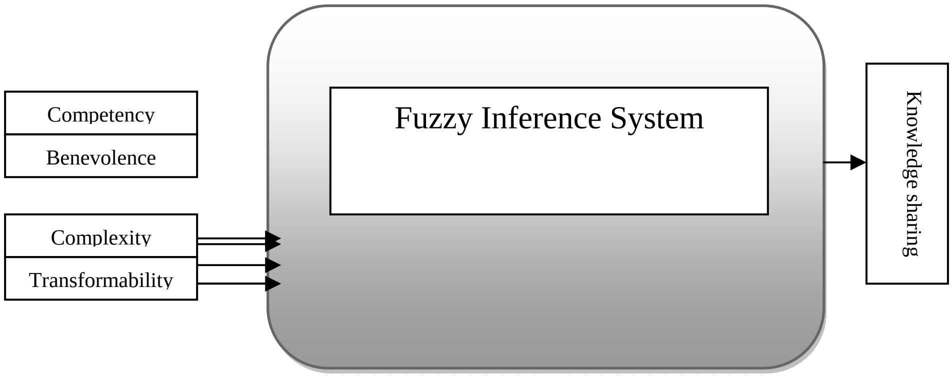


Figure 9.6: Output variable in the developed fuzzy logic system

Knowledge sharing level can also be low, medium or high. Figure 9.7 shows membership function of knowledge sharing.

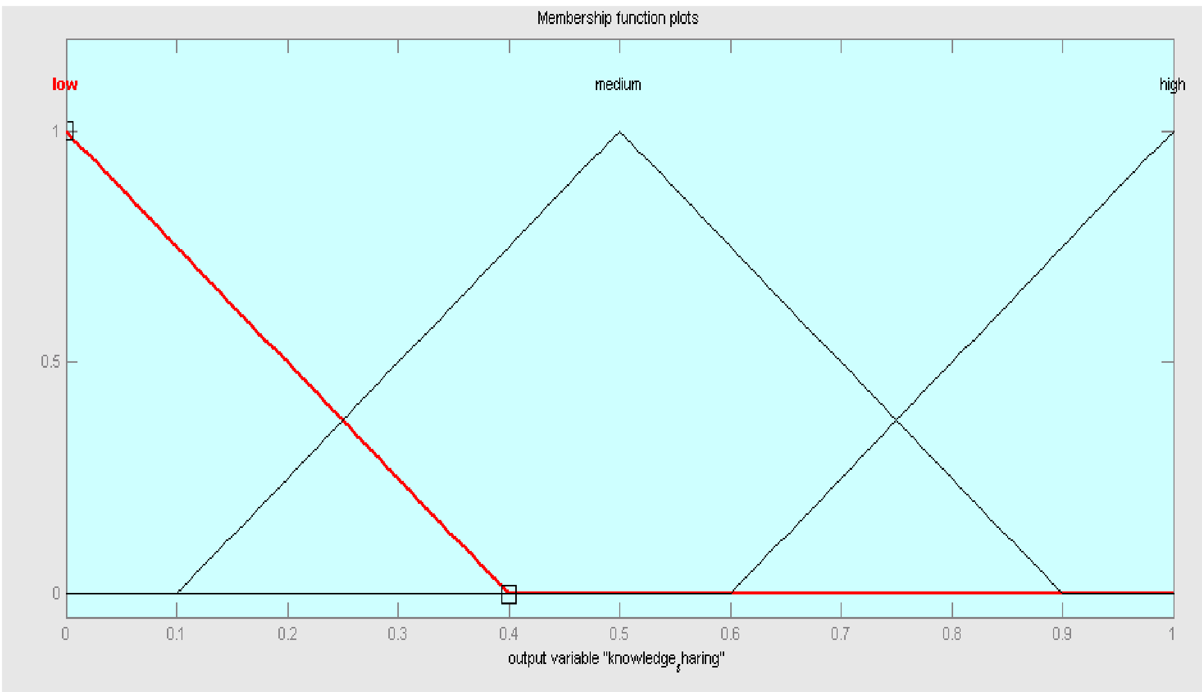


Figure 9.7: Knowledge sharing function membership

Based on input variables and the output variable, an overall view of the developed Fuzzy logic system has been presented in Figure 9.8.

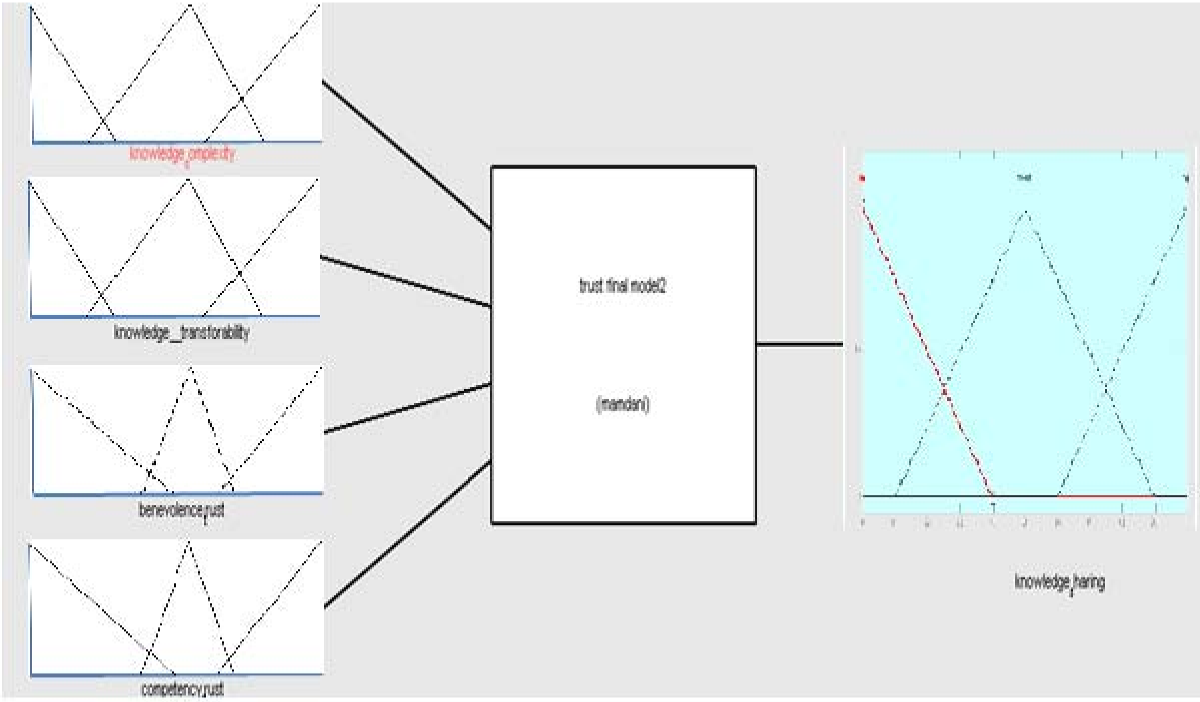


Figure 9.8: Overview of the fuzzy logic system in knowledge sharing measurement

In this research, the Mamdani fuzzy logic system is used to design and develop a knowledge sharing measurement fuzzy logic system. As shown in Figure 9.9, these kinds of fuzzy logic systems need fuzzy rules.

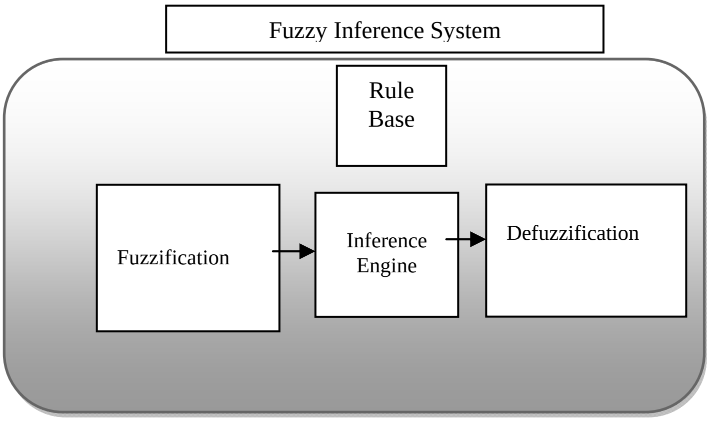


Figure 9.9: Fuzzy Inference System

In this sample, 81 fuzzy rules (each variable has 3 objects ^4 variables = 3^4=81) used to design the system. The fuzzy rules are based on the number of the objectives of each variable. Competence-based trust has three objectives including trust, unknown and distrust as well as other variables. Figure 9.10 below gives a brief overview of the rules in the designed fuzzy logic system.

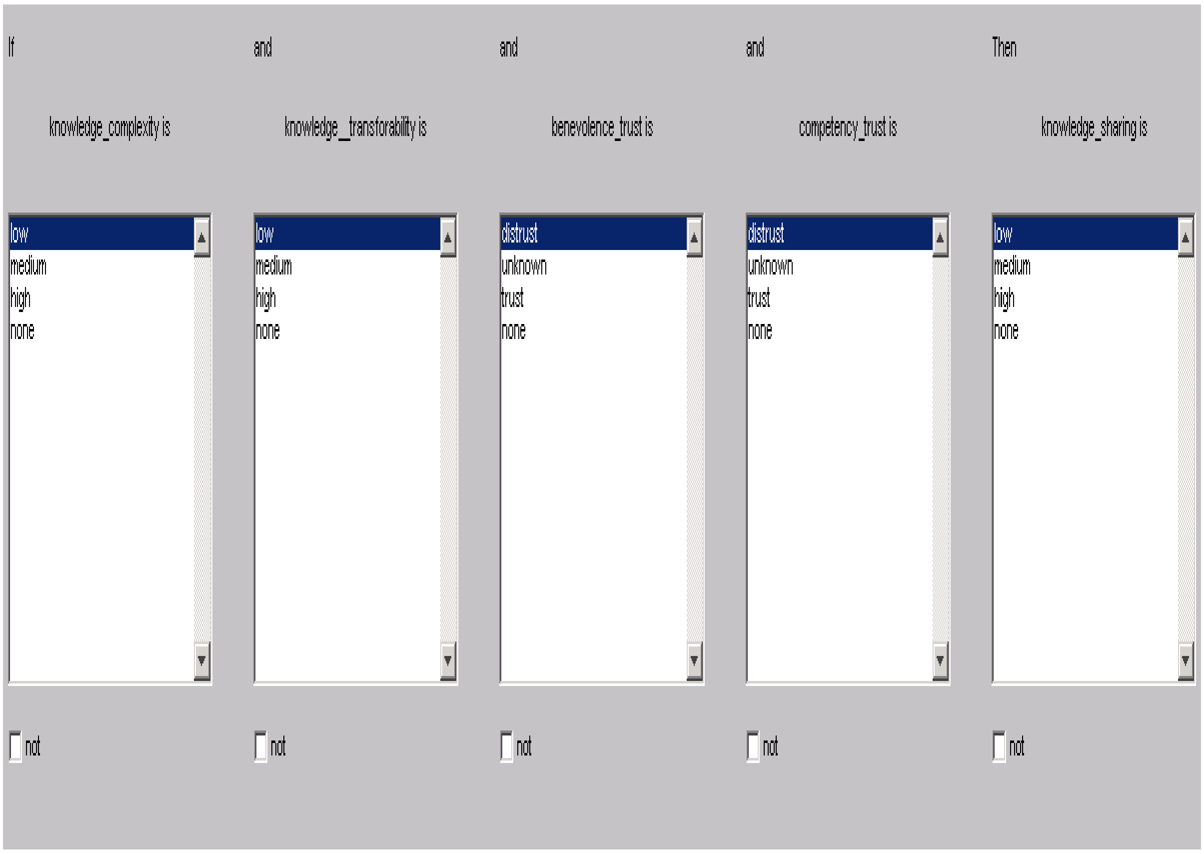


Figure 9.10: Brief overview of the rules in the designed fuzzy system

Figure 9.10 shows all the input and output variables have three objectives. Also, trust-based variables are between -1 and 1 and all other input and output variables are between 0 and 1. Based on the literature and the importance of each variable in knowledge sharing, and the value of the variables in Figure 9.10, fuzzy rules have been created. For example, low complex knowledge needs high benevolence trust and low competence trust. As a result, importance of benevolence trust in low complex knowledge is high. Similarly, for high transferable knowledge importance of competence-based trust is lower than benevolence-based trust.

9.3 Experimental studies in fuzzy logic systems

Before explaining the final results, the relationships between input variables and final results are investigated. Figure 9.11 shows the relationships between competence-based trust and benevolence-based trust in knowledge sharing.

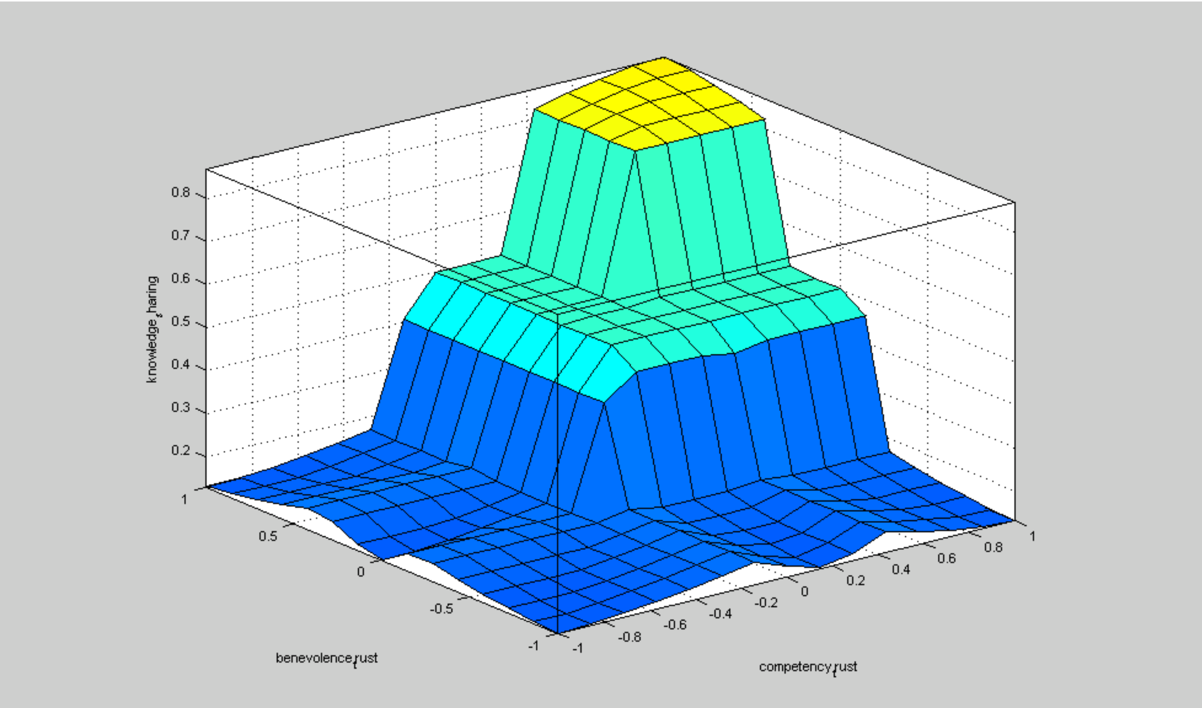


Figure 9.11: Relationship between trust dimensions and knowledge sharing

As shown in Figure 9.11, the highest level of knowledge sharing occurs when trust dimensions are at their highest levels. Knowledge sharing is very low when both dimensions of trust are negative or very low. Also, when an individual is unknown, trust levels are at an unknown level and knowledge sharing is at the middle level. However, in this situation, individuals evaluate other members and try to know more about the others.

Also, there is a relationship between the complexity or transferability of a knowledge and trust dimensions, and as discussed in Chapter 7, trust benevolence is important in less complex knowledge and competence-based trust is more important in highly complex knowledge. Figures 9.12 and 9.13 show the importance of trust dimensions in the sharing of complex or transferable knowledge.

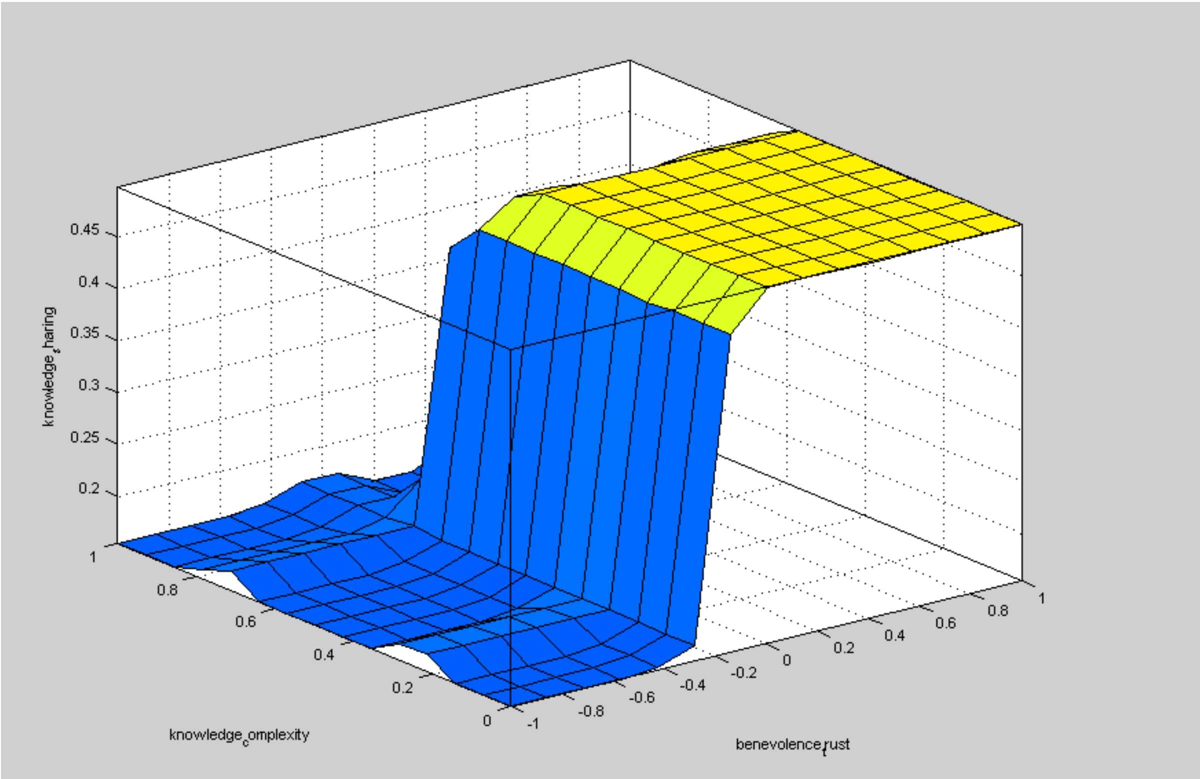


Figure 9.12: Benevolence trust role in sharing different complexity levels of knowledge

As is clear from Figure 9.12, low complex knowledge needs high levels of benevolence trust. In transferability of a particular knowledge, benevolence trust is a high priority where the knowledge is more transferable as is shown in Figure 9.13.

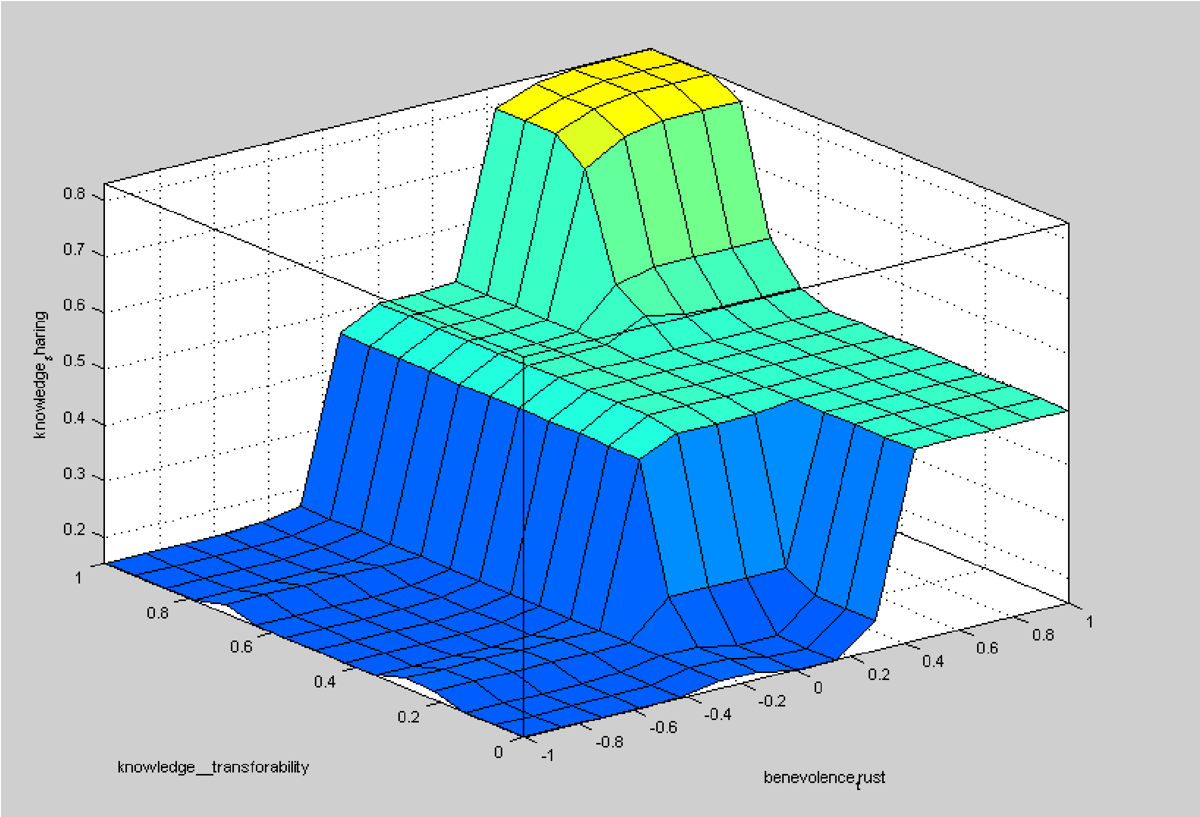


Figure9.13: Benevolence trust role in sharing different transferability levels of knowledge

Similarly to knowledge complexity, the transferability of a particular knowledge depends on trust dimensions, and for low transferable knowledge, a high level of competence-based trust is needed; for highly transferable knowledge, a high level of benevolence-based trust is required.

Based on the variables, the relationships between variables, and the developed fuzzy logic system, the final results are as shown in Figure 9.14. The most important issue is that the level of knowledge sharing is dynamic and depends on variables fluctuation such as trust fluctuation over time. As soon as one of the variables' value changes the level of knowledge sharing will also change. For example, figures 9.14 and 9.15 show effect of trust level fluctuation on knowledge sharing.

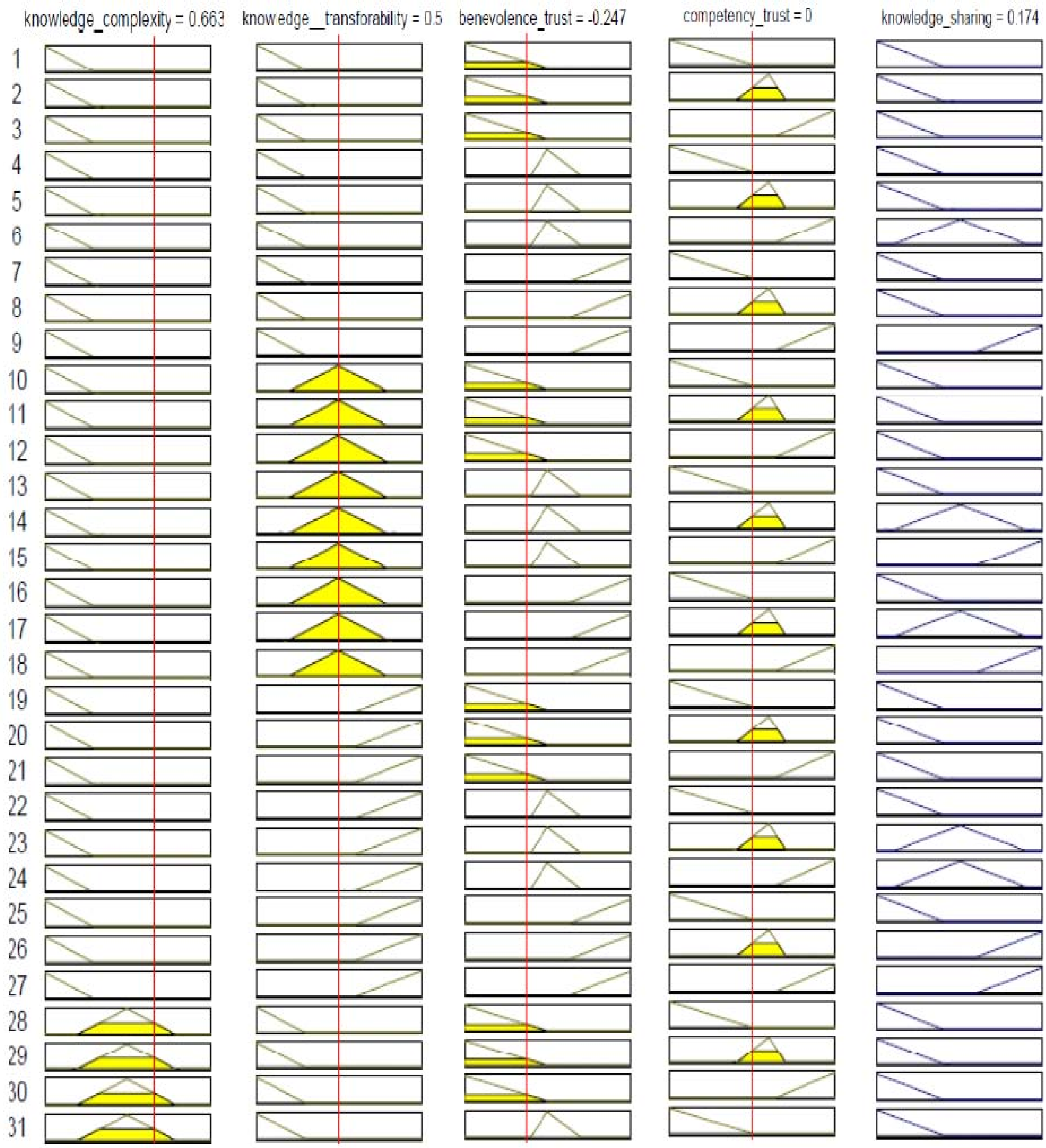


Figure 9.14: Final results in fuzzy logic systems

As seen in Figure 9.14, the model is dynamic and based on variables changes, the knowledge sharing level can be calculated. The different values of the variables and knowledge sharing level can be found in Figure 9.14. For example; where knowledge complexity is 0.663, transferability is 0.5, trust benevolence is negative and competency trust is unknown, knowledge sharing is low and is about 0.174.

In Figure 9.15, some variables are changed and the figure shows new results.

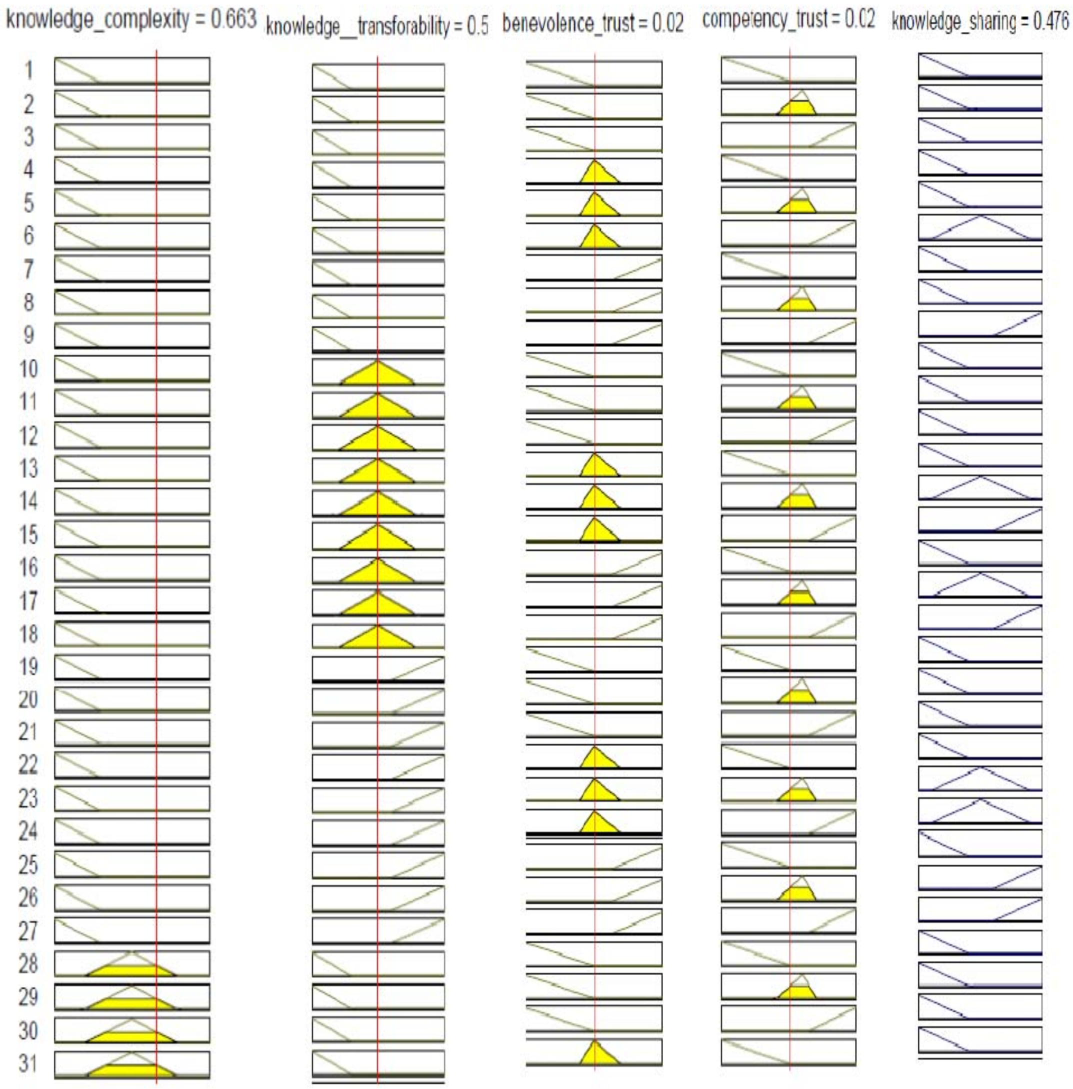


Figure 9.15: Changed final results in fuzzy logic systems

As shown in Figure 9.15, trust level is improved and knowledge sharing level increases to the middle level.

In the developed fuzzy logic system, input variables were assumed randomly and the results were calculated based on these assumptions. However, trust dimensions measurement and knowledge complexity measurement as well as transferability need to develop an application based on measurement techniques that were discussed in Chapters 5, 6 and 7. In the next part of this chapter, results for knowledge sharing framework are shown based on an application that is programmed to measure knowledge sharing levels, Knowledge complexity and transferability, and trust dimensions.

9.4 Experimental studies in the developed prototype

In this section, we present a prototype that has been designed and developed by using JAVA Programming language to measure all the input variables and finally measure knowledge sharing levels between individuals.

9.4.1 Trust measurement data

As was discussed in Chapters 5 and 7, trust between members of a community should be like a matrix and in the developed application trust dimensions input is an n*n matrix where n is the number of community members. Figure 9.16 shows a community with n members and trust dimensions between the members.

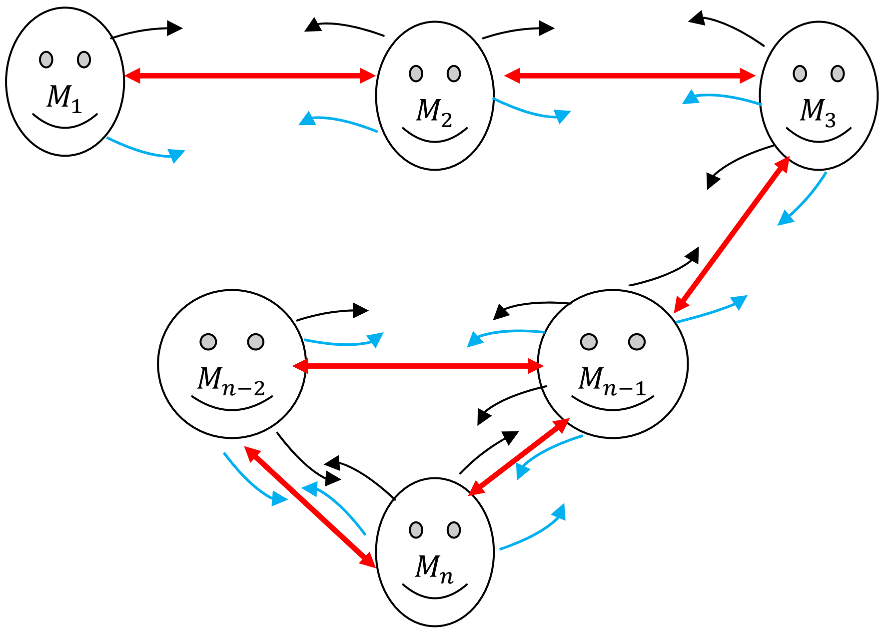


Figure 9.16: Sample community with n members

Based on Figure 9.16, trust matrices for benevolence-based trust and competence-based trust can be shown as follows:

Benevolence-based trust =Tb=

	1	2	3	…	n
1	1	$Tb1,2$	$Tb1,3$	...	$Tb1,n$
2	$Tb2,1$	1	$Tb2,3$	...	$Tb2,n$
3	$Tb3,1$	$Tb3,1$	1	...	$Tb3,n$
…	...	...	...	1	...
n	$Tbn,1$	$Tbn,2$	$Tbn,3$	...	1

Competence-based trust =

	1	2	3	…	n
1	1	$Tb1,2$	$Tb1,3$	...	$Tb1,n$
2	$Tb2,1$	1	$Tb2,3$	...	$Tb2,n$
3	$Tb3,1$	$Tb3,1$	1	...	$Tb3,n$
…	...	...	...	1	...
n	$Tbn,1$	$Tbn,2$	$Tbn,3$	...	1

Trust values can be assigned directly by the members regularly (for example monthly) or can be calculated by some software. An appropriate way to calculate trust value is by using AHP methodology (Analytical Hierarchy Process) that was discussed in detail in Chapter 5. And one of the most useful softwares in this issue is expert choice software. This software can consider all experts' ideas about the trust value of one member in another member and calculate the accurate trust level. Figure 9.17 gives a sample of expert choice software that is used to evaluate the performance of an employee and different experts such as his/her direct supervisor, manager, pair worker, subordinates and other related people have given their idea about this employee's performance. Similarly, the same process can be applied to measure trust levels based on different ideas of experts.

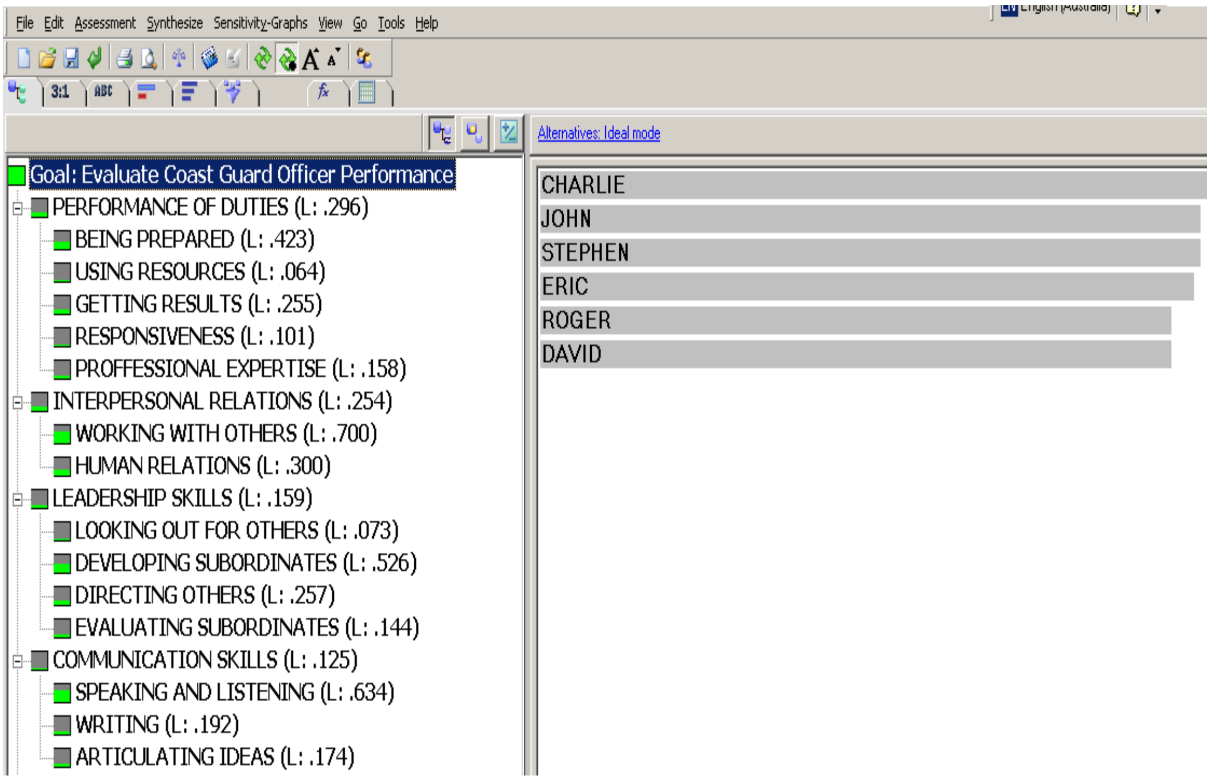


Figure 9.17: Example of expert choice software (Expert choice team, 2010)

The selected expert's ideas could be calculated in an equal weight or some of the expert's ideas could be assigned a higher importance. For example, direct supervisors, due to their high level of communication with employees, know more about them and their ideas may more important than those of indirect managers. Therefore, for each community, there are two trust repositories including a competence-based trust repository and a benevolence-based trust repository and each repository contains a matrix of trust values. In this research, it is assumed that the community being investigated is a normal community and the trust level is distributed throughout the whole the community based on normal distribution as shown in Figure 9.18.

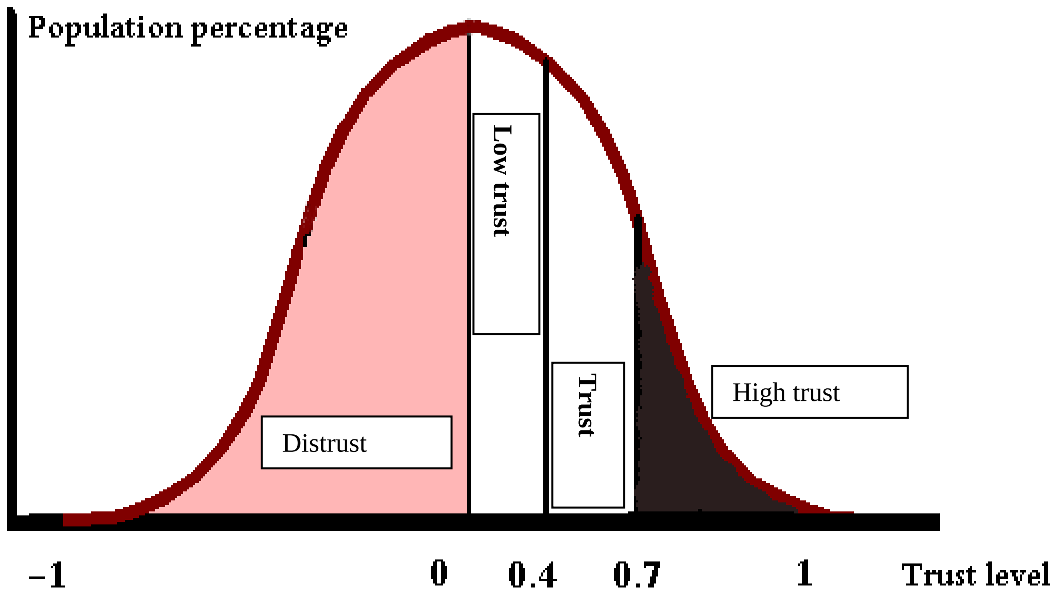


Figure 9.18: Normal trust level distribution used in this research

It is very important that consider the issue that trust level is dynamic and trust value should be determined in a specific time slot and t_0 is the time that this research uses to calculate the trust levels. Also, trust depends on knowledge ontology that is discussed in the next section. The importance of trust for different kinds of knowledge is different. For example, as discussed earlier, low complex trust needs high benevolence-based trust. To address these issues in knowledge sharing measurement prototype, some rules are applied based on Figure 9.19.

Figure 9.19 shows trust classification in the developed prototype and as is clear from the figure, both of the trust dimensions are divided into four categories: high trust, low trust and distrust.

	Trust					
	trust benevolence			trust competency		
	min	max	Mean	min	Max	mean
high trust	0.9	1	0.95	0.9	1	0.95
	0.8	0.9	0.85	0.8	0.9	0.85
	0.7	0.8	0.75	0.7	0.8	0.75
trust	0.6	0.7	0.65	0.6	0.7	0.65
	0.5	0.6	0.55	0.5	0.6	0.55
	0.4	0.5	0.45	0.4	0.5	0.45
low trust	0.3	0.4	0.35	0.3	0.4	0.35
	0.2	0.3	0.25	0.2	0.3	0.25
	0.1	0.2	0.15	0.1	0.2	0.15
	0	0.1	0.05	0	0.1	0.05
dis trust	-0.1	0	-0.05	-0.1	0	-0.05
	-0.2	-0.1	-0.15	-0.2	-0.1	-0.15
	-0.3	-0.2	-0.25	-0.3	-0.2	-0.25
	-0.4	-0.3	-0.35	-0.4	-0.3	-0.35
	-0.5	-0.4	-0.45	-0.5	-0.4	-0.45
	-0.6	-0.5	-0.55	-0.6	-0.5	-0.55
	-0.7	-0.6	-0.65	-0.7	-0.6	-0.65
	-0.8	-0.7	-0.75	-0.8	-0.7	-0.75
	-0.9	-0.8	-0.85	-0.9	-0.8	-0.85
	-1	-0.9	-0.95	-1	-0.9	-0.95

Figure 9.19: Trust dimensions classification in the model

Similarly, knowledge complexity and transferability are discussed in the next part of the chapter.

9.4.2 Knowledge related variables measurement in sample ontologies

This system requires two ontology files which present the backgrounds of the two members who are sharing the knowledge and in this experiment pizza ontologies are used for the two people. One ontology is related to meat pizza ontology and another one related to vegetarian pizza ontology, both of which were discussed in Chapter 6. Also, it is necessary to obtain the trust benevolence and competency between these two people as input. The system can calculate the differences between these two ontology files and the sharing values according to the knowledge terms that users use in knowledge sharing. As a sample, for this research, two knowledge exchangers have been chosen, one of which uses vegetarian pizza ontology and the other uses meat pizza ontology and they want to share knowledge about "pizza". Figure 9.20 gives an overview of this sample where the sender's ontology is related to vegetarian pizza ontology and the receiver's ontology is related to meat pizza ontology.

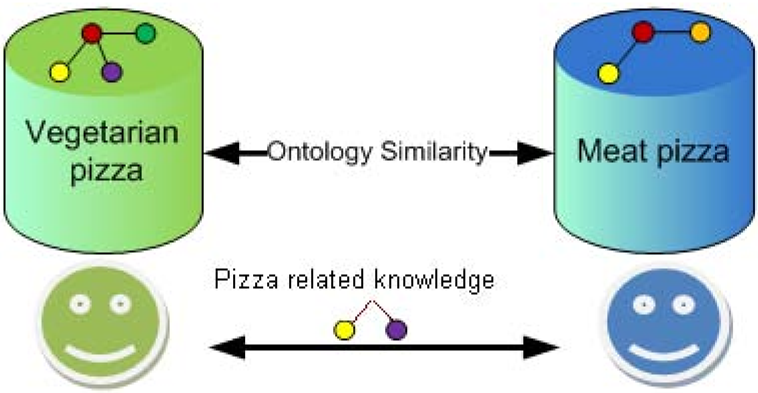


Figure 9.20: Knowledge sharing between two different ontologies – pizza not topping, vegetable pizza

As can be seen in Figure 9.20, two different ontologies are used between two knowledge exchangers in this case. Two different ontologies have been modified as meatyPizza.owl ontology and vegetarianPizza.owl ontology. In this research, open online sources are used to define these two different ontologies.

Also, sub-classes and properties are defined for each class as shown in Figure 9.21.

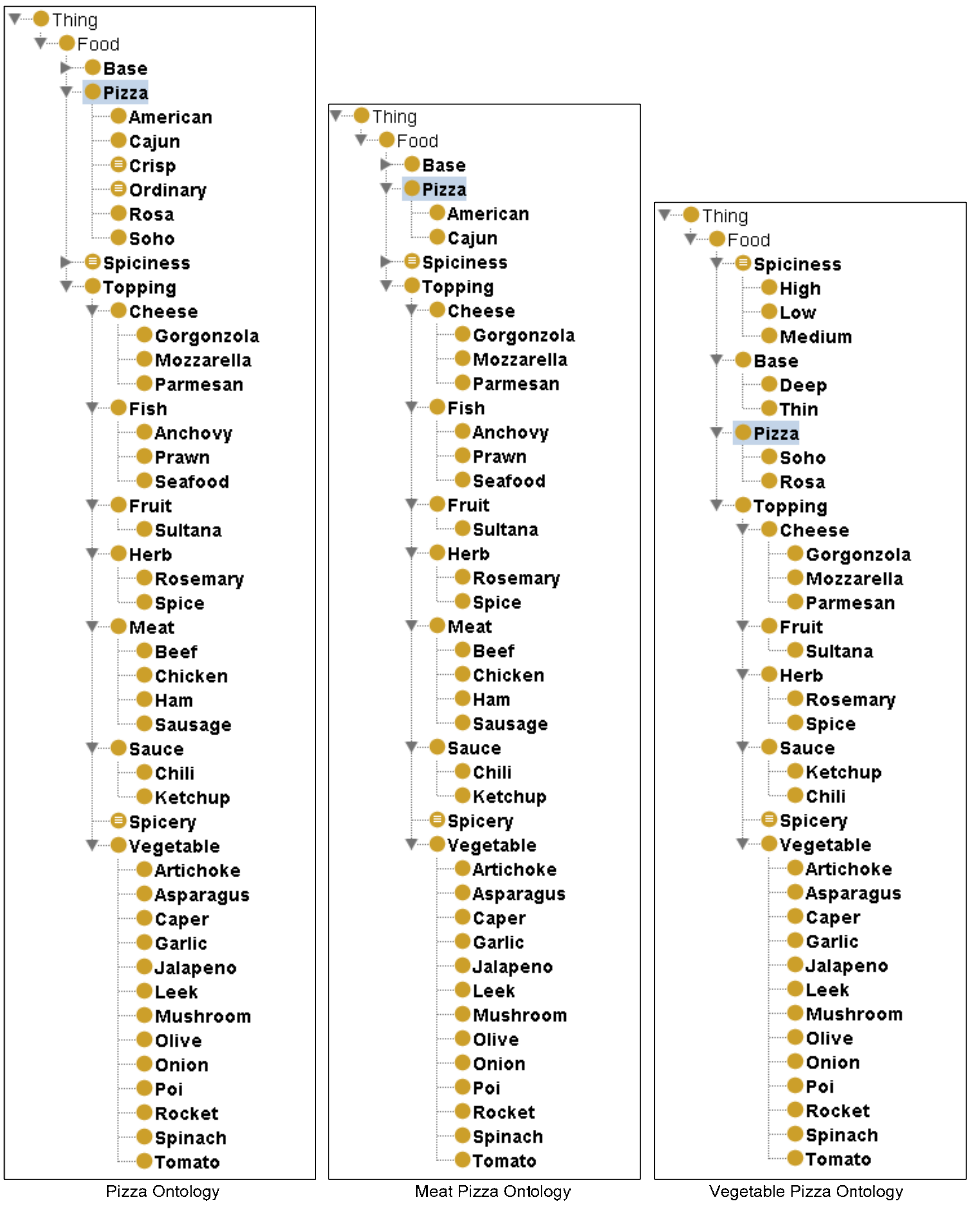


Figure 9.21: Classes, subclasses and properties

Knowledge complexity and transferability are also categorized as is seen in Figure 9.22 below.

	knowledge					
	knowledge complexity			knowledge transferability		
	min	max	mean	Min	Max	Mean
high complex	0.95	1	0.975	0.95	1	0.975
	0.9	0.95	0.925	0.9	0.95	0.925
	0.85	0.9	0.875	0.85	0.9	0.875
	0.8	0.85	0.825	0.8	0.85	0.825
	0.75	0.8	0.775	0.75	0.8	0.775
complex	0.7	0.75	0.725	0.7	0.75	0.725
	0.65	0.7	0.675	0.65	0.7	0.675
	0.6	0.65	0.625	0.6	0.65	0.625
	0.55	0.6	0.575	0.55	0.6	0.575
	0.5	0.55	0.525	0.5	0.55	0.525
low complex	0.45	0.5	0.475	0.45	0.5	0.475
	0.4	0.45	0.425	0.4	0.45	0.425
	0.35	0.4	0.375	0.35	0.4	0.375
	0.3	0.35	0.325	0.3	0.35	0.325
	0.25	0.3	0.275	0.25	0.3	0.275
simple	0.2	0.25	0.225	0.2	0.25	0.225
	0.15	0.2	0.175	0.15	0.2	0.175
	0.1	0.15	0.125	0.1	0.15	0.125
	0.5	0.1	0.3	0.5	0.1	0.3
	0	0.5	0.25	0	0.5	0.25

Figure 9.22: Knowledge complexity and knowledge transferability classification

9.4.3 Knowledge sharing measurement results

Based on knowledge sharing measurement formula that was proposed in Chapter 7 (Equation 7.9), there are four auxiliary variables in the formula and these four variables are classified based on their value in Figure 9.23.

	K1			K2			K3			K4		
	min	max	mean	min	max	mean	Min	max	mean	min	Max	mean
very important	0.95	1	0.975	0.95	1	0.975	0.95	1	0.975	0.95	1	0.975
	0.9	0.95	0.925	0.9	0.95	0.925	0.9	0.95	0.925	0.9	0.95	0.925
	0.85	0.9	0.875	0.85	0.9	0.875	0.85	0.9	0.875	0.85	0.9	0.875
	0.8	0.85	0.825	0.8	0.85	0.825	0.8	0.85	0.825	0.8	0.85	0.825
	0.75	0.8	0.775	0.75	0.8	0.775	0.75	0.8	0.775	0.75	0.8	0.775
important	0.7	0.75	0.725	0.7	0.75	0.725	0.7	0.75	0.725	0.7	0.75	0.725
	0.65	0.7	0.675	0.65	0.7	0.675	0.65	0.7	0.675	0.65	0.7	0.675
	0.6	0.65	0.625	0.6	0.65	0.625	0.6	0.65	0.625	0.6	0.65	0.625
	0.55	0.6	0.575	0.55	0.6	0.575	0.55	0.6	0.575	0.55	0.6	0.575
	0.5	0.55	0.525	0.5	0.55	0.525	0.5	0.55	0.525	0.5	0.55	0.525
low important	0.45	0.5	0.475	0.45	0.5	0.475	0.45	0.5	0.475	0.45	0.5	0.475
	0.4	0.45	0.425	0.4	0.45	0.425	0.4	0.45	0.425	0.4	0.45	0.425
	0.35	0.4	0.375	0.35	0.4	0.375	0.35	0.4	0.375	0.35	0.4	0.375
	0.3	0.35	0.325	0.3	0.35	0.325	0.3	0.35	0.325	0.3	0.35	0.325
	0.25	0.3	0.275	0.25	0.3	0.275	0.25	0.3	0.275	0.25	0.3	0.275
not important	0.2	0.25	0.225	0.2	0.25	0.225	0.2	0.25	0.225	0.2	0.25	0.225
	0.15	0.2	0.175	0.15	0.2	0.175	0.15	0.2	0.175	0.15	0.2	0.175
	0.1	0.15	0.125	0.1	0.15	0.125	0.1	0.15	0.125	0.1	0.15	0.125
	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3	0.5	0.1	0.3
	0	0.5	0.25	0	0.5	0.25	0	0.5	0.25	0	0.5	0.25

Figure 9.23: Auxiliary variables value classification

Figure 9.24 shows the level of importance of K1 and K2 as two auxiliary variables in the proposed formula (Chapter7, Equation 7.9) in knowledge complexity measurement.

knowledge complexity	trust competency	trust benevolence	K1	K2
highly complex	high trust	high trust	VERY IMPORTANT	not important
highly complex	high trust	trust	VERY IMPORTANT	not important
highly complex	high trust	low trust	VERY IMPORTANT	not important
highly complex	high trust	Distrust	VERY IMPORTANT	0.001
highly complex	trust	high trust	VERY IMPORTANT	not important
highly complex	trust	trust	VERY IMPORTANT	not important
highly complex	trust	low trust	VERY IMPORTANT	not important
highly complex	trust	Distrust	VERY IMPORTANT	0.001
highly complex	low trust	high trust	VERY IMPORTANT	not important
highly complex	low trust	trust	VERY IMPORTANT	not important
highly complex	low trust	low trust	VERY IMPORTANT	not important
highly complex	low trust	Distrust	VERY IMPORTANT	0.001
highly complex	distrust	high trust	0.001	not important
highly complex	distrust	trust	0.001	not important
highly complex	distrust	low trust	0.001	not important
highly complex	distrust	Distrust	0.001	0.001

Figure 9.24 Auxiliary variables importance in a high complex knowledge

As is shown in Figure 9.24, the importance of trust competency (that is shown byK1) in a high complex knowledge is very high. Figure 9.25 shows the importance of k3 and k4 (Chapter 7, Equation 7.10) when knowledge is high transferable.

knowledge transferability	trust competency	trust benevolence	K3	K4
highly transferable	high trust	high trust	not important	VERY IMPORTANT
highly transferable	high trust	trust	not important	VERY IMPORTANT
highly transferable	high trust	low trust	not important	VERY IMPORTANT
highly transferable	high trust	Distrust	not important	0.001
highly transferable	trust	high trust	not important	VERY IMPORTANT
highly transferable	trust	trust	not important	VERY IMPORTANT
highly transferable	trust	low trust	not important	VERY IMPORTANT
highly transferable	trust	Distrust	not important	0.001
highly transferable	low trust	high trust	not important	VERY IMPORTANT
highly transferable	low trust	trust	not important	VERY IMPORTANT
highly transferable	low trust	low trust	not important	VERY IMPORTANT
highly transferable	low trust	Distrust	not important	0.001
highly transferable	distrust	high trust	0.001	VERY IMPORTANT
highly transferable	distrust	trust	0.001	VERY IMPORTANT
highly transferable	distrust	low trust	0.001	VERY IMPORTANT
highly transferable	distrust	Distrust	0.001	0.001

Figure 9.25: Auxiliary variables' importance in highly transferable knowledge

S importance of trust dimensions for other levels of knowledge complexity (complex, low complex, simple) and knowledge transferability (transferable, low transferable, hard transferable) have been shown in Appendix 2.

Based on the main and auxiliary variables, a prototype is implemented in JAVA and uses JDK1.6, JWNL 1.4 to retrieve WordNet 2.0 and OWLAPI 2.2.0 to read ontology files. For different values of trust between knowledge exchangers, the result for knowledge sharing between two members from two ontologies (meat pizzas ontology and vegetarian pizza ontology) and the knowledge that was discussed in Chapter 6 is shown in the tables below (it is assumed that the knowledge sender is from the meat pizza ontology and knowledge receiver is from the vegetable pizza ontology):

CaseNo	k1	k2	k3	k4	Kc	Kt	Tb	Tc	KS1	% of KS1
1	0.2	0.8	0.8	0.2	0.32323	0.75	1	1	0.7134	71.34
2	0.2	0.8	0.8	0.2	0.32323	0.75	1	0.8	0.6398	63.98
3	0.2	0.8	0.8	0.2	0.32323	0.75	0.8	1	0.6442	64.42
4	0.2	0.8	0.8	0.2	0.32323	0.75	0.8	0.8	0.5707	57.07
5	0.2	0.8	0.8	0.2	0.32323	0.75	0.8	0.4	0.4236	42.36
6	0.2	0.8	0.8	0.2	0.32323	0.75	0.4	0.8	0.4324	43.24
7	0.2	0.8	0.8	0.2	0.32323	0.75	0.4	0.1	0.1751	17.51
8	0.2	0.8	0.8	0.2	0.32323	0.75	0.1	0.4	0.1816	18.16
9	0.2	0.8	0.8	0.2	0.32323	0.75	0.001	0.001	0.0007	0.07
10	0.2	0.001	0.999	0.001	0.32323	0.75	-0.8	0.8	0.3533	35.33
11	0.2	0.001	0.999	0.001	0.32323	0.75	-0.6	0.6	0.2650	26.50
12	0.2	0.001	0.999	0.001	0.32323	0.75	-0.1	0.4	0.1768	17.68
13	0.001	0.8	0.001	0.225	0.32323	0.75	0.8	-0.8	0.2835	28.35
14	0.001	0.8	0.001	0.225	0.32323	0.75	0.6	-0.6	0.2126	21.26
15	0.001	0.8	0.001	0.225	0.32323	0.75	0.4	-0.1	0.1420	14.20
16	0.001	0.001	0.001	0.001	0.32323	0.75	-0.8	-0.1	0.0004	0.04
17	0.001	0.001	0.001	0.001	0.32323	0.75	-0.6	-0.5	0.0002	0.02
18	0.001	0.001	0.001	0.001	0.32323	0.75	-0.4	-0.8	0.0001	0.01
19	0.001	0.001	0.001	0.001	0.32323	0.75	-0.1	-0.9	0.0003	0.03
20	0.001	0.001	0.001	0.001	0.32323	0.75	-0.8	-0.8	0.0011	0.00
21	0.001	0.001	0.001	0.001	0.32323	0.75	-1	-0.8	0.0013	0.00
22	0.001	0.001	0.001	0.001	0.32323	0.75	-0.8	-1	0.0013	0.00

Table9.1: Knowledge sharing result for knowledge sender

Table 9.1 shows the results for one party in the knowledge sharing process. As can be seen in Table 9.1, the shared knowledge is more complex and also more transferable. Complexity of the knowledge reduces the knowledge sharing level and for different levels of trust values, knowledge sharing level is calculated by the model. The results should be compared with results of another party as, in the proposed model, the final knowledge sharing level is the minimum value of the knowledge sharing level between two parties. Results for another party are given in Table 9.2.

CaseNo	k5	k6	k7	k8	K'c	K't	T'b	T'c	KS2	%KS2
1	0.1	0.9	0.8	0.2	0.85	0.964	1	1	0.5570	55.70
2	0.1	0.9	0.8	0.2	0.85	0.964	1	0.8	0.4784	47.84
3	0.1	0.9	0.8	0.2	0.85	0.964	0.8	1	0.5242	52.42
4	0.1	0.9	0.8	0.2	0.85	0.964	0.8	0.8	0.4456	44.56
5	0.1	0.9	0.8	0.2	0.85	0.964	0.8	0.4	0.2884	28.84
6	0.1	0.9	0.8	0.2	0.85	0.964	0.4	0.8	0.3800	38.00
7	0.1	0.9	0.8	0.2	0.85	0.964	0.4	0.1	0.1049	10.49
8	0.1	0.9	0.8	0.2	0.85	0.964	0.1	0.4	0.1736	17.36
9	0.1	0.9	0.8	0.2	0.85	0.964	0.001	0.001	0.0006	0.06
10	0.1	0.001	0.999	0.001	0.85	0.964	-0.8	0.8	0.3908	39.08
11	0.1	0.001	0.999	0.001	0.85	0.964	-0.6	0.6	0.2931	29.31
12	0.1	0.001	0.999	0.001	0.85	0.964	-0.1	0.4	0.1956	19.56
13	0.001	0.9	0.001	0.225	0.85	0.964	0.8	-0.8	0.1403	14.03
14	0.001	0.9	0.001	0.225	0.85	0.964	0.6	-0.6	0.1052	10.52
15	0.001	0.9	0.001	0.225	0.85	0.964	0.4	-0.1	0.0703	7.03
16	0.001	0.001	0.001	0.001	0.85	0.964	-0.8	-0.1	0.0005	0.05
17	0.001	0.001	0.001	0.001	0.85	0.964	-0.6	-0.5	0.0004	0.04
18	0.001	0.001	0.001	0.001	0.85	0.964	-0.4	-0.8	0.0003	0.03
19	0.001	0.001	0.001	0.001	0.85	0.964	-0.1	-0.9	0.0004	0.04
20	0.001	0.001	0.001	0.001	0.85	0.964	-0.8	-0.8	0.0001	0.01
21	0.001	0.001	0.001	0.001	0.85	0.964	-1	-0.8	0.0001	0.01
22	0.001	0.001	0.001	0.001	0.85	0.964	-0.8	-1	0.0001	0.01

Table 9.2: Knowledge sharing level for another party

And in the final stage, the results of Table 9.1 and Table 9.2 are compared and the final knowledge sharing level is calculated and presented in Table 9.3.

CaseNo	KS1	KS2	KS	%KS
1	0.7134	0.5570	0.5570	55.70
2	0.6398	0.4784	0.4784	47.84
3	0.6442	0.5242	0.5242	52.42
4	0.5707	0.4456	0.4456	44.56
5	0.4236	0.2884	0.2884	28.84
6	0.4324	0.3800	0.3800	38.00
7	0.1751	0.1049	0.1049	10.49
8	0.1816	0.1736	0.1736	17.36
9	0.0007	0.0006	0.0006	0.06
10	0.3533	0.3908	0.3533	35.33
11	0.2650	0.2931	0.2650	26.50
12	0.1768	0.1956	0.1768	17.68
13	0.2835	0.1403	0.1403	14.03
14	0.2126	0.1052	0.1052	10.52
15	0.1420	0.0703	0.0703	7.03
16	0.0004	0.0005	0.0004	0.04
17	0.0002	0.0004	0.0002	0.02
18	0.0001	0.0003	0.0001	0.01
19	0.0003	0.0004	0.0003	0.03
20	0.0011	0.0001	0.0001	0.01
21	0.0013	0.0001	0.0001	0.01
22	0.0013	0.0001	0.0001	0.01

Table 9.3: Final result in knowledge sharing calculation between two parties

As seen in Table 9.3, the maximum knowledge sharing level between these two parties is 55.70% and it occurs when both parties have a high level of trust to another parties. As the shared knowledge (knowledge related to pizza topping) is more complex, competence trust is more important than benevolence trust.

9.5 Data analysis

Based on the data in Tables 9.1, 9.2 and 9.3, results can be discussed using the figures. Figure 9.26 shows the knowledge sharing level for the measured complexity level of knowledge (.85) for different trust levels and in a meat ontology (transferability =.964).

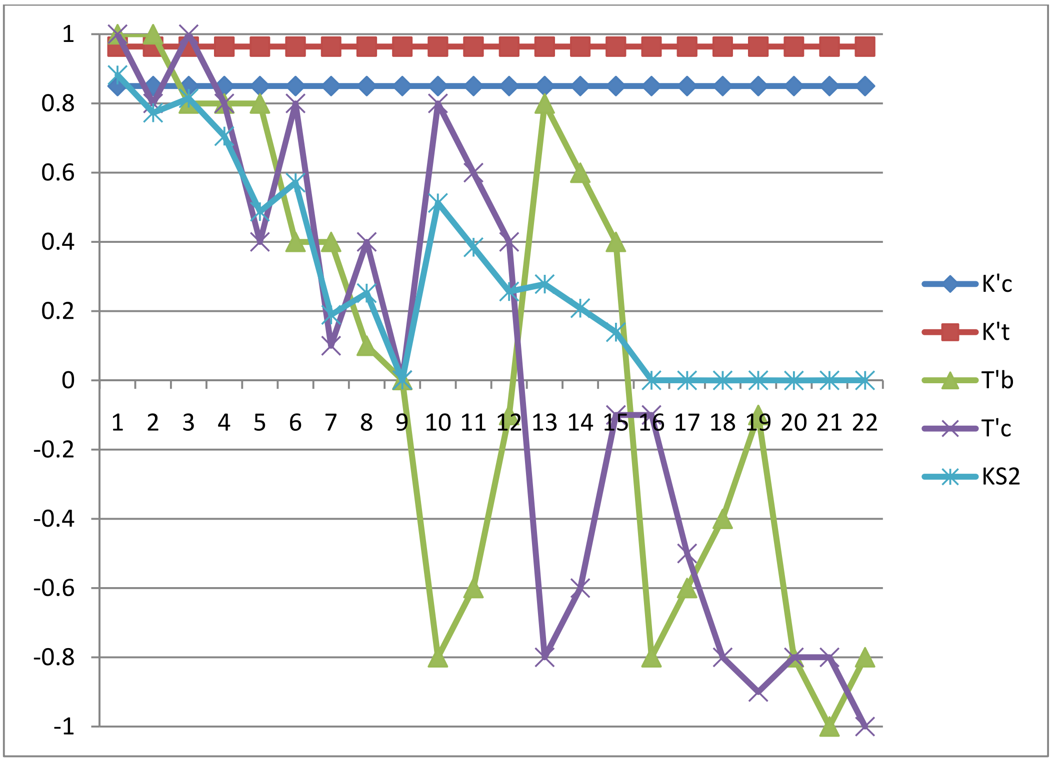


Figure 9.26: Knowledge sharing of complex knowledge at different trust levels (transferability=.96)

As seen in Figure 9.26, for high levels of benevolence and competence, trust knowledge sharing is high. Knowledge sharing is almost zero when trust dimensions are less than zero and it shows that distrust between knowledge sharing parties causes knowledge sharing to stop and communication fails between two parties.

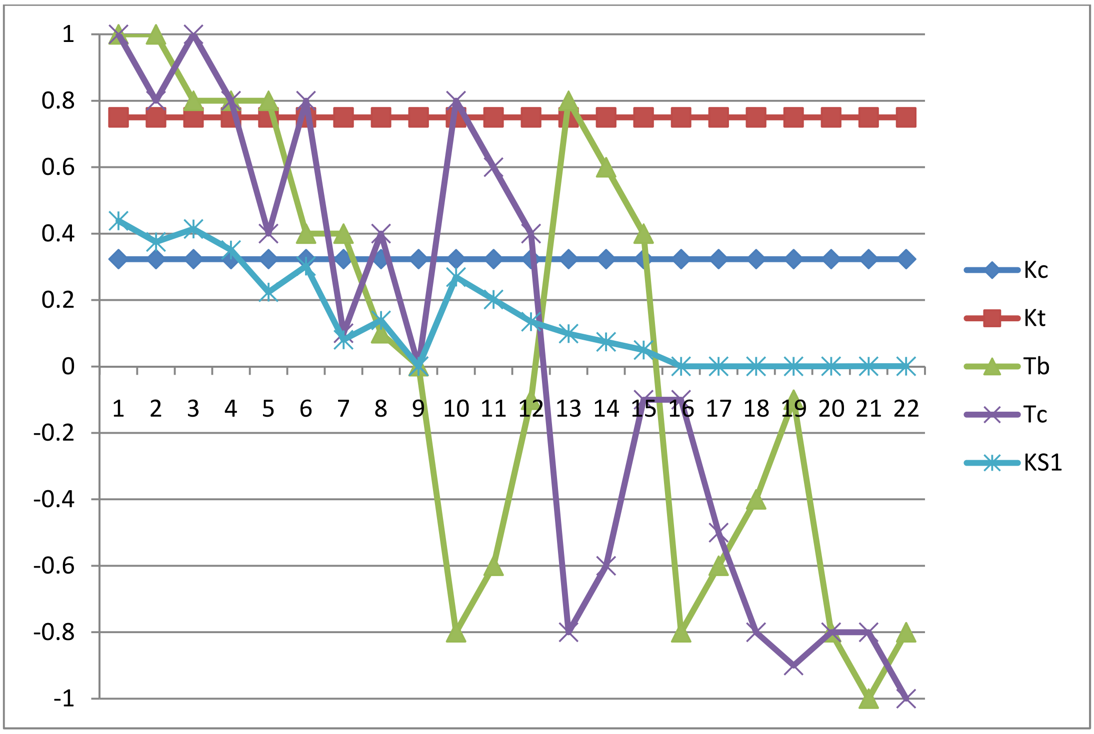


Figure 9.27: Knowledge sharing in low complex knowledge (Transferability=1)

As seen in Figure 9.27, if complexity of the shared knowledge decreases to 0.32 (transferability is 0.75), the knowledge sharing level will be changed based on trust dimensions values. As seen in Figure 9.27, knowledge sharing level is improved due to less complexity of the knowledge(0.32<0.75).

Similarly, Figures 9.28 and 9.29 show knowledge sharing level at different levels of knowledge transferability and complexity. In Figure 9.28, knowledge complexity is reduced to 0.2 and with same values of knowledge transferability in the Figure 9.26.

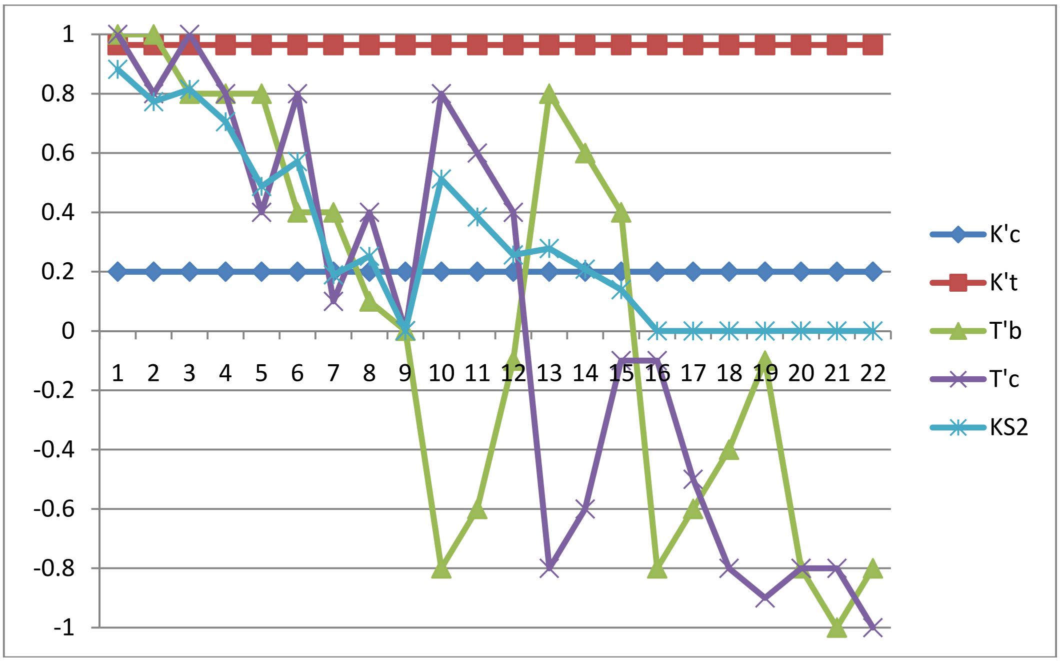


Figure 9.28: Knowledge sharing of complex knowledge at different trust levels (complexity=.2)

As seen in Figure 9.28, the knowledge sharing level is improved when the knowledge is at a lower level of complexity. And Figure 9.29 shows the knowledge sharing level when complexity of the shared knowledge is 0.32 and transferability is reduced to 0.2.

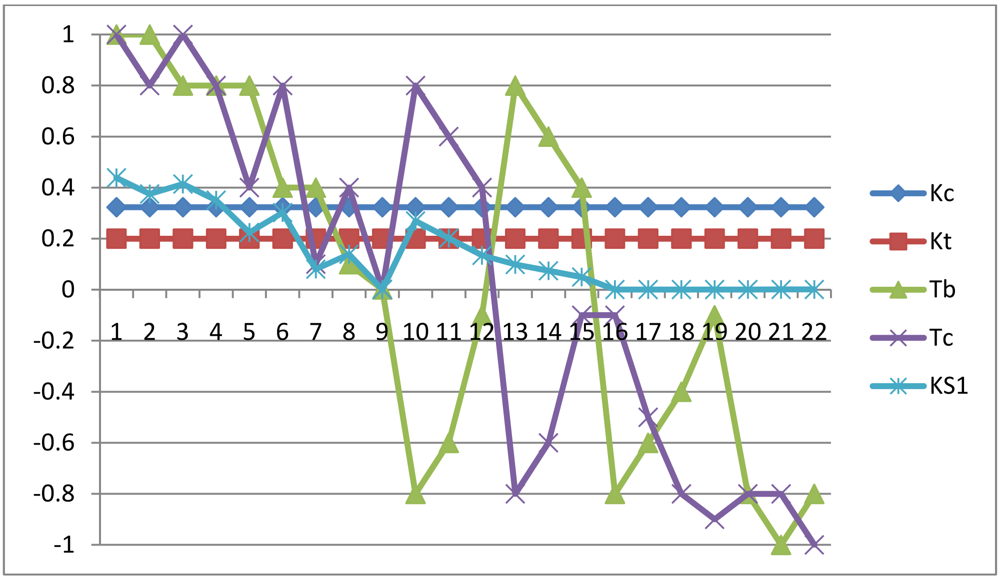


Figure 9.29: Knowledge sharing of low complexity knowledge (Transferability=.2)

Figure 9.29: indicates that when knowledge transferability is reduced and knowledge complexity is at the same level as it was in Figure 9.27, the knowledge sharing level is also reduced (it is assumed that trust levels remain the same)

The maximum knowledge sharing happen where knowledge is less complex and more transferable and competence trust and willingness trust are at the highest level. Figure 9.30 shows the highest level of knowledge sharing.

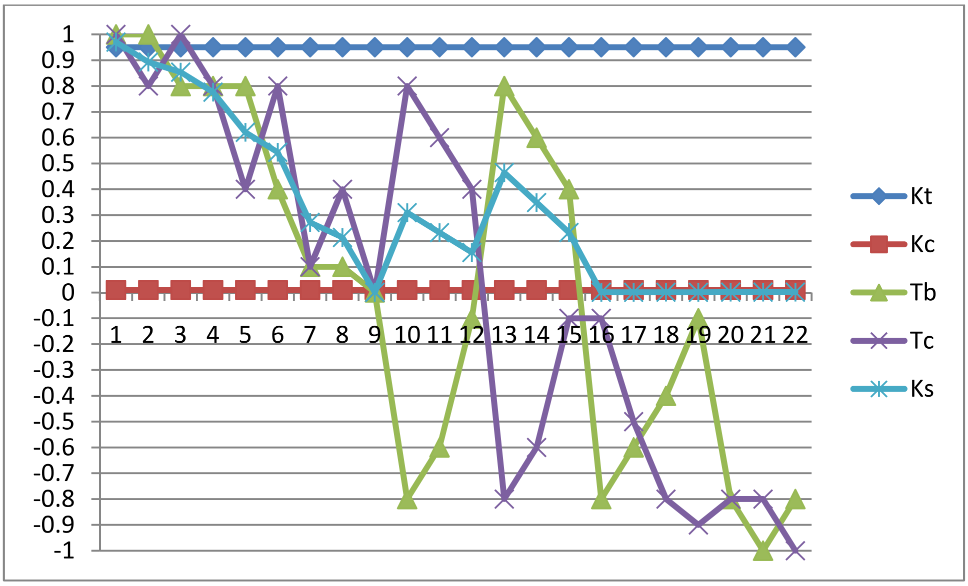


Figure 9.30: High levels of knowledge sharing (Kt=0.95 and Kc=0.1)

As seen in Figure 9.30, low complexity and highly transferable knowledge with high levels of competence trust and high levels of benevolence trust produce high levels of knowledge sharing.

9.6 Discussion of results support for the prototype

10 Research outcomes support the correctness, completeness and effectiveness of the knowledge sharing variables in the proposed

framework. To evaluate the importance of trust-based variables, the knowledge sharing level is measured when the level of trust between members of a network is low or negative. As indicated by Figure 9.31, the knowledge sharing level is almost zero and knowledge cannot be disseminated when members of a network have negative trust in each other.

knowledge complexity	knowledge transferability	Trust competency	Trust benevolence	knowledge sharing
0.32323	0.75	-0.8	-0.1	0.0004
0.32323	0.75	-0.6	-0.5	0.0002
0.32323	0.75	-0.4	-0.8	0.0001
0.32323	0.75	-0.1	-0.9	0.0003
0.32323	0.75	-0.8	-0.8	0.0011
0.32323	0.75	-1	-0.8	0.0013
0.32323	0.75	-0.8	-1	0.0013

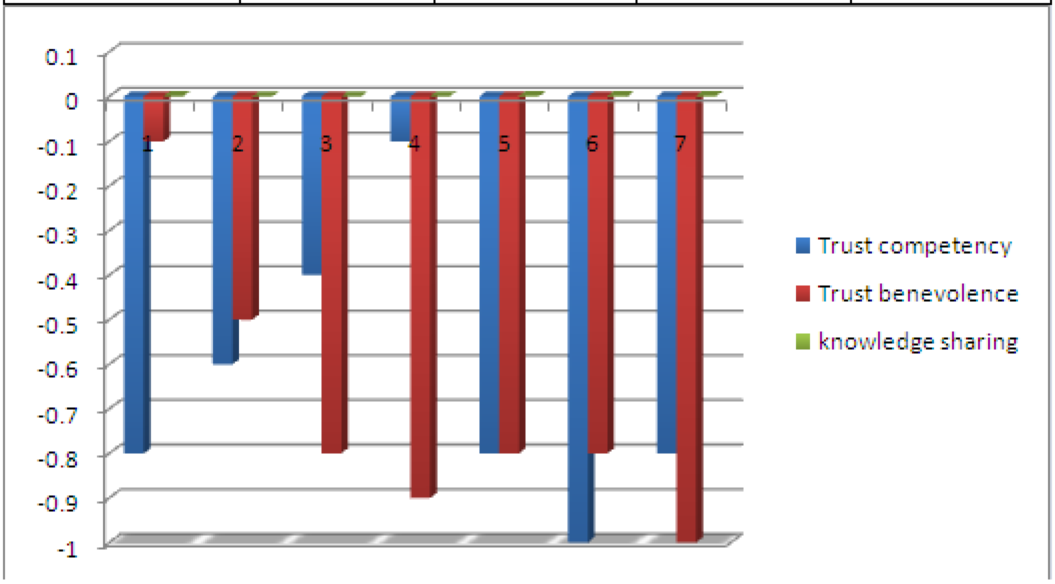


Figure 9.31: Importance of trust in knowledge sharing

It can be deduced from Figure 9.31 that competence-based trust and benevolence trust are effective variables and should be considered in any framework related to knowledge sharing measurement. To discover more about the role of trust-based variables in knowledge sharing, it is useful to compare Figure 9.31 with Figure 9.32.

knowledge complexity	knowledge transferability	Trust competency	Trust benevolence	knowledge sharing
0.32323	0.75	1	1	0.7134
0.32323	0.75	1	0.8	0.6398
0.32323	0.75	0.8	1	0.6442
0.32323	0.75	0.8	0.8	0.5707
0.32323	0.75	0.8	0.4	0.4236
0.32323	0.75	0.4	0.8	0.4324

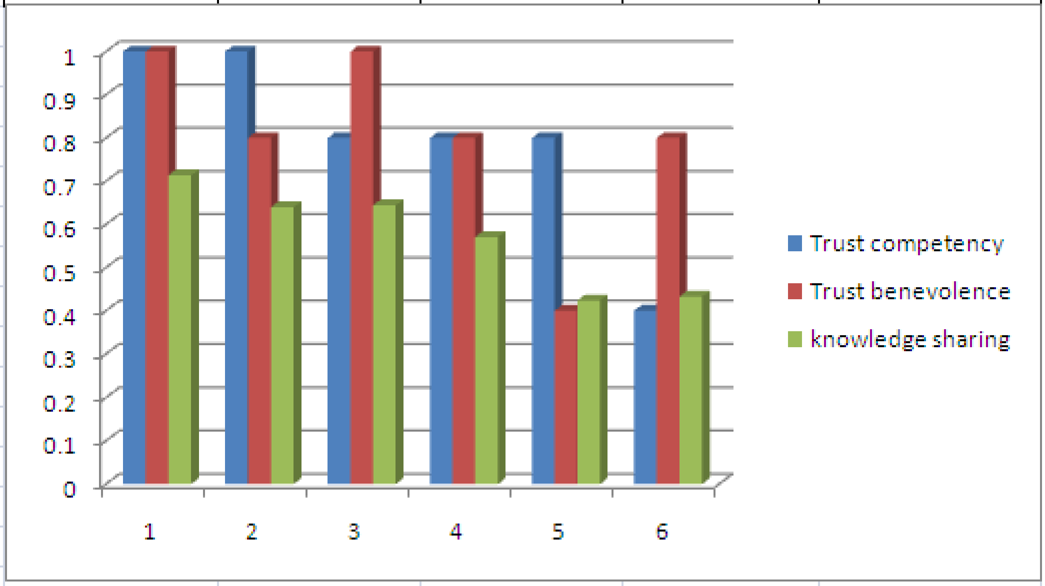


Figure 9.32: Importance of positive trust in knowledge sharing

Comparing Figures 9.31 and 9.32, it is clear that trust is a key variable in knowledge sharing measurement and it verifies the correctness and effectiveness of the trust-based knowledge sharing variables in the proposed framework. Also, the research outcomes support the idea that complexity and transferability of a particular knowledge are the correctness and effectiveness variables in knowledge sharing. Figure 9.33 shows knowledge sharing levels between network members when all the members have high a level of trust in each other (competency trust value= benevolence trust value=1).

knowledge complexity	knowledge transferability	trust competency	trust benevolence	knowledge sharing
0.05	0.98	1	1	0.9635
0.2	0.98	1	1	0.881
0.4	0.82	1	1	0.699
0.4	0.62	1	1	0.609
0.6	0.42	1	1	0.409
0.8	0.25	1	1	0.2225
0.95	0.255	1	1	0.14225

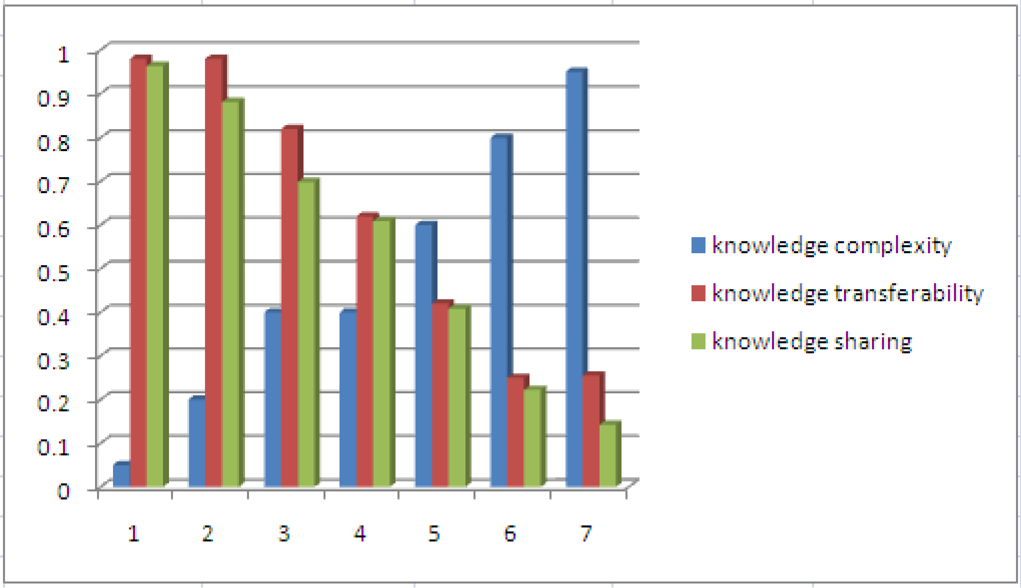


Figure 9.33: Importance of complexity and transferability of knowledge in knowledge sharing

As can be seen in Figure9.33, although the trust level between members is the same for all members of the network and equal to one, the knowledge sharing level has decreased due to the increase in complexity and decrease in transferability of the knowledge. The result demonstrates the correctness of the variables related to complexity and transferability and verifies the knowledge sharing variables proposed in the framework.

9.7 Conclusion

This chapter discusses the research outcomes in fuzzy logic systems and also in the developed system to measure knowledge sharing based on the proposed framework presented in Chapter 7. In a fuzzy logic system, variables are defined in fuzzy Mamdani systems and fuzzy rules are applied to measure knowledge sharing. The main processes in this system include fuzzification, fuzzy Reasoning and defuzzification. The results in fuzzy logic systems are discussed in this chapter and outcomes are indicated. The rest of the chapter focuses on research outcomes of the system that is developed to measure complexity and transferability of a particular knowledge based on ontologies repositories. The system is designed to calculate the main variables in the proposed model and measure knowledge sharing levels based on measured variables. The results obtained from the developed system are discussed, with several figures and different levels of knowledge sharing being indicated.

9.8 References

Expert choice team. (2010). software sample (Publication. Retrieved 20 July, 2010, from http://www.expertchoice.com).

Chapter 10: Knowledge capital in knowledge sharing

10.1 Overview

For many years, physical asset indicators have been used as the main evidence of an organization's successful performance. However, the situation has changed following the information technology revolution in the knowledge-based economy and the new ideas that have emerged in the field of economy. Brain power has become the most important factor in economic life, and business performance has not been limited only to physical assets. This is the age of intellectual capital, which is defined as the collective ideas, innovation, reputation, trust, knowledge sharing and so on. Intellectual capital (IC) is used in this research to measure knowledge capital that can be created by knowledge sharing and trust in an organization and classified to three categories: human capital, social capital and market capital. In recent years, based on the information technology revolution and due to the fast growth of communication tools, communication within organizations, between employees, customers and market components has now become the most important asset in a knowledge-based economy and knowledge sharing can increase the value of a firm. In a knowledge-based economy, knowledge is a core competency and the key to competitive advantage for businesses. The knowledge is derived from either internal or external resource data. Also, knowledge validity and trust between agents of the business such as customers-to-customers, employees-to-employees, employers-to-employees, employers-to-customers are major components of the modern business environment. As was discussed in the literature, after the1980s, different measurement methods have been presented which focus on intellectual capital such as Balanced Scorecard method (BSC), Skandia navigator model, Investor assigned market value. However, “Trust” and “Knowledge/knowledge sharing” are important variables in intellectual capital evaluation that are not covered by the current models. In this chapter, based on the proposed framework of knowledge sharing, a trust- and knowledge sharing-based model is proposed to increase the intellectual capital of an organization as much as possible by creating a knowledge sharing network and optimizing the way that a particular knowledge can be shared within a network.

10.2 Knowledge and Trust in Intellectual Capital

Trust is a vital issue in creating a relationship that adds value to knowledge sharing and should be discussed in all kinds of intellectual capital. Social capital, human capital and market capital are all based on trust and it can be assumed that trust is a key variable in intellectual capital measurement. Additionally and importantly, knowledge itself cannot lead to success, as knowledge sharing and knowledge flow is of prime importance in an organization. Knowledge sharing depends on trust between trusted and trusting agents in a specific knowledge context and within a specific time slot.

Based on the definition of intellectual capital and all the variables that were discussed previously, equation 10.1 is used to calculate intellectual capital within a community:

$$\text{Intellectual capital} = f\ (\text{social capital, human capital, market capital})$$

(Equation 10.1)

This research focuses on the value that knowledge sharing can create within a community or an organization. Social capital, human capital and market capital and relations between these assets with knowledge sharing are discussed in this section.

10.2.1 Social Capital Measurements

Social capital in this research is more related to people's willingness to make connections and the density of the information that is transmitted in those connections. Social capital can be calculated by the number of connections, and information density within a particular time slot. The following formula shows the proposed method for measuring social capital in a network with n members:

$$\text{TSC (t)} = \sum SC(Ri,j)$$

$$\text{While } 0 \le i \le n \times (n-1)/2,\ 0 \le j \le n \times (n-1)/2$$

TSC: Total social capital, SC: Current social capital, t: At time t, Rij: Relation between agent i and agent j, n: Number of members in the network

(Equation 10.2)

The above equation shows that the total social capital can be calculated by the value of all relations in the time t. The relation between social capital in time t1 and social capital in time t0 is shown below.

$$\sum \Delta SC(i,j) = \sum (KS(i,j) \text{x } Fv(i,j))$$

While 0≤i≤n x (n-1)/2, 0≤j≤n x (n-1)/2

Fv = time + budget + opportunity cost required to spend to increase social capital in the time slot, $KS(i,j)$ = knowledge sharing level between i and j that is shared in communication

(Equation 10.3)

The method that is used to measure social capital considers the costs that persons incur to create or improve their social capital including time, direct cost, and opportunity cost.

10.2.2 Human Capital Measurements

In order to measure human capital, it is necessary to measure the knowledge value of education, innovation, and skills. Knowledge value of education can be calculated by measuring cost incurred to gain the knowledge. In this method, it is assumed that education is a product that one buys and pays for. Thus, all of the costs involved in the process of gaining a formal education are calculated. The main costs for this category are as follows:

Investment – Investment in a formal education system such as cost of education in school, university, and some short-term courses or any tuition fee one pays to obtain knowledge in a formal environment.

Time – Time that one spends in the class including studying time and time related to the education system.

Opportunity cost – Opportunity cost is related to the cost of the opportunities that one loses due to spending time and money on education. For example, if one continues his/her Masters degree and does not work, s/he cannot earn money and loses some opportunities.

Also, human capital includes the knowledge value of skills. Basically, skills are gained from experience. In this category, the main costs are as follows:

Cost of training – this kind of cost is related to job training, mentoring training and all the costs business firms incur to improve their employee's knowledge.

Cost of experience – practice can improve people's productivity and business firms spend huge sums of money on their employees to increase their experience. This experience is a valuable asset and most of the business firms try to recruit experienced people from their competitors.

Time and opportunity cost – business firms invest in a new employee who has just filled the position to improve knowledge up to the required level. Business firms also lose opportunities in the labor market.

Human capital also includes the knowledge value of innovation and it is related to people's competency in innovation and creativity. Although basic knowledge is important in this category, the most important parameter here is environment. A dynamic environment may be the ideal environment to enhance the employees' competency and a high level of trust is the important variable in creating this environment. The total value of human capital is the sum of these three categories.

10.2.3 Market Capital Measurements

In the economy field, there is marginal propensity to buy, sell, or replace and analyze business components. Different components of a business are listed below.

1. SuPplier to COmpany (SPCO)
2. SuPplier to CoMpetitor (SPCM)
3. COmpany to CuStomer (COCS)
4. CuStomer to CuStomer (CSCS)
5. Potential Customer to COmpany (PCCO)

These different categories of market capital can be calculated using the following equation:

$$\text{TMC (t0)} = \sum \text{MC}(R(i,j)) \text{while } 0 \leq i \leq n \text{ x } (n\text{-}1)/2,\ 0 \leq j \leq n \text{ x } (n\text{-}1)/2$$

(Equation 10.4)

$$\text{TMC (t1)} = \text{TMC (t0)} + \sum (KS(i,j) \text{x } Fv(i,j)$$

(Equation 10.5)

TMC: Total market capital, MC: Current market capital, Rij: Relation between customer i and customer j , n: Number of the customers in target markets, $KS(i,j)$:Knowledge sharing density between customer i and customer j, $Fv(i,j)$:Value of the shared knowledge between customer i and customer j

From the business perspective, the marginal propensity to sell or buy refers to market components and their decision to sell or buy. Marginal propensity is related to different variables such as customer expectation, wealth, replacement cost, emergence need and some other variables that affect on buying or selling a product or service. In a business interaction, it is necessary that the value of market capital (MC (t1)) for each market component be equal to or greater than marginal propensity(MP(t1)).

$$MC(i) => MP(i)$$

i=member i, $MC(i) = market\ capital\ for\ member\ i,$

$MP(i) = marginal\ propensity\ for\ member\ i$

(Equation 10.6)

In company-to-customer or company-to-supplier relationships, the time and money necessary to build market capital should be spent by the company. However, exploiting the customer-to-customer relationship is the best option for a business where the cost and time to improve market capital are spent by the business' customers. New promotion plans such as "word of mouth" are created based on customer-to-customer relations to improve the embedded market capital of customers.

To calculate the knowledge capital that can be created by knowledge sharing in each category of intellectual capital, it is important to discuss the knowledge sharing network.

10.3 Knowledge Sharing Network

A knowledge sharing network is shown in Figure 10.1. In a knowledge sharing network, there are several relations between the knowledge sources and knowledge receivers as seen in Figure 10.1.

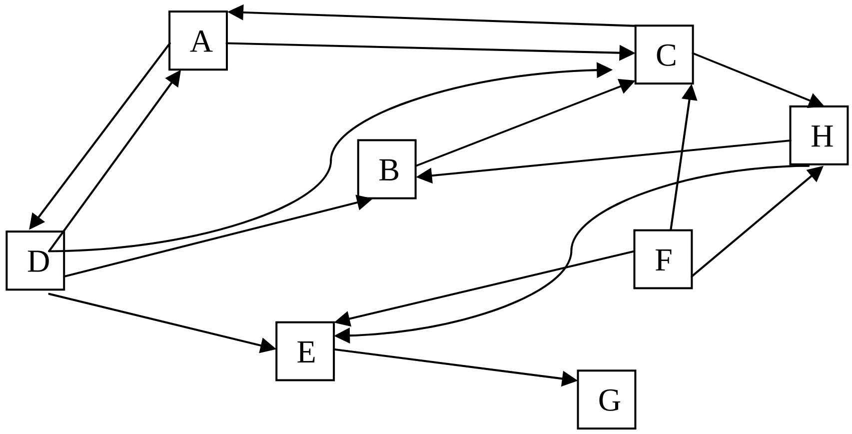


Figure 10.1 Knowledge sharing network

In order to enhance the effectiveness of knowledge sharing between network members, the proposed model explained in Chapter 7 is applied by using trust and ontology techniques to determine the knowledge sharing level. The most important issue in a knowledge sharing network is the selection of the member who will initiate the knowledge sharing within a community. For example, in Figure 10.1, member G receives knowledge from member E and if the initial point of knowledge sharing starts with G, knowledge will not be shared within the network and member G will keep the shared knowledge and will not pass it to others.

Several procedures are proposed for selecting the best member to start sharing the knowledge. The first procedure proposed is based on the number of the connections that each member has with others and rank the members based on their connection numbers. By this way, connection calculation matrix is developed and is shown in Figure 10.2.

Number of the connections =

	A	B	C	D	E	F	G	H	Sum
A	0	0	1	1	0	0	0	0	2
B	0	0	1	0	0	0	0	0	1
C	1	0	0	0	0	0	0	1	2
D	1	1	1	0	1	0	0	0	4
E	0	0	0	0	0	0	1	0	1
F	0	0	1	0	1	0	0	1	3
G	0	0	0	0	0	0	0	0	0
H	0	1	0	0	1	0	0	0	2
Sum	2	2	4	1	3	0	1	2	–

Figure 10.2: Matrix of the connections

As can be seen in Figure 10.2, member D is the best knowledge sender and member C is the best knowledge receiver in the network. Therefore, it can be assumed that member D is the best member to start the knowledge sharing process and member C is the member to be the last person to gain the shared knowledge. This procedure is applicable only in a situation where all members can send or receive all of the knowledge and knowledge sharing level is equal to 1. However, as discussed in this thesis, network members have different levels of trust and knowledge sharing and knowledge cannot be shared completely between all members. In this case, a person who has the most relations with others cannot be assumed to be the trusted person and it is required to measure knowledge sharing level between members based on the explained model in Chapter 7. To find the knowledge sharing level of each relation, it is required to use matrices based on a proposed formula is that explained in Chapter 7 as follows:

$$Ks=[((1-Kc)*|Tb|*K1)+((1-Kc)*|Tc|*K2)+(Kt*|Tb|*K3)+(Kt*|Tc|*K4)]/2$$

Kc = knowledge complexity , Tb= trust benevolence, K1 = importance of benevolence trust in knowledge complexity, Tc=trust competency, K2 =importance of competency trust in knowledge complexity, Kt =knowledge transferability, K3= importance of benevolence trust in knowledge transferability , K4= importance of competency trust in knowledge transferability

(Equation 10.7)

Eight matrices should be calculated to measure knowledge sharing values between members in a network with M members. These eight matrices are shown below.

$$Kc = \begin{array}{c|ccccc} & A & B & C & \dots & M \\ \hline A & 0 & KcA,B & KcA,C & \dots & KcA,M \\ B & KcB,A & 0 & KcB,C & \dots & KcB,M \\ C & KcC,A & KcC,B & 0 & \dots & KcC,M \\ \dots & \dots & \dots & \dots & 0 & \dots \\ M & KcM,A & KcM,B & KcM,C & \dots & 0 \end{array}$$

Figure 10.3: Knowledge complexity matrix

Another matrix is related to knowledge transferability and is shown in Figure 10.4.

$$
Kt = \begin{array}{c|ccccc}
 & A & B & C & \dots & M \\
\hline
A & 1 & KtA,B & KtA,C & \dots & KtA,M \\
B & KtB,A & 1 & KtB,C & \dots & KtB,M \\
C & KtC,A & KtC,B & 1 & \dots & KtC,M \\
\dots & \dots & \dots & \dots & 1 & \dots \\
M & KtM,A & KtM,B & KtM,C & \dots & 1
\end{array}
$$

Figure 10.4: Knowledge transferability matrix

And as discussed in Chapter7, benevolence trust and competence-based trust can be shown as two matrices illustrated in Figure 10.5 and Figure 10.6 respectively.

$$
Tb = \begin{array}{c|ccccc}
 & A & B & C & \dots & M \\
\hline
A & 1 & TbA,B & TbA,C & \dots & TbA,M \\
B & TbB,A & 1 & TbB,C & \dots & TbB,M \\
C & TbC,A & TbC,B & 1 & \dots & TbC,M \\
\dots & \dots & \dots & \dots & 1 & \dots \\
M & TbM,A & TbM,B & TbM,C & \dots & 1
\end{array}
$$

Figure 10.5: Benevolence trust matrices

$$
Tc = \begin{array}{c|ccccc}
 & A & B & C & \dots & M \\
\hline
A & 1 & TcA,B & TcA,C & \dots & TcA,M \\
B & TcB,A & 1 & TcB,C & \dots & TcB,M \\
C & TcC,A & TcC,B & 1 & \dots & TcC,M \\
\dots & \dots & \dots & \dots & 1 & \dots \\
M & TcM,A & TcM,B & TcM,C & \dots & 1
\end{array}
$$

Figure 10.6: Competence trust matrices

Also, four more matrices are developed to calculate the importance of trust for different levels of knowledge complexity and transferability (k1,k2,k3,k4 as explained in Equation 10.7) based on Figures 9.19 to 9.23 in Chapter 9.

Based on the knowledge sharing formula and calculated matrices, the result of knowledge sharing level value for each relation can be calculated thus:

$$
Ks = \begin{array}{c|ccccc}
 & A & B & C & \ldots & M \\
\hline
A & 0 & KsA,B & KsA,C & \ldots & KsA,M \\
B & KsB,A & 0 & KsB,C & \ldots & KsB,M \\
C & KsC,A & KsC,B & 0 & \ldots & KsC,M \\
\ldots & \ldots & \ldots & \ldots & 0 & \ldots \\
M & KsM,A & KsM,B & KsM,C & \ldots & 0
\end{array}
$$

Figure 10.7: Knowledge sharing matrix

Based on the knowledge sharing matrix in Figure 10.7, the knowledge sending and receiving levels for each member are found. Figure 10.8 shows a knowledge sharing network with the values of knowledge sharing level for a particular knowledge in a specific time between network members.

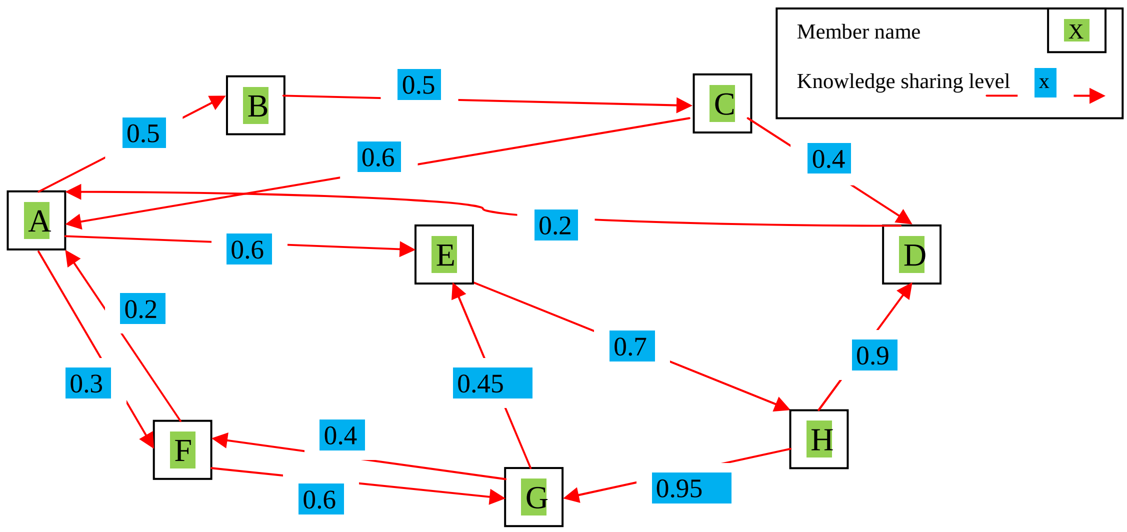


Figure 10.8: Knowledge sharing network with knowledge sharing level values

As seen in Figure 10.8, some of the members in the network are connected to more members; for example, member A receives knowledge from three other members and sends knowledge to three as well. However, some of the members can share knowledge more effectively than can others. For example, member H can share the particular knowledge that is planned to be shared in the network much better than others. Due to the intelligence of members in the network, it is supposed that members who obtain the shared knowledge from different resources evaluate the received knowledge and gain the maximum level of benefit from the shared knowledge.

Knowledge that is gained by member N= Max(Ksi, N) i=A,B,...,M M=Number of members

(Equation 10.8)

For example, if member D receives 90 percent of the shared knowledge from member H and 40 percent from member C, the level of knowledge shared with member D will be 90 percent. Again, the main issue is to determine the optimum member to start knowledge sharing in the network in order to reach the highest level of knowledge sharing between members. First, one of the members is selected as the member who starts knowledge sharing in the network. Suppose the member is C. Figure 10.9 shows the effectiveness of the shared knowledge in the network that is explained in Figure 10.8 (to make the related calculations easier, the percentage of the knowledge sharing level is taken into account in the calculations).

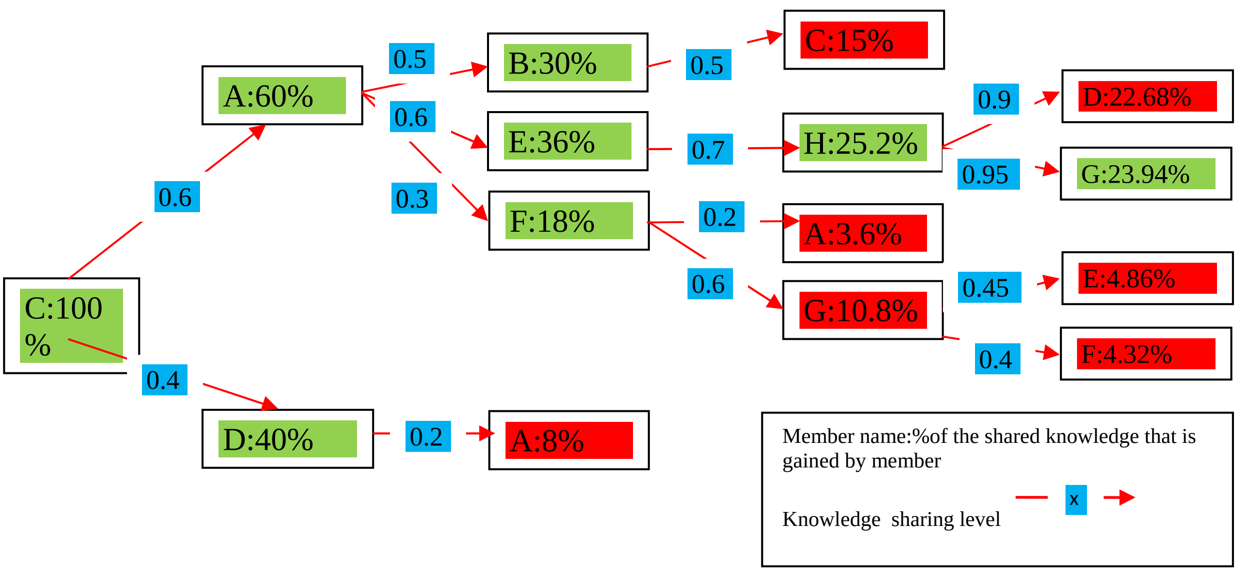


Figure10.9: Knowledge sharing level when the start point to share knowledge is member C

Based on Figure 10.9, the total percentage of knowledge sharing can be calculated as follows:

Total knowledge sharing in the network= 100+60+40+30+36+18+25.2+23.94=333.14

Knowledge sharing effectiveness can be calculated by dividing the total value of the calculated knowledge sharing by the maximum knowledge sharing that can occur within a network.

Knowledge sharing effectiveness= (total knowledge capital that is gained by network members)/ (maximum value that can be shared in the network)

(Equation 10.9)

Maximum value that can be shared in a network= number of members*knowledge value

(Equation 10.10)

In this sample, the maximum knowledge sharing level is 800 (8*100(the maximum knowledge sharing for each member). Hence, the knowledge sharing effectiveness can be calculated as follows:

Knowledge sharing effectiveness= 333.14/800=0.41 (or 41%)

This means that, overall, 41% of the actual knowledge is shared within the network.

If the knowledge sender's knowledge as the main resource to share the knowledge is not accounted for in the calculation, the total knowledge sharing level among other members of the network will be 233.14 and as seen in Figure 10.7, some members such as member F will receive only 18% of the actual knowledge.

Member C cannot be the best member to start to share knowledge in this network because of the numbers of the connections and value of knowledge sharing between this member and members A and D. In the next step, member A as the most connected member is selected as the start point and the results are shown in Figure 10.10.

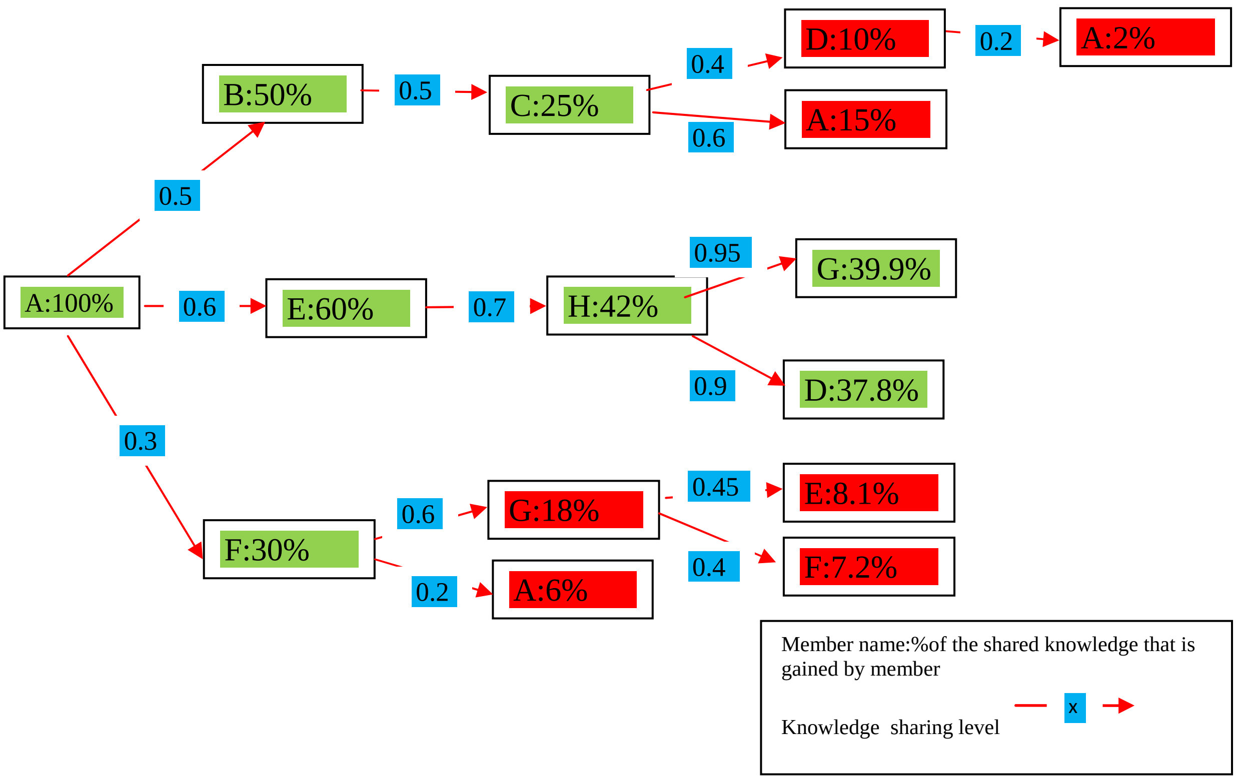


Figure 10.10: Knowledge sharing level when the start point to share knowledge is member A

Based on Figure 10.10, the total percentage of knowledge sharing can be calculated as follows:

Total knowledge sharing in the network=

100+50+60+30+25+42+39.9+37.8= 384.7

As can be seen, the total knowledge sharing is improved and the effectiveness of knowledge sharing in the network can be calculated as follows:

Knowledge sharing effectiveness= 384.7/800=0.48 (or 48%)

Overall, by starting from member A, almost half of the shared knowledge can be disseminated throughout the network. Another way to determine the best member to start sharing knowledge is to find the best knowledge sender within a network. The same network in Figure 10.6 is used to evaluate and propose a solution to discover the best knowledge sender within the network. Table 10.1 shows the percentage of the shared knowledge in each relation in the network.

	A	B	C	D	E	F	G	H	Total
A	0	50	0	0	60	30	0	0	140
B	0	0	50	0	0	0	0	0	50
C	60	0	0	40	0	0	0	0	40
D	20	0	0	0	0	0	0	0	20
E	0	0	0	0	0	0	0	70	70
F	20	0	0	0	0	0	60	0	80
G	0	0	0	0	45	40	0	0	85
H	0	0	0	90	0	0	95	0	185
Max	60	50	50	90	60	40	95	70	

Table10.1: Percentage of the shared knowledge in each relation in the network

The last column shows the total value of knowledge sharing that can be sent by each member and the last row shows the maximum knowledge that a member can be gained in the network. As is clear from Table 10.1, member H is the best sender and is selected to be the first point to share the knowledge in the network. Figure 10.11 shows the calculation of knowledge sharing effectiveness when the start member is H.

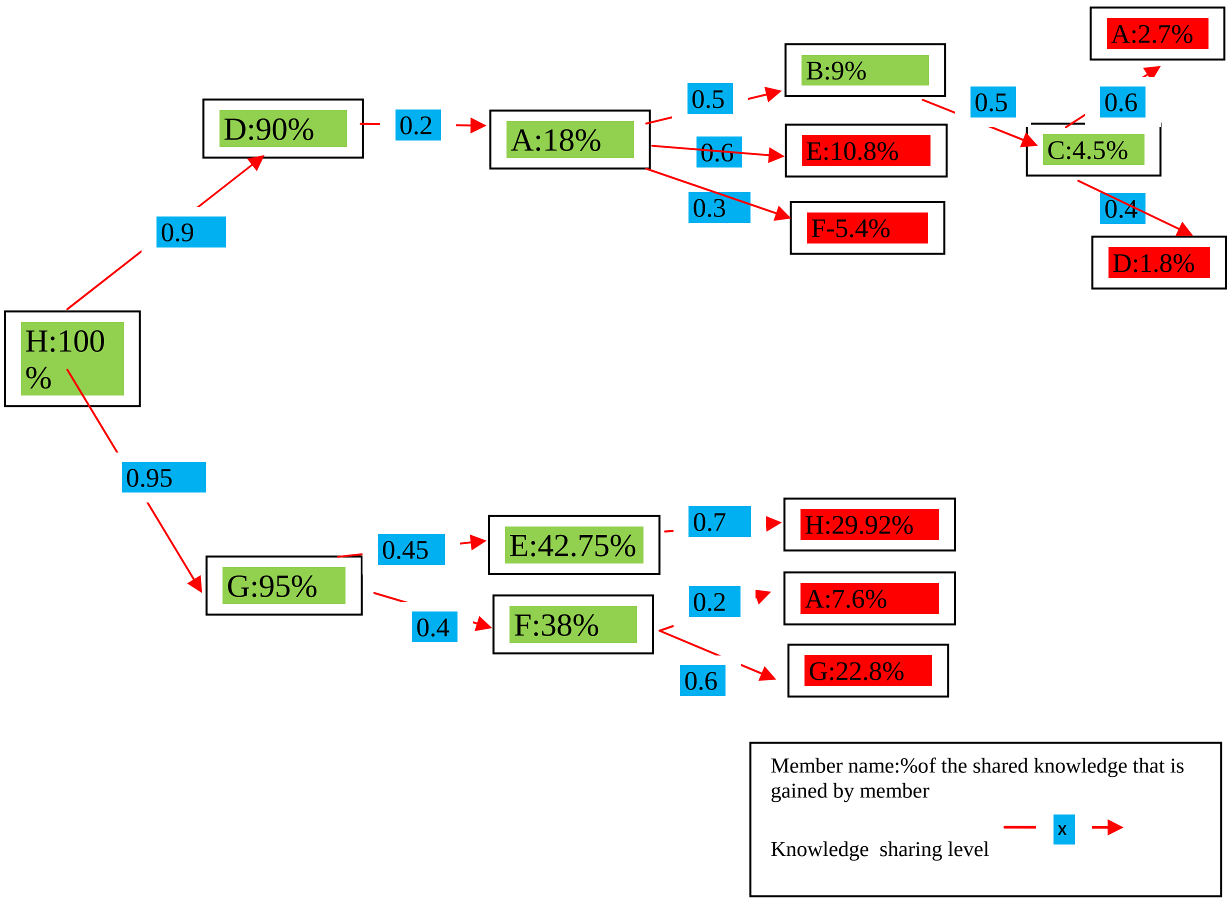


Figure 10.11: Knowledge sharing level when the start point to share knowledge is member H

Total knowledge sharing in the network = 100+90+95+18+38+42.75+9+4.5= 397.25

Again, the total knowledge sharing is improved and the effectiveness of knowledge sharing in the network can be calculated as follows:

Knowledge sharing effectiveness= 397.25/800=0.496 (or 49.6%)

Overall, the best member to start to share knowledge is the member that is the best one in sending knowledge. As a result, the total value of sending knowledge should be calculated as shown in Figure 10.9.

$$
Ks = \begin{array}{c} \\ A \\ B \\ C \\ \dots \\ M \end{array}
\begin{array}{cccccc}
A & B & C & \dots & M & \text{Total send} \\
0 & KsA,B & KsA,C & \dots & KsA,M & \sum_{i=A}^{M} KsA,i \\
KsB,A & 0 & KsB,C & \dots & KsB,M & \sum_{i=A}^{M} KsB,i \\
KsC,A & KsC,B & 0 & \dots & KsC,M & \sum_{i=A}^{M} KsC,i \\
\dots & \dots & \dots & 0 & \dots & \dots \\
KsM,A & KsM,B & KsM,C & \dots & 0 & \sum_{i=A}^{M} KsM,i
\end{array}
$$

Figure 10.12: Total knowledge sharing of each member

Based on Figure 10.12, the best member to start to share knowledge is the one who has the maximum value of knowledge sending. The formula is shown as equation 10.11.

Optimum point to start to share knowledge =

$$\text{Max}((\sum_{i=A}^{M} KsA,i), (\sum_{i=A}^{M} KsB,i), (\sum_{i=A}^{M} KsC,i),\dots,(\sum_{i=A}^{M} KsM,i))$$

(Equation 10.11)

As discussed previously, knowledge sharing value can be calculated for a particular knowledge and it is clear that for different knowledge complexity and transferability, the value of knowledge sharing will be different. Also, the total value of knowledge sharing from the starting point is related to the value of knowledge sharing by members who received the shared knowledge earlier. For example, in Figure 10.13, member H is the highest knowledge sender in the network and shares knowledge with D and G. Member D is just a knowledge receiver and cannot transfer the shared knowledge to another member. Also, member G can share just 10% of the shared knowledge with member E. As a result, the knowledge sharing effectiveness of member H is less compared with that of other members.

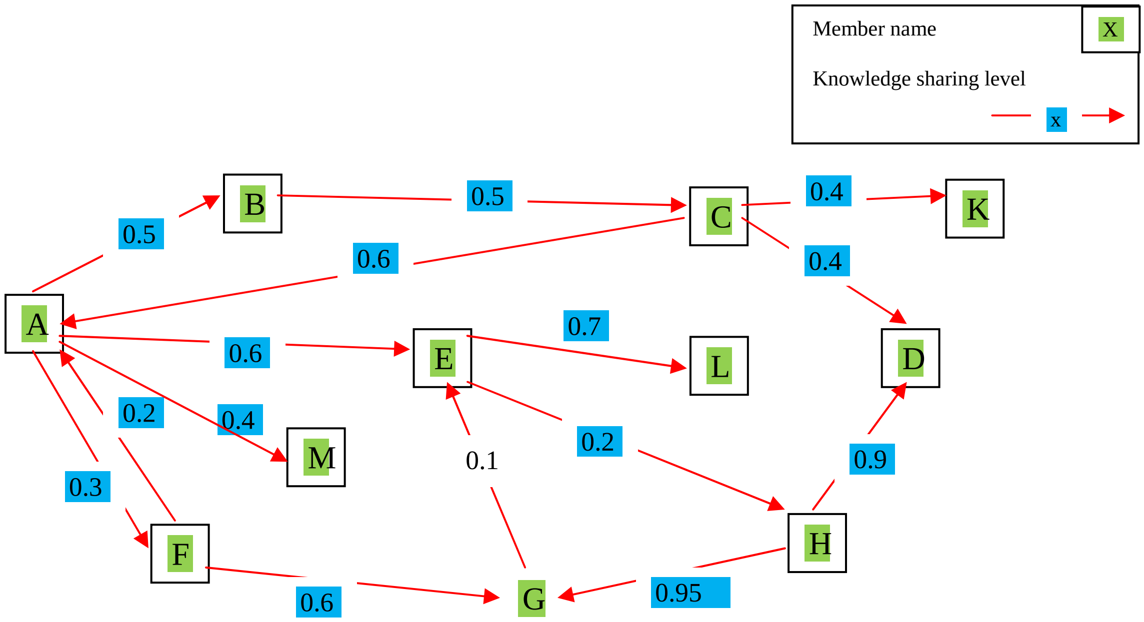


Figure 10.13: Sample knowledge sharing network

Figure 10.14 shows a framework for finding the total optimum member to share knowledge within a network. As shown in Figure 10.13, the proposed framework examines all the connections between members of a network and calculates the knowledge sharing value for each connection. Then, based on the total knowledge sending value of each member, members are ranked the maximum to minimum knowledge sharing effectiveness is calculated for each one. The highest knowledge sharing effectiveness is selected as the best result and the relevant member is the best starting point for the sharing of knowledge.

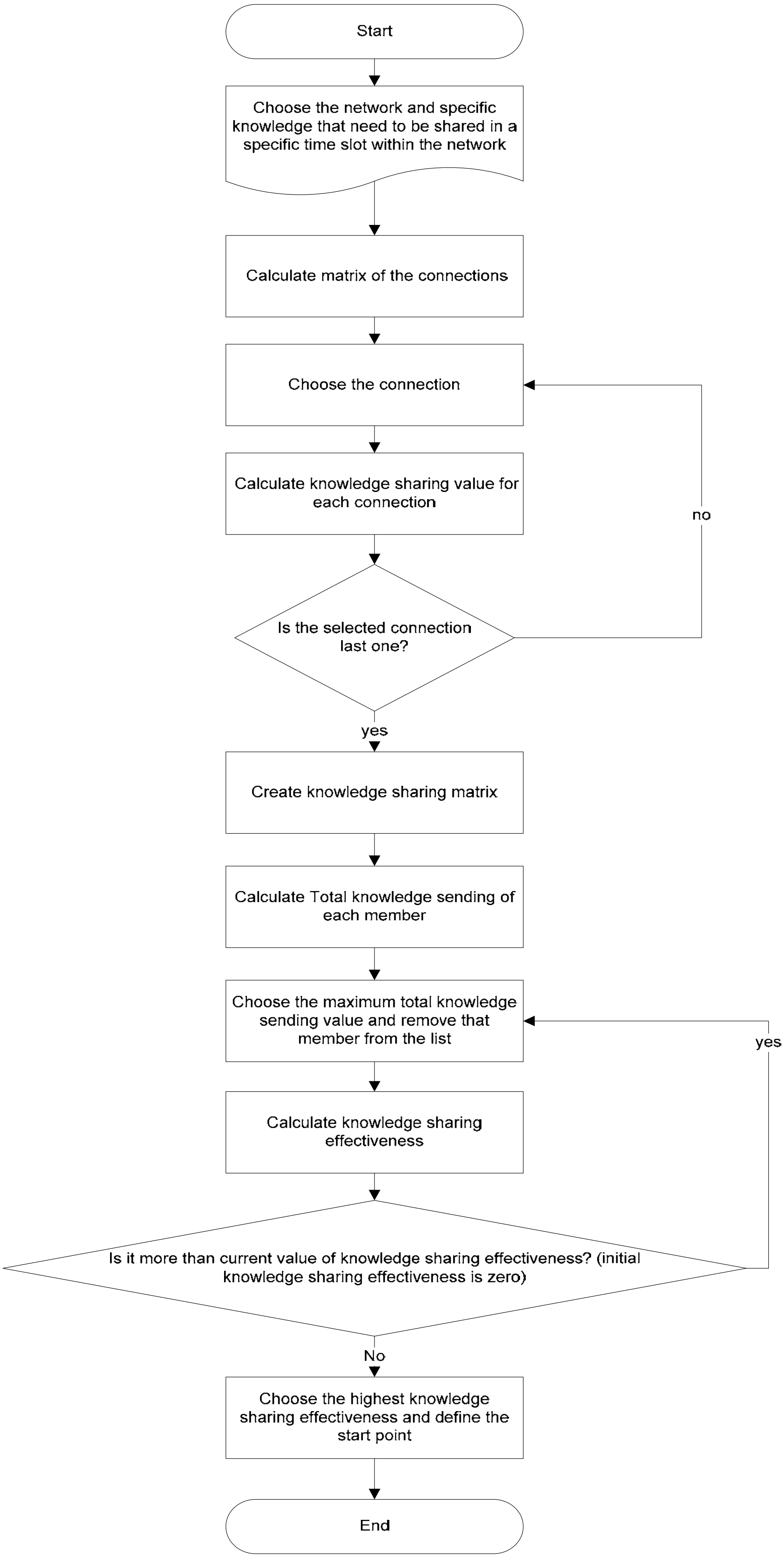


Figure 10.14: Process for finding the optimum member to start sharing knowledge

With the proposed procedure, the next section shows how the capital produced by knowledge sharing within a network can be calculated.

10.4 Knowledge capital measurement

As the importance of intellectual capital is increasing in a knowledge-based society, knowledge as a major resource of intellectual capital is becoming more important. It is very important to measure this capital as it is a key to competitive advantage for a business. This chapter focuses on the measurement of the knowledge capital that is created by knowledge sharing within a network. To understand more about this capital, a simple example is used to demonstrate the value of knowledge sharing in a network. Suppose, a particular knowledge is required to be shared within a small unit in an organization with 5 members and the ability of all members to learn the required knowledge is equal. The organization needs to invest $1000 to educate these members and share 100% of the required knowledge as shown in Figure 10.15, so the overall cost of education for 5 members is $5000.

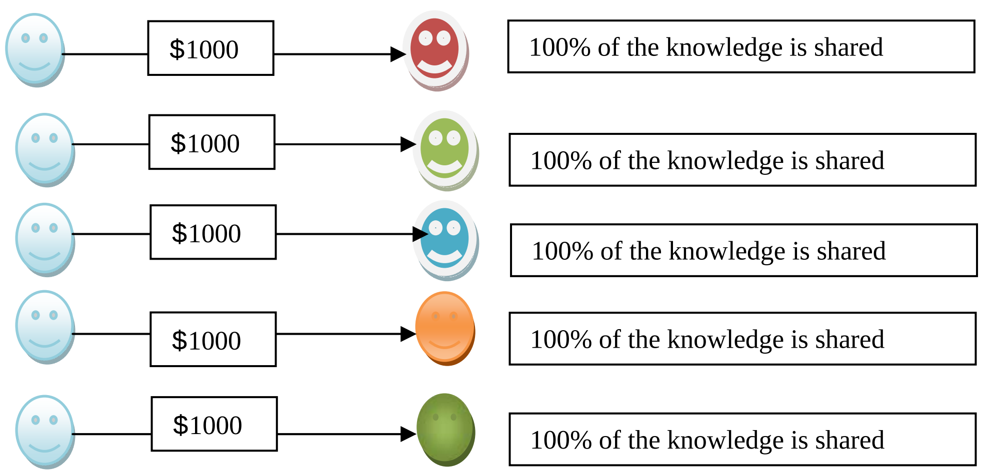


Figure 10.15: Transfer of knowledge from one knowledge source to different receivers

As seen in Figure10.15, $5000 is spent to share the required knowledge between 5 members and as a result the amount of investment is $5000. One way to reduce the required investment is to transfer knowledge to a group of members. Figure 10.16 shows that 5 members are divided into three categories and it is assumed that members have equal ability to acquire knowledge.

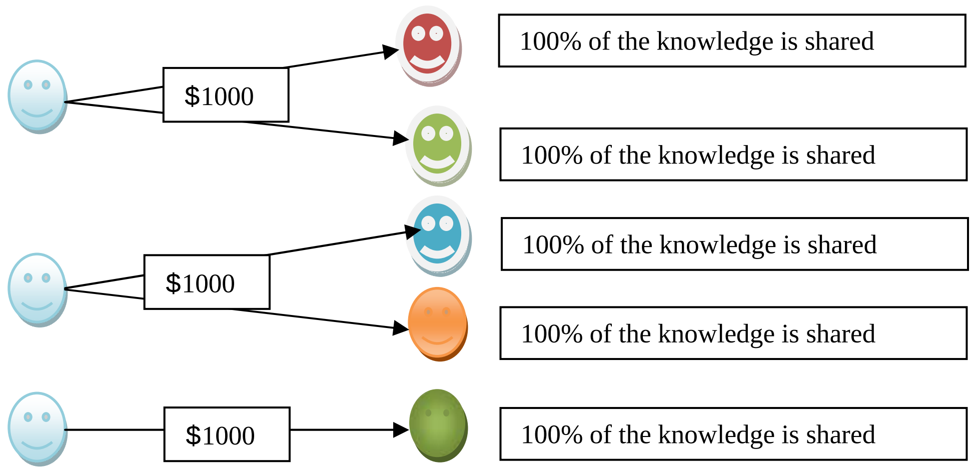


Figure 10.16: Transfer knowledge from knowledge source to group receivers

As shown in Figure 10.16, the organization spends just $3000 and obtains the same result. A knowledge sharing mechanism can play a key role in creating an effective way to send the required knowledge from knowledge source to knowledge receivers. Figure 10.17 shows knowledge sharing mechanisms for sharing the required knowledge in the sample organization. If all the members trust each other and the shared knowledge is simple and transferable to all, knowledge can be transferred using the model that is shown in Figure10.17.

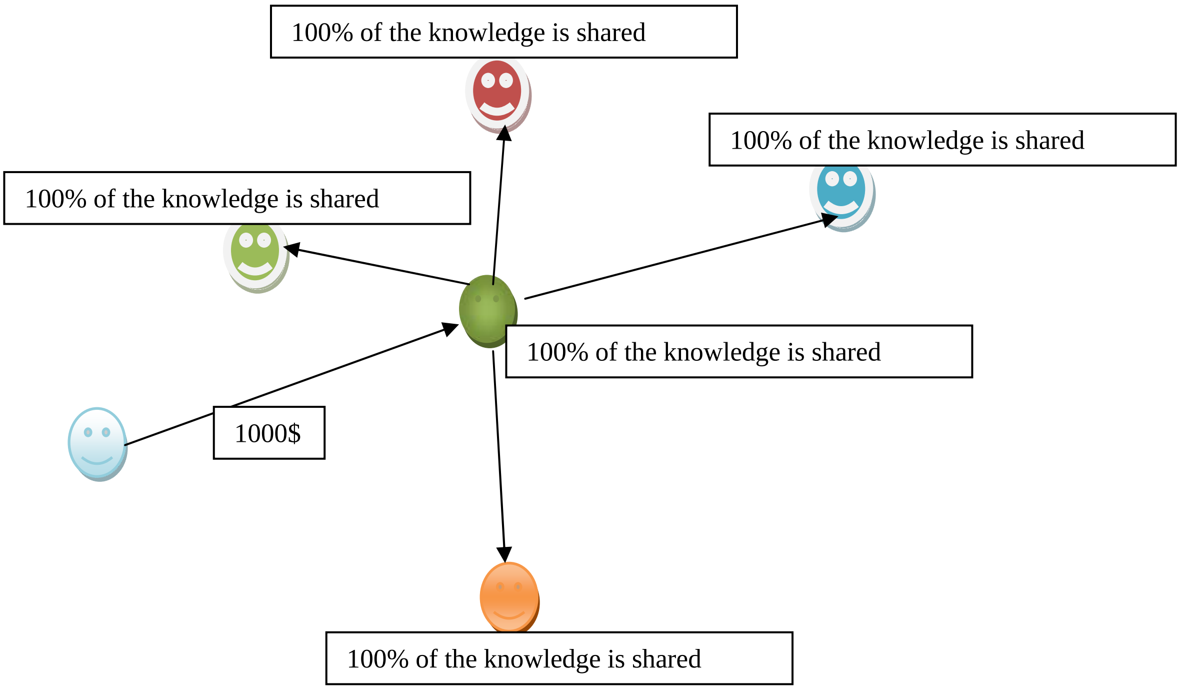


Figure 10.17: Role of knowledge sharing in transferring knowledge from knowledge source to receivers

Figure 10.17 shows the ideal situation in knowledge sharing. All the members trust other members and knowledge complexity is very low and transferability of the knowledge is very high. As seen in Figure 10.17, $1000 investment can create $5000 capital to the organization and their improvement in quality or quantity of the product or service of their unit can be used to measure productivity of the capital. However, in the real world, knowledge sharing is less than 100% in most cases, and organizations are looking for suitable models to maximize their knowledge capital with a limited and specific investment. In Figure 10.17, if the knowledge sharing value of each connection is less than 100%, knowledge capital will be less than $5000 as shown in Figure 10.18.

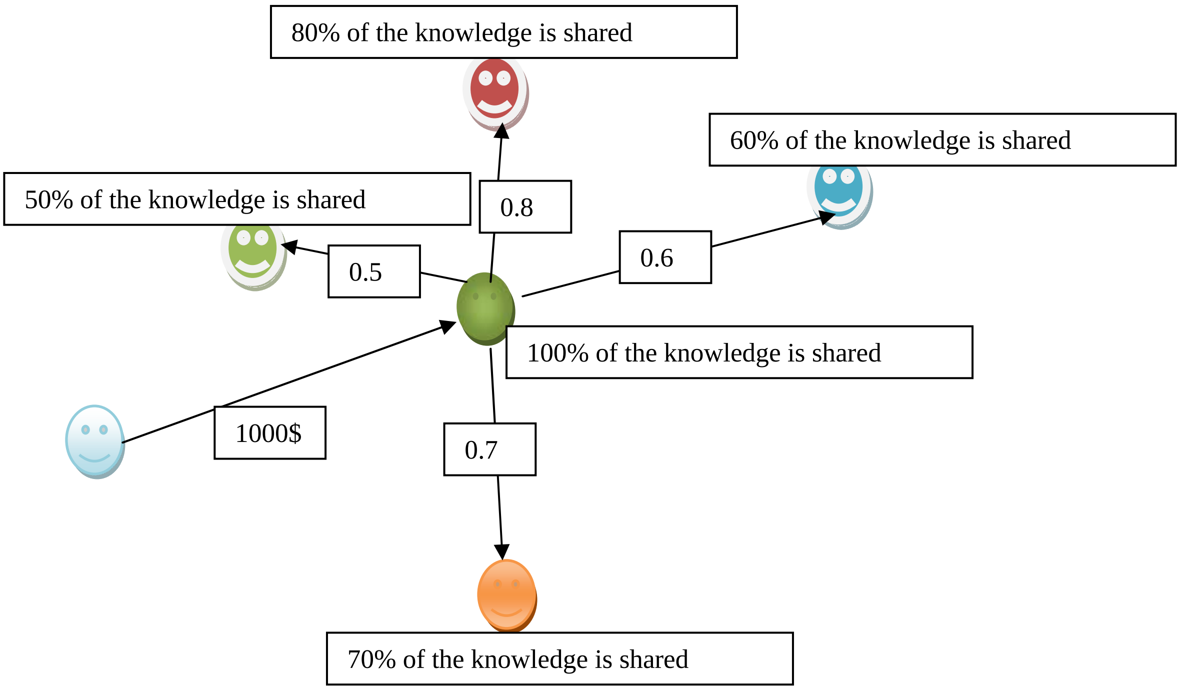


Figure 10.18: Role of knowledge sharing in transferring knowledge from knowledge source to receivers when knowledge is not shared completely

As shown in Figure 10.18, part of the required knowledge is shared between the network members and the value of knowledge capital that is shared in the network is $3600(1000+700+500+800+600).

The same procedure that is presented in Figure 10.14 can be applied in order to measure knowledge capital. In this section, knowledge capital in different categories of intellectual capital is examined.

10.4.1 Knowledge capital measurement in human capital

As was discussed in human capital measurement, this kind of intellectual capital can be calculated by measuring the cost incurred to gain the knowledge or cost that an organization incurs to improve employees' knowledge. Cost can be direct such as teacher cost, venue hire cost (if education is physical) or it may be indirect such as opportunity cost as discussed previously. Knowledge sharing is the best method to increase human capital with minimum direct and indirect costs. There is no need for knowledge learner to quit his/her job in order to be educated, and knowledge can be shared by their colleagues. Figure 10.19 shows human capital changes due to knowledge sharing within a network.

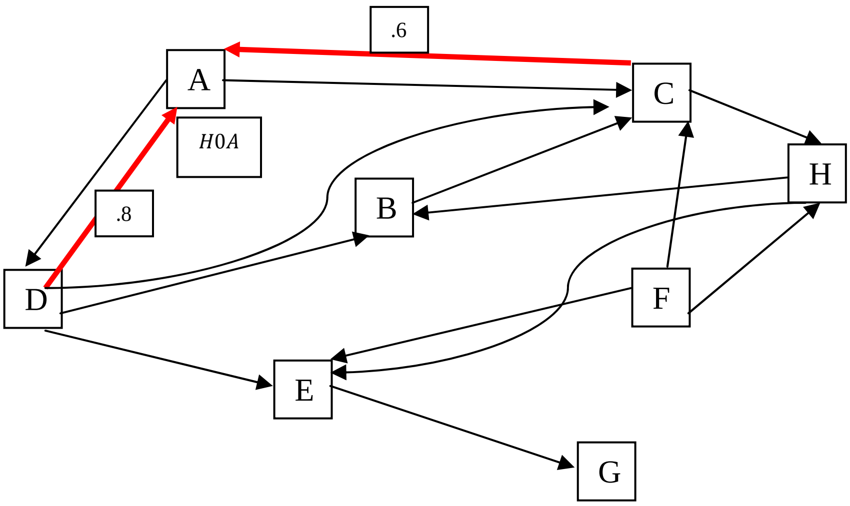


Figure 10.19: Human capital changes due to knowledge sharing within a network

Member A's initial human capital is H0A and the value of knowledge that this member has received from another member can be calculated as follows:

$H1A$= H0A+ max(knowledge sharing level from member D to A, Knowledge sharing level from member C to A) * value of the shared knowledge

(Equation 10.12)

Example,

$H1A$- H0A= Δ HA = max(knowledge sharing level from member D to A, Knowledge sharing level from member C to A) * value of the shared knowledge = 0.8*1000(value of knowledge) =$ 800

The formula can be developed for all the members of a network and the human capital changes for each member can be calculated using this formula:

$$\Delta \text{Hi} = \text{max knowledge sharing level thet member i recieves from other members} * \text{value of the shared knowledge} \quad i = A \ldots M \quad (\text{M is the last member})$$

(Equation 10.13)

And total changes in human capital of the network,

$$\text{Total } \Delta H = \sum (\Delta \text{Hi}) \quad i = A \ldots M \quad (\text{M is the last member})$$

(Equation 10.14)

As an example, the network that was presented in Figure 10.8 is examined to calculate the total human capital that can be created by the particular knowledge with a value of $1000. The knowledge sharing level for this particular knowledge is calculated for each connection and member H is selected to start the knowledge sharing within the network as shown in Figure 10.20.

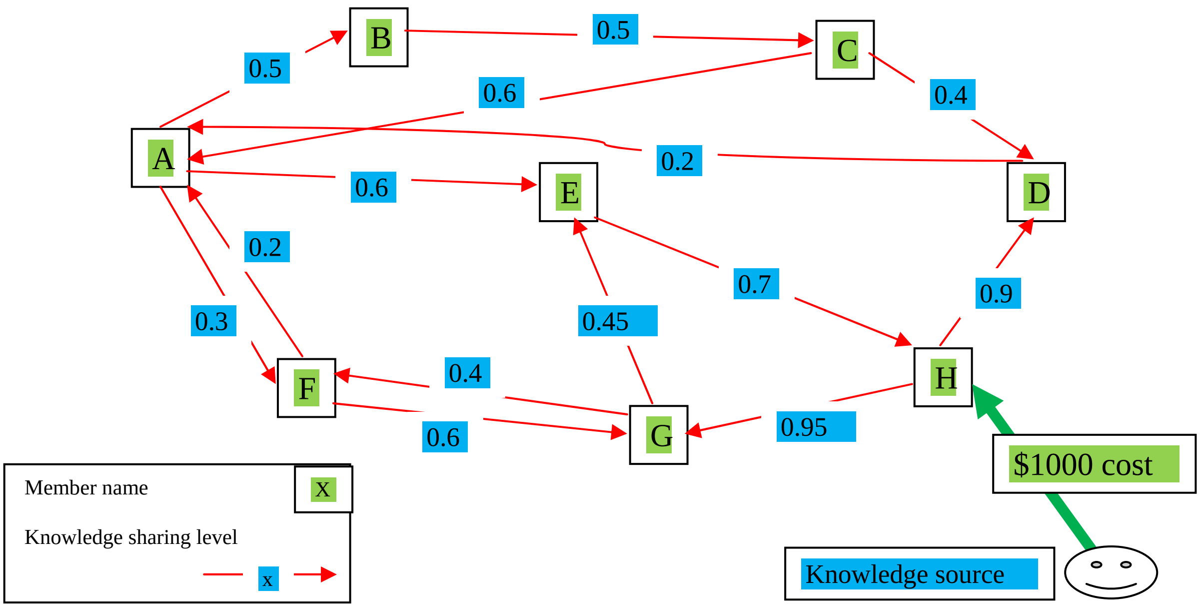


Figure 10.20: Knowledge capital measurement when member H is selected as the first member to share knowledge

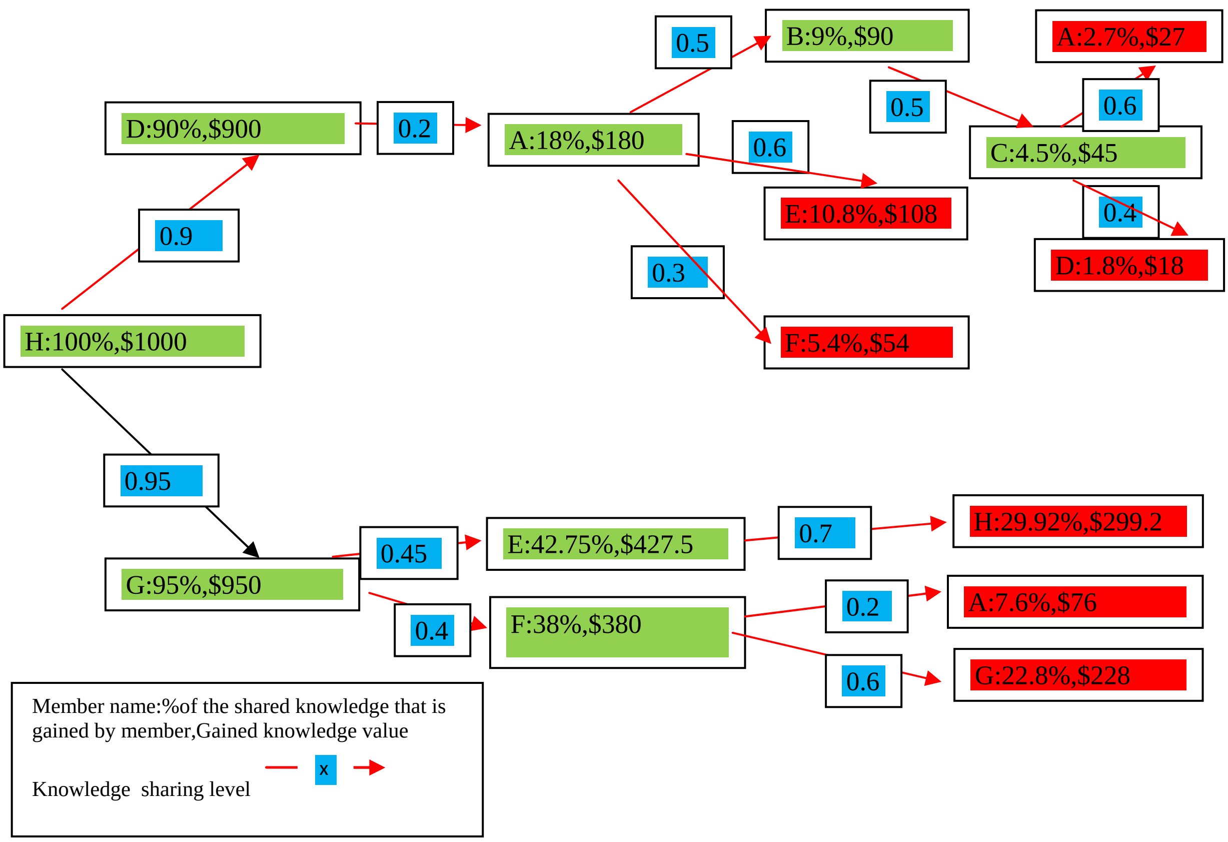


Figure 10.21: Human capital improvement in each member

Based on Figure 10.21, the total improvement in human capital due to the shared knowledge can be calculated as follows:

Total Δ H= 1000+900+950+180+427.5+380+90+45 = $3972.5

To increase knowledge sharing based human capital, it is important to increase the number of connections between network members and to improve the knowledge sharing level in current connections. Sometimes, a particular knowledge that an organization wants to be shared between members is crucial and a certain amount of knowledge should be shared between members. In this situation, more than one member should be selected as the starting point to share knowledge and in future work this issue can be considered for further investigation.

10.4.2 Knowledge capital measurements in social capital

As discussed earlier, social capital refers to connections between members of a network and can be calculated by the number of connections as well as the value of the connections.

To measure social capital, it is important to calculate the total numbers of connections in a network. The total numbers of connections as shown by equation 10.2 can be arrived at with the following formula:

Total numbers of connections = $n \times (n-1)$, n= numbers of members in the network

It is important to note that connection A to B is different from connection B to A and that is why the total number of the connections is not divided by two. For example, when there are 5 members in the network, the total number of the connections is 5*(5-1)=20 as shown in Figure 10.22.

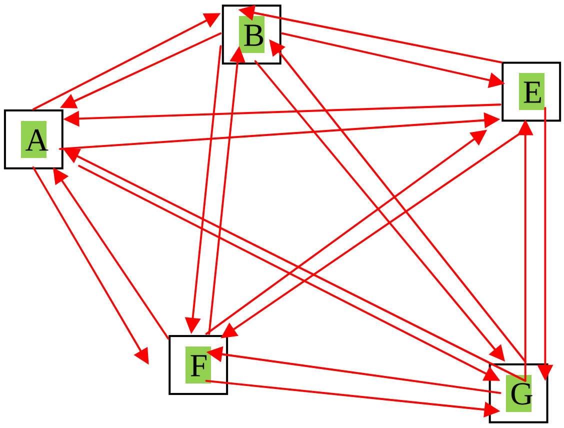


Figure 10.22: Total number of connections in a network with 5 members

If the value of all the connections be equal, social capital can be calculated as follows:

Social capital=(number of connections/(n*(n-1))) * value of each connection

(Equation 10.15)

Values of all connections are not equal in a network; therefore, the social capital of each connection is different. Total social capital based on knowledge sharing level between members can be calculated as follows:

Total social capital = ∑(knowledge sharing level for each connection)*(knowledge value)

(Equation 10.16)

Overall, human capital is a measure of the value of transferred knowledge for a person, and social capital refers to the value of the connections in a network. Improvement in social capital can affect human capital and improve the value of human capital in a network.

10.4.3 Knowledge capital measurements in market capital

Market capital measurement is close to human capital measurement and the difference between these two types of intellectual capital is related to the fact that human capital is related to internal human resources, whereas market capital is related more to external resources. For example, customers are considered to be external resources for a business and knowledge sharing between customers is included in market capital. Figure 10.23 shows an example of market capital in a network.

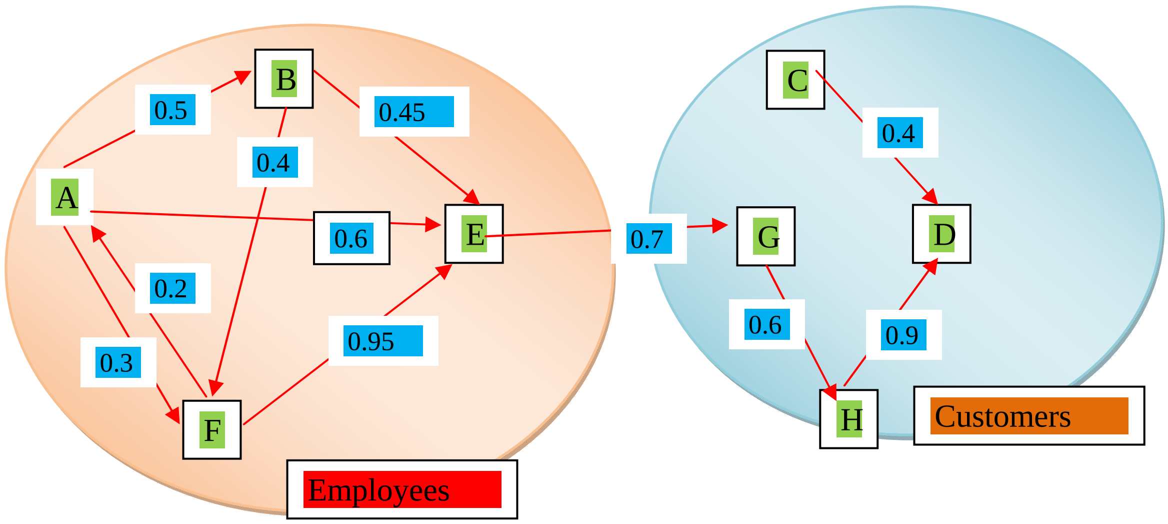


Figure 10.23: Market capital network

As shown in Figure 10.23, knowledge can be transferred from employees of an organization to customers, thereby creating market capital. Hence, a high level of social capital in an organization can help a business to achieve a high level of market capital. Member E in Figure 10.23 is the member that has a direct relationship with customers. For example, the sales department or after-sales department staff have a direct relationship with customers. Member A as a manager starts to share knowledge and 60% of the shared knowledge is acquired by member E. Figure 10.24

shows the calculation of market capital between customers in this network.

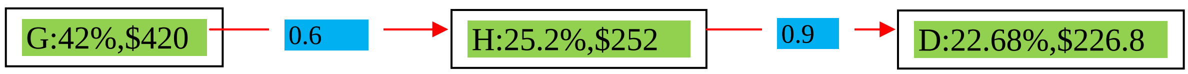


Figure 10.24: Market capital measurement for the network presented in Figure 10.23

As seen in Figure 10.23, the total market capital that can be created by knowledge sharing between customers is $898.8. As discussed previously, the relationship between market components and their decision to sell or buy, refers to the marginal propensity to sell or buy. Also, it was mentioned that marginal propensity is related to different variables such as customer expectation, wealth, replacement cost, emergence need and some other variables that affect on buying or selling a product or service. Knowledge sharing can help a business to improve market capital and lead the customers' marginal propensity to reach the point where they start to buy or sell.

$$M1i = M0i + \max(\text{knowledge sharing level from other members}) * \text{value of the shared knowledge}$$

$M1i$ =Market capital at time t1 $M0i$ =Market capital at time t0 i=A…M

(Equation 10.17)

$$M1i - M0i = \Delta Mi = \max(\text{knowledge sharing level from other members}) * \text{value of the shared knowledge}$$

i= A…M

(Equation 10.18)

If $M1i \Rightarrow MPi$ then, customer i will buy or sell the product or service

MPi = Marginal propensity of member i

(Equation 10.19)

A high level of knowledge sharing between customers is good for a business when the shared knowledge is positive. However, the shared knowledge can be negative and may decrease the value of market capital in a network. For example, a customer is unhappy with the quality of service and starts to share her/his dissatisfaction with other consumers. In this situation, the value of the knowledge sharing is negative and should be deducted from the current market capital.

Knowledge sharing measurement can be used not only to measure knowledge capital, but also to find the relationships between different kinds of intellectual capital. Strong relationships between employees can improve social and human capital and also it can affect and improve market capital. Market capital can save considerable investment as organizations do not need to spend huge amounts of money in order to share particular knowledge about new brands or their current services or products. The ideal position for an organization is a situation where all the intellectual components are at a high level, strengthening the sustainability for a business where employees, customers and other business components are satisfied and have strong relationships with each other. Knowledge can be created and disseminated with low cost between all related parties and problems can be easily detected and solved.

In the next section, experimental studies are conducted to examine the formulas that are used to measure knowledge capital in knowledge sharing.

10.5 Experimental studies

The simulation that has been developed and explained in Chapter 9 is used for experiments in this chapter. Based on the BISIM (Business Intelligence Simulation Model), a network with different numbers of members is created. In the created network, based on different trust dimensions levels, knowledge complexity and knowledge transferability, the knowledge sharing value of each connection is calculated by using the formula that is proposed in this thesis to measure knowledge sharing level.

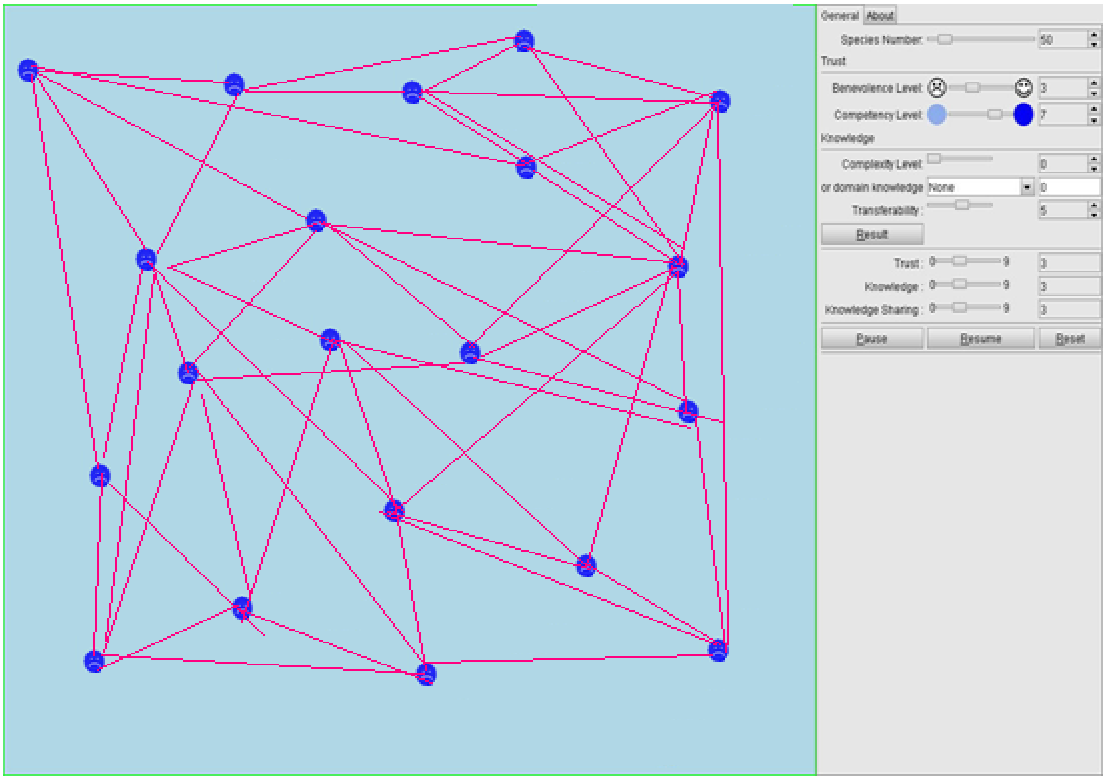


Figure 10.25: Simulation model in a network with 20 members

Figure 10.25 shows the simulated model of a network with 20 members. Based on this simulated network, Figure 10.26 shows the value of knowledge sharing for each relation in the simulated model.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	0	0.23	0.4	0	0.6	0.4	0.7	0	0	0
A2	0.33	0	0.6	0.5	0.8	0.7	0	0	0	0
A3	0.54	0.61	0	0.18	0.75	0.6	0	0	0.68	0
A4	0.6	0.52	0.6	0	0.45	0.54	0	0	0.64	0
A5	0.86	0.8	0.5	0.19	0	0.68	0	0	0.65	0.56
A6	0.85	0.65	0.65	0.15	0.58	0	0	0.56	0.62	0.58
A7	0.26	0.58	0.68	0.16	0.35	0.62	0	0.58	0.61	0.59
A8	0.65	0.78	0.68	0.18	0.65	0.35	0.8	0	0.62	0.57
A9	0.5	0.5	0.64	0	0.64	0.54	0.95	0.5	0	0.54
A10	0.86	0.55	0.62	0	0.87	0.58	0.46	0.62	0.68	0
A11	0	0.62	0.65	0	0.95	0.75	0.86	0.68	0.67	0.48
A12	0	0	0.64	0	0.92	0.85	0.57	0.35	0.68	0.43
A13	0	0	0.45	0	0.84	0.82	0.48	0.38	0.64	0.49
A14	0	0.25	0.24	0	0.82	0	0.46	0.39	0.65	0.45
A15	0.25	0.36	0.25	0.21	0.83	0	0.45	0.34	0.58	0.42
A16	0.36	0.56	0	0.23	0.84	0	0.48	0.35	0.59	0.24
A17	0.5	0.25	0	0.25	0.86	0.65	0.44	0.37	0.52	0.21
A18	0.69	0.64	0	0.32	0.82	0	0.45	0.25	0	0.25
A19	0.48	0.19	0	0.35	0.84	0.58	0.48	0.26	0	0.26
A20	0.45	0.15	0	0	0.72	0	0.46	0.27	0	0.28

	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20
A1	0	0	0	0	0.9	0.5	0	0	0	0
A2	0	0.5	0.9	0.4	0	0	0	0	0	0.5
A3	0.47	0.15	0.89	0.39	0.86	0.61	0.6	0.65	0.84	0.25
A4	0.49	0.19	0.85	0.38	0.84	0	0	0.69	0	0
A5	0.48	0.18	0.87	0.65	0	0.71	0.8	0	0.68	0.56
A6	0.46	0.12	0.87	0.59	0.37	0.78	0	0.85	0.59	0.45
A7	0.43	0.15	0	0.58	0	0	0.54	0.84	0	0
A8	0.48	0.16	0.59	0	0.68	0	0	0	0.49	0.58
A9	0.49	0.18	0.84	0.56	0	0.68	0.65	0.74	0.48	0.56
A10	0.48	0	0.68	0.54	0.78	0.64	0.64	0.76	0	0
A11	0	0.24	0.67	0.52	0	0.65	0	0	0.65	0.68
A12	0.45	0	0.84	0	0.89	0	0	0	0.67	0
A13	0.24	0.26	0	0.64	0.68	0.7	0.85	0	0.16	0.78
A14	0.25	0.27	0.47	0	0	0.54	0.74	0.48	0	0.58
A15	0.23	0.16	0.68	0.75	0	0.58	0.72	0	0.1	0
A16	0.57	0.18	0.67	0.74	0.68	0	0.73	0.86	0	0.68
A17	0.58	0	0.69	0.76	0.67	0.48	0	0.84	0	0.56
A18	0.54	0.28	0.68	0	0	0.65	0.75	0	0.4	0
A19	0.59	0.36	0.65	0.65	0.85	0	0	0.56	0	0.87
A20	0.65	0.4	0.58	0.63	0.84	0.75	0.76	0.61	0.23	0

Figure 10.26: Knowledge sharing level of each connection in the network

Based on knowledge sharing levels, the summary of knowledge sending and receiving levels for each member is shown in Figure 10.27. The maximum level in each column is highlighted in green.

	Summary of knowledge sending	summary of knowledge receiving	Numbers of sending connections	Numbers of receiving connections
A1	3.73	8.18	7	15
A2	5.23	8.24	9	17
A3	9.07	7.6	15	14
A4	6.79	2.72	12	11
A5	9.17	14.13	15	19
A6	9.72	8.66	17	14
A7	6.97	8.04	15	14
A8	8.26	5.9	15	14
A9	9.99	8.83	17	14
A10	9.76	6.35	15	15
A11	9.07	7.88	14	17
A12	7.29	3.78	11	16
A13	8.41	12.42	15	17
A14	6.59	8.78	14	15
A15	6.91	9.04	16	12
A16	8.76	8.27	16	13
A17	8.63	7.78	16	11
A18	6.72	7.88	13	11
A19	7.97	5.29	15	11
A20	7.78	7.05	15	12
Total knowledge sending	156.82	...	...	...
Total knowledge receiving	...	156.82	...	...
Total sending connections	...	...	282	...
Total receiving connections	...	...	...	282

Figure 10.27: Summary of the connections in the network

Figure 10.27 shows that member A9 is the best member to share knowledge and member A5 is the best one to receive the shared knowledge. Also, A5 has the most numbers of connections with the members in receiving knowledge, while members A6 and A9 have the most connections to share knowledge. To find the knowledge capital of the network, a particular knowledge with the value of $1000 is injected into the network to evaluate the results and indicate the total value that can be created by the shared knowledge. The simulated model calculates the total knowledge capital of the shared knowledge for all situations where knowledge starts to be shared. Overall, knowledge can start to be shared from each of the members in the network and results for each position are calculated in Figure 10.28.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
A1	1000	597.6	476	298.8	747	507.96	700	406	522	418.32	358.56
A2	688	1000	600	500	800	737	547.2	412.72	576	448	443.7
A3	645	610	1000	305	750	729.8	646	408.68	680	436.1	475.02
A4	614.04	571.2	600	1000	714	697	608	390.32	640	416.5	490
A5	860	800	500	400	1000	713.4	617.5	358.15	650	560	480
A6	850	650	650	325	730.8	1000	595	560	620	580	460
A7	592.36	580	680	290	688.8	620	1000	580	610	590	453.6
A8	650	780	680	390	650	575.64	800	1000	620	570	480
A9	606.81	564.48	646	282.24	705.6	688.8	950	551	1000	560.5	490
A10	860	696	620	348	870	620.65	646	620	680	1000	480
A11	817	760	650	380	950	750	860	680	670	532	1000
A12	791.2	736	640	234.5	920	850	646	476	680	515.2	450
A13	722.4	672	450	336	840	820	608	459.2	640	490	507
A14	705.2	656	419.9	328	820	584.98	617.5	390	650	459.2	393.6
A15	713.8	664	415	332	830	592.12	551	340	580	464.8	417.6
A16	722.4	672	420	336	840	599.25	560.5	350	590	470.4	570
A17	739.6	688	430	344	860	650	531.5	370	559	481.6	580
A18	705.2	656	410	328	820	584.98	506.35	277.5	533	459.2	540
A19	722.4	672	420	350	840	599.25	518.7	260	546	470.4	590
A20	619.2	576	360	288	720	489.6	462.84	285.6	487.2	403.2	650

	A12	A13	A14	A15	A16	A17	A18	A19	A20
A1	298.8	649.89	675	900	522	648	588	507.96	506.91
A2	500	900	581.4	619.2	630	765	642.6	544	702
A3	305	890	569.6	860	623	756.5	650	840	730.8
A4	285.6	850	544	840	595	722.5	690	504	663
A5	400	870	650	774	710	800	672	680	678.6
A6	325	870	590	765	780	739.5	850	590	678.6
A7	235.2	605.2	580	584.8	546	630	840	571.2	496.94
A8	390	702	464	680	491.4	596.7	672	571.2	580
A9	262.08	840	560	571.2	680	714	798	542.64	655.2
A10	348	756.9	585	780	640	696	760	591.6	590.38
A11	380	826.5	617.5	735.3	674	760	722.4	650	680
A12	1000	840	667.5	890	663	736	722.5	670	655.2
A13	336	1000	646	680	700	850	714	571.2	780
A14	328	713.4	1000	634.68	582.2	740	621.6	557.6	580
A15	332	722.1	750	1000	589.3	720	604.8	564.4	491.02
A16	336	730.8	740	680	1000	730	860	571.2	680
A17	344	748.2	760	670	610.6	1000	840	584.8	560
A18	328	713.4	570	634.68	650	750	1000	557.6	485.11
A19	360	730.8	650	850	652.5	672	564.48	1000	870
A20	400	626.4	630	840	750	760	645	489.6	1000

Figure 10.28: Knowledge capital for each member at different knowledge sharing start points (all value in $)

Figure 10.28 shows the knowledge capital of the shared knowledge for each member. As is clear from Figure 10.28, in the first row, member A1 starts to share a particular knowledge whose value is $1000. Similarly, in the next rows the start points to share the same knowledge are the other members and in each status, knowledge capital for each member is calculated. To analyze the results, the total knowledge capital that can be created by sharing knowledge needs to be calculated. Figure 10.29 shows the total knowledge capital values that can be created based on which member starts to share the knowledge.

	Summary of knowledge sending	summary of knowledge receiving	Numbers of sending connections	Numbers of receiving connections	Total value
A1	3.73	8.18	7	15	11328.8
A2	5.23	8.24	9	17	12636.82
A3	9.07	7.6	15	14	12160.5
A4	6.79	2.72	12	11	11945.16
A5	9.17	14.13	15	19	13173.65
A6	9.72	8.66	17	14	13208.9
A7	6.97	8.04	15	14	11774.1
A8	8.26	5.9	15	14	12342.94
A9	9.99	8.83	17	14	12668.55
A10	9.76	6.35	15	15	13188.53
A11	9.07	7.88	14	17	14094.7
A12	7.29	3.78	11	16	13783.1
A13	8.41	12.42	15	17	12821.8
A14	6.59	8.78	14	15	11781.86
A15	6.91	9.04	16	12	10673.94
A16	8.76	8.27	16	13	12458.55
A17	8.63	7.78	16	11	12351.3
A18	6.72	7.88	13	11	10976.02
A19	7.97	5.29	15	11	12338.53
A20	7.78	7.05	15	12	11482.64

Figure 10.29: Total knowledge value for each member (value in $)

Figure 10.29 shows that the best member to start to share knowledge is member A11 and in this status, the total knowledge capital in the network will be $14094.7. The effectiveness of knowledge sharing in this status is 70.48% ((14097.7/20000)*100). Member A15 will create the minimum knowledge capital if selected as the member that starts to share the same knowledge. In this status, $10673.94 knowledge capital can be created and the effectiveness of knowledge sharing in this status is 53.36% ((10673.94/20000)*100).

The proposed procedure in this chapter chooses member A9 first as the member who begins to share knowledge due to high level of this member's total knowledge sending value. Then this is compared with other members based on their total knowledge sending value and it is found that member A11 is the best member to share the knowledge that is used to measure the complexity and transferability of knowledge sharing in a specific time slot.

As seen in the outcomes, knowledge sharing can create value in a network, and in a network with a large number of members, such as a large company or a society, the created value can equate to billions of dollars. It is important to find ways to maximize knowledge capital that can be created by a message to customers or employees or any other stakeholders. Knowledge can be analyzed to increase transferability and decrease complexity so that it can be shared more effectively and create more value in a network. Also, the member or members that initiate the sharing of knowledge should be evaluated and selected based on techniques that were discussed in this thesis. These techniques can also be used to ascertain which members are not active members and have fewer connections with others. Then, the results can be used to improve their connections.

The network may be comprised of employees, customers, competitors, suppliers and others, depending on their needs and perspectives. Because of these different categories of members, there are different types of capital such as human capital and market capital which, due to the importance of knowledge in today's economy, can be used in the decision-making process.

Also, a high level of knowledge sharing effectiveness can create sustainability for a business or a network because it leads to knowledge being disseminated among all members of a group or community, such as customers with different backgrounds. This allows a company to create a portfolio of customers and their market will not be limited to just a small portion of the network.

10.6 Discussion of proof of concept in intellectual capital measurement

Research outcomes support the correctness, completeness and effectiveness of the variables in intellectual capital measurement. To evaluate the importance of trust-based variables, knowledge capital is measured when the trust level between members of a network is low or negative. As seen in Figure 10.30, knowledge capital is very low and intellectual capital within the network has greatly declined.

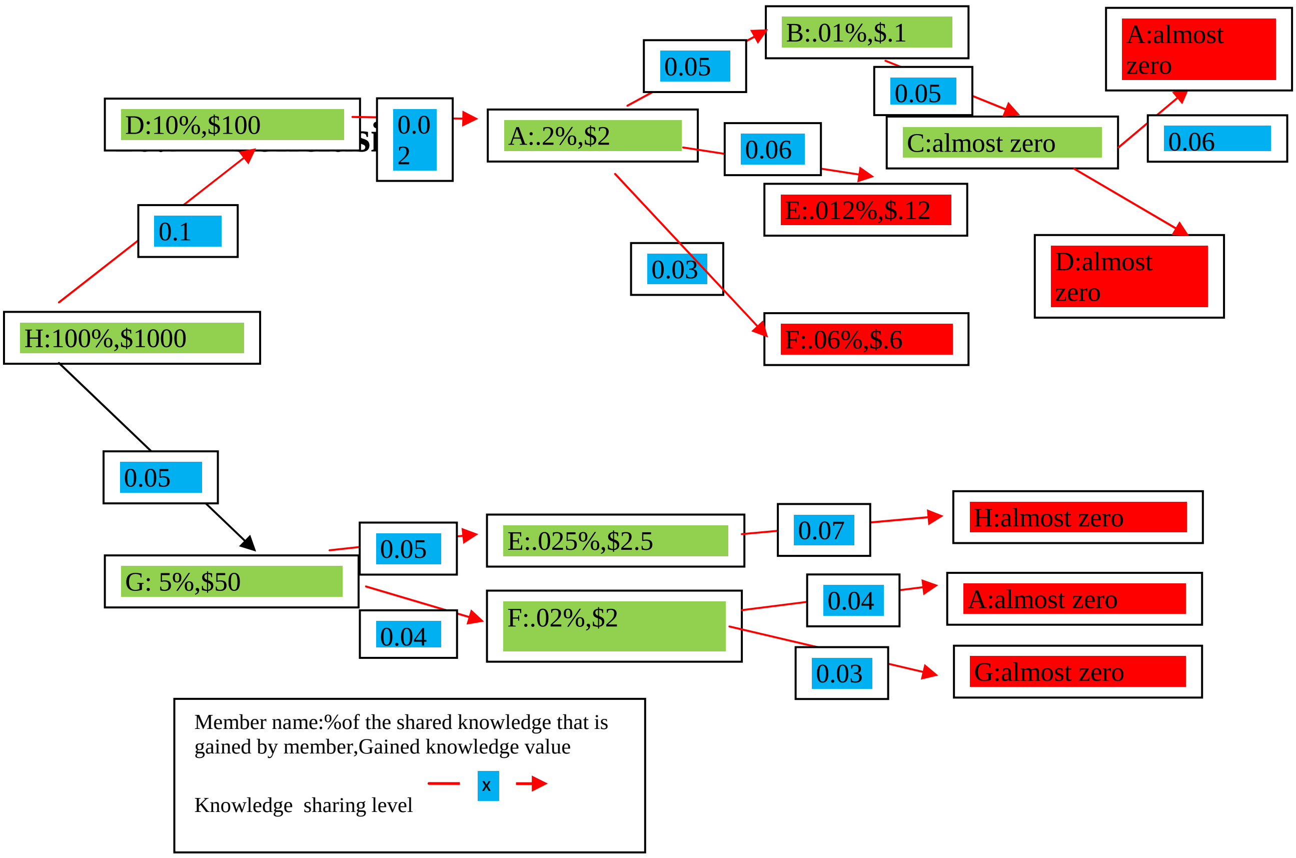


Figure 10.30: Knowledge capital in a low trust network

Total knowledge capital of the network can be calculated as:

Total knowledge capital= 1000+50+100+2+2.5+2+.1=1156.7$

Result outcomes from Figure 10.30 can be compared with the result outcomes from Figure 10.21 where knowledge sharing level is high due to the high level of competency and benevolence trust. Figure 10.21 calculates the knowledge capital in a network where the trust value between members is based on normal distribution (some members have a high trust value in others and some have low trust value). As calculated previously, knowledge capital in Figure 10.21 is equal to 3972.5$ which is almost four times that of the knowledge capital value in Figure 10.30. The results support the correctness and effectiveness of the knowledge sharing variables that are used to measure the knowledge capital of a community or a network. Similarly, knowledge sharing value can be reduced by a high level of knowledge complexity and low level of knowledge transferability.

10.8 Conclusion

Managers need some metric variables to make decisions about the ways by which they can improve their knowledge capital within their organization. This chapter proposed a technique to measure knowledge capital based on the knowledge sharing level between members of an organization. This technique is dynamic and based on trust, knowledge complexity, knowledge transferability, numbers of connections and the member that initiates the sharing of knowledge can calculate the total knowledge capital in an organization.

Chapter 11: Recapitulation and Future Work

11.1 Overview

Knowledge sharing is a major issue in a knowledge-based society. As communication tools rapidly improve, and virtual environments increase sharply, some challenges have emerged in creating a global digital ecosystem where all people are able to share their ideas with anyone and acquire knowledge from any person. Still, there are more than 800 million illiterate adults (aged 15 years and over) (UNESCO Education Team, 2000) and the rate of student graduation from colleges or universities in the US is less than 30 percent of the population (Snoops, 2004). Knowledge needs to be understandable if it is to be shared between individuals, and this sharing of knowledge among individuals with different educational levels, cultures, skills and experiences is proving to be a challenge in the development of a knowledge-based society. This thesis has proposed a framework to improve knowledge sharing level and has proposed a model for reporting the current level of knowledge sharing. Also, a procedure is proposed to measure knowledge capital that can be created by knowledge sharing in a network or a community. In this chapter, a recapitulation of this thesis is presented, followed by some suggestions for further future development of the proposed framework.

11.2 Issues faced in knowledge sharing measurement

Based on the literature, research problems were identified related to knowledge sharing and five main research issues were proposed to solve key problems identified in the knowledge sharing concept. These five issues are related to:

1. Variables in knowledge sharing
2. Knowledge sharing measurement
3. Reporting knowledge sharing level
4. Validation and verification of knowledge sharing framework
5. Knowledge-based capital created by knowledge sharing

These five research issues are defined below.

11.2.1 Variables in knowledge sharing

Due to the limited lifecycle of knowledge in a knowledge-based economy, knowledge rapidly creates and loses its value, so a major main concern is how created knowledge can be disseminated quickly. Knowledge owners should be encouraged to share knowledge freely, although no-one can be forced to disclose knowledge against his/her will. Hence, one concern is how individuals can be motivated to share their knowledge and which variables have a greater impact on encouraging knowledge owners to share their ideas and knowledge and collaborate in a knowledge-based society.

11.2.2 Knowledge sharing measurement

The following concerns are related to measuring the knowledge sharing level within a community or an organization. How this level of knowledge sharing can be measured is a particular concern of pioneer businesses and organizations. Access to an effective measurement model in knowledge sharing can help decision makers to have a better view of the weaknesses and strengths of a community or an organization and help them in their future decision making process. Therefore, the measurement of the knowledge sharing level is one of the concerns of this research.

11.2.3 Reporting knowledge sharing level

Decision makers and strategic planners need to be aware of knowledge flow in their organization or their community. As knowledge is becoming the main resource, effective systems should be used to report the current level of knowledge. However, the main concern in reporting knowledge sharing is related to the entity of the variables that affect knowledge sharing. Most of the variables are subjective and may not make sense for decision makers in their decision making process. As a result, the development of a suitable report system to provide reliable as well as sensible data for decision makers is a major concern.

11.2.4 Validation and verification of knowledge sharing framework

Solutions proposed for research issues must be validated. Validation ensures that there will be confidence in the methodologies used to measure and report knowledge sharing level are reliable. The practicality and usefulness of the given framework to measure and report knowledge sharing level is another issue of this research.

11.2.5 Knowledge-based capital created by knowledge sharing

The last concern of this research is related to the knowledge-based capital that is produced by knowledge sharing. The focus here is on addressing business requirements in a knowledge-based economy and the best business scenario that organizations need to establish. Therefore, organizations need to use effective systems to create knowledge capital, measure and report it, maintain and improve it. This is a main concern of business owners in future.

11.3 Solutions proposed to address research Areas

Research issues are addressed in five areas as outlined below.

1. Identifying knowledge sharing variables
2. Developing a knowledge sharing measurement model
3. Developing a knowledge sharing reporting mechanism
4. Validation and verification of proposed framework
5. Developing a model to measure knowledge capital

11.3.1 Identifying knowledge sharing variables

Knowledge communication has three main components: receiver or sender of knowledge, knowledge channels and knowledge decoding or encoding. Knowledge channels are more related to the level of technology in knowledge sharing between individuals and in this research it is supposed that technology is available for all the individuals within a community and everyone has access to the tools and technologies that are required for effective communication. Hence, this research focuses more on the knowledge sender or receiver, and encoding or decoding of knowledge. Variables that affect knowledge sharing are classified into two categories based on these two components and are discussed in detail below.

a. Variables related to willingness and competence to share knowledge in a given context and during the specific time slot. Benevolence trust and competence-based trust are proposed as two key variables related to knowledge sender or receiver to share knowledge.
b. Variables related to measuring complexity and transferability of knowledge in a given context and during the specific time slot. Ontologies are used to determine the numeric values of complexity and transferability of knowledge to be shared between knowledge sender and knowledge receiver. These variables are more related to encoding or decoding of the shared knowledge.

11.3.2 Developing a knowledge sharing measurement model

In order to measure knowledge sharing level, a trust- and ontology-based framework is devised to measure the numeric value of knowledge sharing. The similarity between knowledge sender ontology and knowledge receiver ontology is used to measure the transferability of the shared knowledge. Complexity of knowledge refers to ontology structure and indicates the level of difficulty with which knowledge can be presented. Also, competence trust shows the ability of both knowledge receiver and sender to share knowledge, and benevolence trust indicates the willingness and motivation of the knowledge sender or receiver to share knowledge. All the variables are measured numerically and knowledge sharing level is a numeric value between 0 and 1.

11.3.3 Developing a knowledge sharing reporting mechanism

Simulation techniques are used to create a management dashboard for decision makers and show the knowledge sharing level between employees and customers. A Business Intelligence Simulation Model (BISIM) is developed for use as a business intelligence system to show the situation in a network or a community based on the knowledge sharing level between members.

11.3.4 Validation and verification of proposed framework

Validation and verification involve checking that the results that have been drawn by the proposed methodology are reliable as is the way in which the data is collected. Also, the results can be generalized for wider communities. This is to ensure that all techniques and methods in the methodology do really work for the purpose of knowledge sharing measurement. In this thesis, simulation experiments are used in order to validate the methodology for determining the knowledge sharing value of a particular knowledge in a given context during a specific time slot. Specifically, in this research the three following prototypes are validated.

1. Knowledge sharing measurement prototype: The objective of this prototype is to determine the knowledge sharing level of a particular knowledge in a specific time slot. Experimental studies are discussed and the results are presented.

2. Knowledge sharing reporting Simulation: The BISIM (Business Intelligence Simulation Model) is developed to report knowledge sharing level and experimental studies are used to validate the prototype.

3. Knowledge sharing capital Simulation: Experimental studies are used to validate the formulas that are used to measure knowledge capital that can be created by knowledge sharing.

11.3.5 Developing a model to measure knowledge capital

Knowledge capital can be created by knowledge sharing and intellectual capital techniques are defined to measure this capital. Three main dimensions of intellectual capital are: human capital, social capital and market capital. Based on these three dimensions, knowledge capital embedded in humans, knowledge capital embedded in relations and knowledge capital embedded in customers, can be calculated.

11.4 Recapitulation of the proposed framework

Figure 11.1 presents the proposed framework for knowledge sharing measurement and also measures the knowledge capital that can be created by knowledge sharing.

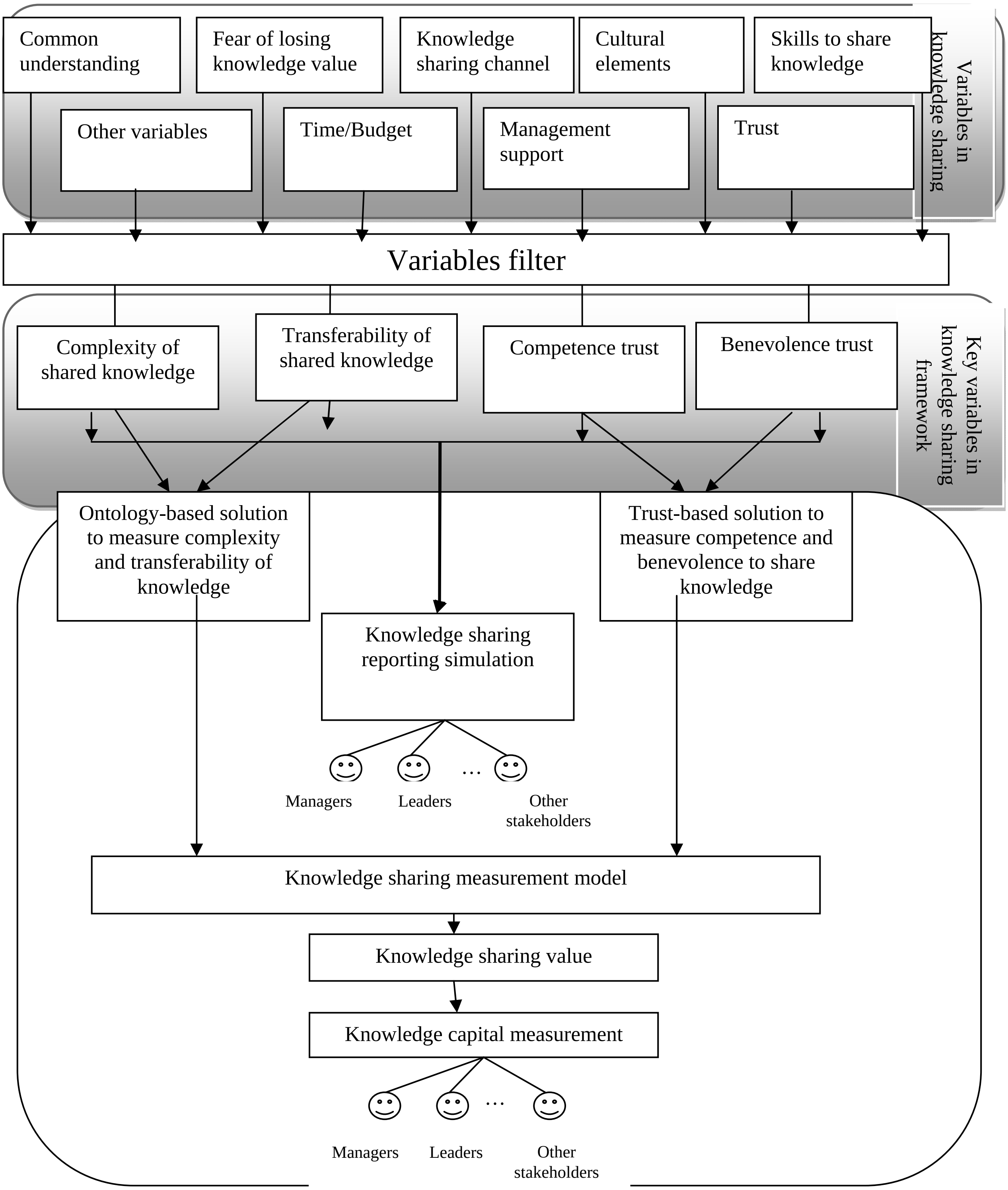


Figure11.1: Proposed framework for knowledge sharing

A model based on ontologies and trust concepts is developed to measure different variables of the proposed framework.

11.4.1 Measuring benevolence and competence trust

Trust matrices are developed to measure benevolence and competence trust between members of a community.

$$\text{Benevolence based trust} = Tb = \begin{array}{c|ccccc} & 1 & 2 & 3 & \dots & n \\ \hline 1 & 1 & Tb1,2 & Tb1,3 & \dots & Tb1,n \\ 2 & Tb2,1 & 1 & Tb2,3 & \dots & Tb2,n \\ 3 & Tb3,1 & Tb3,1 & 1 & \dots & Tb3,n \\ \dots & \dots & \dots & \dots & 1 & \dots \\ n & Tbn,1 & Tbn,2 & Tbn,3 & \dots & 1 \end{array}$$

Figure 11.2: Benevolence trust matrix

$$\text{Competence based trust} = Tc = \begin{array}{c|ccccc} & 1 & 2 & 3 & \dots & n \\ \hline 1 & 1 & Tc1,2 & Tc1,3 & \dots & Tc1,n \\ 2 & Tc2,1 & 1 & Tc2,3 & \dots & Tc2,n \\ 3 & Tc3,1 & Tc3,1 & 1 & \dots & Tc3,n \\ \dots & \dots & \dots & \dots & 1 & \dots \\ n & Tcn,1 & Tcn,2 & Tcn,3 & \dots & 1 \end{array}$$

Figure 11.3: Competence trust matrix

Figures 11.2 and 11.3 show the proposed matrices for measuring trust levels between members of a community.

11.4.2 Measuring complexity of knowledge

Knowledge complexity in measured by calculating ontology complexity. Ontology complexity is related to the complexity of conceptualization of the domain of interest. It is measured to reflect how easy any ontology is to understand. The complexity of an ontology can be determined by the characteristic features of: (i) usability and usefulness and (ii) maintainability. For example, a more complicated ontology indicates a more specified knowledge. However, it is difficult to comprehend and requires a high value of competence-based trust. Usability and usefulness of the knowledge may then decrease which produces a major impact on knowledge sharing. Additionally, complicated ontology is hard to maintain.

In order to measure the complexity of ontology, the number of ontology classes, number of datatype properties, object properties, constraints, and hierarchical paths are considered. Number of Ontology Classes (NoOC) is needed to obtain average value. Number of Datatype Properties (NoDP) illustrates how well concepts are being defined. In OWL, the datatype properties are indicated as owl:dataTypeProperty. Number of Object Properties (NoOP) illustrates how well spread of concepts within the ontology. In OWL, the object properties are indicated as owl:objectProperty. The Number of Constraints (NoC) illustrates how well relations are being restricted. In OWL, the constraints are indicated as owl:allValuesFrom, owl:someValueFrom, owl:hasValue, owl:cardinality, owl:minCardinality, and owl:maxCardinality. Lastly, Number of Hierarchical Paths (NoHP) illustrates how fine concepts are being presented. In OWL, the hierarchical paths are represented as owl:subClassOf.

To calculate complexity of an ontology O, a numeric measurement is defined by function Complex(O) using the above parameters in the following formula:

$$\text{Complex(O)} = \left(\frac{\sum(\text{NoDP}+\text{NoOP}+\text{NoC}+\text{NoHP})}{\text{Max(NoDP)}+\text{Max(NoOP)}+\text{Max(NoC)}+\text{Max(NoHP)}}\right)/\text{NoOC}$$

(Equation 11.1)

Where Max(NoDP) is maximum number of datatype property, Max(NoOP) is maximum number of object property, Max(NoC) is maximum number of constraint, and Max(NoHP) is maximum number of hierarchical path. The complexity value ranges between 0 and 1 where 0 means the ontology is not very complicated, while 1 means the ontology is very complicated.

11.4.3 Measuring transferability of knowledge

Transferability of the knowledge is more closely related to the members' backgrounds and their domain ontology. The degree of similarity of ontologies is used to ascertain the level of transferability between two members. Transferability of the knowledge for both transmitter and receiver will be given a value between 0 and 1.

To measure the transformability of two knowledge backgrounds, ontology similarity is considered and calculated. By means of obtaining the senses and hyponyms of each concept in the ontologies, and based on the structure of the ontologies, the similarity of two ontologies can be calculated. Precisely stated, knowledge transferability is signified by ontology similarity. Nevertheless, there may be more than one sense for each concept. The senses of subclasses of ontology can be determined by their ancestors to which sense from the root of the ontology it is determined by users.

The model developed by Wang and Ali (Wang and Ali, 2005) is used to measure the similarity between two ontologies. In this model, the difference of set of concepts, S1, captured in ontology 1, O1, from set of concepts, S2, captured in ontology 2, O2 as (Wang and Ali, 2005)

$S1 - S2 = \{x | x \in S1 \wedge x \notin S2\}$

The semantic difference between O1 and O2 can be defined by function Dif(S1, S2) in the following formula (Wang and Ali, 2005)

$$Dif(S1, S2) = \frac{|S1 - S2|}{|S1|}$$

(Equation 11.2)

Based on the above formula, if the two ontologies are totally different, the difference value is given 1 or the similarity value is given 0. Conversely, if the two ontologies are the same, the difference value is given 0 or the similarity value is given 1. Therefore, the similarity of set S1 from set S2 is defined as

The similarity between S1 and S2 = $\{x | x \in S1 \wedge x \in S2\}$

The semantic similarity between O1 and O2 or the transferability can be defined by function Trans(S1, S2) in following formula

$$Trans(S1, S2) = 1 - \frac{|S1 - S2|}{|S1|}$$

(Equation 11.3)

It is also compared in both directions i.e. Trans (S1, S2) and Trans (S2, S1) which may produce a different value.

In domain ontology where two individuals (receiver and sender) are sharing their knowledge (a class in ontology), they first need to agree on a sense of shared knowledge. Sense sets will be provided to summarize the semantics of the shared knowledge (the class in ontology). Basically, the sense set is a set of synonymous words denoting the concept of the class in ontology. A sense set is extracted from the electronic lexical database WordNet which is available online as Java WordNet Library (JWNL). JWNL is used to obtain the semantic meanings of concepts contained in ontologies.

11.4.4 Measuring total knowledge sharing level

Based on definitions of benevolence and competence trust values, as well as the complexity and transferability of a particular knowledge, the knowledge sharing level can be measured by the equations given below.

Knowledge sharing= [*(complexity of knolwedge ∗ benevolence trust ∗ Importance of benevolence trust) + (complexity of knolwedge ∗ competency trust ∗ Importance of competency trust) + (transformability of knolwedge ∗ benevolence trust ∗ Importance of benevolence trust) + (transformability of knolwedge ∗ competency trust ∗ Importance of competency trust)]/2*

$$Ks1=[((1-Kc)*|Tb|*K1)+((1-Kc)*|Tc|*K2)+(Kt*|Tb|*K3)+(Kt*|Tc|*K4)]/2$$

(Equation 11.4)

Kc= knowledge complexity (because knowledge sharing reduces by increasing complexity, 1-Kc is used in the formula so if 1-Kc increases, knowledge sharing level will be increased). Tb= trust benevolence K1= Importance of benevolence trust in different level of knowledge complexity Tc= trust competency Kt= knowledge transferability K2= Importance of competency trust in different level of knowledge complexity K3= Importance of benevolence trust in different level of knowledge transferability K4= Importance of competency trust in different level of knowledge transferability

Also, the willingness and competency of a receiver to acquire knowledge can be calculated as follows:

$$K's1 = [((1-K'c)^* \mid T'b \mid {}^*K5) + ((1-K'c)^* \mid T'c \mid {}^*K6) + (K't^* \mid T'b \mid {}^*K7) + (K't^* \mid T'c \mid {}^*K8)]/2$$

(Equation 11.5)

K' s1=competence and ability of the receiver to gain the share knowledge K' c= knowledge complexity for the receiver (because knowledge sharing reduces by increasing complexity, 1-K' c is used in the formula so if 1- K' c increases, knowledge sharing level will be increased).

T' b= receiver's trust benevolence K5= Importance of receiver's benevolence trust in different level of knowledge complexity T' c= receiver's trust competency K' t= receiver's knowledge transferability K6= Importance of receiver's competency trust in different level of knowledge complexity K7= Importance of receiver's benevolence trust in different level of knowledge transferability K8= Importance of receiver's competency trust in different level of knowledge transferability

and

$$Total\ Ks = \min [(K's1, Ks1$$

(Equation 11.6)

It is important to know that the measured level of shared knowledge is within a specific time slot and also it is the first time that the measured knowledge is shared between sender and receiver. Knowledge sharing is a function of time and the level of knowledge sharing is measured at timeT0. Also, if the same knowledge is repeated, the receiver will find it easier to acquire the shared knowledge and it will change the competency and personal ontology of the receiver.

11.4.5 Developing a model for a knowledge sharing reporting mechanisms

In the area of digital economy, the most important challenges are related to producing and using data, information, and knowledge. The BISIM

(Business intelligence Simulation Model) simulator is developed to provide an effective reporting system for knowledge sharing measurement. The main aim of this simulation is to represent the development of knowledge sharing in different areas including an organization's strategic plan, where "Knowledge Creation" and "Knowledge Sharing" are vital to the organization's knowledge management process. To encourage people to share their knowledge and help with making decisions, the BISIM simulator projects the level of knowledge sharing within communities and addresses the trust level between members. According to the Knowledge Sharing principle, members rely on an effective relationship between one another to exchange knowledge and the key factor in making an effective relationship is Trust. Two of the most regularly cited forms of trust - Competence and Benevolence - are used in this simulation for knowledge sharing measurement. While Competence-based trust represents the essential capability to share particular knowledge in a specific time slot, benevolence-based trust represents the willingness to share that particular knowledge in the same time slot. In order to improve knowledge sharing and develop a strong relationship between community members, this research has designed and implemented a BISIM simulator using a Business Intelligence concept.

11.4.6 Knowledge capital measurement

Knowledge sharing creates capital in a community and based on intellectual capital classification, the capital produced by knowledge sharing is classified in this thesis under three categories: human capital, market capital and social capital. Human capital is related to embedded knowledge in employees and can be calculated using the following equations.

$$\Delta Hi = \text{max knowledge sharing level thet member i recieves from other members} * \text{value of the shared knowledge} \quad i= A \ldots M \quad \text{(M is the last member)}$$

(Equation 11.7)

And total changes in human capital of the network,

$$\text{Total } \Delta H = \sum (\Delta Hi) \quad i= A \ldots M \quad \text{(M is the last member)}$$

(Equation 11.8)

Social capital is embedded value in the connections and can be calculated by Equation 11.9 as follows:

$$\text{Total social capital} = \sum(\text{knowledge sharing level for each connection}) * (\text{knowledge value})$$

(Equation 11.9)

Market capital measurement is similar to human capital and the difference is the fact that human capital is related to internal employees and market capital is related to external resources such as customers.

11.4.7 Validation and verification

Three proof-of-concept prototypes are created to validate and verify the procedures and framework in three aspects: knowledge sharing measurement prototype, knowledge sharing reporting prototype, and knowledge capital measurement. Through prototypes evaluation, proof-of-concept experiments are developed to verify the claims.

However, there are many improvements that can be made through future work. In the following sections, several issues are considered which can be addressed by future work.

11.5 Future work

Some future works are related to improving the effectiveness of knowledge sharing in current social network websites by using the proposed model in this thesis. Another part of the proposed future work is related to practical results in business that can be generated by this thesis. Future work will also be devoted to developing other solutions and techniques such as text mining that can be appropriately used in a future model to measure the complexity and transferability of a particular knowledge.

11.5.1 Future work on social networks

Recently, social networks have become rapidly growing elements in the domain of knowledge sharing. Knowledge sharing framework can be used in social networks. The traditional meaning of 'social network' relates to a community of people that form a relationship with each other due to shared interests such as social activity, sport, entertainment or any other purposes. When it comes to online social networking, web sites are commonly used by the online members to develop relationships between the virtual communities. The websites are called social websites and there are lots of social web sites on the Internet. The Internet has cuased a significant increase in the numbers of the social networks as well as the members of each community and numerous other benefits are provided by the Internet. One of those benefits includes diversity because the Internet gives individuals from all around the world access to social networking sites. It means that although someone is located in the United States, he/she can develop an online friendship with someone in Europe or Australia. One of the most popular social network websites is Facebook. This social network website is used as an example to explain how the proposed framework can help social network websites to improve their quality of services. Based on statistical reports of the Facebook website, more than 500 million active users are using this online social network to connect with each other and 50% of the users log on to Facebook on any given day. Each member has 130 friends on average users spend 700 billion minutes per month on Facebook (http://www.facebook.com/press/info.php?statistics, 2010) It is almost the third most populated country in the world after China and India and also the most populated digital country in the history of humanity. The number of the users is still growing significantly and it is projected to hit one billion users in the next few years. Users speak different languages and are from different cultures and about 70 % of Facebook users are located outside the United States. Within this social network, website members can share their ideas or their knowledge on their wall page and their friends have permission to see the shared ideas or knowledge and put their own knowledge on the same page as well. The shared knowledge or idea can be in different formats such as text, video, picture. Figure 11.4 shows a sample page on a Facebook website.

Figure 11.4: Wall page forsharing ideas and knowledge on Facebook

As seen in Figure 11.4, ideas and knowledge can be shared on the wall page of the user, and user's friends are able to review the shared knowledge or ideas. As discussed previously, a user's friends can be from different countries and speak different languages. Although users can write their message in their own language, understanding the knowledge shared by the friends from other languages and backgrounds is the main issue. There are more than 70 translations available on the site; over 300,000 users have helped translate the site through the translations application (http://www.facebook.com/press/info.php?statistics,2010)

Still, communication between users from different languages is a significant issue and most communication belongs to users with the same languages or those who use a third language such as English to communicate with each other. To facilitate communication and increase transferability of knowledge among users from different languages, even if they do not know each other's language, some solutions are proposed based on the model in this thesis. Solutions are divided into two main categories including solutions which improve transferability of a particular knowledge and solutions related to the complexity of that knowledge.

11.5.1.1 Transferability on face book

Translation capabilities are a key issue in social networks and many techniques have been proposed by computing research laboratories to improve automatic translators. These techniques can be deployed on Facebook to handle low-density languages and increase the ability of people from low-density languages to communicate and share their ideas. To deploy this idea it is necessary that all users select a default language as their preferred language in their communication. The preferred language can be changed at any time and users can select more than one language. For example, a person who is French and knows English well, can select both French and English as default languages.

Figure 11.5 shows the facility that needs to be added in the basic information section on Facebook.

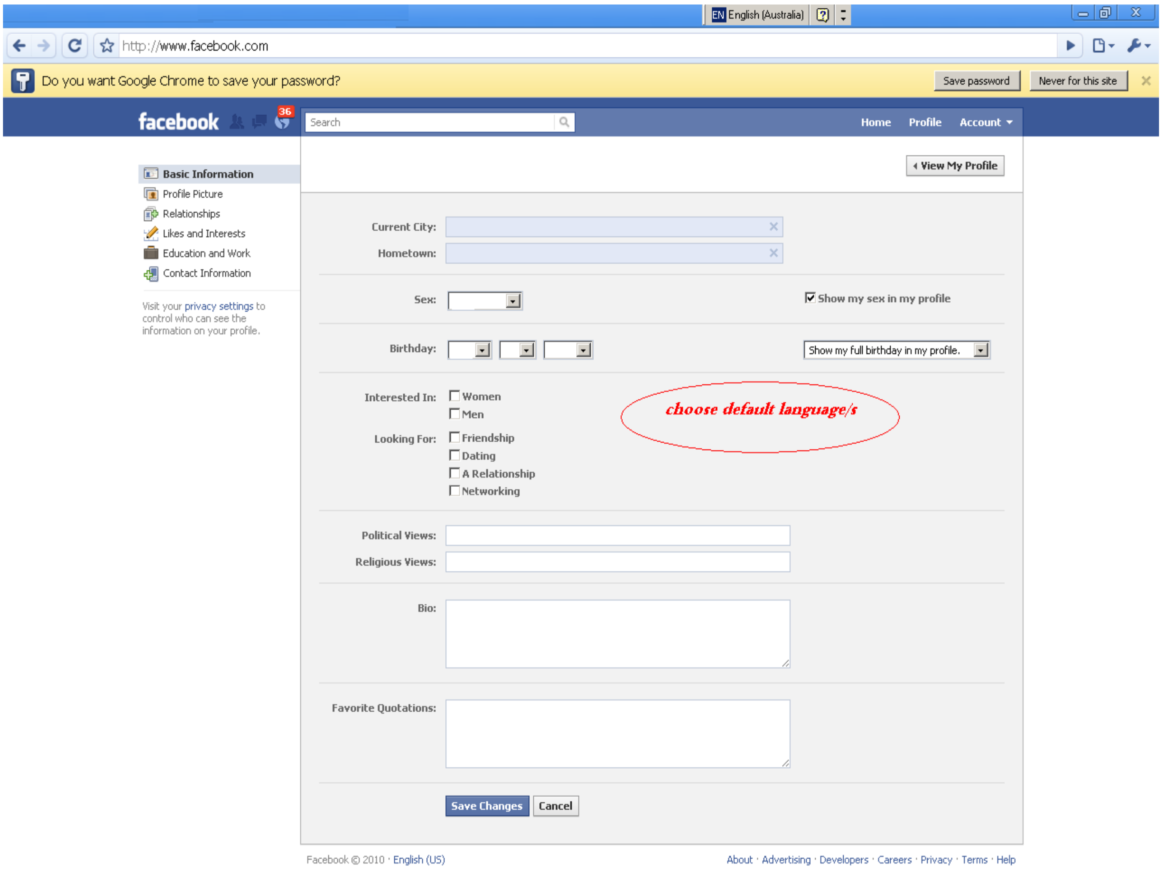


Figure 11.5: Proposed facility to be added to basic information (http://www.facebook.com, 2010)

The shared ideas and knowledge can be shown on a friend's wall in two languages; the first one can be the original language used by the knowledge sender who has shared the message, and the next language can be the preferred language that all users have chosen as a default language.

Figure 11.6 shows a shared knowledge display on a friend's wall on Facebook. In this way, the ideas and shared knowledge can be more transferable and friends from different languages can receive and understand the messages.

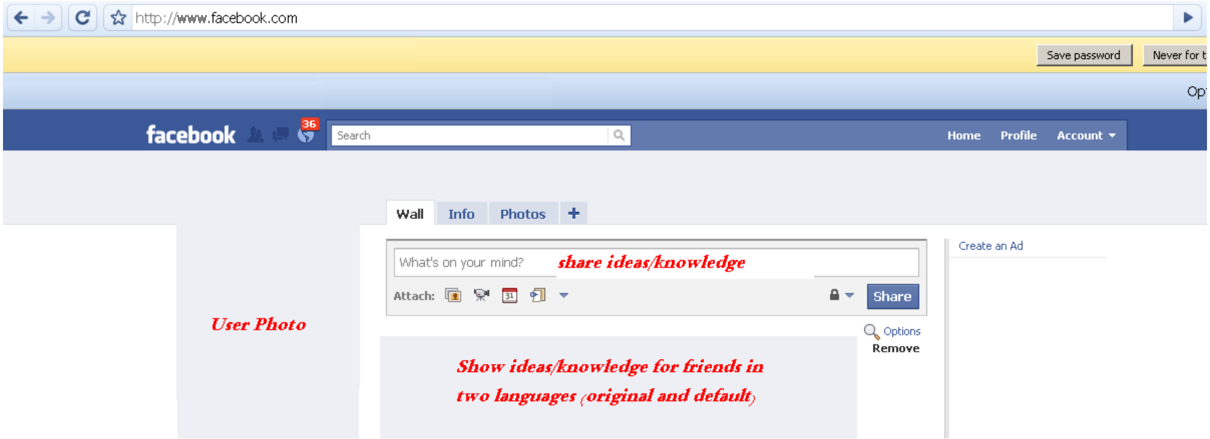


Figure 11.6: Shared knowledge interface on friend's wall

Several problems associated with language translation and these problems have been troubling translators for years. It is difficult to capture the same meaning when translating between two completely different languages because most translation software in the market is based on literal word-to-word replacement and they cannot accurately obtain the semantic meaning of a sentence. As a result, a third person may have to be used as editor to modify the translated message. In this case, the knowledge sender can allow highly trusted persons or some defined friends in each language category to modify the translated message.

Further research is needed into the effect of new facilities on knowledge sharing between individuals from different languages, and more work is needed to develop automatic translator tools in different languages, especially low-density languages.

11.5.1.2 Complexity on face book

Another main issue that was discussed previously in the model is the unique understanding of the shared knowledge. Facebook users are from different countries with different cultures, education, skills and etc. The shared knowledge can be understood in different meanings or it may be too complex to be understood by some of the friends. For example, a user may share some ideas related to his/her professional job and only his/her co-workers may be able to acquire and understand the shared knowledge and his/her family friends may not be able to acquire the related knowledge. Based on the ontologies techniques in the proposed model in this thesis, friends can be categorized by their ontologies and several tools can be provided to the knowledge sender enabling the sharing of knowledge in some specific ontologies. With currently available tools, the user can choose from several some options in order to share the messages. Figure 11.7 shows the available tools for sharing messages on face book.

As seen in Figure 11.7, the knowledge sender is allowed to choose from several options including “any one”, ”friends of friends”, ”friends” , “specific people” and “only me “ to limit accessibility to the shared knowledge. Overall, these options are more trust-based and based on the privacy of the shared knowledge, other users are permitted to review the knowledge. Also, there is a ranking option that allows a user to classify his/her friends to mutual friends and normal friends and this one also is trust-based.

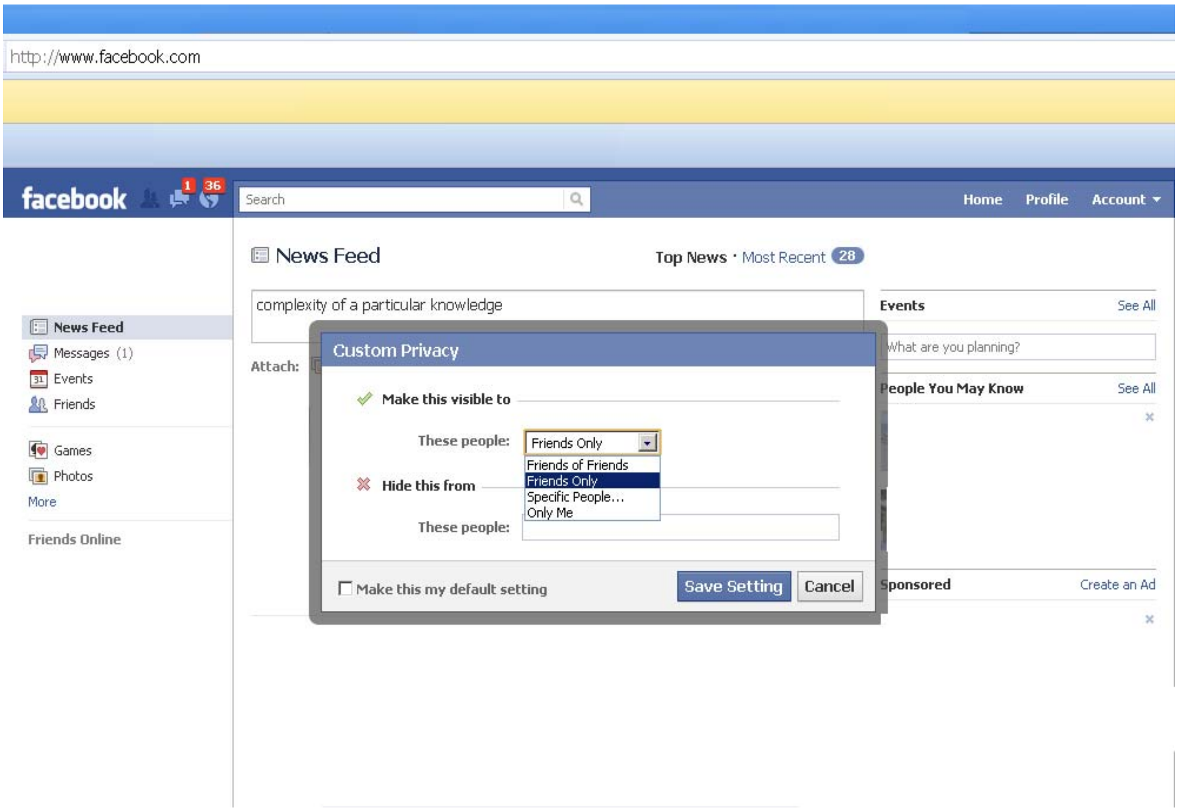


Figure 11.7: Available tools for choosing the friends who are allowed to review the message

However, another category can be created based on the proposed framework and ontology techniques. In the proposed classification, friends who are working in the same workplace, have the same educational backgrounds, skills, political beliefs and other unique characteristics, can be classified in one category and the knowledge sender can share his/her knowledge in one or some of these categories. Further studies are needed to investigate this kind of classification of knowledge sharing and reduction of knowledge complexity.

11.5.2 Future work in e-commerce

Traditional retailers have been increasingly downgraded in the last decade (Reynolds, 2002) and customer-to-customer interactions are generated potential e-commerce in retailing (McGoldrick, 2002). eBay is the best example of customer-to-customer online business. eBay allows customers to bid against each other rather than against the traditional bookmake,r and also sell their own merchandise directly to another consumer. In a traditional market, several variables such as physical buildings, face-to-face communication with the seller, viewing the product for sale, and other related variables inspire customer confidence and trust to pay and buy a product or service. In e-commerce, it is also necessary to provide suitable tools with which customers can assess the buyer's or seller's trust level and reputation. Also, due to lack of face-to-face communication, both parties should make sure that an accurate message is transmitted to the other party and that the knowledge has been shared correctly. In most of the e-commerce websites, trust level measurement mechanisms are implemented based on buying and selling records and users can be categorized in different trust levels. Figure 11.8 shows the mechanism of a ranking system based on a user's previous records. Figure 11.8 shows that users are ranked under 12 categories, with the user in twelfth category being the most trusted user.

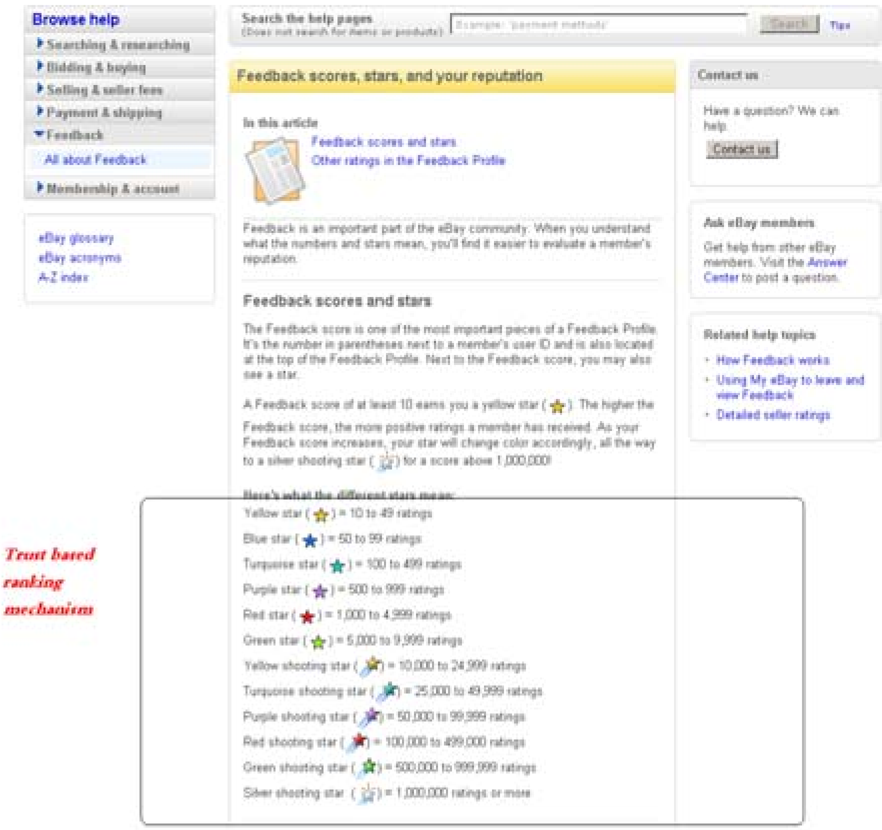


Figure 11.8: Trust-based ranking mechanism to rank users based on previous records

Moreover, each user is able to check the trust level of the seller and buyer before deciding to buy or sell a product or service. This is one way to increase the confidence in online commerce. For example, Figure 11.9 shows the records of a seller who has offered to sell a product on an e-commerce website. As can be seen, the customer is able to check his/her records regarding “item as described”, “communication”, ”postage item” and “postage and handling changes”.

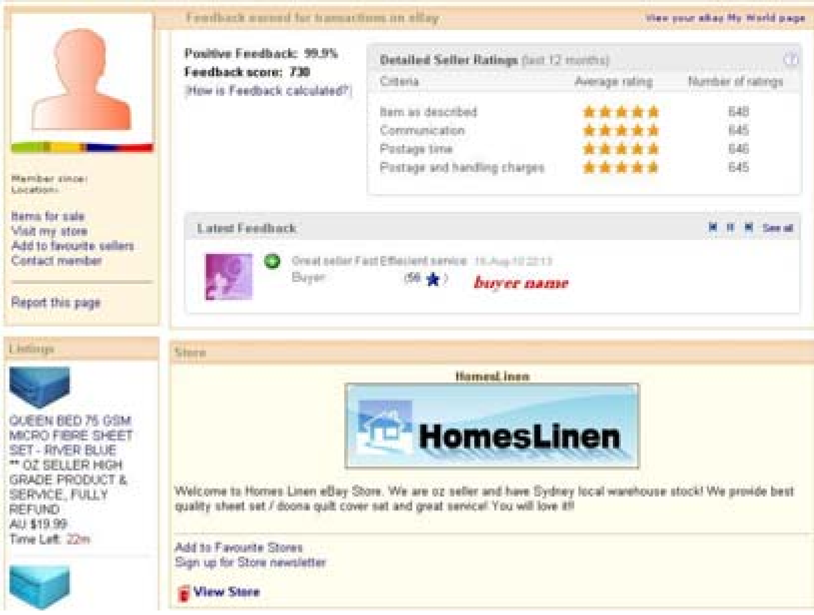


Figure 11.9: Records of a buyer

However, all the data are derived from the customers and the knowledge sharing framework can be used as a supporting system to make the communication between buyer and seller more effective. The system is more related to evaluating buyer and seller backgrounds and their ontologies and proposing the most suitable message that can be offered by the seller in order to share precise information about the product and increase his/her willingness to buy the product or service. The related variables in the supported systems can be defined as follows:

1. The seller's trust willingness is related to seller's the willingness to sell the product or service in the last 12 months. Some parameters can be designed to measure this variable. For example, this includes the numbers of the products or services that are offered by a defined seller in the last 12 months, as well the numbers of logs in by the seller (low weight).

2. The seller's competence-based trust is related to the score that he/she has gotten from previous buyers. As stated earlier, a buyer is able to evaluate the handling ability of a seller.
3. The buyer's trust willingness is related to buyer's willingness to buy the product or service in the last 12 months. Some parameters can be designed to measure this variable. For example, the numbers of the products or services that have been bided on by a defined buyer in the last 12 months, also the numbers of logs in by the buyer (low weight).
4. The buyer's competence-based trust is related to the score that he/she has obtained from previous sellers. As mentioned previously, the seller is able to evaluate a buyer as well.

Also, based on information about buyer and seller's backgrounds, occupation, skills, professional domains and also information from previous payments, personal ontologies can be developed for each buyer and seller. It is possible to determine the domain knowledge of the buyer and seller and design the best was to represent the knowledge through ontology. The message that a seller chooses to advertise or describe the product or service is the knowledge that should be shared effectively. Also, it is possible to measure complexity and transferability of the shared knowledge between buyers and sellers. However, further studies are required to develop the support systems to help buyers and sellers to represent their requirements clearly and more investigation is needed to measure these system's effects on successful business interactions.

11.5.3 Future work on text mining for knowledge sharing framework

Text mining is a method that is developed in order to achieve the goal of retrieving useful information (Edda and Jorg, 2002). Most text mining methods use the keyword based approaches to extract information and meaningful numeric indices from the text. For example, the raw word or term frequencies generally reflect how important a word is in each document. However, another approach in text mining chooses the phrase technique to construct a text representation for a set of document (Wu, 2007). A phrase-based approach is semantic-based and performs better than does the key-word based one. Both of these approaches can be applied in a knowledge sharing framework. In the first approach, especially in knowledge sharing between group members such as free conversations, text mining can be applied to count the words and, based on the words and numbers of repetitions, the ontology related to each party can be detected. The result of this detection can be used to measure transferability of the shared knowledge between members. However, further research is needed to modify existing algorithms in this approach to incorporate with knowledge sharing framework. Also, a phrase-based approach in text mining could also be useful. In this approach, unknown information and knowledge can be discovered by knowledge receivers who are not able to know and understand the information, and text mining techniques can help them to detect the purpose of knowledge sharing and meaning of the unknown parts. This can reduce the complexity of knowledge.

Overall, text mining provides useful tools to measure the complexity and transferability of a particular knowledge and further research is needed to modify related algorithms to measure knowledge representation variables in a knowledge sharing framework.

11.5.4 Future work on using knowledge sharing framework in available business solutions

As discussed previously, most business solutions such as ERP, CRM, SCM etc. are process-based. However, in a knowledge-based society, process-based business solutions cannot satisfy the new requirements of a business. For example, word of mouth marketing and customer-to-customer marketing strategies are important concepts that are mostly based on trust and knowledge sharing between customers, and available business solutions are not able to provide exact information to address the requirements of these new methodologies. Similarly, intellectual capital in financial management, and reliable tools to measure and report different dimensions of this capital, are key issues and traditional business solutions cannot cover all the requirements. This can also be discussed in human resource management where new training methodologies such as mentoring-based training is going to replace traditional on the job training approaches. Trust and knowledge sharing between mentor and trainer are key issues. Overall, business solutions need to be merged with new concepts in business and further research is required to consider variables like trust and knowledge sharing in the new versions of business solutions.

11.5.5 Future work on business performance measurement

The knowledge sharing framework can be used in several organizations to evaluate the improvement of business performance based on knowledge capital in an organization. For example, the relationship between market capital improvements and total sales could be examined. In this way, organizations can evaluate their investment to create or share a new knowledge between their employees. Or, another example relates to human capital improvement with an organization's output. For example, the role of improvement in human capital by increasing productivity, quantity and quality of the products, can be calculated.

11.6 Conclusion

Knowledge sharing is one of the key issues in a knowledge-based society and economy. It was defined and discussed in detail in this thesis and main variables were identified to measure the effectiveness of knowledge sharing. This chapter was focused on proactive researches that can be undertaken to improve knowledge sharing measurement based on the proposed model in this thesis. Knowledge sharing is a key issue in social network websites and some research issues were identified in order to improve knowledge sharing in social networks. The number of members in social networks is rapidly increasing and it would not be surprising, in the next few years, the world's most populated digital country will emerge on the Internet. Innovative methods are required to accelerate knowledge sharing and help human beings to build a world where everyone can keep his/her own language but is also able to communicate with anyone in the world. The knowledge sharing framework in this thesis points to further studies and defines several research issues to help researchers create methods to assist all community members with different backgrounds communicate with others. The framework also can be applied to businesses, facilitating their success in a competitive and dynamic environment. The framework can be used in current business solutions such as ERP and business intelligence applications and can also be used to report reliable information to decision makers about the trust and knowledge sharing level between and within business components.

To conclude, knowledge life cycle is too short and will be even shorter in future and novel knowledge should be shared very fast with minimum budget and in high scale. Also, members should be able to gain the share knowledge and use it in their daily life and participate in knowledge sharing processes to share the gained knowledge to others and increase knowledge flow. The percentages of the members who participate in knowledge sharing processes should be increased and it can lead a huge development in a world that any one gain the up dated knowledge and share the innovated knowledge to others.

11.7 References

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Appendix

Selected Journal paper

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Ontology based Approach in Knowledge Sharing Measurement

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Abstract: For many years, physical asset indicators were the main evidence of an organization's successful performance. However, the situation has changed following the revolution of information technology in the knowledge-based economy and in the new ideas in economy; knowledge assets are a critical strategic resource in economy. Knowledge management [KM] tools have become very important and in order to gain a competitive advantage, it is necessary to create, store, share and apply knowledge. Knowledge sharing is one of the key issues in knowledge management. One of the main challenges facing pioneer firms is to provide an effective strategy to exchange knowledge formally or informally. In this paper, we will discuss the effectiveness of knowledge sharing and our proposal for an effective knowledge sharing strategy. Based on a review of knowledge sharing literature, we will focus more on the trust and knowledge contexts as key issues in knowledge sharing. Trust is the most important issue when creating a relationship, knowledge sharing and partnership. Moreover, there are a number of forms that trust can take in these relationships and the most regularly cited forms are competence and benevolence trust. In this paper, we will explore these two forms of trust and will examine their role in knowledge sharing and how they can be defined and measured. On the other hand, we will apply ontologies to explore the knowledge context. Ontologies are used in widespread application areas particularly to provide a semantically shared domain knowledge in a declarative formalism for intelligent reasoning. Even ontology enables knowledge sharing; however, the complexity of knowledge being conceptualized in the ontology is critical to the success of knowledge sharing efforts. Other factors like trust in the source of knowledge can also affect knowledge transfer. In this paper, we propose metrics to measure the complexity of ontology for knowledge sharing. Finally, the effectiveness of our proposed knowledge sharing methodology is presented both using a fuzzy-inference engine and a crisp system.

Keywords: Knowledge sharing, Trust measurement, ontology, competency trust, willingness trust, tacit knowledge, knowledge transformability, knowledge complexity
Categories: I.2.4, I.2.8

Introduction

Knowledge, in its different forms, is increasingly recognized as a crucial asset in modern organizations [Bonifacio, 2002]. Over the past two decades, knowledge management has become most important in the knowledge-based economy. Dustdar [2005] defines knowledge Management [KM] as “processes, culture, and ways of communicating” and argues that knowledge management (KM) represents the processes that enable an organization to act “in response to the changing internal and external environments in which they operate”[p.591]. Although knowledge management has been investigated in the context of decision-making support systems [DSS] for over a decade, interest in and attention to, this topic has exploded recently [Nissen, 1999]. Knowledge asset is now explored as a factor of no less importance than the traditional business inputs of labor and finance [Forbes, 1997]. There are many definitions of knowledge management. Swan [1999] defines KM as “any processes or practice of creating, acquiring, capturing, sharing, and using knowledge, wherever it resides, to enhance learning and performance in organizations”. Perrot explains that Knowledge management is the identification, storage, protection of knowledge for future operational and strategic benefit of the organization; this may be implicit or explicit [Perrott, 2006]. In most of the knowledge management definitions, knowledge sharing is one of the key elements. Now, it is going to become more common for scholars and practitioners in various fields to turn their attention to knowledge management systems [KMS] as a means of sharing knowledge in organizations. [Alavi, M., 1999] posits that knowledge sharing is the fundamental means through which employees can contribute to knowledge application, innovation, and ultimately the competitive advantage of the organization [Jackson, 2006]. Research has shown that trust is one of the key issues in knowledge sharing between individuals. Trust, a mutual expectation that partners will not exploit the vulnerabilities created by cooperation [Sako, 1998], has been recognized as an important factor affecting knowledge sharing [Ridings, 2002]. Moreover, there are a number of forms that trust can take in knowledge sharing and the most regularly cited forms are competence, benevolence and contractual trust. Willingness and competency trust are considered as the most critical forms [Ahmed, 1999] and in this paper, we will explore these two forms of trust and will examine their role in knowledge sharing and how they can be defined and measured. On the other hand, knowledge context is also a key issue in knowledge sharing. Context has been recognized by many KM researchers as being crucial to improving the understanding and sharing of knowledge [Goldkuhl, 2001]. We will apply ontologies to explore knowledge context. Ontologies are developed in common application domains such as the semantic web, medical informatics, e-commerce, etc. Mainly, ontologies are developed to provide a semantically shared domain knowledge in a declarative formalism for intelligent reasoning. Besides, complexity of knowledge is critical to the success of knowledge sharing efforts. Presumably, the knowledge is conceptualized in declarative formalism i.e. Ontology having quality data, stability, and completeness. When the ontology is less complex, we may not need a high value of competence-based trust. In contrast, if the ontology is rather complicated, a high value of competence-based trust is required. Yet, some knowledge is difficult to codify in ontology which is not the concern of this paper.
In this paper, we propose metrics to measure the complexity of ontology for knowledge sharing. Then, we propose metrics to measure the transformability of specific knowledge within different ontologies and based on different values of trust [competency and willingness trust], we propose metrics to measure the effectiveness of knowledge sharing between sender and receiver of the specific knowledge.

Background

Knowledge Sharing

Knowledge sharing is one of the most critical elements of effective knowledge processing and organizations often face difficulties when trying to encourage knowledge sharing behavior [Saraydar, 2002]. It has been estimated that at least $31.5 billion are lost per year by Fortune 500 companies as a result of failing to share knowledge [Babcock, 2004]. Knowledge sharing refers to the provision of task information and know-how to help and collaborate with others to solve problems, share ideas, or implement policies or procedures [Cummings, 2004]. Davenport and Prusak define knowledge sharing as equivalent to knowledge transfer and sharing amongst members of the organization [Davenport, 1998]. Knowledge sharing can occur in different forms such as written correspondence, face-to-face communications or through networking with other experts, documenting, organizing and capturing knowledge for others [Cummings, 2004]. Knowledge sharing is important for companies to be able to develop skills and competence, increase value, and sustain competitive advantages due to innovation that occurs when people share and combine their personal knowledge with others[Matzler, 2007]. The importance of knowledge sharing raises the issue of how organizations can effectively encourage individual knowledge sharing behavior and what factors enable, promote or hinder sharing of knowledge. It is important to explore the factors affecting knowledge sharing and remove barriers to participation in knowledge sharing within and between communities. Researchers have found that organizational culture affects knowledge sharing and the benefits of a new technology were limited if long-standing organizational values and practice were not supportive of knowledge sharing across units. [De Long, 2000]. Among the many cultural dimensions that influence knowledge sharing, trust is the most important dimension and a culture that emphasizes trust can help to alleviate the negative effect of perceived cost on sharing [Kankanhalli, 2005]. Trust provides conduits for the knowledge exchange and learning needed to solve problems and achieve shared goals [Preece, 2004]. “Trust” has been recognized as being “at the heart of knowledge sharing” [Davenport, 1998] and “the gateway to successful relationships” [Wilson, 1993]. High levels of trust are the key to effective communications as trust improves the quality of dialogue and discussions [Dodgson, 1993]. The willingness to share knowledge is a key issue in knowledge sharing [Connelly, 2003] and, in this paper, we consider willingness trust as one of the key variables in knowledge sharing measurement. Some of the researches show that management support affects both the level and quality of knowledge sharing through influencing employee willingness to make a commitment. Moreover, in an organizational context, willingness to share knowledge can be improved by management support, rewards and incentives and organizational structure [Wang, 2009]. In interpersonal and team contexts, willingness to share knowledge depends more on the level of team cohesiveness [Bakker, 2006] and the diversity of team members [Ojha, 2005]. It is understood by different researchers that the ability and competency to share knowledge and to send or receive knowledge is the most critical issue in knowledge sharing [Jap, 2001].We consider competency trust in our paper as the next key variable in knowledge sharing measurement and again it is one of the key issues. The reason is that competency trust refers to how the partner is expected to perform, or does perform, in relation to the underlining functions of the relationship [Heffernan, 2004]. Competency trust is defined as whether a partner has the capability and expertise to undertake the purpose of relationship and meet the obligations of the relationship [Doney, 1997]. In overall, willingness and ability to share knowledge and willingness and ability of receiver to achieve knowledge are key issues in knowledge sharing and in the proposed method to share effectiveness of knowledge sharing in this paper; these two variables are considered to be key variables.

Knowledge sharing also depends on the nature, definition and properties of knowledge, which influence the ease with which knowledge can be shared and accumulated [Argote, 2003]. In general, knowledge can be classified as explicit or tacit knowledge according to the degree to which people can share easily with others [Nonaka, 1994; Nonaka& Takeuchi 1995]. Explicit knowledge consists of facts, rules, and policies that can be expressed and codified in writing or symbols and can be easily shared [Zander, 1995]. However, most knowledge is tacit and cannot be codified. Tacit knowledge is often ambiguous, difficult to interpret scientifically and cannot easily be reduced to formal grammars and records in a database [Preece, 2004]. According to the economic value of knowledge, knowledge can be classified into general and specific knowledge [Becella-Fernandez, 2004]. General knowledge is held by a large number of individuals and can easily be shared but, specific knowledge is possessed by a very limited number of individuals and is not easily shared [Yang, 2008]. Specific knowledge may be technical or contextual and includes the knowledge of tools and techniques for addressing problems in that area by people such as physicians or engineers [Yang, 2008]. In this paper, the nature of knowledge is defined by two key variables. “Complexity” of knowledge is used to measure the ease with which particular knowledge can be shared. It is obvious that explicit knowledge and routine or day-to-day knowledge that people share in their daily conversation is less complex, while technical knowledge is more complex. We propose an ontology-based model to measure complexity of knowledge. Each individual has his/her own ontology [personal] and based on this personal ontology, the complexity of knowledge can be measured. In relative terms, explicit knowledge can be easily modelled and represented in personal ontology. As a result, these two kinds of knowledge are easy to share. "Transformability" of knowledge is the next variable used to measure the nature of knowledge in this paper. It is based on the fact that, in most cases, knowledge senders and receivers are from different backgrounds such as engineering, business, medicine etc. and when individuals from different backgrounds start to share knowledge, the meaning of this knowledge for each party may differ. In this paper, ontologies are used to measure transformability of knowledge between individuals from different backgrounds by comparing the similarity of their ontologies.

In the next section, trust is discussed in detail and key issues such as trust definition, trust building and trust measurement are reviewed. Then, knowledge definition and complexity and transformability of knowledge are discussed as the key issues in knowledge sharing measurement.

Trust

Trust is an essential ingredient in any successful society [Alesina, 2002]. Mayer defines trust as "the willingness of a party [trusting agent] to be vulnerable to the actions of another party [trusted agent] based on the expectation that the other [trusted] will perform a particular action important to the trusting, irrespective of the ability to monitor or control that other party [Mayer, 1995]. Williams defines trust as "one's willingness to rely on another's actions in a situation involving the risk of opportunism" [Williams, 2001]. Trust can be viewed as an attitude [derived from trustor's perceptions, beliefs, and attributions about the trustee based upon trustee's behavior] held by one individual toward another [Whitener, 1998]. Trust is necessary for the exchange of knowledge, goods and services, and any organization/team or community has to build and sustain a mutual level of trust in the other party's actions [Kugler, 2007].

Trust consists of different components and dimensions. McKnight defines trust components as trusting intention and trusting beliefs. Trusting intention describes one's willingness to depend on the other party in a given situation, and trusting belief is defined as one's belief that the other person is benevolent, honest, or predictable in situation [McKnight,1998]. Moreover, Bhattacherjee [2002] defines different dimensions of trust as the "ability [expertise, information, competence, expertness, dynamism], integrity [fairness in transaction, fairness in data usage, fairness in service, morality, credibility, reliability, dependability], and benevolence [empathy, resolving concerns, goodwill, responsiveness]". Similarly, Mayer suggested that trust evaluations are composed of perceptions of the ability, benevolence and integrity of the target [Mayer, 1995]. Ability is the group of skills, competencies, and characteristics that enable a party to have influence within some specific domain; benevolence is the extent to which a trustee is believed to want to do good to the trustor, aside from an egocentric profit motive; and integrity involves the trustor's perception that the trustee adheres to a set of principles that the trustor finds acceptable [Ammeter, 2004]. The concept of competence trust refers to "reliability" and "integrity" as two important dimensions of trust [Caniels, 2004]. Reliability refers to the extent to which an exchange partner has the required expertise to perform the job successfully [Ganesam, 1994]. Integrity refers to the expectancy that the partner's word or statement can be relied on [Doney, 1997].

In this paper, we focus on competence and willingness trust as two key issues in knowledge sharing measurement. In the next section, we discuss ways to build competence and willingness trust and how to measure them for use in our model.

Trust Building and Trust Level Measurement [TL]

Trust value changes according to positive and negative experiences in a specific context [Campo, 2006]. Our research will focus on the two most important dimensions of trust by considering benevolence and competency as the two dimensions of trust. Competence trust refers to trust that is created by ability, contracts, laws, governance mechanisms, and structural assurances, while benevolence trust refers to trust due to goodwill intentions [Pavlou, 2006]. Competence and willingness trust are viewed as independent constructs. It has been empirically proven that they are distinct variables that usually have different relationships with other variables [Pavlou, 2006]. The proposed distinction between competence and benevolence trust is consistent with the economic literature wherein benevolent sellers are committed to acting in a goodwill fashion, while competent sellers are committed to fulfilment [Dellarocas, 2003].

Benevolence is related to willingness within a community and is based on the idea that individuals will not intentionally harm another when given the opportunity to do so. This kind of trust would be positive in scenarios where agents within a community may believe in others' willingness to share knowledge. On the other hand, they may refuse to accept others' willingness, and in such scenarios willingness trust would be negative. We assign 1 for the highest level of willingness trust (benevolence trust) within a community, and -1 for the lowest level of trust within a community. All the values for willingness trust will be within a closed interval [-1, 1]. A benevolence trust relationship between two entities A and B is represented as Tb[A,B] which signifies agent A's willingness attitude towards agent B.

The second dimension of trust is competency. This kind of trust refers to the trusting agent's belief in the trusted agent's capability. It describes a relationship in which an individual believes that another person is knowledgeable about a given subject area. Competence-based trust can also be negative or positive and agents can believe in others' ability or they completely reject others' ability in a given subject area. Again, we assign 1 for the highest level of competence-based trust within community and -1 for the lowest level of competence-based trust within the community. All the values for competence trust will be within a closed interval [-1,1]. Competence trust relationship is defined by Tc[A,B] which signifies agent A's competence attitude towards agent B. An illustration of trust change over time is shown below in Fig.1.

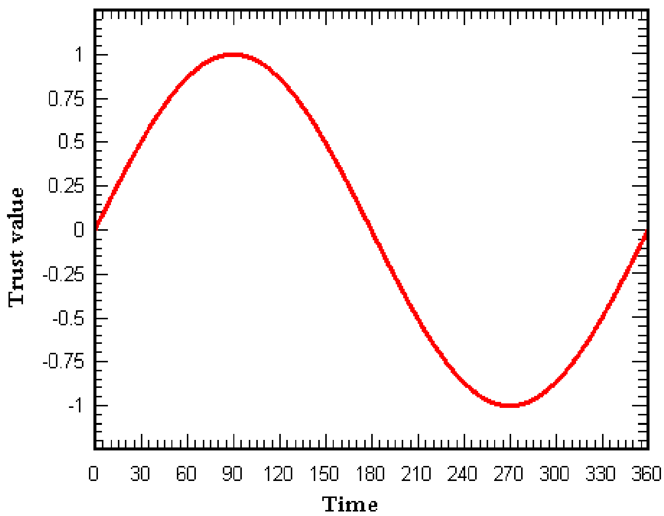

Figure 1: Trust level changes in different time

Two important variables in the trust network of a specific knowledge domain are: 1] the number of members in the network; and 2] the level of trust between that member and other members in the network. The system is defined by having N members T={$\alpha_1,\alpha_2,\alpha_3,\alpha_4,\alpha_5....,\alpha_n$} n= 1,2,3,…,N and 3 trust levels O={Distrust[-1], unknown[0], high trust[1]}.

Some basic rules must be followed in order to establish a trust matrix within a community in a specific knowledge domain. The most important rules are:

1. Everyone trusts him/herself when s/he wants to share the specific knowledge.
2. If A's trust in B is t1, we cannot assume B's trust in A is the same and equal to t1.
3. If A's trust in B is t1 [for example high trust] and B's trust in C is t1 [high trust], we cannot assume A's trust is C is t1. [Although another's trust affects member's trust of each other, the transitive rule is not considered in trust].

Based on the trust rules, a trust matrix can be developed as:

$$
\begin{array}{c|c|}
 & \alpha 1 \quad \alpha 2 \quad \alpha 3 \quad \ldots\ldots \quad \alpha n \\
\end{array}
$$

$$
T[benevolence] = Tb = \begin{vmatrix} \alpha 1 \\ \alpha 2 \\ \alpha 3 \\ \ldots\ldots \\ \alpha n \end{vmatrix} \begin{pmatrix} 1 & tb12 & tb13 & \ldots. & tb1n \\ tb21 & 1 & tb23 & \ldots.. & tb2n \\ tb31 & tb32 & 1 & \ldots\ldots & tb3n \\ \ldots. & \ldots.. & \ldots.. & 1 & \ldots.. \\ tbn1 & tbn2 & tbn3 & \ldots.. & 1 \end{pmatrix}
$$

Matrix 1: benevolence trust

$$
\begin{array}{c|c|}
 & \alpha 1 \quad \alpha 2 \quad \alpha 3 \quad \ldots\ldots \quad \alpha n \\
\end{array}
$$

$$
T[competency] = Tc = \begin{vmatrix} \alpha 1 \\ \alpha 2 \\ \alpha 3 \\ \ldots\ldots \\ \alpha n \end{vmatrix} \begin{pmatrix} 1 & tc12 & tc13 & \ldots. & tc1n \\ tc21 & 1 & tc23 & \ldots.. & tc2n \\ tc31 & tc32 & 1 & \ldots\ldots & tc3n \\ \ldots. & \ldots.. & \ldots.. & 1 & \ldots.. \\ tcn1 & tcn2 & tcn3 & \ldots.. & 1 \end{pmatrix}
$$

Matrix 2: competency trust

In a crisp system, the value of the variables in the two matrices would be between -1 and 1. In a fuzzy logic based system, the value of the variables would be one of the following linguistic variable: Distrust, unknown, high trust. In a simple model, we assume that all members have the same weight and are equal 1. However, in a developed model, each member can be assigned a different weight.

There is no need to normalize the matrices because all the variables are between -1 and 1. But, if we assign different weights to the different members, we will need to normalize the matrices. Based on the matrices, the value of benevolence trust and competency trust for each member of the community can be calculated using the following formulas:

Benevolence trust of member n to other members in community = $\sum_{m=1}^{N} tbnm$

Competency trust of member n to other members in community = $\sum_{m=1}^{N} tcnm$

Benevolence trust of all members in community to member n = $\sum_{m=1}^{N} tbmn$

Competency trust of all members in community to member n = $\sum_{m=1}^{N} tcmn$

Average of benevolence trust within community= $\sum_{m,n=1}^{N} tbnm$ /N

Average of competency trust within community= $\sum_{m,n=1}^{N} tcnm$ /N

Knowledge

There is no universal definition of knowledge and knowledge management. Knowledge is a combination of the data and information being produced by human thought processes. Knowledge management is the process by which organizations generate value from their intellectual and knowledge-based assets [Smith, 1995]. Drucker defines knowledge as an input resource that will have a greater impact than will physical capital in the future [Drucker, 1993]. Knowledge can be categorized in two different classes: explicit and tacit knowledge. Explicit knowledge can relatively easily be formulated by means of symbols and can be transferred to others easily [Nonaka, 1995]. Tacit knowledge is defined as non-codified, disembodied know-how that is acquired via the informal take-up of learned behavior and procedures [Howells, 1996]. Also, as we discussed earlier, knowledge can be distinguished into general knowledge and specific knowledge. General knowledge is explicit and is easily understood by locals and neighbors [since both their ontologies are similar]. Specific knowledge is more technical and difficult to understand and depends on an individual's background and knowledge level [ontologies are different]. It is necessary to understand the nature of knowledge in order to analyze the process of knowledge sharing between and within organizations or individuals. The characteristics of knowledge influence the outcome of knowledge sharing [Nonaka, 1995].

The impact of the nature of knowledge on knowledge sharing is part of this research's objective. The nature of the knowledge also affects the importance of trust in knowledge sharing. When the knowledge seems simple, competence-based trust is not necessarily important and in this case, people care more about benevolence-based trust. On the other hand, when the knowledge is complex and professional, people care more about competency-based trust.

In this paper, we divide knowledge type into easy or complex knowledge [complexity of knowledge], and easy or hard transformable knowledge [transformability]. We propose metrics to measure the complexity of knowledge by using ontology, choosing personal ontology. Ontologies have to be created explicitly by hand and require a process of explicit community negotiation to achieve a consensus on the shared understanding that is to be expressed [Novak 2004]. Also, we will develop a proposed model and measure the transformability of knowledge by comparing the two ontologies [sender and receiver of the knowledge] and ascertaining whether or not there are similarities. Numerically, we will represent the complexity and transformability of knowledge to be between 0 and 1. Fig. 2 shows the complexity/transferability functions of the knowledge.

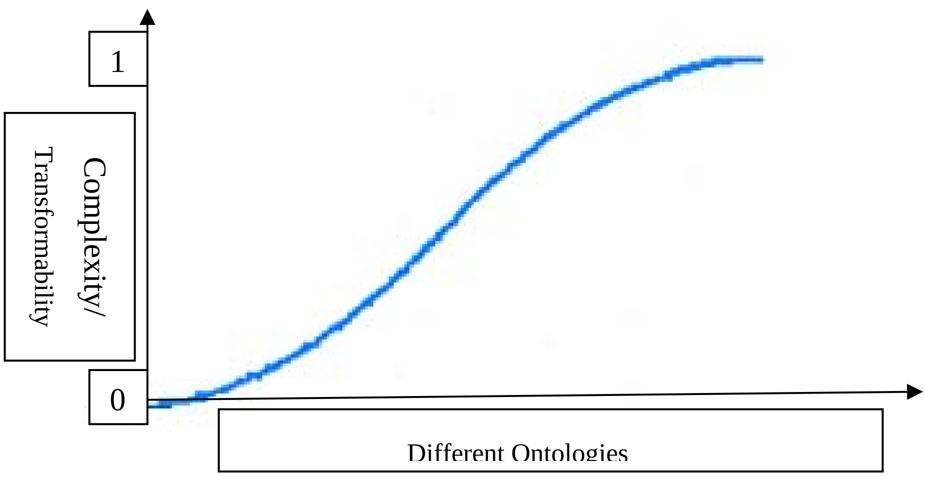

Figure 2: Complexity/ transferability of the knowledge

Ontologies have widespread application in areas such as semantic web, medical informatics, e-commerce, etc. Mainly ontologies are used to provide a semantically shared domain knowledge in a declarative formalism for intelligent reasoning. Besides, complexity of knowledge is critical to the success of knowledge sharing efforts. Presumably, the knowledge is conceptualized in declarative formalism, i.e. with an ontology having quality data, stability, and completeness. When the ontology is less complex, we may not need a high value of competence-based trust. In contrast, if the ontology is rather complicated, a high value of competence-based trust is required. Ontology complexity is related to the complexity of conceptualization of the domain of interest. It is measured to reflect the ease with which any ontology is to be understood. Definition of ontology complexity is clarified in features that characterize complexity of ontology i.e. [i] usability and usefulness and [ii] maintainability. There is no unified metric to date that reflects the complexity of ontotology. In this section, we present our metrics: Total Number of Datatype Properties [TNoDP], Average Datatype Properties per Class [ADP/C], Total Number of Object Properties [TNoOP], Total Number of Constraints [TNoC], Average Constraints per Object Property [AC/OP], Total Number of Hierarchical Paths [TNoHP], and Average Hierarchical Paths per Class [AHP/C]. The metrics give an indication of how well and how finely concepts are being defined. A detailed presentation and discussion of these metrics, along with their definition can be found in Zadjabbari et al. [Zadjabbari, 2010]. A high numerical value for these metrics shows that concepts are being well presented within an ontology. We assume that the complexity of the ontology being evaluated is written in Web Ontology Language [OWL]. Fig. 3 shows the complexity measurement of the knowledge.

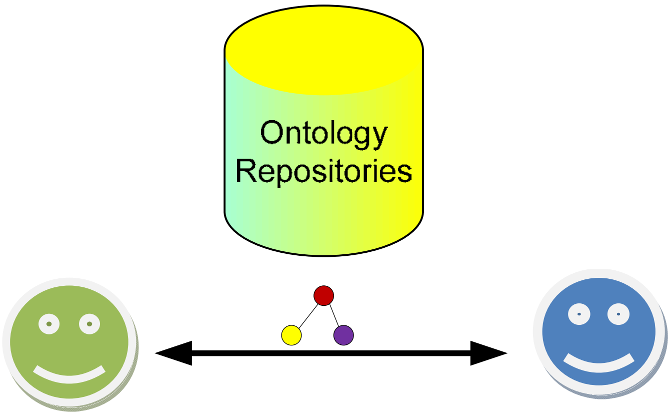

Figure 3: complexity measurement of the knowledge

As shown in Fig. 3, all the shared knowledge can be evaluated against the knowledge in the ontology repositories to calculate complexity of the knowledge. We will show complexity of the knowledge for the knowledge transmitter by Kc and for knowledge receiver by K'c. Both Kc and K'c will be given value between 0 and 1.

Transformability of the knowledge is more related to the members' backgrounds and their domain ontology. We will use the similarity of ontologies to measure the level of transformability between two members. Fig. 4 shows the transformability measurement of the knowledge.

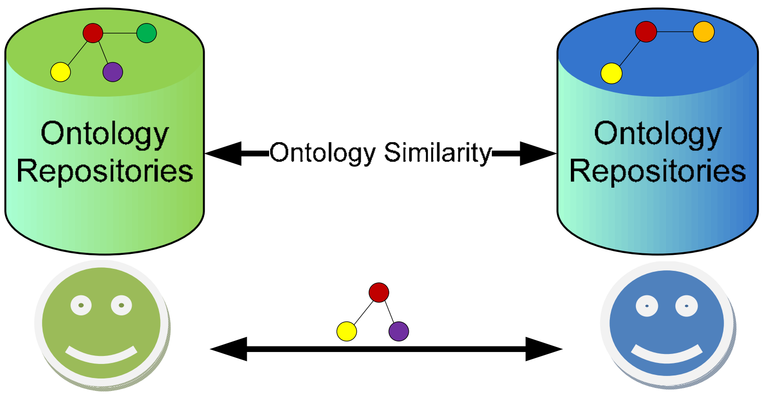

Figure 4: Transformability measurement of the knowledge

We will show transformability of the knowledge for the knowledge transmitter by Kt and for knowledge receiver by K't. Both Kt and K't will be given a value between 0 and 1.

New Proposed Model in Knowledge Sharing

Overall, two main factors related to knowledge sharing efforts are trust and knowledge context. Two specific types of trust in the knowledge sharing process are benevolence-based trust and competence-based trust. Besides, complexity and transformability of knowledge is critical to the success of knowledge sharing efforts. In contrast, if the ontology is rather complicated, a high value of competence-based trust is required. It is important to note that some knowledge is difficult to codify in ontology which is not the concern of this paper.

Based on these variables, a knowledge sharing measurement model is proposed in Fig. 5.

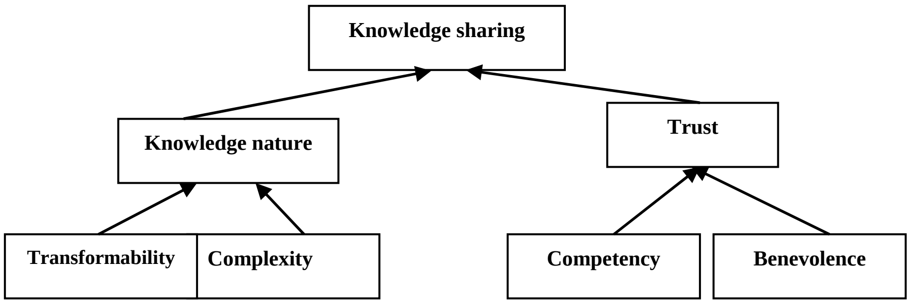

Figure 5: Knowledge sharing measurement model

Based on Fig. 5, the equations below are proposed to measure knowledge sharing:

Knowledge sharing= F [knowledge nature, trust]

$$0 \le \text{Knowledge sharing} \le 1 \quad \text{.......... (1)}$$

Trust= F [competence, benevolence] = T [A, B] = F (Tb [A, B] , Tc [A, B])

$$0 \le Tb[A, B], Tc[A, B] \le 1 \quad \text{.......... (2)}$$

[3]Knowledge nature= F [transformability, complexity]

$$0 \le \text{transformability, complexity} \le 1 \quad \text{.......... (3)}$$

In knowledge sharing, both knowledge sender and knowledge receiver have to be evaluated and both parts are important. As seen in Fig. 6, if the knowledge sharing level for sender be Ks and knowledge sharing level for receiver be K's, the final knowledge sharing level will be the minimum of Ks and K's.

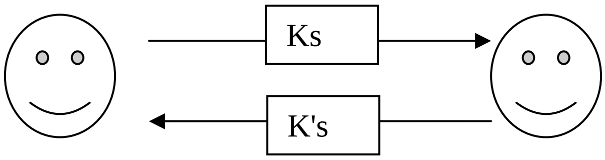

Figure 6: Knowledge sharing between two parties

Knowledge sharing = min (Ks , K's)
$0 \leq$ Knowledge sharing ≤ 1
.... (4)

Due to the fuzzy nature of variables, we can use fuzzy logic to measure knowledge sharing. In this paper, we have validated our model in both Crisp and Fuzzy systems. In the next section, the fuzzy system is used to measure the knowledge sharing level between two parties.

Knowledge Sharing Measurement in Fuzzy Systems

Fig. 7 shows a Fuzzy Inference System used to measure knowledge sharing level in specific knowledge and in defined trust level.

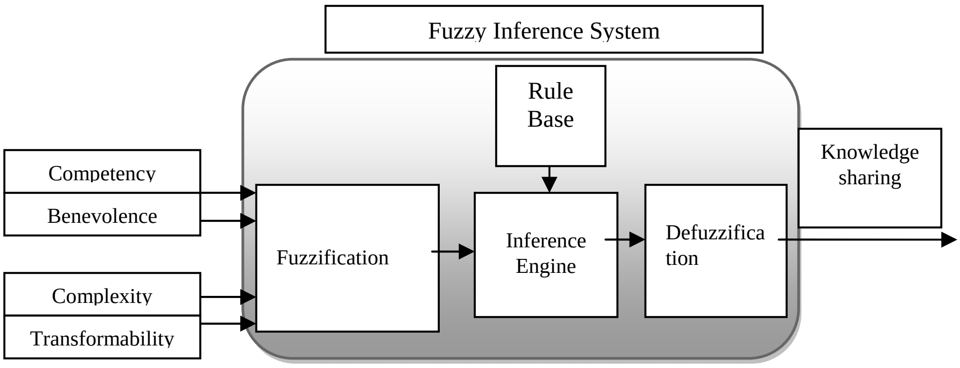

Figure 7: Fuzzy Inference system to measure knowledge sharing

Fuzzy Inference Systems [FIS] can efficiently handle the situations that cannot be characterized by a simple and well-defined deterministic mathematical model. This method utilizes simple rules and a number of simple membership functions to derive the correct result. The subjective and heuristic FIS is particularly efficient for various aspects of uncertain knowledge. The FIS structure is composed of three basic elements: fuzzification, fuzzy reasoning, and defuzzification.

3.1.1 Fuzzification

Crisp input variables are first transformed into fuzzy values based on input membership functions [MF]. These fuzzy variables will then be used to apply rules formulated by linguistic expressions of the fuzzy rule base. The membership function [MF] essentially embodies all fuzziness for a particular fuzzy set. The shape of the membership function [triangular, trapezoidal, Gaussian, etc.] is chosen based on the work that need to be conducted. In this work, four crisp input variables are transformed into fuzzy sets as shown in Fig. 7. It is clear from Fig. 7 that for the two first two input variables [competency and willingness], the crisp universe of discourse is considered to be between -1 and 1. The fuzzy membership functions include the linguistic fuzzy sets of Negative, Zero, and Positive. Other two crisp input variables [Complex and Structure] are laid in the universe of discourse [0 1], which are transformed to fuzzy linguistic variables of Low, Medium, and High. All fuzzy sets are a Generalized Bell shape.

3.1.2 Fuzzy Reasoning

As shown in Fig 7, information flows from four-input variables to a single-output. Though there are various ways to represent human knowledge using the fuzzy rule base, the most common way is to form it into natural language expressions of the if–then type. An expression in such a form is commonly called the if–then rule based form. It typically expresses an inference such that, if we know a fact [premise], then we can infer, or derive, another fact called a conclusion. This form of knowledge representation can express human empirical and heuristic knowledge in our language of communication. In the inference engine, the truth value for the premise [If part] of each fuzzy logic rule is computed and applied to compute the conclusion part of the rule [Then part]. The output fuzzy sets of all rules are then combined to form a single fuzzy set for the output variable.

3.1.3 Defuzzification

As shown in Fig 7, defuzzification is the last stage of a Fuzzy Inference System, which converts the conclusion made by the fuzzy inference into a crisp output value. The output linguistic variables are Absolutely Unsatisfactory, Unsatisfactory, Satisfactory, and Ideal. Of the different available methods of defuzzification, this paper implements the most popular defuzzification method, centre of gravity, formulated as:

$$P = \frac{\int_p \mu_c(p) \times p\,dp}{\int_p \mu_c(p)\,dp}$$

Where p is the fuzzy output value of each rule and P is the crisp output value of the Fuzzy Inference System.

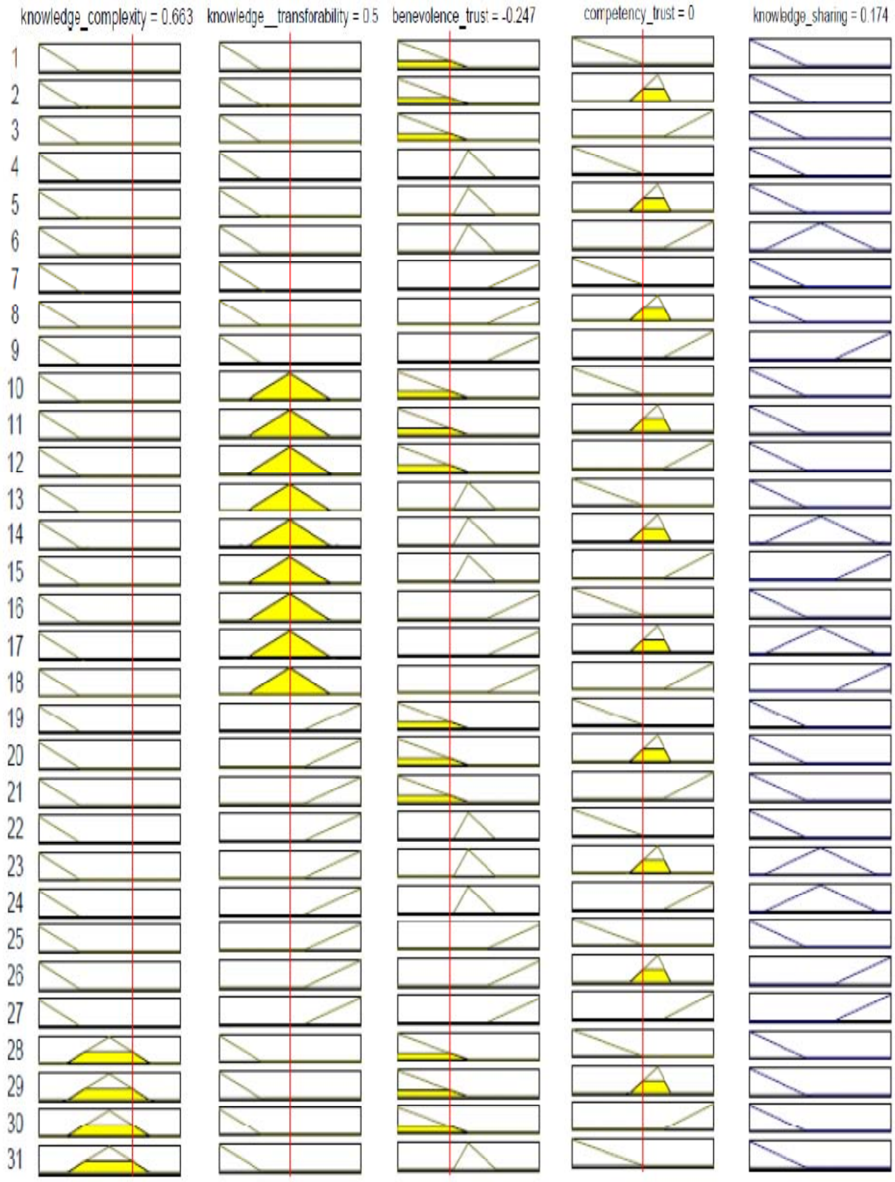

Figure 8: Results in fuzzy systems

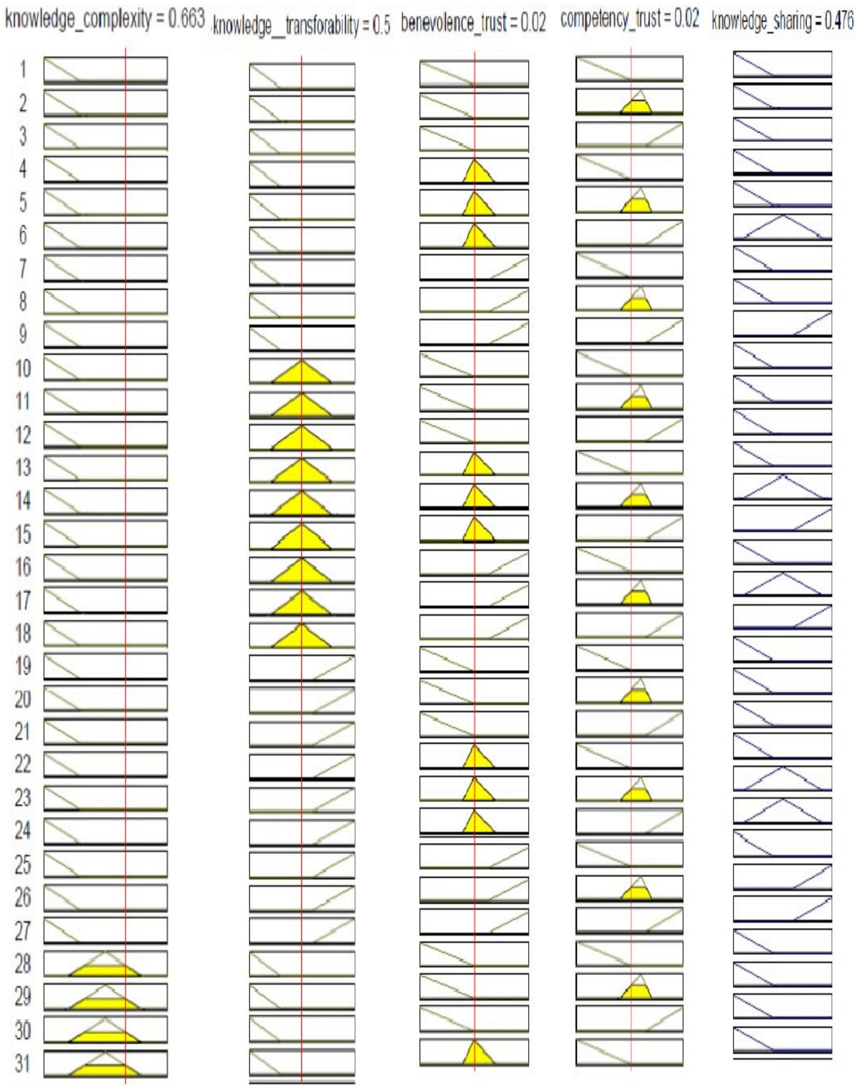

Figure 9: Knowledge sharing for different values of benevolence trust

Results

Result in Fuzzy Systems

Matlab software is used to simulate and test our model in Mamdani Fuzzy systems. As is seen in Fig. 7, input variables are knowledge complexity, knowledge transformability, trust competency and trust benevolence and output variable is knowledge sharing. Based on the literature review and the effect of input variables on knowledge sharing, fuzzy rules are used to measure knowledge sharing level. Input variables have a fuzzy value in the model. Knowledge complexity and knowledge transformability could be low, medium or high. Willingness and competency trust could be distrust, no idea [when one party does not has any idea for another party or the other party is new] and high trust. Knowledge sharing as an output variable could be low, medium or high. A dynamic model is designed in Matlab and it can measure knowledge sharing based on input variables changes and the model is dynamic.

Fig. 8 shows that the model is dynamic and, based on changes in input variables, the knowledge sharing level fluctuates. For example, in the first sample, the knowledge complexity is .663 and knowledge transformability is 0.5 and benevolence trust and competency trust are -0.247 and 0. The knowledge sharing level in this position is calculated as 0.174. In the next figure the value of all variables is the same but we have increased the value of benevolence trust to 0. As a result, as seen in Fig. 9, the value of knowledge sharing is increased to 0.476.

This dynamic model measures knowledge sharing from one party to another party and as discussed previously, in the mathematical formula real knowledge sharing between two parties is the minimum of two values [knowledge sharing from party A to B and knowledge sharing from party B to A.

Result in CRISP System

We engineered a system to measure the complexity and transformability of specific knowledge in different ontologies. As a sample, we have chosen two knowledge exchangers one of which uses vegetarian pizza ontology and the other uses meat pizza ontology and they want to share knowledge about "topping".

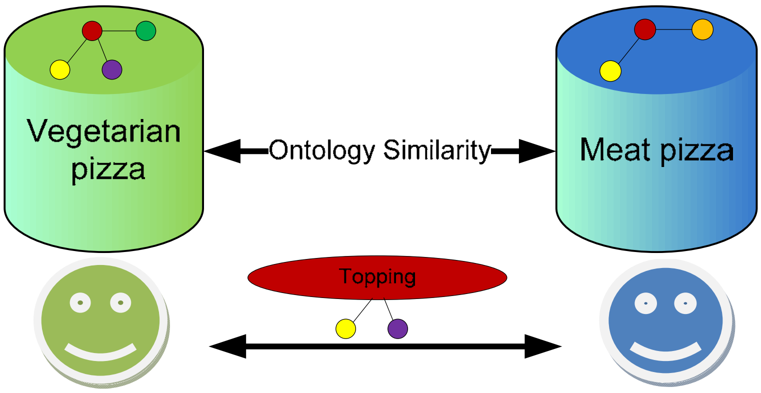

Figure 10: Knowledge sharing between two different ontologies

As can be seen in Fig. 10, two different ontologies are used between two knowledge exchangers in this case. We modified two different ontologies as meatyPizza.owl ontology and vegetarianPizza.owl ontology. We used open online sources to define these two different ontologies. Some of the main sources used in our program are:

- ✓ www.owl-ontologies.com
- ✓ www.w3.org
- ✓ www.protege.stanford.edu
- ✓ www.co-ode.org/ontologies
- ✓ www.daml.org
- ✓ www.purl.org
- ✓ www.co-ode.org

The main classes in these ontologies are defined as :

- ✓ Meat
- ✓ Fruit
- ✓ Herb
- ✓ Nut
- ✓ Sauce
- ✓ Fish
- ✓ Vegetable
- ✓ Topping

Also, sub classes and properties are defined for each class as shown in Fig. 11.

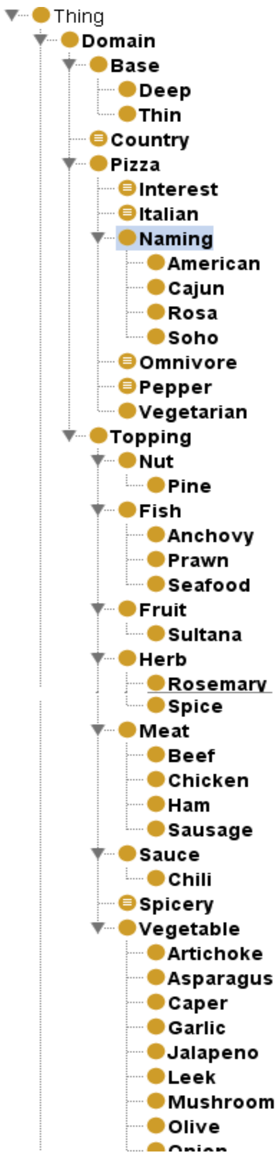

Figure 11: Classes, subclasses and properties

Based on different values of trust between knowledge exchangers, the result for this specific knowledge (topping) is shown in the table below:

Kc	Kt	Tb	Tc	K'c	K't	T'b	T'c	KS1	KS2	KS
0.857143	0.944444	0.8	0.8	0.857143	1	0.8	0.8	0.720635	0.742857	0.720635

0.453357	0.720635	0.491286	0.185714	0.184786	0.072	0	0	0.435718	0.435718	0.435718	0.435718	0.185714
0.453357	0.741371	0.491286	0.185714	0.184786	0.072	0	0	0.742857	0.453357	0.741371	0.491286	0.185714
0.720635	0.720635	0.720635	0.720635	0.720635	0.720635	0.720635	0.720635	0.435718	0.435718	0.435718	0.435718	0.435718
0.2	-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8	0.8	0.2
0.8	0.8	0.2	0.2	0.2	-0.8	-0.8	-0.8	0.8	0.8	0.8	0.2	0.2
1	1	1	1	1	1	1	1	1	1	1	1	1
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.2	0.2	0.2	0.2	0.2
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143

0.184786	0.072	0	0.719194	0.453357	0.719194	0.491286	0.185714	0.184786	0.072	0	0	0.482397
0.184786	0.072	0	0.742857	0.453357	0.741371	0.491286	0.185714	0.184786	0.072	0	0	0.742857
0.435718	0.435718	0.435718	0.719194	0.719194	0.719194	0.719194	0.719194	0.719194	0.719194	0.719194	0.719194	0.482397
-0.8	0.8	-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8	0.8
0.2	-0.8	-0.8	0.8	0.8	0.8	0.2	0.2	0.2	-0.8	-0.8	-0.8	0.8
1	1	1	1	1	1	1	1	1	1	1	1	1
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143
0.2	0.2	0.2	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	0.8
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.2
0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143

0.453357	0.482397	0.482397	0.185714	0.184786	0.072	0	0	0.180159	0.180159	0.180159	0.180159	0.180159
0.453357	0.741371	0.491286	0.185714	0.184786	0.072	0	0	0.742857	0.453357	0.741371	0.491286	0.185714
0.482397	0.482397	0.482397	0.482397	0.482397	0.482397	0.482397	0.482397	0.180159	0.180159	0.180159	0.180159	0.180159
0.2	-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8	0.8	0.2
0.8	0.8	0.2	0.2	0.2	-0.8	-0.8	-0.8	0.8	0.8	0.8	0.2	0.2
1	1	1	1	1	1	1	1	1	1	1	1	1
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143
0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143

0.180159	0.072	0	0	0.179258	0.179258	0.179258	0.179258	0.179258
0.184786	0.072	0	0	0.742857	0.453357	0.741371	0.491286	0.185714
0.180159	0.180159	0.180159	0.180159	0.179258	0.179258	0.179258	0.179258	0.179258
-0.8	0.8	0.2	-0.8	0.8	0.2	-0.8	0.8	0.2
0.2	-0.8	-0.8	-0.8	0.8	0.8	0.8	0.2	0.2
1	1	1	1	1	1	1	1	1
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143
0.2	0.2	0.2	0.2	-0.8	-0.8	-0.8	-0.8	-0.8
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444	0.944444
0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143	0.857143

Table 1: Result in Crisp model

Conclusion and Future Works

Billions of dollars every year are spent on improving knowledge sharing within and between organizations. Governments spend huge amounts of money to share knowledge between citizens in order to increase the knowledge level of society. Knowledge sharing is not easy and no-one can force others to share their knowledge. On the other hand, it is not easy to measure the level of knowledge sharing in order to improve it. Decision makers need some metric variables to make decisions about ways to improve knowledge sharing. We have proposed a new model in knowledge sharing measurement. This model is dynamic and is based on the nature of trust and knowledge. We have defined knowledge in two dimensions including complexity of the knowledge and transformability of the knowledge. We have applied ontologies to represent complexity and transferability of knowledge. Also, we applied fuzzy logic to measure the trust level within the community and to define benevolence and competency as two main dimensions of trust. Then, mathematical formulas were proposed to measure each part of knowledge sharing. We are going to develop the model as a new business intelligence application to provide real and on-time information about knowledge sharing so that decision makers have a better view of a community's ability to share knowledge. Further studies can be done to develop the model for unstructured knowledge and apply text mining techniques to measure the effectiveness of knowledge sharing in different domains such as business, politics [such as election speeches effectiveness], medicine etc. From a leadership perspective, leaders' speeches and behavior are very important in creating motivated employees and improving business performance and this model can be developed to measure the effectiveness of speech in sharing knowledge.

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