Developing an organizational knowledge management strategy
the power behind thermodynamics and social networks

Perez-Vega, O.

Award date:
2010

Eindhoven, August 2010

Developing an Organizational Knowledge Management Strategy: the power behind thermodynamics and social networks

by
Oscar Perez-Vega

BSc. Food Engineering- Universidad de las Américas Puebla, Mexico, 2002
Student identity number 0663504

in partial fulfilment of the requirements for the degree of

Master of Science
in Innovation Management

Supervisors:
Prof. dr. G.M. Duijsters, TU/e, ITEM
dr. A. Sabidussi, TU/e, ITEM

TUE. Department of Industrial Engineering and Innovation Science
Series Master Theses Innovation Management

Subject headings: knowledge management, social network analysis, organizational strategy

Abstract

Knowledge management plays a crucial role for the development of organizational dynamic and innovative capabilities. However, when organizations try to define what the appropriate strategy to manage knowledge, several conceptual and organizational issues arise due to the nature dynamics of knowledge and organizations.

Within the knowledge management literature, several attempts have been made in order to capture the behavior of knowledge inside organizations (e.g. SECI or Bi-dimensional models); however, these models are not completely able to capture organizational dynamics, since they are not able to integrate three strategic elements: dynamics in the nature of knowledge, dynamics inside organizations, and the influence of human interactions in the transference and creation of knowledge. As a result, the development of knowledge management strategies becomes limited to satisfy the constant changes existing within organizations.

In this thesis project, we made a new attempt to capture the behavior of knowledge inside organizations, by developing a model which integrates the three strategic elements of knowledge and organizational dynamics. In addition we designed a methodology which can be used by practitioners in order to develop a relevant and customized knowledge management strategy to satisfy current organizational needs. Therefore, this project contributes to the knowledge management theory and to practitioners in this field.

Preface and Acknowledgments

The following paper presents the graduation thesis project required to fulfill the degree of Master of Science in Innovation Management at Eindhoven University of Technology. This project was developed under the supervision of prof. dr. G.M. Duijsters and dr. A. Sabidussi of the Innovation, Technology, Entrepreneurship and Marketing Group at the Department of Industrial Engineering and Innovation Science.

I would like to thank both of my supervisors, Geert and Anna, for the guidance and support they provided me to complete this thesis project. In addition, I would like to thank my friends and colleagues with whom I had the opportunity to discuss and learn along this graduation process, their feedback, contributions and openness was very valuable to achieve a new “conceptualization” of the world.

I addition, I would like to thank the support I received from the National Council of Science of Technology of the Government of Mexico (CONACYT) which was essential to obtain my Master degree at Eindhoven University of Technology (TU/e) in the Netherlands.

During my two year program, I would like to acknowledge the grateful experiences I had in TU/e; therefore, I would like to thank all my friends, colleagues and professors who made a difference in my life and along this enriching path. Also, I would like to thank my family and relatives for the support they provided me for coming to the Netherlands; but especially I would like to thank my wife, Lesly García Chávez, for the unconditional support you gave me, and your openness to start this new adventure and life experience. Thank you!

Oscar Pérez Vega

Eindhoven, the Netherlands, 2010

Table of Contents

List of figures

List of Tables

1 Introduction

Nowadays markets are characterized as dynamic, competitive and turbulent. These characteristics demand firms a constant search for new alternatives to create competitive advantages; for example, reduce product development times, increase quality standards, understand diverse needs of consumers and explore new emerging markets (Rolland & Kaminska-Labbé, 2008). In other words, today firms are constantly being challenged to increase their capacity to innovate, not only in products and services, but also within their processes and forms of collaboration.

The dynamic capability of an organization describes its ability to learn, adapt, change and renew over time (Teece et al., 1997). Nevertheless, management of knowledge plays a crucial role to develop these dynamic and innovative capabilities (Kanter, 1983; Teece et al., 1997; de Man et al, 2008; Conway & Steward, 2009; Hislop, 2009). After an empirical study, Cohen and Levinthal (1990) conclude that the ability of an organization to acquire, assimilate, transform and exploit knowledge becomes critical to develop innovative products for the market. However, when organizations try to define what is the appropriate strategy to manage knowledge, several conceptual and managerial issues arise; like, how does knowledge behaves inside an organization, the type of approach that should be implemented, the place where valuable knowledge is located or the way to capture and retain it. In this sense, Morgan (1997) explains that in order to achieve an effective management level, organizational leaders need to have a deep understanding of situations.

In the field of knowledge management (KM), several attempts have been made to explain and describe the behavior of knowledge inside organizations; however, for the development of this project we will concentrate on three relevant efforts previously made. The first attempt refers to the basic conceptualization and definition of knowledge. According to its natural form (or epistemology), there are two elemental ways to define knowledge (Polanyi, 1967): 1) Explicit knowledge, refers to the knowledge that is objective, impersonal, context independent and easy to share; for example, operation manuals, databases or computer programs; and 2) Tacit knowledge, refers to the knowledge that is subjective, personal, context specific and difficult to share; for example, experiences, skills or know-how.

However, if only an isolated approach is considered between the two perspectives, directions to manage knowledge will result in a very narrow and rigid strategy. For example, if an organization only focuses on its explicit knowledge (i.e. codification strategy), main efforts will attain to the capture and storage of knowledge in databases and manuals, and will fail to capture experiences and know-how of employees. On the other hand, focusing only in a tacit form of knowledge (i.e. personalization strategy), main efforts will attain to provide spaces where experiences and ideas of employees can be shared, and will fail to capture them in physical files. Therefore, a combination and balance of both perspectives, tacit and explicit, is required to have a better understanding of changes in the behavior of knowledge, and consequently achieve an effective management approach.

The second attempt refers to the SECI model, developed by Nonaka (1994), which has been one of the most influential KM models in the last decade (Hislop, 2009; Gourlay, 2006). This model suggests that the creation of knowledge emerges from the continuous interaction between tacit and explicit knowledge. And that the creation of organizational knowledge is a process starting with individuals, moving up to a collective stage, and finally reaching the organizational level (this is described as an 'upward spiral' process). In spite of being a popular model, it has also been criticized due to some conceptual deficiencies (Hislop, 2009; Gourlay, 2006; Rose, 2007). First, it assumes that all tacit knowledge will be converted (at some point) into explicit knowledge; which according to the conceptual definition of knowledge, it is not possible. Second, it conceptualizes organizations as ideal interconnected systems, not considering the existence of organizational barriers, such as political, communicational, technological or physical fragmentations. Third, the conceptualization of the dynamics of knowledge becomes limited, because it only considers one dimension, the tacit and explicit knowledge dimension. We can conclude from this second attempt that even considering a combination between the two perspectives can still fail to capture dynamics of organizational knowledge.

A prominent publication reviewing the most influential articles in the field of KM identifies some gaps existing in previous works which aim to suggest directions for management of knowledge (Nonaka & Peltokorpi, 2006). In particular, four opportunity areas are identified: 1) a need to understand knowledge as a dynamic process; 2) the need to conceptualize organizations as dynamic and disaggregated systems; 3) the need to include dynamics of human interactions as a source influencing the creation (and transference) of knowledge; and 4) the existence of a limited number of models able to describe the dynamic behaviors of knowledge and organizations.

The third attempt we would like to refer is to a bi-dimensional model recently developed by Rose (2007). The aim of this model is to capture knowledge and organizational dynamics. The author integrates two dimensions: the 'natural form of knowledge' (tacit and explicit) and the 'organizational architectural design' (rigid and organic); and, suggests that processes for the creation and transference of knowledge arise from the combination of these two dimensions. In addition to his model, Rose uses a novel thermodynamic based approach to propose four processes through which knowledge can be transferred and created. Details about this model and about these four processes will be provided in chapter 2 of this paper. The main advantage of this model is that allows the analysis of organizations as disaggregated systems containing different knowledge zones. Although Rose is able to capture knowledge and organizational behaviors, this proposal is still not able to capture the influence of human interactions in the creation and transference of knowledge. Nevertheless, we believe that the relevant contributions provided by Rose in this model can be a starting point to close this remaining gap.

Human interactions within organizations refer to those interpersonal relationships formed or developed by employees across functions and divisions inside an organization (Cross et al., 2002; Kleiner, 2002). These types of relationships may have a strong influence in the operation of an organization affecting the decision making process (Krackhardt & Hanson, 1993; Cross et al., 2002; Kleiner, 2002; Patton 2008). However, managing (or influencing) interpersonal relationships is not a simple task, since they are constantly changing, and have no formal communication channels or formal leaders.

One methodology that has recently captured considerable interests of researchers and practitioners in the organizational field is social network analysis (SNA). This methodology is used for the systematic assessment of social networks, and provides the possibility to study relationships among social entities (individuals or groups), rather than only studying attribute properties. SNA becomes a valuable tool to assess human interactions, because it provides structural properties to characterize a relational network. This characterization not only allows the possibility to identify existing patterns, but also allows the identification of barriers which may constrain the flow of information within the network (Hatala, 2006; Wasserman & Faust, 1994). An important advantage of this type of analysis is the development of network maps, which are helpful to provide a graphical overview of the existing relationships across the network. Nevertheless, especial considerations before using SNA inside organizations need to be taken into account, due to the dynamic nature of relational networks.

Given the relevance and the potential that SNA provides in the assessment of human interactions, we propose to use this methodology to capture its influence in the creation and transference of knowledge. The main objective of this project is to design a methodology which integrates the use of SNA into the practice of knowledge management. Especially, we intend to contribute in a better understanding of the dynamics of knowledge inside organizations, and to provide some guidelines which can be used by practitioners to develop a knowledge management strategy. In addition we intend to develop a theoretical model able to capture knowledge and organizational dynamics, and the influence of human interaction in the creation and transference of knowledge; thus contribute to the KM literature.

The following paper has been divided in four additional chapters, and Figure 1 provides a general overview of the structure of this paper. In chapter 2, we will explain the main contributions the KM model, developed by Rose (2007), makes for the understanding of knowledge dynamics, and present the thermodynamic approach the author suggests for the transference and creation of knowledge. In chapter 3, we will present some basic theoretical concepts needed to develop and interpret a SNA form a practitioner's perspective. In this chapter we will also explain which relational networks need to be analyzed in order to capture flow of information and knowledge, and discuss a network perspective which identifies main challenges organizations might face when developing knowledge sharing initiatives. In chapter 4, we will present our proposed methodology which uses SNA in the development of an organizational KM strategy; and, discuss the model that was also designed for this purpose. Finally, in chapter 5 conclusions will be presented, pointing out some limitations and providing recommendations for future research.

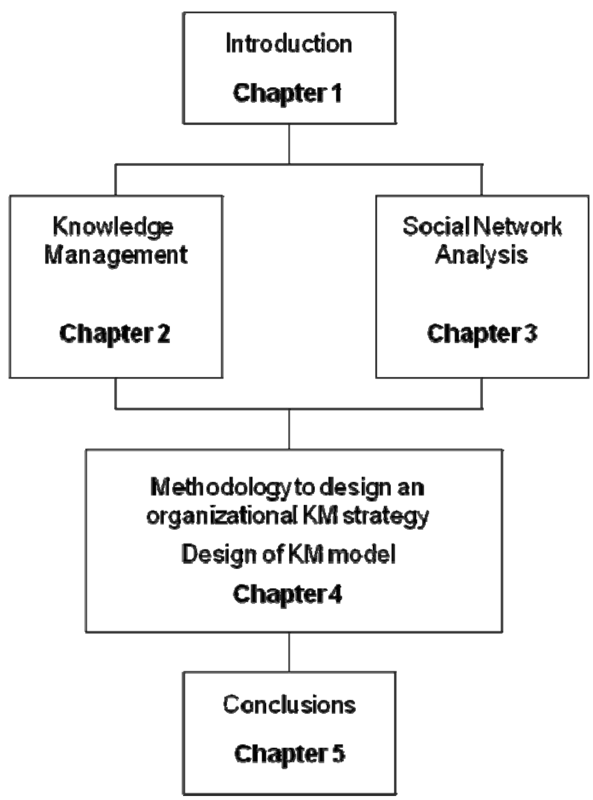


Figure 1 Structure of research project

2 Thermodynamic approach to knowledge management

In the introduction we discussed some important limitations found within some of the current knowledge management (KM) models existing in this field; including, one developed by Rose (2007) that is able to capture dynamics in knowledge and organizations. In his model, the author integrates two dimensions, the knowledge form and the architectural form; and, suggests that the creation and transference of knowledge arises from the combination of these two dimensions. According to us, Rose provides two important contributions to the KM field: 1) provides a model which allows the analysis of organizations as disaggregated systems; and 2) suggests a novel approach to conceptualize the transference and creation of knowledge by using thermodynamic metaphors.

In spite the Rose's model is not able to capture the influence of human interactions in the creation and transference of knowledge; we believe that the contributions of this model can be a good starting point to develop of a new theoretical framework to capture this deficiency. Therefore, in this chapter we will provide a detailed explanation of Rose's model. In addition, we believe that the thermodynamic approach used by the author has not been totally developed, and can still contribute to understand knowledge's creation and transference mechanisms; which we will also explore in this chapter.

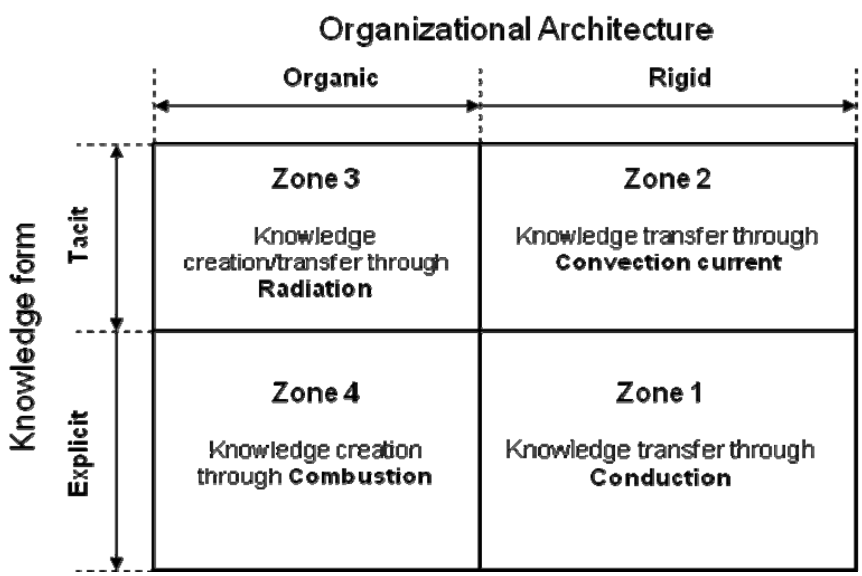
The following chapter is divided in three main parts. First, we will present the Bi-dimensional (BD) model developed by Rose (2007), explaining details about its unique characteristics. Then, we will develop a more extensive description of other possible conceptual similarities we foresee between thermodynamics and the management of knowledge, explaining how these similarities can help us understand *mechanisms* for the creation and transference of knowledge. In our last part, we will make conclusions about the BD model and the thermodynamic approach to knowledge, recommending areas which could possibly add value to the KM field.

2.1 Bi-dimensional model to create and transfer knowledge

According to Rose (2007), conceptualizing the creation of knowledge only within the tacit and explicit dimension cannot explain the flowing and dynamic properties of knowledge. From his perspective, knowledge has 'potential' properties (existing in what he calls a constant state of 'becoming'), which will be determined by the organizational space where it is present. To explain this concept, the author develops a theoretical model integrating two dimension: the 'natural form' of knowledge (tacit/explicit) and the 'architectural form' of the organization (rigid/organic). This model is shown in Figure 2, and from now on we will refer to it as the Bi-dimensional (BD) model.

In the BD model, Rose (2007) suggests that knowledge can continuously flow in any direction between the tacit and explicit form, and its movement will be influenced by the architectural form dominating in the organization, either rigid or organic. Particularly this model suggests that knowledge is contained within four different 'states' (or zones), which are partially tacit, explicit, rigid and organic. He also suggests that within these zones knowledge can be transferred and created.

The identification of different knowledge zones becomes a crucial element for the conception of organizations as disaggregated systems, because it highlights that each zone contains unique knowledge characteristics. In addition, by differentiating these knowledge zones specific mechanisms to transfer or create knowledge can be conceived. Particularly Rose (2007) suggests the use of four different thermodynamic processes to explain these mechanisms: conduction, convection, radiation and combustion. As shown in Figure 2.



Source: Rose (2007)

Figure 2 Bi-dimensional model

The horizontal axis, in the BD model, represents the two possible organizational architecture forms (organic/rigid), and the vertical axis, the two possible knowledge forms (tacit/explicit). According to Rose (2007), organizational differences existing within departments, functions and working groups can be identified within these two dimensions. To exemplify, consider the differences between a manufacturing department and R&D department (Figure 3 we compare two processes within each area). The manufacturing area will be designed in the best way to support mass production of the manufactured goods; where probably (given the implication costs) this design will remain for a long term. Therefore, we can identify that the dominant architectural form in this area will be rigid. In addition, to guaranty the operation's continuity and the standardized production of items, the elaboration of procedures, manuals and specifications will be made; therefore, the dominant type of knowledge this area will mainly be explicit. On the other hand, in the R&D department, an architectural design to support flexibility needed to explore and generate new ideas or products, an organic structural form will be dominating. And, probably the dominant type of knowledge existing in this area could be a tacit, where sharing experiences, ideas and insights would trigger the generation of new ideas and development of innovative products.

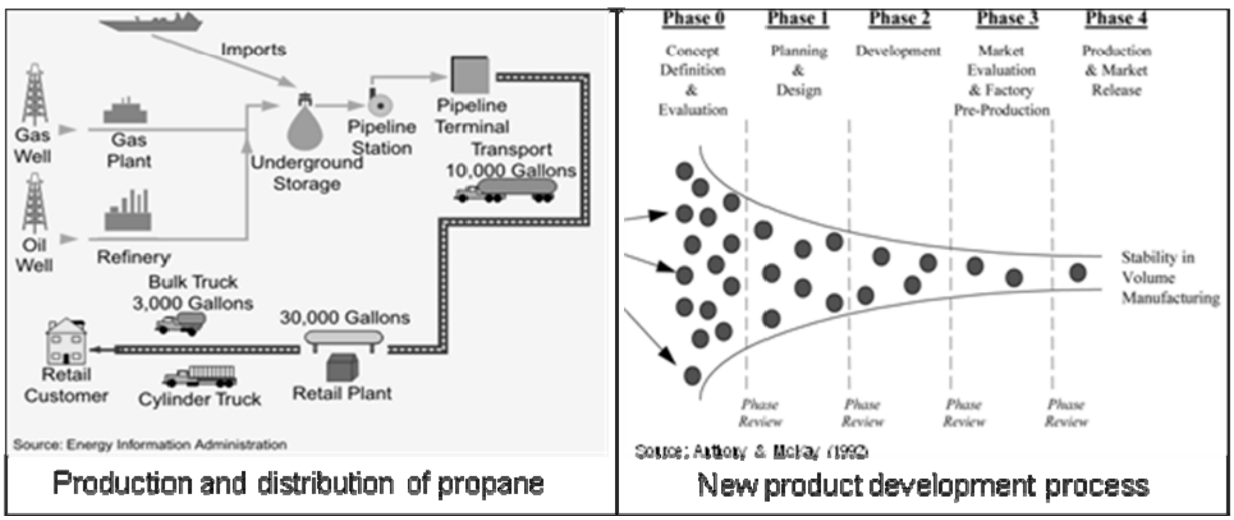


Figure 3 Production process vs. new product development process

As previously explained, the BD model differentiates the unique configuration of four knowledge zones: explicit-rigid, tacit-rigid, tacit-organic and explicit-organic. And for each zone Rose (2007) identifies specific governing thermodynamic mechanisms which illustrate the transference and creation knowledge. In addition, for each area, the author provides specific suggestions for the management of knowledge; which, we will briefly discuss.

Zone 1 Explicit – Rigid: Conduction

Knowledge transference will be achieved through direct physical contact of subjects. Knowledge strategies should focus on the explicit articulation and enactment of rules, guidelines, policies and processes; and special attention should be put in the precise interpretation and application of determined rules.

Zone 2 Tacit – Rigid: Convection

Knowledge transfer will be influenced partially by the intensity of the tacit knowledge source and partially by the environmental characteristics of the medium where knowledge is being transferred. Commonly, rigid structures repress (or diminish) the exploitation of tacit knowledge contained among employees; thus, managerial strategies should promote the liberation of these individual and group potentialities. For example, creating an open a tolerant working environment where principles of individual and group autonomy are respected, or taking care of conditions that contribute and stimulate the qualitative aspects within a working environment, or even enhance the formation of communities of practices among employees.

Zone 3 Tacit – Organic: Radiation

Knowledge transfer as a radiant source could be mainly achieved by the presence and interaction of people among physical spaces within the organizational arena; for example, in a training or coaching program, meetings, or working in teams. Given the enormous variety of possibilities through which radiant knowledge can be dissipated makes it the most inefficient of the processes to transfer knowledge; however, it can also be a very powerful source to create or transfer knowledge that organizations should strongly consider and stimulate.

Zone 4 Explicit – Organic: Combustion

This zone is where new knowledge is mainly created; and to explain this process, a combustion metaphor is used, where knowledge is transformed to produce added value. Mainly, combustion is seen as an adaptive process, where the necessary conditions need to be facilitated. This concept will be explained deeply in the following section.

In conclusion, we believe that the BD model provides three specific advantages. First, it enables capturing both knowledge and structural dynamics inside organizations. Second, it allows the analysis of organizations as disaggregated systems. Third, it suggests the new conceptual approaches to understand mechanisms for the creation and transference of knowledge. Therefore, we believe this model can provide a relevant starting point to design a theoretical model which can also capture the influence of human interactions in the creation and transference of knowledge.

2.2 A thermodynamic approach to knowledge

We acknowledge that the thermodynamic approach used by Rose (2007) is a novel and enriching contribution to conceptualize the creation and transference of knowledge from a new perspective. However, we believe this approach has not been totally developed, and consider that it can still provide powerful insights, relevant to the KM field. Particularly, we believe that a thermodynamic perspective can be helpful to understand the underlying principles of the knowledge transfer and creation mechanisms. Therefore, in the following section we explore further conceptual similarities existing between these two different fields of study, thermodynamics and the management of knowledge.

This section has been divided in three parts. First, we will provide a brief explanation of what thermodynamics is and explain some basic concepts in this field. Then, we will explain the underlying principles for the three ways in which thermal energy can be transferred. Finally, we will provide a wider explanation of the combustion metaphor to create knowledge. And, along each part, we will introduce the links found with the KM field.

Before proceeding, we would like to make some additional remarks:

The use of metaphors implies an invitation for a new way of thinking and a new way of seeing, which may influence the manner in which we can understand a phenomenon; however, a use of metaphors will never give us the perfect or all-purpose point of view, but rather highlight similarities (Morgan, 1997). Therefore, by highlight similarities between thermodynamics and KM, our intention is not to debate if these relationships may exist in reality (or not), but to provide a new perspective which influences the way we think and see the management of knowledge.

Thermodynamic principles are important because they have been able to explain a wide range of phenomenal interactions existing in our universe, going from a molecular to a macroscopic level. The application of these principles currently extends to different fields of study (e.g. biology, mechanics, philosophy, statistics and economics). As a curious fact, thermodynamic laws have caused the amusement of prominent scientist along history; for example, Albert Einstein (1879–1955) who expressed as followed:

> *'A theory is more impressive the greater the simplicity of its premises is, the more different kinds of things it relates, and the more extended its areas of applicability. Therefore the deep impression which classical thermodynamics made upon me. It is the only physical theory of universal content concerning which I am convinced that, with the framework of the applicability of its basic concepts, it will never be over thrown.'*

2.2.1 Thermodynamic background

Thermodynamics[1] is the branch of physics concerned with study of energy (storage, transformation and dissipation) and studies the ability of heat to produce work (Roy, 1995). This field is grounded in three basic phenomenon laws:

The first law of thermodynamics states that *"The total amount of energy of a totally isolated system remains constant, but may change from one form to another"*. This law explains that a system will never be able to produce more energy than the total quantity of energy it originally possesses, but energy can only be transformed from one form to another.

The second law of thermodynamics states that *"The total entropy of any isolated system always increases over time, approaching a maximum value"*. The concept of entropy is difficult to explain due to its philosophical nature, but for practical reasons it can be conceived as the dissipation of energy in a non-usable form, disorder or chaos. This law expresses that with each conversion of energy (from one form to another) part of the total energy will become unavailable for further use.

The third law of thermodynamics states that "*As a system asymptotically approaches absolute zero of temperature all processes virtually cease and the entropy of the system asymptotically approaches a minimum value*". In other words, in any isolated system, an idealized state at zero entropy can only be approached, but will never be reached (no matter the number of energy flows that occur in a process). This law explains that there is no such thing as an 'ideal optimal' system, where no entropy exists.

One of our main interests in this field is the fact that, by using thermodynamic laws, the transformation of energy can be understood and measured. However, an elemental assumption made to link thermodynamics and knowledge management, is the conception of **knowledge as a source of energy**. This assumption is made base on three strong similarities found:

First, energy like knowledge, can be stored, transformed and transferred. For example, knowledge can be stored in a manual or in an individual, it can be transformed from a tacit to explicit, and it can be transferred from a manual to an individual or from individual to individual; whereas, energy can be stored in a fuel, it can be transformed from heat to work, and heat (thermal energy) can transferred from one body to another.

[1] Name deriving from *therme*, referring to heat, and *dynamis*, to power

Second, energy like knowledge can be expressed in a material or immaterial way. For example, the expression of knowledge can be made explicitly or tacitly; and, energy can expressed in an object (containing potential energy), or it can be expressed as heat (not visible).

Third, like energy, knowledge will also tend to have increasing entropic properties, and therefore, transference process can never be 100 % efficient. For example, knowledge will also tend to dissipate over time, and transferring all knowledge (tacit to explicit) can never be possible. Therefore, a managerial and engineering perspective towards both concepts will tend to be finding ways for the optimization of transference processes.

2.2.1.1 Understanding systems

An elemental thermodynamic concept is the definition of a system (see Figure 4). A system is established by defining the boundaries that separates it from the exterior and conditions the way it interacts with its surroundings (Roy, 1995). Once boundaries are identified, an ‘equilibrium state’ can be determined by measuring different variables, such as, pressure, volume, temperature and composition.

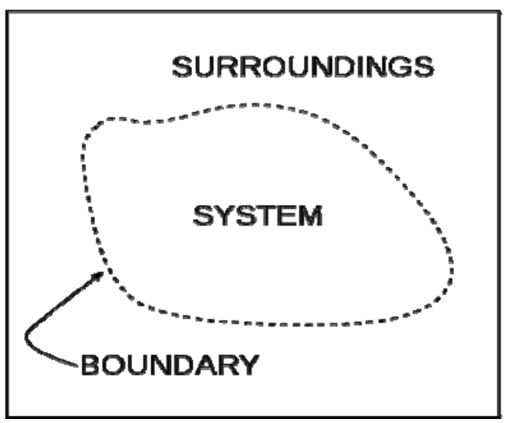


Figure 4 Thermodynamic system

Systems can be classified in three general ways, based on the type of exchange (energy or matter) they have with its surroundings: *isolated systems* when there is no exchange of energy nor matter at all; *closed systems* when only energy is exchanged; and *open systems* when energy and matter are exchanged with the surroundings. It is important to highlight that a totally isolated system cannot exist in nature; however, its conceptualization may be of particular interest when it is subjected to study.

In this case, we see that organizations can also be described as systems, interacting with its surroundings; for example, intellectual capital, raw materials and energy entering to the system, with products and services leaving the system. In addition, the identification of boundaries can be helpful for its study, being these boundaries real or hypothetical; and organizations (and subsystems) could also be classified as closed, open or isolated.

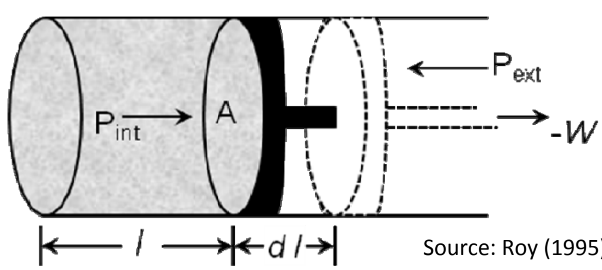
2.2.1.2 Transformation of energy

In general, the transformation of energy will result in the production of work or heat; and the equation explaining the process is:

$$\mathrm{d}E = \mathrm{d}Q - \mathrm{d}W$$ (Equation 1); where

d*E* represents a change in energy, d*Q* a change in heat and d*W* a change in (or production of) work. By definition, work is the amount of energy transferred, by a force, acting through a distance; it is the result of the transference of energy and cannot be stored. And, heat is an equivalent form of energy (thermal), but can also be a result from the transformation of energy into work; it results from a temperature difference, and is not visible at a macroscopic level.

To exemplify the concept of work, let us consider a frictionless piston shown in Figure 5. In a initial state (shadow area), the system is determined by an area A and length *l*. To produce work (*W*), the piston must move (or expand) a specific d*l* distance. However, for the piston to move, the internal pressure[2] (P_{int}) needs to exceed the opposing external force pressure (P_{ext}). Given characteristics of the system (closed system), the only way to increase the internal pressure (to produce work) is by transferring heat into the system, which will cause an expansion of the initial volume, moving the head of the piston. Work is considered as negative when it is performed by the system to the surroundings (as shown in this example), and positive otherwise.



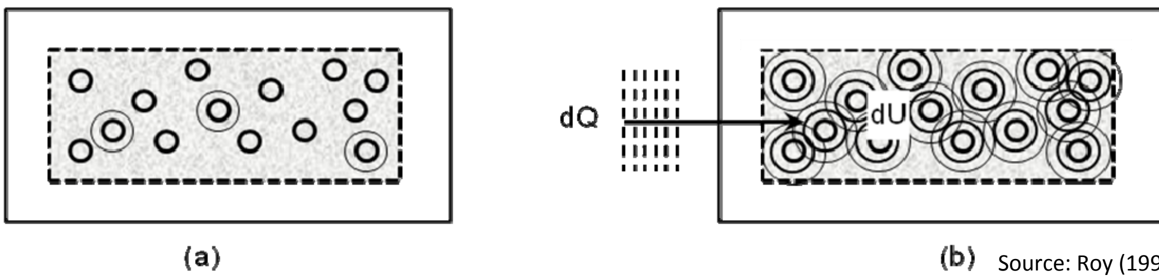
Source: Roy (1995)

Figure 5 Production of work

To exemplify heat, consider the metallic block ad depicted in Figure 6; where, the gray area inside the dotted lines represents a microscopic image of the atoms (small particles shown as circles) inside the

[2] Force = pressure · area; therefore, the internal pressure applied to the area of the piston.

block. In the initial state of the system (letter a), atoms are slowly vibrating. And, as energy is being transfer to the system (in form of heat d*Q*), the vibration of atoms start to accelerate, causing a change in energy of individual particles (letter b). In this case, heat causes a change in the internal energy of the entire system (dU). Even though atoms are moving, it is important to remark that no motion of the system is observable at a macroscopic level, but these vibrations are still able to produce work (like the piston example described above). By definition, if heat is going into the system is considered to be positive, and negative otherwise.



Source: Roy (1995)

Figure 6 Transference of heat to a system

From these last concepts, we would like to highlight some interesting similarities found with the KM field. The production of work could be considered as the desired production of added value of an organization (or a system). Therefore, to produce added value a transformation of energy is needed; which represents making efforts to move the system away from its equilibrium state. In addition, the production of work will result in a change of temperature, producing heat. In this sense, heat (which is a specific form of energy) could be specifically considered as knowledge. Therefore the transformation of energy (or production of work) will result in a difference of heat. Heat causes a change in the internal energy of the entire system, which can also become invisible if seen from a macroscopic level.

2.2.2 Three ways of heat transfer

As we have explained above, heat is a specific form of energy. And, specifically there are three different transference mechanisms in which heat can move or flow: conduction, convection and radiation. In this sense, Rose (2007) suggests seeing the transference of knowledge as the transference of heat, but does not continue to develop an explanation of the underlying principles behind these mechanisms. From our perspective, we believe that in order to understand the transference of knowledge, it is important to understand these heat transference principles. Therefore, in this section we will briefly explain them.

As a general rule, it is important to understand that heat always flows from an object of higher temperature to the one of lower. And that any temperature difference will always trigger a heat transfer mechanism.

2.2.2.1 Conduction

This form of heat transfer occurs through direct physical contact between two objects or solids; as shown in Figure 7, where heat is being transferred from block A to B. In this case, efficiency of heat transfer will depend on relative ease with which energy is transferred between connected objects. Nevertheless, the rate to transfer heat (q) will be determined by the object's physical factors, such as thermo physical properties, size of the object and geometric shape.

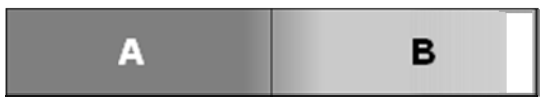


Figure 7 Conduction of heat

In general, conduction may be seen as occurring in two forms: in a differential form where flow of energy is looked from a local perspective, and in an integral form that looks at the amount of energy flowing into or out of a body as a whole (Roy, 1995).

In the differential form heat flux (*q*) represents the amount of energy that flows through a particular surface, and it is defined as the product of thermal conductivity and the negative local temperature gradient. Considering heat transfer only in one dimension, the differential equation is:

$$q_x = -k\frac{dT}{dx} \qquad \text{(Equation 2)}$$

where *k* represents the thermal conductivity[3], -d*T* the gradient difference and d*x* is the distance between the two ends that heat must travel (or measured).

The integral form studies the amount of heat transferred over a body surface per unit of time; it provides an advantage that multilayer conduction may be studied and it is expressed in the following equation:

$$\frac{\Delta Q}{\Delta t} = \frac{A(-\Delta T)}{\frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \ldots} \qquad \text{(Equation 3)}$$

[3] Is the material's property indicating its ability to conduct heat

where the left side of the equation refers to the amount of heat transferred per unit of time, k is the material's thermal conductivity, A is the total surface area, ΔT is the temperature difference between the two ends and Δx/*k* refers to longitude and thermal conductivity of each layer.

The analogy of knowledge transfer by conduction arises from the direct physical contact and connectivity of two parts, where transference will be triggered by a difference of knowledge, the proximity (distance or frequency) between the two parts and each member personal traits (thermal conductivity); for example, reading a manual, using a specific program or employee's in physical contact.

2.2.2.2 Convection

Heat transfer by convection is achieved by flow of fluids (like liquids or gases), and transference rate is affected by the intensity of the heat source and the flow characteristics, such as density of the medium, the differential between the warmer and cooler currents, velocity distribution or turbulence (see Figure 8). Convection can be classified as natural or forced.

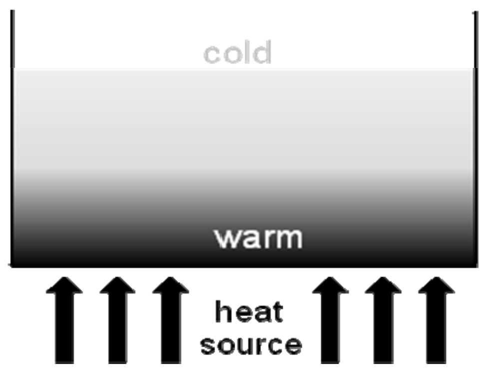


Figure 8 Convection in a fluid pot

Natural convection occurs by the natural circulation of fluids caused by buoyancy differences (changes in density) induced by the heating source. In other words, the heating source provokes the system to become unstable, causing it to mix by the movement of mass. Natural convection is determined by the following expression (known as the Rayleigh number):

$$Ra = \frac{\rho_0 g \alpha \Delta T V}{k \mu} \qquad \text{(Equation 4)}$$

where ρ_0 is the reference density of the medium (typically the average density), g is gravitational acceleration, α is the coefficient of thermal expansion, ΔT is the temperature difference across the medium (cold and warm area), *V* is the volume of the space, k is the thermal diffusivity of the fluid, and μ is the viscosity of the fluid.

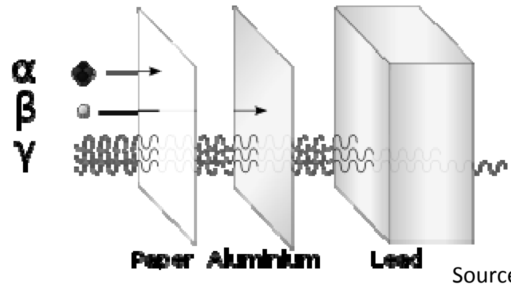
Forced convection is induced by other source such as a fan or pump, and not naturally due to buoyancy forces. For example, if imagine we introduced a pump inside the water reservoir shown in Figure 8, this would cause a forced convection.

The analogy of knowledge transfer by convection is based on conceiving how the intensity of the knowledge source and the density and pressure differences in the medium causing knowledge to flow. Consider it would be possible to determine a dimensionless number where pressure of the environment (like ρ), force of the knowledge source or initiative (like g), culture of the organization (like α), difference in knowledge or expertise (like ΔT), dimensions of the space or group (like *V)*, personality traits or group characteristics (like *k*) and cohesiveness in the system (like μ) could be taken into account to design a knowledge transfer strategy. Therefore, we believe that using a convective approach to design such strategy would be quite powerful, because is an expression that includes variables affecting the convection mechanism.

2.2.2.3 Radiation

Radiation refers to any process in which energy travels through a medium or through space and is ultimately absorbed by other body (without any physical contact between the objects). The intensity of radiation will depend on factors such as, the temperature of the source object, the proximity between objects, and the properties of the medium across which the radiant energy is transferred. However, this type of energy transfer could be considered to be the most inefficient of all forms, since only a small part of the energy radiated from the source will be used. The most typical example is the sun, which transfers solar energy to the earth by means of radiation; where, only a tiny part of the energy dissipated by the sun is absorbed by the earth. Nevertheless, it is evident that this type of heat transfer can also be a very powerful source to generate change; for example, the effects caused by a nuclear bomb.

Roughly, there are three types of radiation particles: alpha, beta and gamma rays (see Figure 9). Alpha rays have a high mass of the particle, but little energy and a low range; these particles can typically be stopped with a thin layer of any material (e.g. sheet of paper). Beta rays consist of smaller particle known as electrons, compared to alpha rays, they have higher energy and higher range, but still this can be stopped by a thin metal layer (e.g., aluminum). Gamma rays consist of photons deriving from the excess energy after emitting alpha and beta rays; this type of rays cannot be easily stopped by any material, but sometimes it needs thick layers of concrete to stop them.



Source: Wikipedia (2010)

Figure 9 Different types of radioactive particles

The analogy of radiation and knowledge transfer seems to be more abstract, since any kind of knowledge that could be transferred would be totally tacit, intangible, and difficult to control, predict or qualify; nevertheless, the source of radiation in this king of transference is quite relevant. Socialization would be an example that could help to conceive this kind of transference, where the outcome of almost all socialization activities could not be predicted since the beginning; however, the people and the medium where it takes place are the ones that can provide added value thru socialization.

In conclusion, we believe that a deeper understanding the different heat transfer mechanisms, can become relevant to the field of KM when knowledge is conceived as a heat, which has flowing properties. And, understanding these mechanisms can provide insights to understand underlying characteristics of the knowledge transference processes. In addition, based on these principles, alternative ways to characterize or measure the flow of knowledge can be derive to evaluate progress of a KM initiative. However, due to the scope of this project and the limitations in time, we are not able to explore more into detail.

2.2.3 Knowledge generation as a combustion process

The last 'thermodynamic' approach in this paper focuses on the metaphor developed by Rose (2007), where the creation of knowledge is seen as a combustion process (chemical reaction). In this case, likewise energy results from the combustion of a fuel, the creation of knowledge can also be described as the psychosocial processing of information in a form that achieves added value (Rose, 2007). In this section, we will explain more into detail this metaphor.

In one hand, data is described as the basic form of information, composed by raw numbers, images, words and/or sounds derived from an observation or measurement (Nonaka, 1994). Information is the result from the arrangement of data, in a meaningful way or pattern (e.g. reports, books, codes or music); however, its arrangement in a in certain way, structure or specific context can also have different meanings. On the other hand, we could also describe atoms as the most basic form of matter; and molecules is formed by the chemically bonding (or arranging) two or more atoms in a specific structural manner. For example, a molecule of water is formed by bonding two hydrogen atoms to one oxygen, or a molecule of methane (mayor component of the natural gas) formed by one carbon and four hydrogen atoms.

To develop this metaphor, information should be specifically seen as a fuel molecule (i.e. methane or propane). A particular characteristic of a fuel molecule is that, when it is burned, it is able to release a high quantity of heat (thermal energy). For example, in Figure 10 we represent the combustion reaction of methane. We can graphically see, that one molecule of methane in the presence of oxygen and an ignition source, it will produce carbon dioxide, water vapor and a high amount of heat (891 kJ/mol of heat); and such amount of heat can then be used for any desired or specific purpose (e.g. heating water).

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + 891\,\mathrm{kJ/mol}$$

Figure 10 Combustion of methane

In addition, fuel can exist in different physical states (or forms) such as, gas like methane, liquid like methanol or solid like wood. One way to classify fuels can be based on the amount of heat they are able to generate in a combustion process, known as heating value. However, a fuel's heating value can also yield different values, depending on the amount of moisture it has at the time of combustion (e.g. green wood vs. dried wood), resulting in an additional categorization of high heating value (low moisture content) and low heating value (high moisture content). In addition to this, fuels can also be classified based on the economical benefits, such as the average cost per heating unit.

Given the characteristics of fuels, we would like to highlight four particular similarities found supporting this metaphor: first, both have the potential to produce a considerable amount of energy (e.g. heat or knowledge) which can be used for specific purposes; second, they can exist in different physical states or forms; third, they can be classified in different ways according to its value, benefits and effort to access them; and fourth, both can be stored but also seen as finite resources.

A metaphor where the creation of knowledge is seen as a combustion process can also help us to understand two important concepts: the generation of by-products, and the inefficiencies of both processes. To explain the generation of by-products, refer once more to Figure 10. In this figure it is visible how the combustion of methane, in addition to heat, will produce carbon dioxide (CO_2) and water (H_2O). Consider that under certain circumstances these by-products could be seen as desired or undesired by-products. For example, from an environmental perspective, the production of CO_2 is not desired since it contributes to global warming; however, consider another (hypothetical) perspective, where the production of CO_2 result would be desired (similarly for the case of H_2O). From this perspective, considered that by-products could also be derived from the creation on knowledge, and in some cases, this could be desired or not; for example a spin of company generated as a by-product (Rose, 2007).

Combustion cannot be considered as a totally efficient process. Since, in order to be considered as a process 100% efficient, it would require capturing and using exactly all of the produce energy (no losses at all). However, in real life this is not possible, since light and heat will tend to dissipate through the environment. Common combustion processes have an efficiency range between 10% and 70%[4]; and, several (context specific) factors will influence its efficiency (i.e. the amount of oxygen present in the air, the fuels moisture content or even the equipment design where the combustion is taking place). In a similar way, the creation of knowledge could not be considered as a totally efficient process, since several factors may influence this process, such as environmental and individual factors.

Here, we find a close link in this knowledge creation as combustion metaphor. We believe that similarities between these two processes can provide a relevant insight for an attempt to optimize the process of knowledge creation. In particular, we found four relevant similarities: first, the main objective of both processes is to produce added value; second, as consequence of both processes by-products will be formed, which under certain circumstances they could be seen as desired or undesired results; third, both processes could be considered as not totally efficient, since energy will be lost in the process and its efficiency is determined by a number of intrinsic and extrinsic factors; and fourth, optimizing both processes can eventually translate into an economical benefit, for example cost saving initiatives.

[4] Engineering Tool Box: www.engineeringtoolbox.com

2.3 Conclusions

As mentioned at the beginning of this chapter, we believe the work developed by Rose (2007) provides two main contributions to the field of KM. First, the author develops a model that is able to capture knowledge and organizational dynamics, where organizations can be analyzed as disaggregated systems. And second, Rose suggests a novel perspective to conceptualize the creation and transference of knowledge inside organizations. Even though the model developed by the author, is not able to capture the influence of human interactions in the creation and transference of knowledge, we believe it is a relevant attempt to explain knowledge dynamics inside organizations; and therefore, be a representative starting point to develop of a new theoretical model.

In summary the BD model identifies four different knowledge zones formed by the possible combinations between the forms of knowledge (tacit/explicit) and two possible architectural forms (rigid/organic). And within these zones, the author identifies different existing mechanisms to explain the transference and creation of knowledge; to explain each of these mechanisms, Rose suggests the use of a thermodynamic perspective. The suggestion of using a thermodynamic perspective towards the management of knowledge is a novel and powerful approach developed in the KM field. However, this perspective had not been extensively developed. In this chapter we have extended part of Rose's perspective and contributed with new insights which can contribute to understand the underlying mechanisms to create and transfer knowledge. In summary, thermodynamics studies heats ability to produce work and thermodynamic principles are able to explain the processes of transformation of energy. To link thermodynamics and knowledge management, we have explained three main analogies: first, knowledge can be seen as energy; second, knowledge can be transferred as heat; and third, the knowledge creation process can be seen as a combustion process. Making these types of analogies can possibly influence the way we see and think about the management of knowledge; and, possibly by understanding the underlying principles of these transference mechanisms alternative indicators to measure progress could be developed in future research.

3 Social Network Analysis

Inside an organization, human interactions (also known social networks) refer to those interpersonal relationships formed or developed by employees across functions and divisions inside an organization (Cross et al., 2002; Kleiner, 2002). According to several researchers, these types of relationships may have a strong influence in the operation of an organization affecting the decision making process (Krackhardt & Hanson, 1993; Cross et al., 2002; Kleiner, 2002; Patton 2008). However, capturing these interpersonal relationships is not easy, since they are constantly changing and have no formal communication channels or formal leaders.

A social structure is formed when two or more actors are connected thru an existing interdependency; for example a friendship, a financial exchange or a belief (Hanneman & Riddle, 2005). Therefore, it is possible to determine the structural properties by uncovering patterns of human interactions within a group or network. In this sense, the identification of the structure within an organization may contribute to identify group dynamics impacting an individual's performance (Hatala, 2006). However, to study these types of relational interdependencies the use of alternative methods and analytic tools are needed, which differ from the ones regularly used in statistics and data analysis (Wasserman & Faust, 1994).

Social network analysis (SNA) is a methodology that has recently captured interests of researchers and practitioners in the organizational field, since it is used for the systematic assessment of social networks. This methodology studies relationships existing among social actors (individuals or groups), instead of only studying the attributes of an actor. Therefore, SNA becomes a valuable tool to identify the structural elements which characterize relational networks, patterns of interaction and relational barriers possibly existing (Hatala, 2006; Wasserman & Faust, 1994). This type of analysis also allows the possibility to develop network maps, which provides a graphical overview of the relationships existing across the network, where actors can be studied within a group context, rather than individually.

Given the relevance and the potential SNA provides in the assessment of human interactions, we propose the use of this methodology as a managerial tool to capture its influence in the creation and transference of knowledge. However, given the unique characteristics relational networks have, there are some important considerations that must be understood to develop and interpret a SNA. Therefore, in this chapter we will explain, from a practical perspective, basic theoretical concepts. In addition, we will use a network perspective to discuss what possible challenges an organization might face when implementing knowledge sharing initiatives.

This chapter has been divided in five different sections. First, we will present some basic theoretical concepts need for the development and interpretation of a SNA. Then, we will present a of a nine step methodology for the development of an organizational SNA. Third, we will explain four different relational networks which can be analyzed to uncover flow patterns of information and knowledge. Then, we will present a network perspective useful to consider for the development of a knowledge sharing initiatives. Finally, draw some conclusions about the use of SNA in the field of knowledge sharing and discuss some limitations this methodology has; in addition we will discuss possible challenges we foresee that practitioners may encountered along the way using SNA.

3.1 Basic concepts about Social Network analysis

Social network analysis is a methodology founded in the fields of sociology, influenced by mathematics and statistics. It is considered as an interdisciplinary methodology grounded in the systematic analysis of empirical data (Freeman, 1997). Currently its use has extended to several fields of study, such as, psychology, anthropology, history, management science (e.g. entrepreneurship or alliance management), and military (Walström, 2003).

There are four basic assumptions behind a network analysis (Wasserman & Faust, 1994): 1) actors and their actions are viewed as interdependent rather than independent, autonomous units; 2) relational ties (or linkages) between actors are seen as channels for transfer or "flow" of resources (being material or nonmaterial); 3) network models provide a perspective on how a network's structure can provide opportunities or constrain an individual's action; and 4) network models conceptualize structure (social, economic, political, and so forth) as lasting patterns of relations among actors. However, to properly understand a SNA, some basic relational concepts should be distinguished. We have divided this section in five sub-sections: social network data, types of relationships, network structural characteristics, characterization of actors and limitations of SNA.

3.1.1 Social network data

Social network data derives from the measurement of relationships existing within a set of actors, being individuals or groups. And, the analysis (or modeling unit) can be done at three different levels: tie level (dyadic), individual level (monadic), and group level (network).

A dyadic analysis studies the tie properties (or relational attributes) among pair of actors; for example, the existence or not of a relationship (i.e. friendship), or its strength (i.e. very close friends).

A monadic analysis studies actors and its ties, at an aggregated level. This evaluation is helpful to characterize actors based on its tie's properties of the position it has in a network; for example, a central actor or a bridging actor. Ego-network analysis is an additional study can be made at an individual level (see Figure 11). It studies relationships of a particular individual (or ego), and characterizes them in terms of size, diversity or any other attribute affinity with its' alters. In an ego-network analysis, no attempt is made linking the relationships of other individuals (or alters).

Finally, network level analysis will study characteristics of all existing relationships among a group of people. This type of analysis represents the study of ties at the most aggregated level possible, providing a kind of helicopter view of the entire network (see Figure 12); where structural properties like total number of existing ties, or average distance between actors will be analyzed.

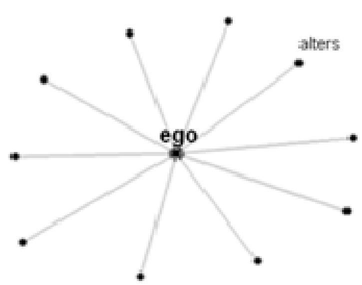


Figure 11 Ego-Network

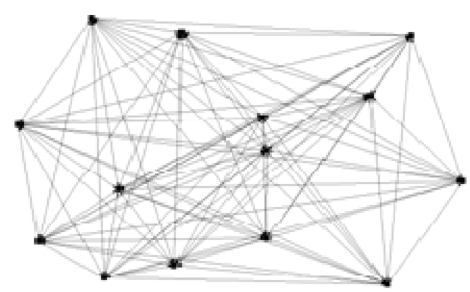


Figure 12 Complete Network

When relationships between actors are being measured, there two important properties that also needs to be considered: determine whether the tie is directional or non-directional, and determine if the tie will be measured dichotomously or in a value scale. A relationship has direction, when the tie is directed from one actor to another (having origin and destination). Non-directional ties simply exist between two actors. For example, one country exporting to another has direction; whereas two countries simply sharing borders would be non-directional. A relationship can be measured dichotomously, as existing or not; or it can also be valued according to its strength or frequency. For example, a friendship can exist or not, but it can also vary in intensity or frequency of interaction (i.e. very close friends vs. recently met).

3.1.2 Type of relationships

The types of relationships which can be measured can vary enormously. However, different relationships can also occur at the same time, or even one relationship can derive from another. For example, a friendship can coexist together with a transactional relationship (i.e. selling or buying), or an advice network can be derived from a currently existing friendship network. In spite of all the possible types of existing relationships, Knoke and Kuklinsky (1986) suggest its classification into seven different groups: individual evaluations, transfer of material resources, transfer of non-material resources, interactions, movement, formal roles and kinship; which, we summarize and provide an example in Table 1.

Table 1 Categorization of relationships

Type of relationship	*Description*	*Example*
Individual evaluations	Personal relationships, usually considering the positive or negative affection of one person to another	Friendship, liking or respect
Transfer of material resources	Ties related with the transfer of material resources or other forms of social support	Selling, buying, lending or borrowing
Transfer of non-material resources	Communication specific ties between actors	messages, gossips or novel info
Interactions	Ties that involves physical interaction or presence in the same place at the same time	Sitting together, attending an event or conversing
Movement	Refers to the ties developed by individuals when moving between networks	Communities, changing jobs or change in status
Formal roles	Ties which are dictated by power and/or authority	Boss/employee or teacher/student
Kinship	Ties based on marriage or descent relationships	Parents, children, or relative

As we have also explained, relationships can additionally be characterized. And to characterize them, three important properties should be considered: strength, multiplexity and consistency.

Tie strength is determined by a combination of the amount of time, the emotional intensity, the intimacy and the reciprocity which characterize the relationship (Granovetter, 1973). Measuring strength in a relationship could be determined by simply asking each actor to specify its strength, or by confirmatory answers, given by two actors, recognizing the existence of a relationship.

Multiplexity refers to the tendency for different kinds of ties to occur together (Wasserman & Faust, 1994). Within the organizational context multiplexity is commonly unavoidable since, at least one formal relationship between two individuals is determined. Therefore, the interpretation of existing relationship should be made cautiously, since this might lead to causality problems (Waldstrom, 2003).

A consistent relationship could be measured by confirmation and reciprocity. As explained, confirmation occurs when both individuals confirm the existence of a relationship; and reciprocity occurs a tie from ego is corresponded by his alter.

3.1.3 Structural characteristics

As we have explained along this chapter, the uniqueness of SNA is that allows the identification of structural properties of a relationship network. Therefore in this section we will briefly explain what these structural measurements are. Even though there are several structural measurements that determine in a characterization of a network, we will focus on four elemental measurements which will allow us to achieve a basic and practical network characterization: centrality, cohesiveness, subgroups and reciprocity.

3.1.3.1 Centrality

Centrality measurements can help us to determine an actor's position within a network. In general, a central actor is the one involved with the most number of actors; however, there are three different ways to determine a central position of an actor: degree, closeness and betweenness.

Degree is one of the most elemental ways of determining an actor's centrality. An actor having the most number of connections (or ties) in the network will have the highest level of centrality degree (Wasserman & Faust, 1994). For example, consider the network shown in Figure 13. In this case, actor **j** is the one with the highest degree values because it is the one with the most number of connections; whereas, actor **q** has the lowest degree with only one connection.

It is important to mention that in the case of directional relationships, a degree measurement could be distinguished between out-degree (outgoing) and in-degree (incoming) relationships. And, in some cases the distinction between these relationships could be associated with an actor's preference or power type relationships.

Closeness measures the relative distance of an actor to others. Specifically closeness values determine how close an actor is to all the other actors in the network (Wasserman & Faust, 1994). For example, actor **l,** in Figure 13, is the one which is in a closer position to reach all other actors within the network, and actor **q** is the one who is less close to others in the network.

Geodic distance is a term derived from the closeness measurement; representing the length of the shortest path between two nodes. Therefore, a geodesic path would be the most "efficient" path connecting two actors (Hanneman & Riddle, 2005).

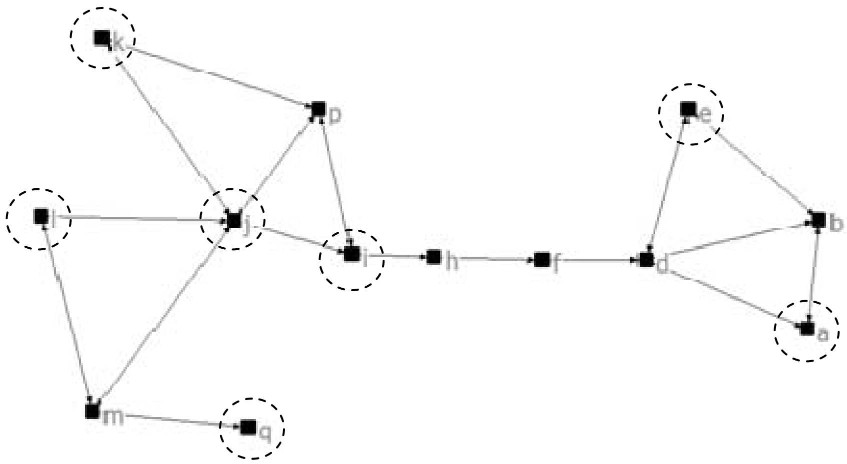


Figure 13 Actors with different centralities

Betweenness considers if an actor is located in between other actors, which may represent a relative control over paths in the network. The idea behind this measurement is that an actor plays a central role if it lies between other actors, especially in a geodesic path. In the example of Figure 13, the actor with the highest level of betweenness is **i**, and actors **k**, **l**, **q**, **e** and **a** have the lowest levels.

3.1.3.2 Cohesiveness

Cohesiveness is one of the most relevant measurements, which determines how connected (or cohesive) a network is. It measures the extent to which individuals are connected to others and the extent to which the network as a whole is connected. In general, the more cohesive a network is the one where more actors are connected to each other. Cohesiveness measurements are determined by measuring two network properties: density and structural holes.

Density determines the level of connectivity within the network; which is determined by analyzing the number of actual links existing in the network, compared to the total possible links that can exist (Hatala, 2006). Therefore, density is measured as percentage, and the greater the density value is, the greater the cohesiveness of the network. Depending on the specific situation, different density levels may have negative or positive impacts on the network. For example, highly dense networks may have a positive impact on the creation of social capital or the flow of information; however, this may also cause a network to be too close regarding the acceptance of an external member, or may cause high levels of group thinking. On the other hand, lowly dense networks could indicate a poor connection degree between actors, which may also have an impact in the level of trust within a group. Therefore, determining an appropriate density level within a network requires the assessment of the function of the group, and its need to be tightly connected (Hatala, 2006).

A **structural hole** could be explained as concept opposite to a density measurement, since it stresses the importance for individuals to have connections to a variety of networks (or subgroups) rather than many connections within a single network (Burt, 1992). Individuals connecting different networks (or sub-networks) can exercise certain influence or act as brokers by bridging networks that are not directly linked. In particular individuals with broad, low density networks with many non-redundant contacts have access to more information and can reap the benefits of the tertius gaudens[5] (Burt, 1992).

To explain both concepts density and structural holes, let us refer to the network shown in Figure 14. In this network it is possible to identify three different subgroups. It is possible to observe that subgroup 1 is the one containing the highest density, since all actors in the subgroup are totally connected with each other. Then, it is also possible to observe that the entire network (including actors from subgroups) is partially fragmented, or has a structural hole; and, in this case only actor **h** is in a position able to transfer information or resources between each subgroups (possibly benefiting from a brokering position).

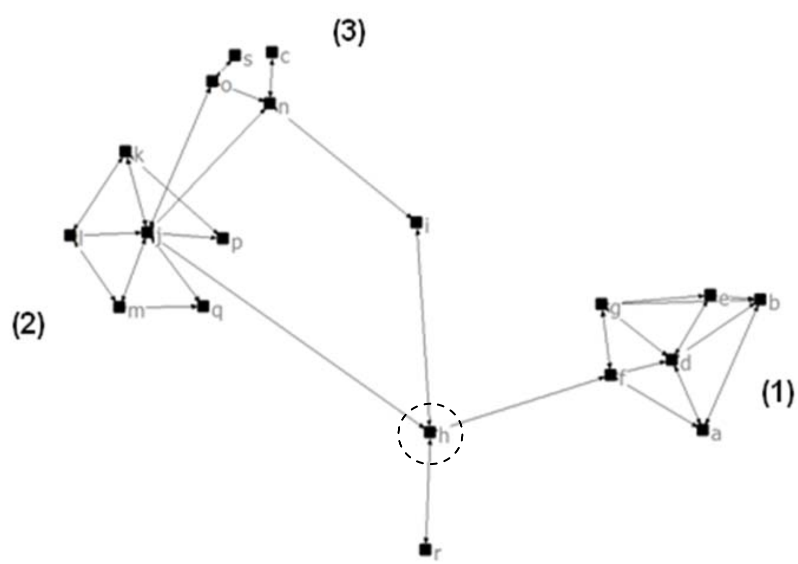


Figure 14 Density and Structural holes

[5] a situation in which one party benefits from a conflict among two others

3.1.3.3 Clustering

The identification of cohesive subgroup of actors (or clusters) existing within a network, is also an advantage of a SNA. Cohesive subgroups are a subset of actors among whom there are relative strong, direct, intensive or frequently ties (Wasserman & Faust, 1994). A clique is defined as a subset of nodes that are completely connected and do not appear in any other subgroups (Scott, 1991); in other words, a clique can be seen as a small group actors choosing each other as members of a clique. Using an 'n-clique' procedure allows to uncover the existing cliques (or subgroups) existing in a network, defining different criteria to constrain or relax the strength in measuring subgroups.

3.1.3.4 Reciprocity

Reciprocity measurements provide a deeper interpretation during the analysis of the cohesiveness of a network, because for a group to be fully cohesive there must be a "give and take" relationship between members (Hatala, 2006). For example, Riedl and Van Winder (2003) explain that for the performance to increase within a workplace, a level of reciprocity must be seed in order to increase the likelihood that organizational members will provide assistance to each other without the fear or not receiving the same in return; which could also represent the existence of certain level of trust.

3.1.4 Characterizing actors

As we have previously explained, actors can be characterized according the properties of its relationships and by the position it has inside a network (determined by analyzing monadic variables). For example, Allen (1976) distinguishes four different actors based on its attributes and their position (see Figure 15): *stars* are those actors with the greatest number of ties in a network (like actors **d** and **j**); *bridges* are those actors who have relationship with members outside the group (like actor **h**); a *liaison* links several individuals or subgroups together (actors **i** and **c**); and *isolates* are those actors who have very few or no contact at all with other network members (as actors **s** and **r**).

Similarly, Stephenson (in Kleiner, 2002) distinguishes actor based on the role they have on the flow of information. She defines *hubs* as those people with the most number of connections; *gatekeeper* actors who function as information broker, facilitating or impeding flow into different parts of the network; and *pulse taker* actors who's network is relatively sparse and diverse, allowing it accessing to new sources of information.

It is important to highlight, than an actor, inside a network, may play different key roles according to the type of relationship that is being measured. In addition, some actors can also have unique properties by the different roles it plays on different relational networks. To this kind of classifying actors, we will refer as the identification of a network's "key actors".

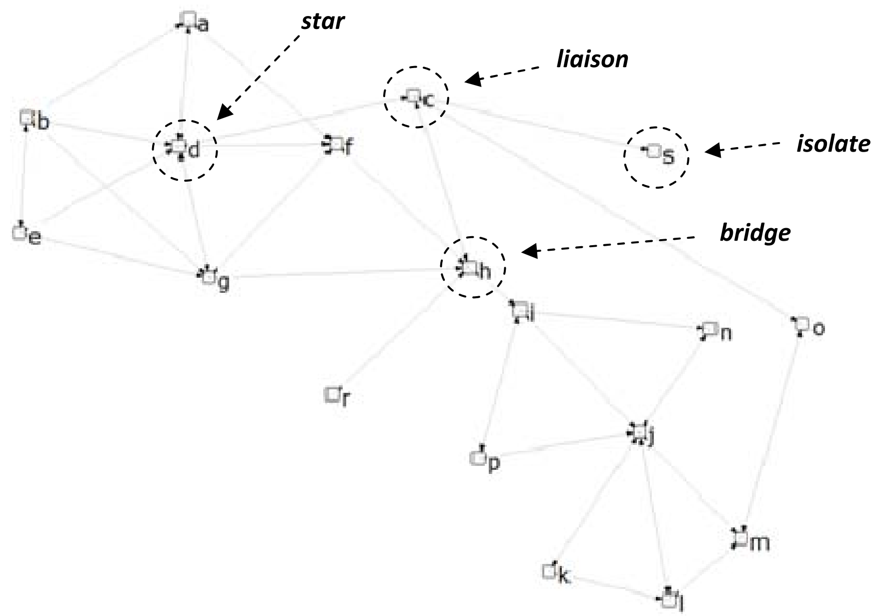


Figure 15 Identifying different actors in a network

When developing a SNA, an actor's attribute data should also be collected and studied. Individual actor variables can include: gender, age, location, educational level, performance, etc. However, determining the specific data to be collected will depend according to the purpose of the study.

3.1.5 Limitations of a SNA

In general, three are the main limitations that should be considered when conducting a SNA (Hatala, 2006). The first limitation refers to the *respondent rate*. Unlike other type of analysis, a complete respondent rate is required to conduct a complete network analysis. To avoid this, careful attention must be put in the definition of the network and defining its boundaries.

The second limitation refers to the *sensitivity of the questions* used in this type of analysis. Social network questions can sometimes be interpreted, by employees, as being sensitive or possibly threatening; which will naturally retain people to participate. However, to avoid this being a big issue, a proper environment of high levels of trust, transparency and proper involvement of key players (top managers) must be developed, which stimulates employee's willingness to participate (Hatala, 2006).

Finally the third limitation refers to the issue that this type of analysis is also *time sensitive*; in other words, relationships are dynamic and they will constantly emerge and diminish. For example, a SNA could be compared to a snap shot taken by a camera, where certain relationships will probably occur only at the time the study was done. However, an advantage of this analysis is that it is possible to identify patterns of existing relationships, which can also be characterized in strength and relevance. Nevertheless, this type of analysis requires to be used continuously over certain periods of time, especially, when an analysis intends to measure the effectiveness of an intervention which might probably alter the network's structure. In these cases, it is important to plan a pre and post-analysis in order to properly measure its impact.

In this first section, we have explained some elemental concepts to explain what a social network analysis is and highlighted some possible limitations which need to be considered. These explanations have been basically developed from a practitioner's perspective, and for a basic understanding of this topic. However, if a deeper and more technical level is required we recommend the use of two relevant references: Wasserman and Faust (1994), and Scott (1991).

3.2 Nine steps to develop a SNA

The scope of this project is to provide a practitioner's perspective for the use of SNA as a managerial tool. Therefore, to illustrate how a SNA should be conducted in practice, this section presents a nine-step guideline summarizing the development of this type of analysis. This nine-step summary was based on the work published by Hatala (2006).

Step 1 – Determine type of analysis

The first step before conducting a SNA is to determine the type of analysis to be made, ego-network or complete network analysis. The definition of boundaries is particularly import, because a miss-specified network boundary may include or exclude not only some set of relevant or irrelevant nodes, but also all relationships between those nodes and other in the population (Wasserman & Faust, 1994). These boundaries can physically exist or not, or even network members can also be spread over different locations.

Step 2 – Defining relationships to be measured

The following step consists on defining the type of relationship to be measured, and what the purpose and conceptual framework behind each relationship are. As explained in the previous section, there are different types of relationships; therefore, it is very important this step is clearly defined.

Step 3 – Collecting network data

The third step is related to the form of collecting such network data. Network data can be collected via interviews, observations, surveys or archival documents. However, the selection will depend on factors like accessibility to the network members, resources available (e.g. historical documents) or time available for the analysis. Further information about advantages and disadvantages of each technique could be found in Wasserman and Faust (1994). Nevertheless, questionnaires are the most used technique for an organizational network analysis.

Step 4 – Measuring relationships

In the fourth step it is required to determine how the relationship is going to be measured; which must be aligned with the relationship it is intended to measure. Issues such as dichotomous vs. valued relationships or directional vs. non-directional should be specified in this phase.

Step 5 – Defining relevant attributes of actor

The definition of an actor's attribute characteristics should also be defined. And, as explained earlier, some relevant attributes may include gender, place of residence, education degree or performance. These attributes should also be aligned with the purpose of the study.

Step 6 – Carrying out the SNA

The sixth step is defined as the act of carrying out the SNA. In this step it is necessary to take into consideration the possible limitations which may be encountered, such as, developing a proper environment, communicating the intention of the study, involvement of top management, and motivation of network members to participate.

Step 7 – Analyzing network data

To analyze the network data, specific software is required. Particularly, we recommend using the software packages developed by Analytic Technologies[6] because it may have the following advantages:

[6] UCINET & NETDRAW (developed by Borgatti, Everett & Freeman, www.analytictech.com)

the software is commercially available from internet, it is continuously upgraded and because there are enough available material for learning about its use. However, the International Network for Social Network Analysis association (INSNA) provides a list[7] of additional software packages which can be used for the analysis of social networks.

Step 8 – Creating descriptive indices

This step refers to the analysis of network data using the descriptive indices we have previously explained (centrality, cohesiveness, cluster and reciprocity). Based on these measurements, the identification of key actors within the network will be possible.

Step 9 – Presenting network data

The last step refers to the way in which data will be presented and communicated to others. Network data can be presented in a graph or a matrix. A graphic form (also known as sociograms) provides a visual representation of the structure of the network. In addition, it provides the advantage of mapping ties providing an overall view of the relational network. However, if the is very large, and interpretation of sociograms becomes difficult, thus a matrix form would be more suitable. A matrix form allows presenting the mathematical transformation of the information in a matrix.

3.3 Networks to measure flow of information and knowledge

The main focus on this project is to analyze relational networks where relevant organizational information and knowledge are likely to flow. For this purpose, we specifically suggest assessing four relational networks: the social network, the work-related activity network, the expert advice network and the idea generation network. And, in this section we will explain the theoretical background behind our proposal.

3.3.1 The social network

Several researches have provided evidence about the importance of social relationships for obtaining information, learning how to perform a specific work or task, or solve organizational problems (Cross, et al. 2001a, Cross, et al. 2001b, Kleiner, 2002; Allen, 1976; Kuijkuit & van Ende, 2007). For example, Allen (1976) found that engineers and scientists were more likely to turn to a person for information than to an impersonal source such as a database or a file cabinet. And, Cross et al. (2001a) found a similar tendency in managers when seeking critical information for the successful development of a project. It is

[7] www.insna.org

clear that social relationships are a basic element for obtaining and transferring information and knowledge; and generally, the benefits gained from social relations could be categorized in (Cross et al., 2001b): a) solutions, when people are able to provide information which provides an answer or directly solves a problem; b) meta-knowledge, when actors play a brokering role by pointing at people or other sources where information can be retrieved; c) problem reformulation, when beyond providing information, people become engaged in making interventions or shaping the dimensions of a problem in a way that the information seeker considers relevant; d) validation, when seeking information from another person derives confidence or assurance; and e) legitimization from contact with a respected person, when seeking information is a symbolic act with social significance.

Within organizations, employees may also seek for help from other members when they have developed a trusting relationship which allows them to expose their information needs or share information (Allen, 1976; Cross et al., 2001a; Cross et al., 2002). The development of these relationships seems to be influenced by the frequency of interaction, a shared interest, similar attitude, personality or behaviors; and, in some cases these kinds of relationships will extend beyond the organizational arena. Accordingly, social relationships are able to shape to shape the flow of information and knowledge within a network.

Stephenson (in Kleiner, 2002) affirms that a social network is an accountable indicator of trust within an organization, and states that healthy organizations contain a range of 'social strength' able to withstand stress and uncertainty up to a point that does not over demands people personal time and resources. In this same line, Zhang, et al. (2009) found the existence of a significant reverse u relationship between the amount of social ties and a student's academic performance. Therefore, given the evidence found in literature, we acknowledge the importance of determining social relationship patterns as an indicator of information flow within a network.

3.3.2 The work-related activity network

Structural organization derived from a process, formal reporting relations or physical location, can also facilitate (or constrain) the flow of knowledge and information within group; and, to this specific type of relationships we name the work-related activity network. Cross et al. (2001b) found that inside organizations there are three relevant factors which may have particular influence to the development of work-related relationships: unity proximity, task interdependency and spatial proximity.

Unit proximity refers to employees within the same functional department, where they rely on peers to access job related information. Task interdependency, will normally facilitate the access and transfer of knowledge to those dependent users in order to perform certain task; that is, interdependent jobs necessarily involve kind of similar task information and technical processes, in order to convert and define knowledge (Cross et al., 2001b). Spatial proximity refers to the dimension in which individuals physically work close to one another; for example, Allen (1976) found that physical proximity plays a significant role on influencing the frequency in interaction between organizational members, the kind of knowledge which is spontaneously shared and in the way information and social norms are shaped.

According to Stephenson (in Kleiner, 2002) relationships based on organizational routine operations are able to depict the habitual culture inside the organization. Therefore, we believe that determining the relational structure within the work-related activity network will be relevant for gaining an insight about the organizational structure related to work activities.

3.3.3 The expert advice network

Advice networks have also been widely studied within the management literature (Krackhardt, 1990; Krackhardt, 1992; Krackhardt & Hanson, 1992; Lindenberg, 2000; Cross et al., 2001c; Lezega et al., 2006). According to Waldstrom (2003), advice networks are related to the strength of existing ties, and Krackhardt (1992) found a curvilinear relationship between the strength of a tie and the amount of relevant access to information and knowledge.

Strong tie within networks, tend to closely bond similar people together, providing certain level of trust, motivation and assistance; however, the risk is that at some point the type of information shared within members tends to become redundant. In this sense, weak ties become of great relevance, since they can work to connect separate parts of the network (or outside networks) which are more likely to provide new and relevant information (Granovetter, 1973). Therefore, it becomes relevant to achieve a balance between weak and strong relationships among network members. At some point, weak ties can provide access to information and resources beyond those available in their own social circles; however, strong ties can also have a great impact on motivation, trust and assistance (Granovetter, 1973). In this sense, advice relationships seem to be a combination between weak and strong ties, since people looking for advice expect to receive knowledge and information with certain degree of relevance, probably because they would rely on the reputation and power of the adviser (Krackhardt & Hanson, 1992).

Advice networks are also related to the reputation and power of the members of an organization (Cross et al., 2001c, Lezega et al., 2006); and reciprocity between actors might also represent flow channels containing high levels of knowledge transfer and trust (Lindenberg, 2000). Therefore, we believe that advice networks may differ from simply information seeking behaviors found in the social and work-related networks (other two networks we suggest measuring).

In addition, Lezega et al. (2006) reports that advice networks tend to be more stable relationships over time, and Waldstrom (2003) that the act of asking for advice, builds certain level of trust within personal relationships. However, Stephenson (in Kleiner, 2002) argues that in some cases, key actors within these type of 'experts' networks, might feel threatened by changes and innovation opportunities, since their apparent level of reputation, power and respect might clash with innovating actors. Therefore, we believe that analyzing the expert advice relationships will be helpful to discover trustworthy channels where high levels of knowledge flow, and actors able to balance strong and weak ties within a network. However, when doing an SNA inside an organization, Cross, et al. (2001c; 2002) and Waldstrom (2003) suggest distinguishing between personal and work related advice networks.

3.3.4 The idea generation network

The role of social networks in the process of generation, support and implementation of ideas can be considered a relatively novel research area within the knowledge management literature. Even though, some of the existing literature provide theoretical and empirical explanations for the generation and development of new ideas (Burt, 2004; Perry-Smith, 2006), these commonly assume that it is by weak ties with other non-network members to be the primary source of information which may lead to new creative insights; however, we believe these perspectives might only consider one part of the idea generation process.

Kijkuit and van Ende (2007) found that for ideas to be successfully adopted, the network of people around them should evolve along the process; in the particular case of ideas in the front end phase of a new product development, the authors found that network characteristics should evolve, from a non-redundant, heterogeneous ties containing a weak degree of decision maker involvement, into a smaller more cohesive network with stronger ties to decision makers. In this sense, they suggest that managers should encourage the discussion of generated ideas with colleagues and friends from other units, before employees submit them for review.

According to Stephenson (in Kleiner, 2002) relationships in which people are able to talk and discuss about ideas or thoughts, contain a differentiated level of trust and confidence among the members. She describes these types of networks as containing a naïve, curious and innocent forms of conversations, which enable spaces where people can openly talk about their perceptions, ideas and experiments; and that key actors inside these networks, may take a dim view of traditional processes, which at some point they may clash with the keepers of corporate lore and expertise. Given the relevance of relationships regarding the generation and support of ideas and the impact these may have in its future adoption and diffusion, we acknowledge that analyzing an idea generation network would help us understanding trustful relationships where patterns and flow of free expression of ideas is possible.

In summary, we propose the analysis of these four specific networks in order to capture information and knowledge flow patterns within a network. In particular, we believe that these networks will allow us to generate insights of relational patterns going from common social and work related interactions, to those requiring higher levels of trust between actors, where members are free to express their ideas and ask for a personal and work-related advice. It is important to highlight that even though each type of network study has been previously studied in the transference of knowledge, it is the combination of the analysis of these four networks that we suggest specifically to capture information and knowledge flow within organizations.

In spite our suggestion of distinguishing these four different relational networks, it is important considering the multpliexity issue. Therefore, even though these networks can be analyzed separately, they can actually coexist within the system, or even result one from another (causality effect). Our intention by distinguishing between the analysis of these networks is to highlight the different transference channels, and the identification of different key actors (according to role and position) existing within the network. Figure 16 captures a diagram representing the different systems networks, showing overlapping and coexisting areas.

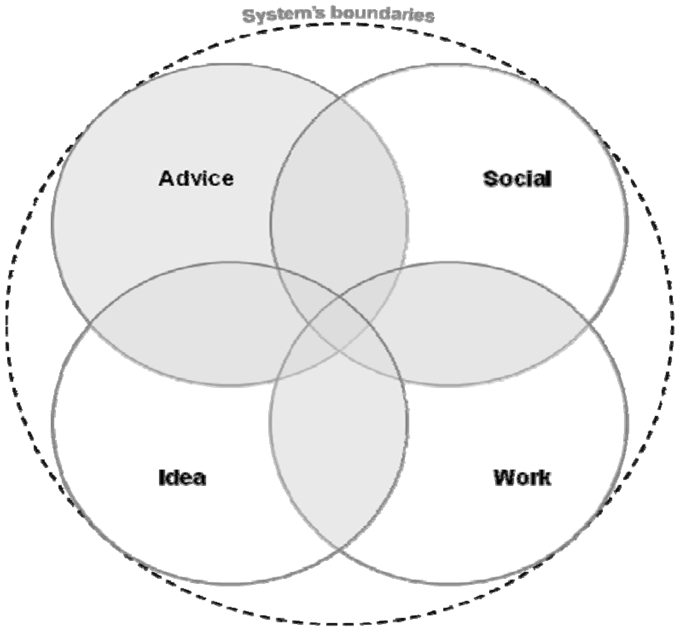
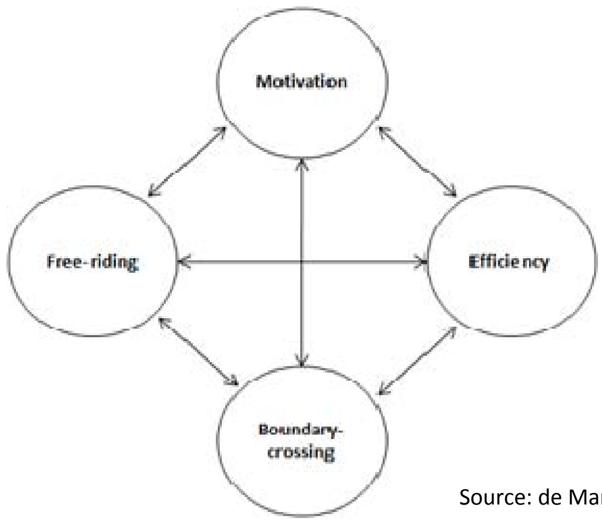


Figure 16 Relational networks within a system

3.4 A network perspective towards knowledge sharing

To complement our perspective on SNA, we suggest considering a network perspective towards the sharing of knowledge which can become relevant for the design of a KM strategy. In general, a network perspective four main challenges (or problems) are identified: motivation to participate, the prevention of free riding behaviors, increase in knowledge sharing efficiency and trespassing any kind boundaries; which are depicted in Figure 17 below (originally developed by Dyer and Nobeoka (2000) and modified by de Man et al. (2008)).

The first challenge refers to motivating members inside the network to share knowledge. An individual's attitude to participate in a knowledge sharing initiative, might be influenced a great number of individual or environmental factors, such as, the result of evaluating tradeoffs between time and efforts required to participate, the degree of risk perceived in sharing his or her knowledge or the existence of any conflict that may threaten any member's status, power or personal's interests (Hislop, 2009). However, before deciding to participate in any knowledge sharing activity, an employee is more likely to face a 'share/hoard' dilemma (Hislop, 2009); that is, he or she will evaluate the potential of any individual consequence (positive and negative) of hoarding or sharing knowledge to the network. For example, a positive knowledge sharing consequences could be enhancing a team or the organizational performance (benefits at group level); whereas a negative consequence could include putting at risk individual's power or status or even that time is required to participate. And, an example of positive consequences of hoarding knowledge (acting as a free rider) could be to avoid risking current power and status levels; whereas, a negative consequence could be not receiving full recognition of what the employee do knows.



Source: de Man et al. (2008)

Figure 17 Challenges to share knowledge within networks

In addition to this personal dilemma, interpersonal trust, emotions and personal traits also play an important role shaping employee's attitude to participate. For example, the lack of trust between individuals is likely to inhibit the extent to which people are willing to share knowledge (Hislop, 2009). Also Spender (2003) found that people's emotions shape the process affecting the way people think and act when they are faced with uncertain situations that go beyond their control, rather than behaviors and decisions only shaped by rational calculations. And finally, it might be possible that some personality traits (i.e. openness and agreeableness) are likely to be positively related to the attitudes towards sharing knowledge; however, there is still research going on to provide a clear conclusion in this area (Cabrera & Cabrera, 2005; Mooradian et al. 2006).

The second challenge is preventing and/or correcting any free riding behaviors inside the network. This challenge increases with the size of the network, since the potential of members behaviors of using resources and not contributing back may considerably increases, and the lack of trust between individuals can also inhibit the extent to which people share knowledge.

In this sense, Kim & Mauborgne (1998) found that an employee's perception of procedural justice can shape its knowledge sharing behaviors and attitudes. Procedural justice refers to the extent to which organizational decision making process is perceived as fair; and, it can be related to how much individuals perceive they are involved in the process of decision making or how clear it is communicated why decisions are made. In addition, material and psychological incentives also play an important role in employee's morale, satisfaction and attitudes (Thatchenkery & Chowdhry, 2007); and as previously mentioned, the perception of risk threatening to lose power and status may influence the people's attitudes.

The third challenge refers to the efficiency in transferring knowledge across the network. Similarly to the previous challenge, the complexity of efficiently transferring knowledge increases with the network's size. For example, the higher the number of actors, the long the time it might take before knowledge required by one actor actually reaches him/her; or, the bigger the network, the higher the costs of maintaining its connectivity (de Man, et al., 2008). Initiatives should focus on the creation of strong ties, creating places where people can meet (events association and meetings), and reduce the number of structural holes.

The last challenge refers to crossing boundaries across network members. Boundaries can be created by time, geography, culture and technology where the larger the differences in backgrounds, the more boundaries are needed to be crossed (de Man et al., 2008). According to Hislop (2009) conflicts, power and politics shape interpersonal and inter-group knowledge sharing; where interest differences, between individuals or groups, affect attitude to participate. For example, the sense of group identity (or community) facilitates the development of trust with other members, since it creates a positive attitude towards sharing knowledge (Roberts, 2006); however, when people develop a very strong sense of identity (with their function, business unit, etc.) they can also become relatively unwilling to share with people outside their areas (Newell et al. 2000).

Considering a network perspective towards knowledge sharing can help us to consider possible challenges that might be needed to overcome in order to successfully share knowledge across networks. However, these challenges should not be considered individually, but rather seen as challenges influencing each other directly or indirectly (consider the arrows existing in the framework). For example, low motivation to share knowledge may enhance free-riding, the need to cross more boundaries may lower the efficiency for knowledge transfer, and efficient knowledge sharing initiative may increase motivation. Nevertheless, we believe that this network perspective should be considered when developing knowledge sharing initiatives; especially when developing an organizational knowledge sharing strategy.

3.5 Conclusions

The objective of this chapter was to presented basic theoretical concepts relevant for the conduction and interpretation of a social network analysis. Therefore, given the information presented in this chapter, it is possible to draw the following conclusions:

1) due to its relational nature, social networks have the ability to influence an organization's operation and affect its decision making process; 2) by uncovering the existing interaction patterns between members inside a network, it is possible to characterize the structure of a network; 3) social network analysis is a scientific based methodology which can be used for a systematic analysis of social networks; 4) discovering and characterizing relationships patterns existing between employees can be relevant for the understanding of how human interactions may influence an organizations operation, decision making process and flow of information and organizational knowledge; 5) social networks are dynamic by nature; therefore a SNA should be done in periodic and continuous bases; 6) for a SNA to be successful, it requires to be properly planed, the encouragement of employees to participate, the development of a transparent and trustworthy environment and the proper involvement (time and participation) of the organization's top managers.

In this chapter we have also explained how the analysis of four specific relational networks (social, work-related activities, expert advice and idea generation) can be relevant to uncover flow patterns of information and knowledge among organizational actors. In addition, presented network perspective on knowledge sharing can be helpful for the development of a knowledge sharing strategy and the implementation of specific interventions, since it illustrates specific challenges that need to be overcome.

4 Integrating social networks into knowledge management

As we have explained along this paper, the final objective of this project is to design a methodology, which integrates the use of social network analysis (SNA) into the practice of knowledge management (KM), in order to capture the influence of human interactions in the creation and transference of knowledge. This methodology will help practitioners to develop a better understanding of dynamics in organizational knowledge. In addition, we intend to design a theoretical KM model which is able to capture three strategic elements: dynamics in the nature of knowledge, dynamics of organizational structure, and dynamics of human interactions influencing the generation and flow of knowledge. Therefore, in this chapter we will provide an explanation of our work.

This thesis project intends to contribute to both practitioners and researchers in the field of KM. On one hand, we intend to design a methodology which can be used by practitioners in the development of a customized KM strategy, according to the unique characteristics existing in their organization. And, consequently extend the organizational capacity to innovate by the proper management of knowledge. On the other hand, we will develop a theoretical KM model, which can be used to study dynamics in organizational knowledge; thus, providing an alternative model which contributes with the literature in this field.

In general, our KM model will be design by integrating the specific analysis of the four relational networks explained in the former chapter (social, work-related, expert advice and the idea generation) into the Bi-dimensional (BD) model developed by Rose (2007). Particularly, we suggest using Rose's model because it already captures dynamics in knowledge and organization's structure; and, suggest the analysis of these particular networks as an alternative to capture relational patterns influencing the flow of information and knowledge.

To design our methodology, we will use the regulative cycle model developed by van Strein (1997), which is particularly used as a problem-solving methodology. The regulative cycle is commonly used in management science, as a design model to solve practical business problems. This model was chosen for two main reasons: 1) the design of a solution is seen as a dynamic and continuous process (cyclic), and 2) it divides the design process into steps: definition, diagnosis, design plan, implementation and evaluation (van Aken et al., 2007).

Similarly to the regulative cycle, we have divided our methodology in five phases. The first phase consists on defining and characterizing a system where the KM strategy will be developed. Then, using the SNA, a diagnosis about the system will be made. The third phase, considers the development of a system's KM strategy by using the output obtained from previous phases and the KM model designed in this paper. In this phase, specific intervention actions and performance indicators measuring progress should be defined. The fourth phase considers the implementation of the KM strategy, bringing into action the specifically defined interventions. Finally, the evaluation phase consists on a careful observation and appraisal of the KM process and the effects caused by the implemented strategy. However, since the methodology is cyclic, once this last phase has ended, a re-design of the KM strategy should be considered. A graphical representation of this methodology is shown in Figure 18.

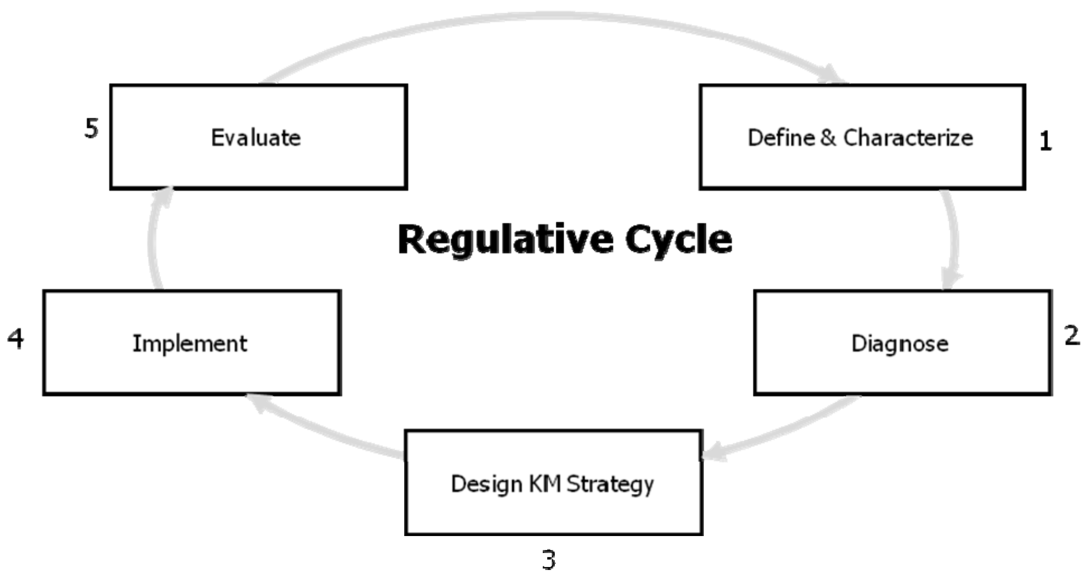


Figure 18 Framework for the development of a KM strategy

To develop a wider explanation of our designed methodology, the rest of this chapter has been divided into six sections. In the following five, we will develop each one of the phases, and in the last section we will present some conclusions and limitations about our designs.

4.1 Definition and characterization phase

The first phase has been divided in two steps: definition and characterization. The first step consists in defining what the 'system of analysis' will be; that is, defining where the KM strategy will be designed. This definition will help us to identify the hypothetical boundaries surrounding the system of study, allowing us to focus on specific characteristics which make the system unique from the rest of the organization. A good starting point to define the system could be considering the organizational chart, which represents a formal structure of how the organization has organized work and rules for its current operation. For example, the system could be defined as an organization's functional unit (e.g. R&D, Marketing, Operations), or by considering certain people within a specific hierarchical position (e.g. vice-presidents, senior managers). However, the system could also be defined according to other organizational needs, such as a project groups or employees involved in certain process (e.g. the development of a new product, customer relationship management). The main objectives in this step are focusing on a specific area of analysis and define the boundaries that will (hypothetically) delimit the system.

The second step consists in characterizing the system according to its dominant form of knowledge and the architectural structure. This type of characterization, at some point, could be seen as hypothetical, because it is made based on an interpretation of what the desired characteristics of the system are. Therefore, we have named this type of characterization as specifying an 'ideal state' of the system.

To characterize the system according to its form of knowledge, simply consists in highlighting whether the dominating form of knowledge existing inside the system tends to be either tacit or explicit. For example, in areas like production or quality control, the dominating form of knowledge will tend to be explicit, since operating procedures and processes in these areas would be likely to be captured into manuals and guidelines. Whereas, in departments like R&D or Marketing, it would not be possible to capture the majority of their operating procedure into manuals, since the dominating form of knowledge would be tacit. However, we recognize that in some cases, this form of characterization cannot be quite easily; therefore, we suggest making an assumption according to what an ideal characterization of the system could be; for example, within an R&D department, possibly a tacit and explicit form of knowledge can be equally present. In this case, we can assume that given the characteristics of a new product development process, a tacit form of knowledge could prevail in this area (i.e. 60% tacit and 40% explicit). It is very important to mention, that this type of characterization does not intends to nullify the existence of any form of knowledge, but only highlight which form is the most dominant.

To characterize a system according to its dominant architectural structure, it is necessary to highlight whether the prevalent form of organizational structure tends to be more a rigid (with high degree of hierarchical relations) or more an organic (flat structure or more process driven). For example, in some areas such as production department, a hierarchical organizational structure will generally tend to dominate, since this may facilitate an efficient operation of an area; whereas in areas like R&D flat organizational structures could tend to dominate. Similar to the previous characterization, if it becomes difficult to define the dominating form, we suggest making an assumption based on the theoretical or desired configuration of the system. For example, within a production department we could assume that 80% of the organizational structure would be rigid and 20% organic.

Characterizing a system according to its dominating form of knowledge and architectural structure, can complement to understand how this 'organizational system' could be differentiated from others according its knowledge and structure composition; thus, highlighting the system's unique characteristics. This type of characterization can also be represented, in what we name, 'ideal state' diagrams; for example, in Figure 19 we represent two diagrams, one representing an R&D unit (a) and the other a production unit (b). The horizontal axis in these diagrams represents the organizational structure composition (O for organic, R for rigid), and the vertical axis the knowledge form (E for explicit, T for tacit).

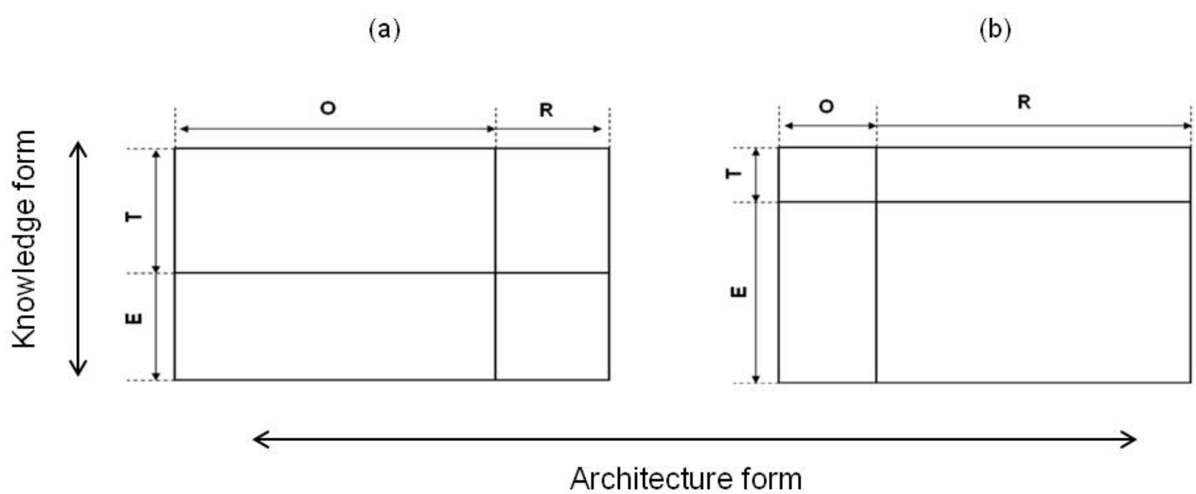


Figure 19 Two Dimensional characterization of a system

We consider important to highlight that in the definition and characterization of an organizational system, we implicitly recognize the impossibility to design an aggregated KM strategy suitable for the whole organization. And, we acknowledge the need to divide a KM strategy into smaller systems of analysis, which need to be characterized according to its specific knowledge characteristics and dynamics. For example, we recognize that the characteristics and dynamics of knowledge from an R&D department will be totally different from the ones in a production area.

4.2 *Diagnosis phase*

The second phase in our methodology, considers making a diagnosis about the relational interactions existing within the system; and, to this phase we will name as discovering the 'real state' of the system. At this phase, our main focus will be to analyze the system's relational interactions regarding the flow of information and knowledge; and to achieve this type of analysis, we suggest focusing on the assessment of four specific relational networks: the social network, the work-related activity network, the expert advice network and the idea generation network discussed in the previous chapter.

As we have explained previously, SNA will be the methodology used to analyze the four different relational networks; thus, for the diagnosis phase we suggest using this methodology following a complete network analysis. It is important to remark that for this analysis, all members within the boundaries of the system should be included, from high hierarchical levels (e.g. senior managers, vice-presidents) to assistant positions (e.g. secretaries). Naturally, those relationships with members not belonging to the system and which cannot be separated will be simply considered as relationships 'outside' the system (or network).

Therefore, to elaborate a SNA two steps need to be considered: the collection of network data, and its analyzing.

Collecting network data

Specifically to collect the network data, we suggest using a single questionnaire (including all questions), which can be sent to employees thru an electronic survey. However, it is important considering that for some network members (e.g. top managers or vice-presidents) an interview could sometime be more convenient in terms of time efficiency.

The questions we suggest using, to analyze each of the four different networks and measure its strength, are shown in Table 2; which, have been elaborated based existing literature. In addition to the network data, personal attribute information should be collected in the survey; therefore, attribute data like gender, time working in the organization, current position, directly reports to, members reporting to you, current position, location site, amount of stress, perceived procedural justice within the organization and/or perceived openness culture within the organization, is also suggested to be included.

Before conducting the collection of the data, we strongly suggest working in a communication campaign that properly communicates the purpose of the analysis and that stimulates their participation. Also remember to consider the participation and support of top level managers, since their participation strongly influences other employees to participate (Cross, et al. 2001a; Kleiner, 2002).

Table 2 Questions to include in the social network analysis

Network	Question	Determining strength
Social	*How often do you "check in", either inside or outside your office, with this person to find out what is going on inside the organization?*	Value scale (0) never; (1) rarely; (2) sometimes; (3) frequently; (4) continuously
Work-related activity	*How often to you exchange information as part of your dairy work routine with this person?*	Value scale (0) no exchange; (1) rarely; (2) some times; (3) really frequent; (4) every day
Expert advice	*To whom do you turn for help or advice whenever you encounter a new work related challenging problem?*	Confirmatory dyad
	To whom do you turn for help or advice whenever you encounter a personal or career challenge?	Confirmatory dyad
Idea generation	With whom do you regularly collaborate or 'kick' around new and relevant ideas?	Dichotomous (0) never (1) regularly

Analyzing network data

For the analysis of network data, the use of specialized software is required, since it will make the analysis possible and simpler. To conduct a basic analysis it is necessary to determine the structural properties and the identification of key relational actors which was also explained in the former chapter. However, to determine an adequate level of strength in the *social* and *work-related activity* networks, we suggest considering a cutoff value of 3 (really frequent). Table 3 provides some basic guideline questions which can be used in the analysis of network data. Nevertheless, the most important analysis will be derived from the insights and the reflection regarding the differences found between the 'ideal state' of the system and SNA results, which might possibly represent a picture of a 'real state' of the system. In addition, a reflection about the different roles key actor's play, about the communication channels they use, the differences in the strength of their ties, isolated actors, and existing sub-groups within the system will be needed.

Table 3 General guideline questions for the analysis of social networks

Overall network characteristics (analyze network structure)
What is the overall network's density?
Are members totally connected (too dense) or is it too fragmented?
Are there any critical points where the network is divided?
Are these divisions caused physical or relational boundaries?

Centrality measure (analyze position and roles of actors)	
	Who are the actors with highest number of connections (highest degree)?
	Which actors are not integrated in the networks (isolated actors)?
	Who are the actors with highest closeness values (actors closest to other members)?
	Who are the actors with highest betweeness values (actors placed in the middle of others)?
Clusters	
	How many sub-groups can they be identified, and what are their characteristics?
	Are there any clear structural holes in the network? Who are the key actors in them?

4.3 Strategy design phase

A step before a KM strategy can be developed requires the identification of the system's 'key business process'; in other words, identifying the principal processes that the system is meant to deliver. For example, within an R&D department, one of the key business processes is the new product development (NPD) process. Particularly, we suggest making the division of key processes at this phase in order to avoid any possible bias when interpreting or analyzing the network data.

Following the identification of the key processes of the system, these need to be characterized according to its dominant form of knowledge. This characterization is similar to the one in the first phase; however, in this case we will only focus on the knowledge dimension. It is important to remark, once more, that this type of characterization does not intends to do an either/or selection between a tacit or explicit form of knowledge, but the main idea behind is to provide insights on how the different processes differentiate in terms of a dominant knowledge characteristics; thus, a differentiation in knowledge dynamics. However, if a process cannot be easily characterized, because it is composed of several sub-processes, an additional (sub-process) division needs to be done. For example, within the NPD process (from idea generation to product launching) dominant forms of knowledge change considerable along the way; therefore, a division of the process would be required into concept definition, planning and design, development, market evaluation and scale up, production and product launch, post launch evaluation. Nevertheless, if within a sub-process, both forms of knowledge (tacit/explicit) tend to dominate, no additional division will be made, but instead we will simply be acknowledge as an overlapping process where both forms of knowledge are equally important. We believe there is no need to continue a sub-process division, because we could run the risk of over-specifying the system's KM strategy, making it too rigid and inflexible.

Before moving on, we consider it is important to summarize the information it has been generated at this moment. First, within the whole organization, a specific system has been selected, where a KM strategy will be developed. Then, the system has been characterized according to its knowledge and architectural dominating forms; this characterization will allow us to define an 'ideal state' of the system, and acknowledge it is composed of four different knowledge zones, where one zone will tend to dominate over others. Then, a diagnosis of four different relational networks was made, with the purpose of capturing employee's interactions and different communication channels where information and knowledge might tend to flow; and, by differentiating these four relational networks, it is also possible to identify close and trustworthy relationships. Finally, key business processes have also been identified, and characterized according to its dominant knowledge form; thus, this last characterization will help us identify unique knowledge characteristics of each process.

Given the information generated at this stage, we believe having enough elements which capture the three strategic elements mentioned at the beginning of this chapter: dynamics in the knowledge forms, dynamics in the organizational structure and processes, and the human interactions influencing the transference and creation of knowledge. And, to capture these strategic elements we propose the theoretical model shown in Figure 20 below. Therefore, with this model we accomplish the objective of designing a model which was able to capture organizational knowledge dynamics; which can now be used to develop a relevant KM strategy. We have named this as the Dynamic Bi-Dimensional (DyBD) model.

Specifically, the design of this DyBD model was achieved by integrating the analysis of four different relational networks into the BD model originally developed by Rose (2007). As shown in Figure 20, the horizontal axis corresponds to the architectural form of organization (organic/rigid) and the vertical axis to the knowledge form (tacit/explicit). From the combination of these two dimensions, four different knowledge zones result: tacit-organic, tacit-rigid, explicit-organic and explicit rigid; and, for each of the different zone Rose (2007) identifies different knowledge transference and creation mechanisms, which he explains in terms of thermodynamic metaphors (namely conduction, convection, radiation and combustion). However, in addition these BD model, our design considers an overlapping zone, in the vertical axis, where tacit and explicit knowledge coexists; which intends to represent processes where both forms of knowledge are relatively important according to the characteristics of the key business processes in each organizational system.

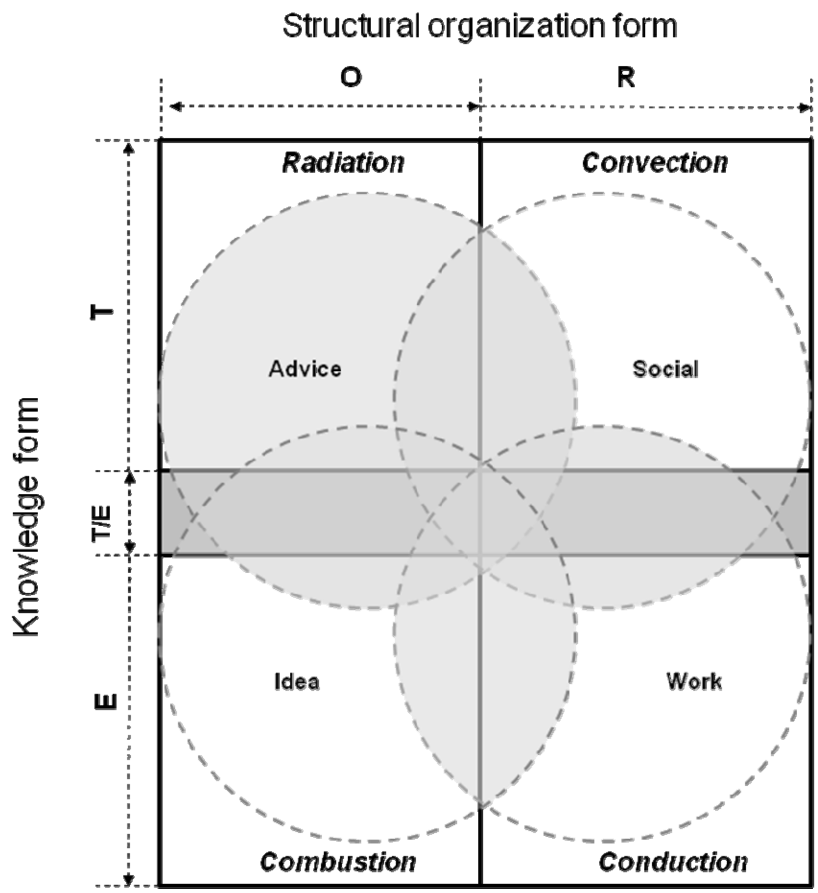


Figure 20 Dynamic Bi-Dimensional Model

In addition, we suggest including the analysis of the four different relational networks (social, work related activities, advice and idea generation) in order to capture the influence of human interactions in the knowledge creation and sharing processes. In particular, we suggest that each of the different relational networks has the potential of providing relevant information (transference channels and key actors) to influence the different knowledge transfer and creation mechanisms (i.e. conduction, convection, radiation and combustion) in each different zone. For example, we suggest that the social network has the potential to provide relevant information about relationship patterns of the general flow of information and knowledge, which can provide an insight about the organizational environment characteristics of the system and influence a convection knowledge transfer mechanism; then, the work related activity network has the potential of providing relevant information about the system's organizational routine operations needed to influence a conductive mechanism; the expert advice network, can indicate those ties where actors could look for trustworthy advice needed to identify radiant sources of knowledge; and the idea generation network could provide insight about ties where actors find the confidence to share their ideas and experiences, facilitating a combustion process. However, given the fact that the four networks can simultaneously coexist within the system (or possibly one derive from another), and can also have an influence on other knowledge zones, we have also depicted them as overlapping.

Summarizing, the new DyBD model intends to capture dynamics of knowledge (tacit/organic), dynamics of organizational structure (rigid/organic) and dynamics of human interactions influencing the generation and flow of knowledge (by capturing dynamics of for different relational networks); therefore, we believe this is a relevant model which can be used to design a relevant organizational KM strategy. In addition, this model represents a new attempt to explain and capture behavior of knowledge inside organizations.

Developing a KM strategy will depend specifically on the system's characteristics and on the organizations resources; however, we specify three specific elements that need to be considered for its development:

1) According to the dominating knowledge zone, which is the principal knowledge transfer (or creation) mechanism that should be enhanced? And, how should the other transference mechanisms should complement?

2) According to the key processes characteristics, which is the principal knowledge transfer (or creation) mechanism that should be enhanced? And, how should the other transference mechanism should complement?

3) According to the actor's position (in the formal organizational structure and in the different relational networks), how can they facilitate the different knowledge transference (or creation) mechanisms? And, what would be the desired network characteristics according to the system's knowledge zone and key processes?

Additional questions that need to be answered are: What specific interventions need to be implemented in order to implement the KM strategy? According to the different knowledge transference (or creation) mechanisms, what organizational variables could be measured? Which are the specific information and technology tools needed to complement the KM strategy? What are the main knowledge sharing challenges that need to be overcome? What will be the change plan needed to accomplish the implementation of the KM strategy? What would be an estimated cost to implement the strategy? In Table 4 we provide a summary of the principal KM considerations that could be used for the development of the customized KM strategy. However, when social systems are designed (like the definition of an organizational KM strategy) it is important to consider the dynamic natures of the system (van Aken, et al., 2007); therefore, it is important to take into consideration that the strategy should not be over specified, since it will lose their flexibility and dynamism.

Table 4 Guideline for the development a KM strategy

	Explicit/Rigid	Tacit/Rigid	Explicit/Organic	Tacit/Organic
Ppal. knowledge source	Physical objects	Human capital + environment	Human captial + resoruces (inc. physical objects)	Highly talent human captial + environment
Principal KM objective	Transference	Transference	Creation	Creation & Transference
Metaphoric mechanism	**Conduction**	**Convection**	**Combustion**	**Radiation**
Key KM strategic component	Physical contact	Radiant source & characteristics of medium	Resources & catalist source	Potency of radiant souce
Focus	Codify & exploit knowledge	Exploit knowledge & enhance socialization	Exploration & creation of knowledge	Creation of knowledge & enhance socialization
Main characteristics of core KM strategy	1) Articulation of rules, guidelines, policies & processes (RGP&G) 2) Precise interpretation and adherence to RGP&G 3) Minimize distance between knowledge soruce & actors	1) Enhance individual and group potential to share their tacit knowledge 2) Create environments that facilitate socialization	1) Enhance deconstruction or fussion of existing knowledge sources 2) Identify new opportunity areas	1) Identify high talent actors 2) Enhance interaction of talented actors with other network members 3) Reduce organizational barriers between actors
Relevant relational network	**Work rel. act. network**	**Social network**	**Idea gen. network**	**Expert advise network**
Main knowledge sharing challenges to overcome	Efficiency Boundary-crossing	Motivation Boundary-crossing	Motivation Free-riding beh.	Motivation Boundary-crossing
Main IT desired characteristics	Codify, storage, retrive & transfer	Accessibility of expert actors	Accessibility to resources and actors	Accessibility to outside networks
Possible key KPI variables	Actors-object distance, Gradient knowledge difference, Conductive properties (actors & objects)	Network's density, Org. cultural openess, tolerance, & personal development, environment stress (pressure differences), socialization areas, personality traits, networks cohesiveness	Resource potential to create new knowledge, network's heating rate or network's ability to identify new potential sources of knowledge	Group and individual's absorptive capacity

4.4 Strategy implementation Phase

The implementation phase will consist on fine tuning the change plan needed for a successful implementation of the KM strategy. A change plan consist on the specific actions that need to be taken, the actors that are to execute those actions, and other actor that need to be involved in the process of implementing a KM strategy. It is important to highlight that part of the change plan has already been developed during the definition of the KM strategy; however, a definitive change plan need to be detailed once it is clear what is precisely to be changed.

Within a change plan several considerations need to be defined, for example: the correct communication of the strategy, the resources need to implement the strategy, the different performance indicators that need to be measured, the organizational changes that need to be achieved, and most important the resistance to change that can be encountered by some actors. To organize a change process, Tichy (1983) suggest the evaluation of three different aspects: the technical and economical issues, the political issues and the cultural issues. In addition, at the implementation phase, it can also be important to consider the SNA results obtained at the diagnosis phase, since key actors and new communication channels could be used in the implementation phase.

4.5 Strategy evaluation Phase

The final phase in our methodology refers to the careful observation and appraisal of the process and the effects the implementation of the KM strategy has made. This evaluation should reveal whether the implementation and the design of the KM strategy has been successfully completed, also whether improvements need to be made, and most importantly, what can be learned for future developments or re-designs of a KM strategy. This evaluation could be focused in: the organizational results achieved, the learning for future strategy re-designs, and the improvements made on the flow and accessibility of information and knowledge, and observed changes within the organizational environment. In some cases it would also be interesting to make a diagnosis using a SNA, similar like the one discussed in the second phase, since it can be possible to evaluate the impact of the implemented KM interventions on the relational network.

As we have explained along this paper, human relationships will change (and adjust) according to the new environmental conditions, and due to its nature. Therefore, once the KM strategy has been evaluated, a new re-design cycle needs to be considered to capture new changes occurring inside the organizational system. As we have discussed at the beginning of this chapter.

4.6 Conclusions

In this chapter we explained the methodology that was designed for the development of an organizational knowledge management strategy. This methodology integrates three key elements: the analysis of the nature of knowledge, the analysis of organizational structure and the analysis of human interactions influencing the transference and creation of knowledge. Therefore, we believe it is a relevant and sounded methodology which can be used in practice, since it allows capturing the natural dynamics of knowledge occurring inside organizations.

In general, our designed methodology considers the development of a knowledge management strategy as an iterative process, and its process is dividend in five steps: definition and characterization, diagnosis, design, implementation and evaluation. Its main advantage is that is able to capture and describe the behavior of knowledge inside organizations as dynamic.

In addition, we have also developed a theoretical knowledge management model which also captures the three strategic elements: dynamics of knowledge, dynamics of organizational structure and dynamics on human interactions which influences the transference and creation of knowledge. And this model is an attempt to close an important gap found within the knowledge management literature.

5 Conclusions

Two were the main objectives in this thesis project: first, to design a theoretical knowledge management model that was able to capture dynamics existing in the natural form of knowledge, dynamics existing within the organizational structure, and the influence of human interactions in the creation and transference of knowledge; and second, to design a methodology which could be used by practitioners for the development of a relevant organizational knowledge management strategy. And in conclusion, these objectives were achieved with the design of the Dynamic Bi-Dimensional model and the design of a five phase methodology cycle to develop a knowledge management strategy.

In the Dynamic Bi-Dimensional model organizational knowledge conceived as existing within two dimensions: the knowledge form, composed by a tacit and explicit form of knowledge; and, the structural organization form, composed by an organic and structural form. And in this model we suggest that the transference and creation of knowledge will be influenced by these two dimensions and the human interactions governed by four specific relational networks, the social network, the work related network, the expert advice network and the idea generation network. In addition, this model allows the conception of organizations as disaggregated systems; and acknowledges that each system contains a unique combination of knowledge, organizational and relational characteristics.

In the five phase methodology cycle, we divided the design of an organizational knowledge management strategy into five specific phases: definition and characterization, diagnosis, design, implementation and evaluation. And, in order to capture the organizational dynamics, either caused by the implementation of knowledge management strategy or caused by other external factors, we propose an iterative methodology which considers the inclusion of a constant re-design of the strategy.

5.1 Implications for practice

This project provides practitioners involved in the field of knowledge management, a new alternative to conceive dynamics within organizational knowledge. Therefore, we intend to facilitate the understanding of knowledge in order to develop a relevant organizational knowledge management strategy. In addition, we provide a practical explanation to the use of social network analysis as a managerial tool which can facilitate the assessment of human interactions, and discover alternative communication channels and key actors within the organization. Finally, provide a deeper explanation of some similarities found between thermodynamics and knowledge, with the purpose stimulate the development of new perspectives to see and think about the management of knowledge; thus, develop new alternatives to measure progress of the knowledge management initiatives.

5.2 Implications for theory

With the design of a theoretical DyBD model we intend to contribute to the knowledge management literature in providing an alternative model able to capture dynamics and behavior of organizational knowledge. Specifically, our model was designed with the attempt to close an important gap existing within the knowledge management literature; which is a model that considers three strategic elements: dynamics within the form of knowledge, dynamics within the organization, and the influence of human interactions in the creation and transference of knowledge.

5.3 Limitations and future research

In this project, we can point out two important limitations. The first limitation, which has an impact on the theoretical implications, is that this project represents only a theory design proposal. This implies that its design has only been based upon the reflection and interpretation of theory and has not been tested in practice.

The second limitation, which has an impact on the practical implications, is that the use of social network analysis for the development of a knowledge management strategy may require additional organizational efforts. Therefore, the design and implementation of such strategy can be time demanding, and will require a continuous follow up.

In addition to the limitations, in the development of this project future research opportunities were identified. First, test the theoretical designs developed in this project; that is, the DyBD model and the five phase methodology cycle. Second, evaluate the assumption made, regarding the potential information the four different relational networks can provide according to the different knowledge zones, and the knowledge transfer (and creation) mechanisms. Third, evaluate the possibility to use the governing principles within the heat transference mechanisms to develop performance indicators to measure progress of knowledge transfer initiatives.

5.4 Personal reflection

From the development of this project, I was able to make the following personal reflections: 1) the management of knowledge is a key element for the development of an organizational capacity to innovate; 2) the development of an organizational knowledge management strategy should be developed according to the specific organizational conditions and needs; therefore it is not possible to provide an all-inclusive solution to develop such strategy; 3) the use of a thermodynamic metaphor towards the management of knowledge can be very helpful to influence the perspective we have about knowledge; therefore, alternative and innovative ways to manage knowledge could be developed using this type of approach; 4) social network inside organizations cannot be managed, but instead they can be influences towards a desired organizational goal; however, to exceed the expected results it is necessary to include the participation of all organizational members and develop high levels of trust within the network.

6 References

Allen, T. (1976). *Managing the flow of technology: technology transfer and the dissemination of technological information within the R&D organization.* London: MIT Press.

Anthony, M.T., McKay, J. (1992), From experience: balancing the product development process: achieving product and cycle time excellence in high technology industries. *Journal of Product Innovation Management,* 9, 140–107.

Burt, R. (1992). *Structural holes- The social structure of competition.* Cambridge: Harvard University Press.

Burt, R. (2004). Structural holes and good ideas. *American Journal of Sociology, 110* , 349–99.

Cabrera, E., & Cabrera, A. (2005). Fostering knowledte sharing through people management practices. *International Journal of Human Resource Management, 16* , 720-735.

Cohen, W., & Levinthal, D. (1990). Absoptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly, 35* , 128-152.

Conway, S., & Steward, F. (2009). *Managing and Shaping Innovation.* New York: Oxford University Press.

Cross, R., Borgatti, S., & Parker, A. (2001c). Beyond answers: dimensions of the advice networks. *Social Networks, 23* , 215-235.

Cross, R., Borgatti, S., & Parker, A. (2002). Making invisible work visible. *California Management Review, 44* , 25-46.

Cross, R., Parker, A., Borgatti, S., & Prusak, L. (2001a). Knowing what we know: supporting knowledge creation and sharing in social networks. *Organizational Dynamics, 30* , 100-120.

Cross, R., Rice, R., & Parker, A. (2001b). Information seeking in social context: structural influences and receipt of information benefits. *IEEE Transactions on Systems, Man, and Cybernetics, 30* , 438-448.

de Man, A., Berends, H., Lammers, I., van Raaij, E., & van Weele, A. (2008). Knowledge and innovation in networks: a conceptual framework. In A. de Man, *Knowledge Management and Innovation in Networks* (pp. 1-31). Cheltenham, UK: Edward Elgar.

Dyer, J., & Nobeoka, K. (2000). Creating and managing high-performance knowledge-sharing network: the Toyota case. *Strategic Management Journal, 14* , 345-367.

Energy information administration. http://dnr.louisiana.gov/sec/execdiv/techasmt/citizens/eia_brochures/eia_propane_prices.htm

Freeman, L. (1997). *The study of social networks.* Retrieved October 2009, from http://www.heinz.cmu.edu/project/INSNA/na_inf.html

Gourlay, S. (2006). Conceptualizing knowledge creation: a critique of Nonaka's theory. *Journal of Management Studies, 43* , 1415-1436.

Granovetter, M. (1973). The Strength of Weak Ties. *American Journal of Sociology, 78* , 1360-80.

Hanneman, R., & Riddle, M. (2005). *Introduction to Social Network Methods. Electronic version.* Retrieved October 2009, from http://faculty.ucr.edu/~hanneman

Hatala, J. (2006). Social network analysis in human resource development: a new methodology. *Human Resource Development Review, 5* , 45-71.

Hislop, D. (2009). *Knowledge Management in Organisations: A Critical Introduction.* Oxford: Oxford University Press.

Kanter, R. (1983). *The Change Masters: Corporate Entrepreneurs at work.* London: Taylor and Francis.

Kim, W., & Mauborgne, R. (1998). Procedural justice, strategic decision making and the knowledge economy. *Strategic Management Journal, 19* , 3232-338.

Kleiner, A. (2002). *Karen Stephenson's quantum theory of trust.* Retrieved from http://www.drkaren.us/KS_publications01.htm

Knoke, D., & Kulinski, J. (1986). *Network Analysis.* Newbury Park: Sage.

Krackhardt, D. (1990). Assessing the political landscape: structure, cognition and power in organizations. *Administrative Science Quarterly, 35* , 342-370.

Krackhardt, D. (1992). The strength of strong ties: the importance of philos in organizations. In N. Nohria, & R. Eccles, *Networks and Organizations- Structure, Form, and Action* (pp. 216-239). Boston: Harvard Business School Press.

Krackhardt, D., & Hanson, J. (1992). Informal networks: the company behind the chart. In L. Puzak, *Knowledge in Organizations* (pp. 37-49). Boston: Butterworth-Heinemann.

Krackhardt, D., & Hanson, J. (1993). Informal networks: the company behind the chart. *Harvard Business Review, 71* , 104-113.

Kuijkuit, B., & van de Ende, J. (2007). The organizational life of an idea: integrating social network, creativity and decision-making perspectives. *Journal of Management Studies, 44* , 863-882.

Lazega, E., Lemercier, C., & Mounier, L. (2006). A Spinning top model of formal organization and informal behavior: dynamics of advice networks among judges in a commercial court. *European Management Review* , 1-10.

Lindenberg, S. (2000). It takes both trust and lack of mistrust: the workings of cooperation and relational signaling in contractual relationships. *Journal of Management and Governance, 4* , 11-33.

Mooriandian, T., Renzl, B., & Matzler, K. (2006). Who trusts? personality trust and knowledge sharing. *Management Learning, 37* , 523-540.

Morgan, G. (1997). Images of Organization. London: Sage.

Newell, S., Scarbrough, H., Swan, J., & Hislop, D. (2000). Intranets and knowledge management:de-centred technologies and the limits of technological discourse. In C. Prichard, R. Hull, M. Chumer, & H. Willmot, *Managing Knowledge: Critical Investigations of Work and Learning* (pp. 88-106). London: Macmillan.

Nonaka, I. (1994). A dynamic theory of organization knowledge creation. *Organization Science, 5* , 14-37.

Nonaka, I., & Peltokorpi, V. (2006). Objectivity and subjectivity in knowledge management: a review of 20 top articles. *Knowledge and Process Management, 13* , 75-82.

Patton, S. (2008). *Social Network Analysis helps maximize collective smarts.* Retrieved from http://www.cio.com/article/6956/Social_Network_Analysis_Helps_Maximize_Collecitve_Smarts?page=1

Perry-Smith, J. (2006). Social yet creative: the role of social relationships in facilitating individual creativity. *Academy of Management Journal, 49* , 85-101.

Polanyi, M. (2967). *The Tacit Dimension.* London: Doubleday.

Riedl, A., & Van Winder, F. (2003). Information and the creation and return of social capital: an experimental study. In H. Flap, & B. Voelker, *Creation and Returns of Social Capital* (pp. 77-103). London: Routledge.

Roberts, J. (2006). Limits to communities of practice. *Journal of Management Studies, 43* , 623-639.

Rolland, N., & Kaminska-Labbé, R. (2008). Networking inside the organization: a case study on knowledge sharing. *Journal of Business Strategy, 29* , 4-11.

Rose, L. (2007). Thermodynamics and knowledge: principles and implications. In R. Rikowski, *Knowledge Management: Social, Cultural and Theoretical Perspectives* (pp. 209-227). Oxford: Chandos Publishing.

Roy, B. (1995). *Principles of Modern Thermodynamics.* Bristol: Institute of Physics Publishing.

Scott, J. (1991). *Social Network Analysis: A Handbook.* London: Sage.

Spender, J. (2003). Exploring uncertainty and emotion in the knowledge-based theory of the firm. *Information Technology & People, 16* , 266 - 288.

Teece, D., Pisano, G., & Shuen, A. (1997). Dynamic capbilities and strategic management. *Strategic Management Journal, 18* , 509-533.

Thatchenkery, T., & Chowdhry, D. (2007). *Appreciative Inquiry and Knowledge Management: A Social Constructionist Perspective.* Chalterma: Edward Elgar.

Tichy, N. (1983). *Managing Strategic Change: Technical, Political and Cultural Dynamics*. Chichester: Wiley International.

van Aken, J., Berends, H., & van der Bij, H. (2007). *Problem solving in organizations: a methodological handbook for business students.* Cambridge: Cambridge University Press.

Van Strien, P. (1997). Towards a methodology of psychological practice, the regulative cycle. *Theory and Psychology, 7* , 683–700.

Walstrom, C. (2003, August). Understanding intra-organizational relations through social network analysis. *PhD dissertation, Department of Organization and Management* . Aarhus: Aarhus School of Business.

Wasserman, S., & Faust, K. (1994). *Social Network Analysis: Methods and Applications.* New York: Cambridge University Press.

Zhang, Y., Rajabzadeh, I., & Lauterbach, R. (2009). Student network centrality and academic performance: evidence from United Nations University. #2009-034. *United Nations University Working Paper Series* , 1-31.