Knowledge Systems Engineering: A Complex System View

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Abstract In this chapter, a new discipline: Knowledge Systems Engineering (KSE) is proposed to establish for the organization and management of knowledge systems. The main features of KSE are systematic and integrative thinking and investigations not only for knowledge management but also for the knowledge enabling (or knowledge facilitating) to innovation. The goal, function, architectures of knowledge system and the contents of the discipline are outlined.

Keywords Knowledge systems engineering • Knowledge management • Knowledge enabling • Knowledge system

1 Introduction

Stepping into the post-industrial age, many concepts have been coined, such as globalization, the new economy, the information economy, the knowledge economy, the experience economy, and the creative economy. Of them, the knowledge economy is seen as the latest stage of development in global economic restructuring. This latest stage has been marked by the upheavals in technological innovations and the globally competitive need for innovation with new products and processes.

Within the past 20 years, we have witnessed the rise of knowledge economy as main driver of global and local economic development. The knowledge economy (1995 to date) creates the possibility for a totally new global paradigm, which brings billions of minds together to create wealth. The explosion of knowledge results in an acceleration of innovation, aimed at making life better and more fulfilling.

Although knowledge has always been central to economic development, only over the last 20 years has its relative importance been recognized, just as that importance is growing. The OECD economies are more strongly dependent on the production, distribution and use of knowledge than ever before. This is because with the earth's depleting natural resources, the need for green infrastructure, logistics

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industry forced into just-in-time deliveries, growing global demand, regulatory policy governed by performance results, and a host of other items high priority is put on knowledge. Knowledge now has become the key economic resource and the dominant – and perhaps even the only – source of comparative advantage (Drucker, 1995).

Comparing with the traditional economy, the knowledge economy has the following key respects:

- The economics are not of scarcity, but rather of abundance. Unlike most resources that become depleted when used, information and knowledge can be shared, and actually grow through application.
- The effect of location is either diminished, in some economic activities: using appropriate technology and methods, virtual marketplaces and virtual organizations that offer benefits of speed, agility, round the clock operation and global reach can be created.
- Laws, barriers, taxes and ways to measure are difficult to apply solely on a national basis. Knowledge and information 'leak' to where demand is highest and the barriers are lowest.
- Knowledge enhanced products or services can command price premiums over comparable products with low embedded knowledge or knowledge intensity.
- Pricing and value depend heavily on context. Thus the same information or knowledge can have vastly different value to different people, or even to the same person at different times.
- Knowledge when locked into systems or processes has higher inherent value than when it can "walk out of the door" in people's heads.
- Human capital – competencies – are a key component of value in a knowledge-based company, yet few companies report competency levels in annual reports. In contrast, downsizing is often seen as a positive 'cost cutting' measure.
- Communication is increasingly being seen as fundamental to knowledge flows. Social structures, cultural context and other factors influencing social relations are therefore of fundamental importance to knowledge economies.

These characteristics of the knowledge-based economy require new ideas and approaches from policy makers, managers and knowledge workers.

Related to the concept of knowledge economy, the term 'creative economy' appeared in 2001 in John Howkins' book about the relationship between creativity and economics. For Howkins (2001), "creativity is not new and neither is economics, but what is new is the nature and the extent of the relationship between them and how they combine to create extraordinary value and wealth". The creative economy resets old borders, by allowing businesses to flourish by means of their own defined business cultures. Through this process the creative economy prompts new perspectives on value creation thus leading the transformation of creative ideas into the tangible production of products and services. Such process can be related to social innovation, i.e., the creative economy can generate new ideas bringing positive impact on the quality and/or quantity of life of members of society. The

creative economy can be regarded as social innovation insofar overall creativity, culture, and knowledge start to be seen as fundamental to economic and social development.

Knowledge as an intangible resource, as factor of production and as capital, must be managed effectively. Knowledge management (KM) is often defined as the ability to get the right information to the right people at the right time. It refers to the systematic process by which knowledge needed for an organization to succeed is created, captured, shared and leveraged. In KM process, producing new knowledge to fulfill the increasing demand is very important.

Some people think the concept of knowledge management itself is limited. In fact, the term management implies control, but knowledge (especially in human brains) is inherently uncontrollable. Hence, the important thing is how to make the knowledge enable to promote development of human endeavor. So the concept of knowledge enabling or knowledge facilitating is more appropriate for the understanding the role of knowledge in real life. No matter how to define KM, the core issue of knowledge management is to place knowledge under guidance in order to get value from it.

2 Knowledge Systems Engineering

Since knowledge management is a complex task, each of the approaches has its own limitations and we must have a systems point of view. Systems sciences have an important role to play in providing methodology and techniques for knowledge management. There exists a need to systematically and actively manage knowledge which resides in the different sources of an organization.

2.1 Knowledge Systems and Knowledge Networks

From the knowledge management standpoint, knowledge processes (KP) play a predominant role in business processes of companies, which strongly depend on human specialized expertise and judgment, continual learning, and implicit or explicit information transformation by knowledge workers. KP often couple with the business process, in which KP support the effective and efficient execution of business activities. In that sense, there is an increasing need for systems that seamlessly support knowledge-intensive business processes to support knowledge work and improve knowledge worker productivity.

In knowledge processes, there exist a series of knowledge processing cycles including the capture, analysis, creation, and application of knowledge within an organization. Some of these processes are realized by a given kind of technological systems and tools. These systems constitute the knowledge processing systems (KPS), a portion of knowledge systems (KS). KPS typically involve

creating/generating, storing/representing, accessing/using/re-using, and disseminating/transferring knowledge processes, which provide an information and communication technology platform to realize knowledge sharing.

Knowledge systems to some extent are seen as enabling technologies for effective and efficient KM, but they are different from the general information systems (IS). In KS, the coordination of information and collaborative work are paid more attention, which implies that collaboration and knowledge sharing can be realized by providing a range of knowledge services to their users. The primary goal of these systems is to increase organizational effectiveness by using knowledge from the past to bear on present activities.

From the cost-efficiency perspective, IS are often dealing with pre-set value objective in minimum or maximum, whereas KS have moving targets since they involve high degrees of contribution from knowledge workers and involved parties. Every system needs goals. But the knowledge system needs different 'specificity' in defining goals. More ambiguity and slacks are needed in knowledge systems which are different from that of information systems. Reductionism involved in IS may not be applied to KS profitably. KS need to focus on people since they are the source of knowledge generation and application.

Knowledge systems are different from information systems mainly in that they embed or presuppose communication capabilities inside the system. Table 1 shows the differences between IS and KS in different aspects (Choi and Choi, 2007).

Table 1 Comparisons between IS and KS

	Information systems	Knowledge systems
Management issues	Artificial system as an asset User as a problem	Knowledge as an asset Sharing as a problem
Organizational issues	Engrafting IS into organizations	Business process to knowledge process
IPO-based features	Accurate input Efficient process Compatible output	Explicit or tacit input Sense-making process Extensible output
Problem-related feature	Problem-solving	Problem- or Opportunity-finding
Organizational learning perspective	Learning bounded to business process	Learning diversified & utilized
Focus of learning (characteristics)	Optimization of what is already learned (preserving and refreshing learning)	New learning & empowerment (innovative)
Locus of value	Business process Efficient design and implementation Reductionism Compatibility/inter-operability	Collaboration Knowledge sharing Utilizing systematic ambiguity Personal expertise

Beside technological systems, there are some other components in knowledge systems including personal systems, organizational systems, business systems, cultural systems, etc.

It's worth mentioning that the knowledge community has much to offer in knowledge systems, since it involves interactions and collaborations among the related parties. Collaboration is key in knowledge creation and sharing. Collaboration within and across organizations can create new value. The word 'collaborate' nowadays is equivalent to 'networking', which in a knowledge-driven organization does not simply mean using ICT networks to communicate, but means paying attention to 'knowledge-worker support network'. IT networks have proved to be a limited mean for disseminating tacit knowledge. Instead, human networks and networking to enable knowledge diffusion and integration in knowledge intensive organizations are important mechanisms that can support product development and innovation as they enable cross-fertilization of tacit knowledge between individuals.

The positive aspects of knowledge networks relate to knowledge processes like improved knowledge transfer and learning. Negative aspects found relate to network size. Communication efficiency is reduced in large networks where network paths are too long. In large networks that require information and communication technology (ICT) social ties are weakened and the possibility to develop common language is limited.

A knowledge network can either be limited to one company or have members from several companies. Networks that have members from several firms are superior to a single firm network in innovation as they represent a greater diversity of knowledge. Global companies with many subsidiaries and geographically distributed units can gain from creating knowledge networks in which experts from different units can communicate and share ideas across unit boundaries.

2.2 Composition, Structure and Function of the Knowledge System

The main components of the knowledge system are the knowledge elements, and the knowledge sources (or retainers). The knowledge elements are the individual components of knowledge (e.g., a particular piece of knowledge that an employee may have about a process within the organization). The knowledge retainers are the repositories of knowledge elements of the domain. These repositories can be both codified knowledge retainers (i.e., knowledge bases) as well as personalized knowledge retainers (i.e., the human knowledge resource of the organization). Once the relevant retainer has been identified, either the knowledge can be retrieved automatically (i.e., when the knowledge is stored in a knowledge base) or manually (i.e., if the knowledge belongs to a human then he/she will be consulted).

Due to the abstractness and intangibility of knowledge, people are prone to accrue knowledge from its carriers such as books, newspapers, electronic media, and so on. But in nature, people or organizations themselves are the real carrier of knowledge. They compose the fundamental elements of KS.

It is well known that any system is a set of interacting or interdependent elements forming an integrated whole. Each system can be delineated by its spatial and temporal boundaries, surrounded and influenced by its environment, described by its structure and purpose and expressed in its functioning. Likewise, knowledge system composes diverse knowledge elements which form a stable structure by their mutual relations, constraints and restrictions. The structure of KS is often in forms of networks, some of which are tangible like information network, and some of which are intangible like interpersonal network. The essential aim of KS is to provide all knowledge requested by knowledge workers. To meet KS's goals, functions of KS in general must include:

- acquiring and organizing knowledge effectively and efficiently;
- retaining and protecting knowledge intentionally;
- transfer knowledge timely to right person in right place at right time;
- facilitating new product or service development;
- operating and managing knowledge asset by market rules;
- building organizational culture to promote knowledge creation, knowledge transfer and knowledge application.

As mentioned above, KS is not only a kind of IT-based system which has predefined goals and tasks. Instead it is a complex system which consists of social system, information system, and knowledge content system. The complexity lies in the subjectivity of knowledge embedded in human brains or organizational memory as well as the uncertainty of environment for knowledge creation. KS is also a kind of complex self-organization system, which implies that new knowledge is an emergence of the system. Therefore, we can study such human-computer system in a systematic way based on systems science theory.

2.3 Categorization of Knowledge

The knowledge element in KS has different types. According to OECD (1996), knowledge can be classified as know-what, know-why, know-how, and know-who four types.

- *Know-what* refers to knowledge about 'facts'. How many people live in New York? What are the ingredients in pancakes? And when was the battle of Waterloo? are examples of this kind of knowledge. Here, knowledge is close to what is normally called information – it can be broken down into bits. In some complex areas, experts must have a lot of this kind of knowledge in order to fulfill their jobs.

- *Know-why* refers to scientific knowledge of the principles and laws of nature. This kind of knowledge underlies technological development and product and process advances in most industries. The production and reproduction of know-why is often organized in specialized organizations, such as research laboratories and universities. To get access to this kind of knowledge, firms have to interact with these organizations either through recruiting scientifically-trained labor or directly through contacts and joint activities.
- *Know-how* refers to skills or the capability to do something. Businessmen judging market prospects for a new product or a personnel manager selecting and training staff have to use their know-how. The same is true for the skilled worker operating complicated machine tools. Know-how is typically a kind of knowledge developed and kept within the border of an individual firm. One of the most important reasons for the formation of industrial networks is the need for firms to be able to share and combine elements of know-how.
- *Know-who* becomes increasingly important. Know-who involves information about who knows what and who knows how to do what. It involves the formation of special social relationships which make it possible to get access to experts and use their knowledge efficiently. It is significant in economies where skills are widely dispersed because of a highly developed division of labor among organizations and experts. For the modern manager and organization, it is important to use this kind of knowledge in response to the acceleration in the rate of change. The knowledge of know-who is internal to the organization to a higher degree than any other kind of knowledge.

Learning to master the four kinds of knowledge takes place through different channels. While know-what and know-why can be obtained through reading books, attending lectures and accessing databases, the other two kinds of knowledge are rooted primarily in practical experience. Know-how will typically be learned in situations where an apprentice follows a master and relies upon him as the authority. Know-who is learned in social practice and sometimes in specialized educational environments. It is socially embedded knowledge which cannot easily be transferred through formal channels of information.

The above four types of knowledge can also be divided into two categories according to accessibility – *explicit* or *tacit*. The former two are of explicit knowledge, and the latter two are of tacit knowledge. Explicit knowledge can be articulated in a written or verbal form including grammatical statements, mathematical expressions, specifications, manuals, and so forth. Hence, explicit knowledge is codified and communicated. While tacit knowledge is hard to articulate with formal language. According to Polanyi (1966), tacit knowledge is knowledge that is difficult to externalize, since tacit knowledge resides in the individual's experience and action. He described tacit knowledge with the idiom "we can know more than we can tell". Polanyi (1966) also emphasized that tacit knowledge is learned by way of know-how and is retained at the unconscious or semi-conscious level. More than 2500 years before, Chinese scholars began to aware of the nature of different kinds of knowledge. A textbook named 'Yi Zhuan' for explanation of 'Yi

Ching (philosophy of Change)' had said: "Writing could not fully describe what the people want to say; speech could not express what the people want to think". This implies that Chinese people in earlier days began to recognize the difference between explicit and tacit knowledge.

Tacit knowledge is personal and context-specific knowledge embedded in individual experience and involves intangible factors such as personal belief, perspective, and the value system (Nonaka and Takeuchi, 1995).

All knowledge has a tacit and explicit component and the degree varies along a continuum. The greater the tacit knowledge dimension the more difficult its transfer and sharing will be. The connection between tacit and explicit knowledge has been recognized in which "tacit knowledge is the means by which explicit knowledge is captured, assimilated, created and disseminated" and where tacit knowledge forms the background necessary for assigning the structure to develop and interpret explicit knowledge. Viewing tacit to explicit knowledge as a continuum hints at a process in which tacit knowledge is converted or transformed into explicit knowledge. This middle ground of knowledge between tacit and explicit is where the domain of implicit knowledge exists. The implicitness enables the possibility of transforming what was originally tacit knowledge into explicit knowledge.

Additionally, knowledge can be categorized into individual knowledge and organizational knowledge. Knowledge is created in human brain. The individual knowledge is the origin of all knowledge. Organization also has its own knowledge, including explicit as patents, design and handbooks and tacit as teamwork experience, working habits etc. Organizational knowledge is created through the collaborative work and crystallized in the organizational knowledge network. The organizational tacit knowledge has its unique characteristics and cannot be bought from outside.

Knowledge can also be categorized into:

1. Encoded knowledge,
2. Embedded knowledge,
3. Embrained knowledge,
4. Embodied knowledge, and
5. Encultured knowledge.

2.4 Knowledge as a Thing, as a Process and as Capability

To more fully understand knowledge, it is beneficial to segregate how knowledge is viewed.

From a static standpoint, knowledge is thought as a thing, owned by somebody as property. Knowledge as an object leads people to focus on databases and other storage devices on identifying, organizing and collecting knowledge. The knowledge-as-a-thing-driven KM model adopts the view of knowledge as an object that can be captured, stored and reused. Thereby, KM is often perceived as merely

a technological solution, consequently a significant amount of attention is placed on implementing platforms and repositories to capture, store, control, manage and reuse structured knowledge.

Knowledge is not only a thing or substance, but is far more part of a process. Based on the dynamic view, knowledge is regarded as a process which focuses more on dynamic aspects of knowledge, such as acquiring, communicating, sharing, creating, adapting, learning, and applying. The knowledge-as-a-process-driven KM model regards knowledge as a flow rather than an object and focuses on knowledge creation, collaboration and practice.

Idea describing the movement of knowledge begins to depict knowledge as a fluid and in dynamic realm. The famous physicist D. Bohm explored the movement of knowledge as thought and consciousness using the analogy of particle physics. He suggests, the whole movement of thought from individual awareness to communication between people is a continual cycle, as an unbroken totality of movement, not belong to any particular person, place, time or group of people.

Both of these ways of thinking about knowledge are useful for understanding different qualities. The question of whether knowledge is a thing or a process is like the wave-particle duality in quantum physics. There are two equally valid experimental processes regarding the properties of light.

Both views are correct from different vantage points. Another related perspective is that of a knowledge value chain. The starting process is knowledge identification or creation, then the knowledge collection and codification. The knowledge repository is followed. The next is knowledge diffusion and utilization. Flow of knowledge along the value chain can add the value.

Knowledge is a human capability rather than a property of an inanimate object such as a book or computer record. Such capability like skill, experience, or intelligence can be used to do or to judge something, now or in the future. Knowledge as a capability can be acquired by an individual as a result of reading, seeing, listening to, or feeling (physically or emotionally) and doing something. Knowledge about work can be best acquired (learned) through work itself.

2.5 Knowledge Systems Engineering

The field of knowledge management has drawn insights, ideas, theories, metaphors, and approaches from diverse disciplines including organizational science and human resource management, computer science and information system, management science, and psychology and sociology, among others. Research on KM in sum can be organized into two different streams, one is IT focused and another is human focused. Both streams have the limitations to KM, therefore a systematic and integrative thinking for KM is required. Accordingly, a new discipline namely knowledge systems engineering (KSE) is proposed in terms of the thought of systems engineering.

Before introducing KSE, let's have a brief review on systems engineering (SE). Systems engineering is an interdisciplinary field of engineering that focuses on how to design and manage complex engineering systems over their life cycles. Issues such as reliability, logistics, coordination of different teams (requirements management), evaluation measurements, and other disciplines become more difficult when dealing with large or complex projects. SE deals with work-processes, optimization methods, and risk management tools in such projects. It overlaps technical and human-centered disciplines such as control engineering, industrial engineering, organizational studies, and project management. SE ensures that all likely aspects of a system are considered, and integrated into a whole.

In the period of more than half a century since the foundation of SE field, it has many successful applications. In the energy industry, the energy systems engineering investigates the energy exploration, transmission and utilization problems from a unified and systemic view, no matter what kind of the resource and end-user are. In the IT industry, information systems engineering investigates the information generation, processing, transmission and utilization in a unified and systemic view, no matter the information are in telecommunication system, computer network or bio-technological system. In KM field, why not investigate knowledge acquisition, manipulation, dissemination and creation from a unified and systemic view?

Upon this point, we suggest to establish a new branch of systems engineering: '*Knowledge Systems Engineering* (KSE)'. It can be defined as the discipline of organization and management of knowledge systems in accordance with the definition of SE.

KSE as an application-oriented discipline, integrates both the technology-centered and human-centered approaches, integrates the knowledge management and knowledge enabling, and can be acceptable by people with science-technology background and with humanity background. For KM issues, any single approach like IT based or human based will fail to fulfill knowledge tasks. This is because IT based approach mainly focuses on explicit knowledge, whereas human based approach more focuses on tacit knowledge. However, both explicit and tacit knowledge are vital for knowledge creation and application.

Therefore, we need to rethink how to design and build a coherent model by means of systems thinking for KM that can leverage knowledge involves a combination of both explicit and tacit knowledge. The major challenge is to properly address the tacit dimension of knowledge. At the heart of KM lie people. Consequently, traditional technology-push models of KM have to be replaced with new models that reflect the human side of knowledge. This requires a radical shift in emphasis from a focus on know-what to a focus on know-how and know-who. From a complexity perspective, in new KM models, knowledge should be regarded as a living entity rather than managed as a static object or a predetermined process.

KSE differs from the Knowledge Engineering in Artificial Intelligence at its area of investigation not only limited to the technological aspect like the existing Knowledge Engineering. Also from the dimensions of research it differs from traditional Human Resource Management and Information Management.

2.6 Complexity of Knowledge Systems

Knowledge is inherently personal, social, distributed, and complex. A knowledge system is a complex adaptive system (CAS) comprising many interacting identities in which cause and effect relationships are intertwined and cannot be distinguished. It is open and adaptive without outside intervene in a changing environment. Complexity of the knowledge system is characterized by adaptation, emergence, self-organization, openness and decentralization.

- *Adaptation*: A knowledge system is a kind of complex adaptive system. A knowledge system is complex in that it is diverse and made up of multiple interconnected knowledge elements and adaptive in that it has the capacity to change and learn from experience. A knowledge system has a non-deterministic character; it can evolve in ways that we may not expect or predict. Knowledge development in a knowledge system is continuous and fluid, with no clearly defined beginning or end.
- *Emergence and self-organization*: Knowledge is complex in nature. And emergence and self-organization are the effective ways to cope with complex systems. As an example of a complex adaptive system, a knowledge system holds emergent properties and includes self-organized entities. A knowledge system is co-constructed and maintained by individuals. It emerges naturally and is derived from the bottom-up connection of multiple personal knowledge networks. A knowledge system houses the learning that occurs in a bottom-up and emergent manner, rather than learning that functions within top-down and hierarchical structures under the control mechanisms of outside forces. A knowledge system has a non-deterministic character and can evolve in inherently non-linear and unpredictable ways.
- *Openness and decentralization*: As with complex systems, knowledge systems are open and their boundaries are difficult to be determined. And, knowledge is decentralized and ubiquitous in nature. Hence, openness and decentralization are central attributes in knowledge systems.

From CAS perspective, the characteristics of the knowledge system respect seven basics maintained by Holland (1996). According to Holland, there are four properties that are in common – aggregation, nonlinearity, flows and diversity. The three mechanisms are tagging, internal models and building blocks. These seven basic characteristics can be used as an effective tool in knowledge management. They offer a way to understand how self-organization emerges from lower-level or local interactions. Self-organization can be seen, at least in some cases, as an effective way of organizing and creating enabling infrastructures for creative work.

The four properties among seven basic characteristics are:

1. *Aggregation*: In a knowledge system, especially for personnel system, agents with some knowledge spontaneously aggregate together on the basis of similar purpose, interest, profession, emotions and benefit. Such agent can be a person, a group or an organization. They constitute a multi-level structure through

aggregation. Agents at the low level are individuals who can aggregate to form the higher level of agents (group or team), and then form the highest level of agents (department or organization). This is the aggregative feature of the knowledge system. Holland points out the formation of complex agents called meta-agents in social systems (whether natural or artificial) based on complex behavior of smaller, simpler agents.

2. *Nonlinearity*: Nonlinear interactions are the norm in CAS and are one of the reasons in the emergent global behaviors which indicate that the system is a CAS. In knowledge systems, knowledge exchange and creation are nonlinear interactive activities. This leads to the fact that the team creativity can be much more than the sum of individual creativity.
3. *Flows*: Another property of CAS is the formation of dynamic networks and flows. Collaboration within and across organizations spurs the formation of interpersonal network. When agents share their own knowledge on the network, a flow of knowledge occurs. Additional behavioral property that can be observed in flows is the recycling effect where knowledge resources are recycled over the flows via the network nodes (agents) thus enriching the emergent behavior.
4. *Diversity*: Diversity refers to agents with different traits in aspects of personality, social status, expertise, etc. The difference between knowledge namely knowledge distance is the precondition of knowledge transfer and sharing among agents. Keeping certain diversity in a team or organization will promote new knowledge generation.

The three mechanisms among seven basic characteristics are:

5. *Tagging*: Tagging is a mechanism which is frequently observed in knowledge systems. Take the transactive memory system (TMS) as an example. In the process of formation of TMS, tagging as an identification mechanism plays an important role. Team members can make 'flags' to tag other persons' knowledge and skills during cooperation. These'flags' then help teammates get to know who knows what and who can do what which are the main contents of the TMS.
6. *Internal Models*: Internal models are a mechanism by which each agent inside a KS has its own internal mechanism and has evolved its model with the style of its own. All of these models form the whole system model with multi-layer structure.
7. *Building Blocks*: Complex system is organized by a lot of small systems as 'building blocks' by different manner of combination. The main feature of the complex system lies in the varieties of combination rather than the number of building blocks.

2.7 System-of-Systems Engineering

We have known that knowledge system is a complex system which comprises personnel system, organization system, technology system, business system and cultural system. Different systems have their own functionalities to support knowledge

work which essentially means the activities of knowledge creation, dissemination, storage and utilization. In this regard, well-defined and implemented KS should satisfy all functions required by the organization.

In twentieth century most systems were developed to satisfy specific functional objectives. The objectives were typically focused on the requirements in a single functional area resulting in a number of vertically independent systems within an organization. By the turn of the century, a new type of system began to emerge. It is the super-system, the meta-system, the system-of-systems (SoS) which is made up of components which are large-scale systems themselves and can be called member system to differ from subsystem. Although its components are widely distributed and loosely related and work independently, the system-of-systems (SoS) can function as an integrated whole with larger capability.

So far there is no widely accepted definition of system-of-systems. The following distinguishing characteristics may help us to understand this notion.

- *Independence of the individual systems*: A system-of-systems is composed of systems that are independent and useful in their own right. If a system-of-systems is disassembled into the member systems, these member systems are capable of independently performing useful operations independently of one another.
- *Mutual influences between member systems*: Different members may influence each other through the network that links them, in which they may work collaboratively within a SoS or counteractively between two SoSs.
- *Geographic distribution*: Different member systems are not only widely distributed spatially and mutually independent in their development temporally, but also workable autonomously. Often, these systems can readily exchange only information and knowledge with one another, and not substantial quantities of physical mass or energy.
- *Organizational factor involved*: SoS is an integration of human, soft elements and hardware system, in which human and soft elements play a large role in making the SoS a flexible 'machine'.
- *Shared mission*: Guided by a common objective, various member systems interact with each other and gradually integrate into a whole, consequently wholeness effect emerges. The shared mission drives the component systems as well as the SoS itself to evolve continuously.
- *Emergent behavior*: The system-of-systems performs functions and carries out purposes that do not reside in any member system. These behaviors are emergent properties of the entire system-of-systems and not the behavior of any member system. The principal purposes supporting engineering of these systems are fulfilled by these emergent behaviors.
- *Evolutionary development*: A system-of-systems is never fully formed or complete. Development of these systems is evolutionary over time and with structure, function and purpose added, removed, and modified as experience with the system grows and evolves over time.

As stated earlier, the knowledge system is a complex system which is composed by organization, technical tools and knowledge carrier, etc. Normally, it cannot be

built up in a single leap, but be integrated with the existing systems and new systems. From this point of view, the knowledge system can be considered as 'system of systems (SoS)', which is a composition of member systems. In knowledge management area, there are many systems like SoS. For example, in a research institution, there are some independent systems including personnel systems, information technology systems, knowledge content system, and interpersonal relationship systems. Such member systems already exist with their own structures and functions, which are different from the sub-systems of the general systems. Another example, studying water supply systems often requires knowledge generated in a number of systems. One system is weather prediction. Another is the study of runoffs and storage of water. A third is the delivery system. Each of these systems often follows their own process in capturing and processing knowledge and usually building a model to study behavior in their area of interest. Provision of intelligent services is also composed of a number of systems. One for example is focusing on customer relationship management (CRM), another getting the resources by knowledge discovery tools to provide the service and still a third is provision of the actual service by accomplished professionals.

SoS aims to let emergence happen to generate SoS growth. It is an ultimate goal for the SoS to achieve the wholeness effect through collaboration and interaction of various member systems and coordination of various soft elements. Occurring in the course of SoS dynamic evolution rather that its stationary state, emergence is the unique innovative quality of SoS in its structure, behavior and state, representing a promotion in SoS capability.

3 Architecture of Knowledge Systems

The knowledge system is a complex system with high abstractness. In order to build up a framework of KSE, we will start to set up the architectures of KS.

3.1 Architecture Model

The designed architecture of KS should facilitate the capture, codification, validation and reuse of knowledge. A complete and well-defined system must be tied to the organization's strategic goals. The complete system can effectively improve the innovation and efficiency within the organization. The proposed architecture includes components of personnel, organization, technology, business and culture, of which people are at the heart of the architecture, as shown in Fig. 1.

In the diagram, the core represents innovative subjects including individuals, teams or groups, organizations, or a population of organizations. Next circle consists of organization and technology, defined as "the place and tool used by people to coordinate their actions to obtain something they desire or value – that is, to achieve

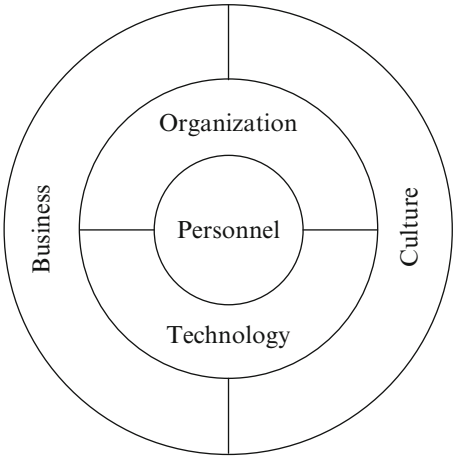

Fig. 1 Architecture of the proposed knowledge system

their goals". The outer circle contains business and culture depicting the conditions for realizing effective and efficient KM in the organization.

All five of components in the KS architecture are necessary and inter-dependent. Personnel are working together by means of technologies to produce knowledge products or provide knowledge-based services. Organizational culture supports a strategic positioning for KM within the organization. In short, it is people who shape the culture, manage the content, deliver the process, work with the technology, and create the value in the KS.

3.2 Personnel Architecture

In the personnel architecture, the main components are knowledge workers. In the knowledge economy, cheap labor is not an advantage, and professional labors with high adaptability to the environment become very important since they are the source of creativity. This makes employees a major asset. Just as Drucker (1999) said: "the most valuable asset of a 21st century institution, whether business or non-business, will be its knowledge workers and their productivity".

Half a century ago, visionary Peter Drucker coined the term 'knowledge worker' to describe a new class of workers who would shape the future of business in an economy driven by information and knowledge as opposed to the production of goods. Knowledge workers are workers who can drive organizational performance and success through the effective use of the knowledge they possess. Typical examples may include engineer, doctor, lawyer, senior manager, architects, scientists, and public accountants, etc. Normally, knowledge workers are requested to have T-shaped expertise. The vertical bar on the T represents the depth of related skills and expertise in a single field, whereas the horizontal bar is the ability to collaborate

across disciplines with experts in other areas and to apply knowledge in areas of expertise other than one's own. T-shaped expertise enables individual specialists to have synergistic conversations with one another. In modern society, the compound workers with π-shaped skills are called for, which implies knowledge workers not only have skills and expertise in one field but also have the knowledge in the other fields.

Knowledge workers bring benefits to organizations in a variety of important ways. These include:

- analyzing data to establish relationships;
- assessing input in order to evaluate complex or conflicting priorities;
- identifying and understanding trends;
- making connections;
- understanding cause and effect;
- ability to brainstorm, thinking broadly (divergent thinking);
- ability to drill down, creating more focus (convergent thinking);
- producing a new capability;
- constructing or modifying a strategy.

The roles of knowledge workers across the workforce are incredibly diverse. Knowledge workers play different roles in their work as controller, helper, learner, linker, networker, organizer, retriever, sharer, solver, and tracker suggested by Reinhardt et al. (2011). Table 2 displays roles and typical knowledge actions of knowledge workers.

For knowledge worker productivity, Drucker (1999) outlines the following six factors.

1. Knowledge worker productivity demands that we ask the question: "What is the task?"
2. It demands that we impose the responsibility for their productivity on the individual knowledge workers themselves. Knowledge workers have to manage themselves.
3. Continuing innovation has to be part of the work, the task and the responsibility of knowledge workers.
4. Knowledge work requires continuous learning on the part of the knowledge worker, but equally continuous teaching on the part of the knowledge worker.
5. Productivity of the knowledge worker is not – at least not primarily – a matter of the quantity of output. Quality is at least as important.
6. Finally, knowledge worker productivity requires that the knowledge worker is both seen and treated as an 'asset' rather than a 'cost'. It requires that knowledge workers want to work for the organization in preference to all other opportunities.

It is the knowledge worker that is the core element of the KS because without the worker, there is no knowledge exchange. Therefore, to be successful, the firm must encourage its employees to reach their maximum potential. This includes employees building their confidence as knowledge workers, realizing the importance of the

Table 2 Different roles of knowledge workers as well as their actions

Role	Description	Typical knowledge actions (expected)
Controller	People who monitor the organizational performance based on raw information	Analyze, dissemination, information Authoring, analyze, dissemination, feedback, information search, learning, networking
Helper	People who transfer information to teach others, once they passed a problem	Authoring, analyze, dissemination, feedback, information search, learning, networking
Learner	People use information and practices to improve personal skills and competence	Acquisition, analyze, expert search, information search, learning, service search
Linker	People who associate and mash up information from different sources to generate new information	Analyze, dissemination, information search, information organization, networking
Networker	People who create personal or project related connections with people involved in the same kind of work, to share information and support each other	Analyze, dissemination, expert search, monitoring, networking, service search
Organizer	People who are involved in personal or organizational planning of activities, e.g. to-do lists and scheduling	Analyze, information organization, monitoring, networking
Retriever	People who search and collect information on a given topic	Acquisition, analyze, expert search, information search, information organization, monitoring
Sharer	People who disseminate information in a community	Authoring, co-authoring, dissemination, networking
Solver	People who find or provide a way to deal with a problem	Acquisition, analyze, dissemination, information search, learning, service search
Tracker	People who monitor and react on personal and organizational actions that may become problems	Analyze, information search, monitoring, networking

knowledge they possess, and encouraging employees to share their knowledge assets among co-workers. To be clear, all workers have knowledge to contribute to the firm. A well-defined and implemented personnel system should provide the mechanism to encourage knowledge workers to participate in the knowledge sharing activities, which enhances the potential for the firm to operate at peak efficiency.

The personnel architecture is closely related to the organizational architecture. They must be planned and designed simultaneously.

3.3 Organizational Architecture

When we transit from an industrial society to a knowledge society, the knowledge-based organization (KBO) has emerged as the dominant structure of both public and private organizations. In the KS, KBO is the main form of organizational structure. The KBO is a management idea, describing an organization in which people use systems and processes to generate, transform, manage, use, and transfer knowledge-based products and services to achieve organizational goals.

KBOs are very different from bureaucratic organizations in terms of organization and leadership. The former organizations emphasize the use of ideas and capabilities of employees to improve decision making and organizational effectiveness, while in contrast, bureaucracies are run with autocratic decision making by senior leadership with unquestioned execution by employees. KBOs are therefore flexible and customer-centric, while bureaucracies are focused on stability and the accuracy of repetitive internal processes. The autocratic leader flourishes in a bureaucracy while charismatic and transformational leadership is important to the knowledge-based organization's effectiveness, and motivating employees towards a collective goal set, mission, or vision.

The KBO lives and breathes knowledge. From day-to-day operations to long-term strategy, creating and applying knowledge is always in the forefront. Any organization can be knowledge-based, regardless of the product or service it produces as long as it takes knowledge seriously. This requires managing its knowledge creation and sharing processes, formulating its competitive strategy with knowledge in mind, and regarding knowledge in every decision it makes.

To model the KBO, it can be regarded as an intelligent complex adaptive system which composes of a large number of self-organizing components that seek to maximize their own goals but operate according to rules in the context of relationships with other components. In an intelligent complex adaptive system the agents are people. The systems (organizations) are frequently composed of hierarchical levels of self-organizing agents (or knowledge workers), which can take the forms of teams, divisions or other infrastructures that have common bonds. Thus while the components (knowledge workers) are self-organizing, they are not independent from the system they comprise (the professional organization).

Real KBO is a learning organization (LO). A learning organization is a kind of knowledge-based organization, where people continuously expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together (Senge, 1990). Normally the phrases knowledge organization and learning organization are used to describe service organizations. This is because most of the value of these organizations comes from how well their professionals learn from the environment, diagnose problems, and then work with clients or customers to improve their situations. The problems with which they work are frequently ambiguous and unstructured. The information, skills, and experience needed to address these problems vary with work cases. The LO can

learn successfully and repeatedly change itself for improved management and use of knowledge; empower people in and out of the organization to learn as they work; and make use of technology to take full advantage of learning.

In LOs, they are increasingly using knowledge-worker team namely knowledge-based team (KBT) to streamline difficult tasks, resolve complicated problem-solving activities, develop new innovative products, and perform a number of other critical tasks that could not be completed in a timely manner by any one individual. Work required by organizations today has become more complex, requiring the capabilities of teams in order to collaborate and work effectively toward solving complex problems. Organizations use teams when faced with complex and difficult tasks. Additionally, as tasks become too complex for any one individual, organizations have to rely on teams.

KBTs often engage in non-routine tasks to produce creative outputs. Therefore, such teams need to consist of a well-balanced diverse group of employees that have the proper knowledge, skills, and abilities to resolve the complicated problems and adapt to the changing requirements. Knowledge-workers need to possess both technical skills and team human resource skills in order to deal effectively in that environment. Shared leadership can effectively lead teams based upon the area of knowledge, skills, or abilities that are required at any given time. This collaborative leadership is not based upon authority but rather responsibility and expertise.

Some teams are designed out of necessity rather than convenience, such as virtual teams. A virtual team is normally a temporary, culturally diverse, geographically dispersed, electronically communicating work group. Members of virtual teams could come from different places located in different geographical locations, or from different units of the same organization. Virtual teams are required to work across boundaries of time and space, relying on IT-based technologies and information systems. Virtual teams provide an extra level of complexity in which knowledge sharing and knowledge transfer must be conveyed between geographically dispersed team members and between organizational units. Here, team members have to adjust for the lack of conveniences that face-to-face teams typically provide, such as relying partially on non-verbal cues. Due to the importance of communication placed on virtual teams, computer-mediated communication tools play a critical role in knowledge sharing and knowledge transfer between team members and organizational units. Some technology tools utilized by virtual teams include: instant messaging and chat, groupware/shared services, remote access and control, Web conferencing, file transfer, e-mail, and telephone.

Virtual teams present unique leadership challenges as their members are geographically dispersed, and usually engage in complex projects that necessitate members to coordinate their inputs and contributions. Leaders of virtual teams have to develop practices that ensure that their members benefit from participating in these virtual teams and that the competencies and diversity in experience or insight of members are understood and leveraged. Understanding how members identify each other's competencies and consult each other, builds a map of the emerging social networks within a virtual team.

An extension of virtual teams is the 'far-flung team', which is described as globally distributed multi-disciplinary virtual teams. Far-flung teams are becoming critical to managing knowledge resources for global organizations. Technology required for far-flung teams to communicate and share knowledge takes two forms: electronic spaces that provide "same time, different place" communication (synchronous), and technology providing "different-time, different place" methods for communication (asynchronous). Some of these technologies utilized for far-flung teams include: audio conferencing, video-conferencing, application sharing, electronic white boarding, threaded discussions, shared document repositories, and workflow organization (Malhotra and Majchrzak, 2004).

With the development of ICTs and the prevalence of the Internet, the world-wide virtual communities evolve rapidly. A virtual community can be recognized as a valuable and effective system for facilitating knowledge sharing, which has all of the following characteristics: an aggregation of people; rational utility; interpersonal interactions in cyberspace without physical co-location; social-exchange processes; and a shared property/identity, objective, or interest. A virtual community is a technology-supported cyberspace, centered upon the communication and interaction of participants to generate member-driven information and knowledge, resulting in the building of interpersonal relationships. A virtual community can be viewed from two perspectives. From a sociological perspective virtual communities can be classified into four types: interest, transaction, fantasy, and relationship. 'Wikipedia' is the most well-known and successful example of a virtual community. 'Wikipedia' is an open knowledge platform which allows anyone with the Internet access to contribute their knowledge by adding new content or editing the existing content shared by other users. From a business perspective virtual communities are driven by four primary motivations: purpose, practice, circumstance, and interest.

3.4 Technological Architecture

The technological architecture of the KS includes all the techniques and tools. KM technology can be divided into the following general categories: groupware, workflow, content/document management, enterprise portals, e-learning, scheduling and planning, telepresence.

- *Groupware* refers to technologies that facilitate collaboration and sharing of organizational information. One of the earliest very successful products in this category was 'Lotus Notes'. Notes provided tools for threaded discussions, sharing of documents, organization wide uniform email, etc.
- *Workflow* tools allow the representation of processes associated with the creation, use, and maintenance of organizational knowledge, such as the process to create and utilize forms and documents within an organization. For example, a workflow system can do things such as send notifications to appropriate supervisors when a new document has been produced and is waiting their approval.

- *Content/Document Management* systems are systems designed to automate the process of creating Web content and/or documents within an organization. The various roles required such as editors, graphic designers, writers, and producers can be explicitly modeled along with the various tasks in the process and validation criteria for moving from one step to another. All this information can be used to automate and control the process.
- *Enterprise Portals* are web sites that aggregate information across the entire organization or for groups within the organization such as project teams.
- Technology of *e-learning* enables organizations to create customized training and education software. This can include lesson plans, monitoring progress against learning goals, online classes, etc. E-learning technology enables organizations to significantly reduce the cost of training and educating their members. As with most KM technology in the business world this was most useful for companies that employ knowledge workers; highly trained staff with areas of deep expertise such as the staff of a consulting firm. Such firms spend a significant amount on the continuing education of their employees and even have their own internal full-time schools and internal education staff.
- *Scheduling and planning* tools automate the creation and maintenance of an organization's schedule: scheduling meetings, notifying people of a meeting, etc. An example of a well-known scheduling tool is 'Microsoft Outlook'. The planning aspect can integrate with project management tools such as 'Microsoft Projec't. Some of the earliest successful uses of KM technology in the business world were the development of these types of tools, for example online versions of corporate 'yellow pages' with listing of contact info and relevant knowledge and work history.
- *Telepresence* technology enables individuals to have virtual meetings rather than having to be in the same place. Videoconferencing is the most obvious example.

These categories are neither rigidly defined nor exhaustive. Workflow for example is a significant aspect of content or document management system and most content and document management systems have tools for developing enterprise portals.

The above technologies can help people complete knowledge-oriented tasks. But as the amount of such tasks increases, the need for automation becomes more and more urgent. In this sense, the notion of intelligent agent is a useful tool for the automation of specialized knowledge intensive tasks. Agents are considered intelligent if they pursue their goals and optimize their performance according to some metrics. An agent should be capable of interacting with other agents (human or software) and are designed in such a way that the system of which they are a part achieves a set of global objectives through the interaction of the various types of agents. An arrangement of agents is called a Multi-agent System (MAS).

Nowadays, Web 2.0 tools become more and more powerful to build and sustain relationships in disperse social communities, to create and extend networks, and to produce synergy effects through aggregated interaction patterns of users. Web 2.0-based enterprise platforms support dynamic knowledge exchange and the emer-

gence of a corporate information structure, which represents the genuine interests and competence domains of employees. In particular, Web 2.0 technologies include blogs, wikis, podcasts/vodcasts, social networks, social bookmarking, multimedia sharing tools, RSS (Real Simple Syndication), etc.

1. *Blogs and microblogs*: Blogs are rich sources of information that support tacit knowledge sharing by establishing a space that gives everyone a voice, enabling people to have discussions, immediately annotate and document their thoughts, and to capture or share personal knowledge and insights in a friendly environment. Allowing people to talk about their personal experiences is one of the main mechanisms for sharing tacit knowledge. Blogs provide such a space for storytelling, which might be their most important benefit for the externalization of tacit knowledge. Immediate feedback on blog posts is also helpful for transferring tacit knowledge. The other potential of blogs in facilitating tacit knowledge is that they enable users to support their ideas and stories by embedding multimedia files (such as images and audio-video presentations) for further explanation of something or for the demonstration of a practical skill. Microblogs such as Twitter and Yammer also provide opportunities for broadcasting as well as keeping up-to-date with new advancements, trends, and publications. They are also helpful in networking and strengthening socialization within and across organizations, which are essential for tacit knowledge creation and sharing.
2. *Wikis*: Wikis can be used to create an informally structured body of knowledge. They can facilitate the knowledge conversion from tacit to explicit and thus increase knowledge dissemination. Wikis affect both the externalization (writing down personal knowledge) and the internalization (processing the information offered by a wiki and integrating it into the individual's knowledge) of tacit knowledge. Wikis assist the sharing of tacit knowledge by providing a field for collaborative knowledge capturing and sharing accompanied with social interactions. Wikis can also be used as a community building exercise where people can contribute in their area of expertise. This will also create a social network driven by expertise, enabling tacit-to-tacit knowledge transfer using the socialization process. Contributions to the Wiki can be recognized and rewarded thus incentivizing the sharing of knowledge.
3. *Social networks (SNs)*: Social networks will help create relationships and connect individuals who may have expertise. Well-developed SNs could leverage crowd opinion and incorporate rewards into the KM system. The main role of SNs in sustaining tacit knowledge flow is in building voluntarily based social communities of practice (CoPs), which is essential for sharing tacit knowledge. SNs enable experts to be located, foster peer-to-peer relationships, promote technical discussions, and provide areas for socializing and the sharing of personal knowledge. Embedded instant messaging and discussion forums support concurrency and the co-presence of users in SNs environments, which helps in trading tacit practical knowledge among participants. In addition, SNs increase the level of interpersonal trust through establishing closer and more

frequent communication among members, which are both necessary for the effective transfer of tacit knowledge.

4. *Multimedia sharing tools (podcasts/vodcasts)*: These tools are particularly useful in the internalization process of knowledge sharing, which can enhance the learning and conceptualizing of existing knowledge. In addition, they are useful in demonstrating technical know-how and transferring hands-on experiences that may not be expressible by verbalization or through other formal documentation methods. The ability to comment, rate, and develop a meaningful discussion about multimedia files shared via social media channels is another advantage of these channels in facilitating the sharing of tacit knowledge.
5. *RSS (Real Simple Syndication)*: RSS seems to be more appropriate for sharing explicit knowledge. It usually gathers and distributes already published knowledge in different places (e.g., blogs). However, it increases the visibility of information published in other places, which in turn helps indirectly to disseminate tacit knowledge widely.
6. *Social bookmarking*: Although social tagging plays an indexing role in structured knowledge sharing, it can also help tacit knowledge sharing by connecting people with common interests and harnessing individuals' collective intelligence as they allocate, organize, and share personalized tags with each other. In addition, it can be used as an annotation tool by adding new tags for specific content. Sometimes, tagging can resemble highlighting key ideas in a book with a marker, enabling the transfer of underlying logic and key information. Another effect of social tagging on the sharing of tacit knowledge is to locate experts with similar interests by following their personalized tags.

3.5 Business Architecture

In the knowledge economy, knowledge is a resource for value creation in a firm which is replacing or perhaps supplementing land, labor, and capital and becomes a new driver to firm development. Like most resources, knowledge is only valuable if it can be transmuted in goods and services that people will pay for. Knowledge (especially in science and technology and management areas) directly involves in the production process and is increasingly becoming the most important factors of production. In today's market, knowledge intensive products (such as computer chips, fine chemical products, etc.) are very popular, whose value most come from the knowledge itself rather than material or scale of production in many cases. Knowledge economization can be found not only in modern service industries but also in traditional industries including manufacturing, forestry, agriculture, and mining.

Knowledge products as the output of knowledge working process can either be tangible or intangible. The so called tangible knowledge products refer to books, drawings, and designs in which knowledge is isolated with its producer or consumer. On the contrast, for intangible knowledge products, knowledge involved cannot

be separated from its carrier and has to be attached to its production behavior and process. Knowledge has the explicit value and can be purchased more or less directly. Skill teaching and technology consulting are the examples.

Knowledge products can be classified into the following four categories in general.

1. *Scientific theory knowledge* including works, academic papers, online documents, etc. Such knowledge is generated by one-time production. With the protection of property right, this kind of knowledge can be printed in a large scale or transmitted through the Internet widely.
2. *Technical knowledge* including technology principles, methods, technical routes, formulations, designs, computer programs, etc. Similar to the first kind of knowledge, it is also created by one-time production and can be sold for many times. The difference is such knowledge can directly create value.
3. *Knowledge service* including consulting service, etc. It is often performed by knowledge intensive organizations, such as accounting firms, audit firms, asset appraisal firms and the like.
4. *Physical products with embedded knowledge* including high-tech products like hybrid rice, integrated circuit chips, smart phones, robots and so on.

Knowledge products not only have the use value, but also have the value under the market economic circumstances. Knowledge market is different from the traditional commodity market, it emphasizes on places or activities related to knowledge exchange like science and technology exchange center, academic conference, technology practice group.

Various knowledge embedded products or services are kinds of physical capital, whereas knowledge itself is a kind of intellectual capital which is seen as the main driver of value creation in today's knowledge-based economy. Both physical capital and intellectual capital are organizational resources from the resource-based view (RBV) which contribute to firm's competitive advantages and consequently facilitate the firm to produce supernormal performance over a sustained period of time.

From human resources or knowledge assets to intellectual capital of a firm, there is a need to conduct a business process by which intellectual resources can be transformed into the value of the firm.

Knowledge asset refers to the accumulated intellectual resources of an organization. It is the knowledge possessed by the organization and its workforce in the form of information, ideas, learning, understanding, memory, insights, cognitive and technical skills, and capabilities. Workforce, databases, documents, guides, policies and procedures, software, and patents are repositories of organization's knowledge assets. Knowledge assets are held not only by an organization but reside within its customers, suppliers, and partners as well.

Knowledge assets are the 'know how' that the organization has available to use, to invest, and to grow. Building and managing intangible knowledge assets are key components for the organization to create value for stakeholders and to help sustain overall organizational performance success.

Measuring the knowledge asset means putting a value on people, both as individuals and more importantly on their collective capability, and other factors such as the embedded intelligence in an organization's computer systems.

As to intellectual capital (IC), it is combination of intangible knowledge assets. IC is knowledge that can be exploited for some money-making or other useful purpose. This term combines the idea of the intellect or brain-power with the economic concept of capital, the saving of entitled benefits so that they can be invested in producing more goods and services. IC in general include the skills and knowledge that a firm has developed about how to make its goods or services; individual employees or groups of employees whose knowledge is deemed critical to a firm's continued success; and its aggregation of documents about processes, customers, research results, and other information that might have value for a competitor that is not common knowledge. In short, IC can create a competitive advantage for a firm, and efficiently organize the firm's information. IC in the production context is an intellectual material including knowledge, information, intellectual property, and experience that can be put to use to create wealth for the firm.

Intellectual capital is normally classified as follows (Edvinsson and Malone, 1997):

- *Human capital*: The value that the employees of a firm provide through the application of skills, know-how and expertise. Human capital is an organization's combined human capability for solving business problems and exploiting its intellectual property. Human capital as the knowledge created by and stored in a firm's human resources namely employees is inherent in people and cannot be owned by an organization. Therefore, human capital can leave an organization when people leave, and if management has failed to provide a setting where others can pick up their know-how. Human capital also encompasses how effectively an organization uses its people resources as measured by creativity and innovation.
- *Structural capital*: The embodiment, empowerment, and supportive non-physical infrastructure, processes and databases of the organization that enable human capital to function. Structural capital includes processes, patents, and trademarks, as well as the organization's image, organization, information system, and proprietary software and databases. Because of its diverse components, structural capital can be classified further into organization, process and innovation capital. Organizational capital includes the organization philosophy and systems for leveraging the organization's capability. Process capital includes the techniques, procedures, and programs that implement and enhance the delivery of goods and services. Innovation capital includes intellectual property such as patents, trademarks and copyrights, and intangible assets. Intellectual properties are protected commercial rights such as patents, trade secrets, copyrights and trademarks. Intangible assets are all of the other talents and theory by which an organization is run.

- *Relational capital*: The relations between an organization and its customers consisting of customer relationships, supplier relationships, trademarks and trade names (which have value only by virtue of customer relationships) licenses, and franchises. The notion that customer capital is separate from human and structural capital indicates its central importance to an organization's worth. The value of the relationships a firm maintains with its customers and suppliers is also referred as goodwill, but often poorly booked in corporate accounts, because of accounting rules. Compared to human and structural capital, customer capital as an essential part of intellectual capital has an incremental importance and influences the realization of organizational values.

Intellectual capital includes many intangible factors and items, and as a result, it is difficult to evaluate IC performance using only traditional crisp values. To evaluate the performance of intellectual capital more appropriately, not only quantitative indexes but also qualitative dimensions or factors that are evaluated by experts should be taken into account.

3.6 Cultural Architecture

Culture plays a predominant role in KM success, particularly in processes related to effective knowledge creation, transfer and sharing. Culture enhances coordination, internal control, a focus on common goals, motivation, and identification with the company and therefore positively influences the company performance.

A knowledge culture is one particular variety of culture. It can be regarded as the basic values, norms and practices followed and learned by knowledge workers collectively, that govern knowledge works' perception, thoughts, feelings and actions. Values are deeply embedded, which implies that they are difficult to talk about and even more difficult to change. Norms and practices, on the other hand, are more directly observable and easier for employees to identify. Knowledge culture enables knowledge workers to interpret their experience in similar ways and behave according to agreed upon norms.

Knowledge culture can influence the knowledge-related behaviors of individuals, teams, organizations and overall organizations. As knowledge workers may belong to different groups at the same time, they carry several layers of cultures within themselves, i.e. national, regional, ethnic, gender, organizational level, etc.

3.6.1 National Culture

Hofstede (2001) defines national culture as a 'collective phenomenon', because it is at least partly shared with people who have lived within the same social environment where it was learned. National culture is the collective programming of the mind that distinguishes the members of one group or category of people from another.

It is the manner in which members of a society habitually deal with those issues that varies among societies, thus forming different cultures. Taking China as an example, 'mianzi', 'guanxi' and 'quanzi' are all Chinese cultures which differentiate from other countries. People who are inside the 'quanzi' will share information and knowledge. If not in the 'quanzi' but having 'guanxi' or 'mianzi' with some people they can get access to knowledge but may have to pay a price (in 'guanxi' or 'mianzi'). Some people who are outside the 'quanzi' may have little idea that it exists much less who the members are.

Different national cultures can influence KM actions in different ways. High power-distance societies, where power disparity and specialization are favored, may foster a focused knowledge acquisition; individualistic societies, where the interests of the individual lie ahead of those of the group, may promote private knowledge storage; masculine societies, where decisive and aggressive management is preferred over intuition and consensus, may encourage prescribed knowledge diffusion; and high uncertainty-avoidance societies, where tolerance for risk and uncertainty is low, may support exploitative knowledge application.

3.6.2 Organizational Culture

At the organizational level, culture is typically defined as shared beliefs, values, and practices within the organization that guide the behaviors of organizational members. Organizational culture impacts the knowledge exchange, the combinative interaction, and the perceived value of organizational members. It is thought to be one of important factors for successful KM. So organizations should establish an appropriate culture that encourages people to create and share knowledge within the organization.

According to Cameron and Quinn (2006), fourfold organizational cultures i.e. clan, adhocracy, market and hierarchy, can be formed based on two main dimensions. One dimension reflects dynamism which is typified with special focus on flexibility and discretion, and the other reflects stability and control which is characterized in stressing on control and predictability. Clan culture is a warm and friendly workplace where people share with each other like an extended family. In contrast, adhocracy culture is a dynamic, entrepreneurial and creative workplace, which encourages individual initiative and provides freedom for people who are willing to stick their necks out and dare to take risks. Market culture is a workplace with hard-driving competitiveness, a results-oriented organization led by tough and demanding leaders who are hard drivers, producers and competitors. Hierarchy culture is a workplace with formalized and structured procedures that govern what people do. Leaders in particular see themselves as being highly capable coordinators and organizers.

Another segmentation of organizational culture comes from Harrison (1995). He called them power, role, achievement, and support. In power culture, leaders are expected to be all knowing and forceful, still, they should display justice and be paternalistic. Role culture has a pyramid shape with clearly defined rules and

expectations. There will be less direct supervision, and performance is monitored through well-established information systems. The values of the role culture are order, dependability, rationality, and consistency. Achievement culture assumes that employees enjoy challenging jobs and prefer tasks that are intrinsically satisfying. Top management trusts employees and gives them the freedom to make decisions and act to meet goals. It relies on self-motivating strategies and is based on competence. It also creates a high-energy environment by using the mission to attract and release its members' energy in pursuit of the common goals. Finally support culture assumes that people derive satisfaction from relationships, mutual respect, trust, and support.

Teams are primary organizational mechanisms for leveraging the diverse specialized knowledge of individuals toward a common goal. Since teams are typically focused on a single objective and may be short-lived, the concept of climate is more appropriate at the team level than is that of culture. Team climate can be thought of as the social-psychological attitudes shared among members toward decision-making, task understanding, and reward structures. Team climate may either promote or inhibit a team's knowledge sharing behaviors.

In the KS, knowledge culture should be seriously taken into consideration. That is to say appropriate knowledge culture that is required to foster KM activities should be developed. 'Good' culture will lead to 'good' KM behaviors and outcomes. Vice versa, successful knowledge processes can influence the knowledge culture. If employees regard the introduction of a knowledge system as advantageous, they might collectively change their perception, thoughts, feelings and actions towards knowledge processes. Or when a new knowledge practice is found to be especially useful, it is embedded in the organizational climate, and perhaps, eventually in culture. In this sense, we can say the knowledge culture brings a positive impact on knowledge activities.

3.6.3 Cultural Barriers to KM Processes

Knowledge culture is one of the key success factors of KM because it affects learning, acquisition, sharing and other related areas of knowledge. In contrast, knowledge culture is also identified as the main barrier to the success of KM in organizations. Different cultures may introduce different barriers to an organization's KM efforts. The following are some of barriers to KM processes.

1. *Selfish culture*: According to Hofstede (2001), in highly individualistic cultures, it is believed that employees perform best as individuals and the decisions made by individuals are of higher quality than decision-making by groups. Highly individualistic cultures believe that withholding information or knowledge and avoiding alliances will lead to greater success. On the other end, collectivistic cultures attribute organizational success to knowledge sharing and openly committing oneself.

2. *Hierarchical culture*: High power distance cultures are often tradition driven. In terms of work culture, employees from high power distance cultures often experience and accept inequality in distribution of power. In such cultures, organizational structure is cross-cultural barriers to KM often a pyramid and there is a lot of supervision. Bosses tightly control employees and people fear speaking openly. High level of inequality between individuals in such culture will result in low sharing of knowledge. This will impact the knowledge process of externalization and internalization. Hierarchical structure and inequality will lead to reduced flow of knowledge and lower chances for knowledge conversion processes to succeed. Thus, for high power distance cultures, knowledge sharing as well as creation will be harder than cultures with lower power distance.
3. *Uncertainty avoidance culture*: Individuals from low uncertainty avoidance cultures prefer clearer instructions and are generally relationship oriented. In contrast in high uncertainty avoidance cultures, individuals accept diversity and are open to change and innovation. High uncertainty avoidance cultures often have a higher tolerance for ambiguity. In organizational settings, employees from high uncertainty avoidance cultures are appealed by technological innovations. They are task oriented and believe in relying on specialists with expertise. Low uncertainty avoidance cultures believe in common sense rather than expertise. As a result low uncertainty avoidance cultures will resist seeking and sharing knowledge as compared to high uncertainty avoidance cultures.
4. *Masculine culture*: Highly masculine cultures differentiate between genders and the roles defined for them in society. In terms of work environment, highly masculine cultures stress on competition and performance while low masculine cultures value relationships. Highly masculine cultures resolve conflict by fighting till one person gives up while low masculine cultures use compromise and negotiation. Highly masculine cultures emphasize competitiveness which can lead to knowledge hoarding. As a result, knowledge sharing and seeking will be discouraged. This will directly lead to lower knowledge creation due to barriers to the process of externalization as well as internalization.
5. *Long-term orientation culture*: In cultures with long-term orientation, individuals value perseverance and keep future rewards in sight. In contrast, short-term orientation cultures are concerned with traditions and primarily look to past as well as present. In terms of work environment, employees from long-term orientation are given resources as well as time to make their contributions. On the other hand, short-term oriented cultures constantly judge managers. Employees from short-term oriented culture also feel the need to protect their 'face' and believe in following traditions. This fear of apprehension may lead to lower sharing of opinions and knowledge. This will lead to lower externalization of tacit knowledge, impacting knowledge sharing as well as knowledge creation processes.

4 Working Processes in Knowledge Systems

KM has been studied in the past 20 years at the individual, group, organizational, inter-organizational, city, country and international levels, with a particular focus on people, processes, technology and learning. KM can be defined as a process in which both explicit and tacit knowledge inside and outside the organization's boundaries are involved. The KM process essentially facilitates:

- generating new knowledge, accessing valuable knowledge from outside sources (a generating and accessing process);
- improving knowledge growth through culture and incentive and representing knowledge in documents, databases, and software (a facilitating and representing process);
- embedding knowledge in processes, products, and/or services and using accessible knowledge in decision making (an embedding and usage process); and
- transferring existing knowledge into other parts of the organization and measuring the value of knowledge assets and/or impact of knowledge management (a transferring and measuring process).

The working processes of KS can be divided into two levels including knowledge operation level and knowledge management level respectively. These two processes form a two-layer structure, as shown in Fig. 2. Knowledge operation process is the knowledge collection process and/or new knowledge generation process in which people collect, share and use knowledge to accomplish their work. Whereas knowledge management process is to manage the knowledge operation process to

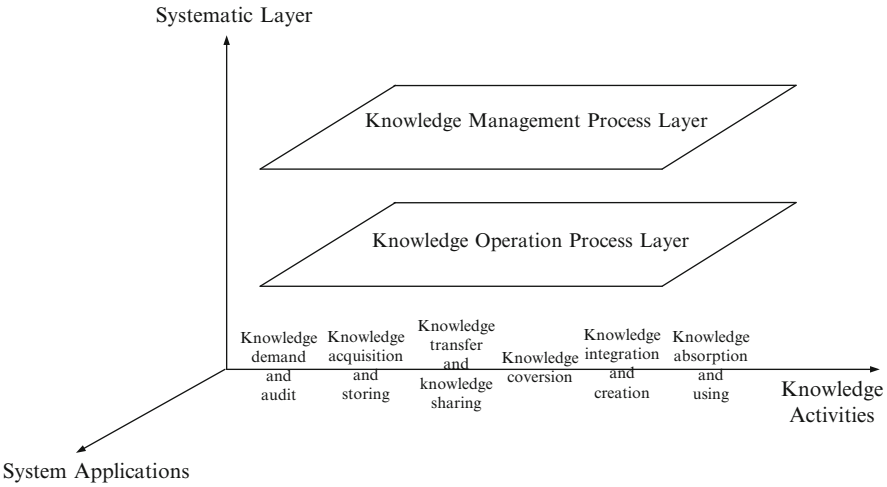

Fig. 2 Working processes of knowledge systems

provide a better knowledge application and innovation environment. Both of the processes have close connection and clear difference.

Knowledge operation process contains a group of systematically related actions directed to meet a specified result or end. Where many activities are involved, they are, not necessarily sequential, knowledge demand analysis, knowledge acquisition, knowledge storing, knowledge transfer, knowledge sharing, knowledge conversion, knowledge integration and creation, knowledge assimilation, knowledge application, and so on.

4.1 Knowledge Demand and Audit

Knowledge demand analysis and knowledge audit are the starting point for knowledge operation processes of knowledge systems. They are used to provide a sound investigation into the company or organization's knowledge needs and 'health'.

Knowledge demand analysis is to know what kind of knowledge is needed for the work or activities within the organization. Knowledge demands in organizations cover many aspects including individual or collective demands, object-driven or general demands, formal or informal demands, internal or external demands, etc.

To identify the different knowledge demands and status by a person and organization, the knowledge auditor plays an important role since he/she can give an organization a comprehensive picture of its strengths and weakness, allowing it to focus its efforts in the right direction.

Every so often, a company may hold a knowledge audit. By auditing, the company can know what knowledge exists, where knowledge is stored and who knows what, and see whether the existing knowledge is being properly managed. Knowledge audit is essential in the development of an effective KM system. Knowledge audits not only disclose what knowledge the company has and who within the company holds that knowledge but can also highlight redundant knowledge. If each individual employee in a company has knowledge which is outdated or no longer applicable to current needs, and this is multiplied by the number of employees in a company, and compounded by outdated knowledge held in central files, the magnitude of the problem soon becomes clear. A knowledge audit can act like a long overdue spring clean and eliminate knowledge which is no longer needed. The purpose of the audit, and the job of the auditor, is to reassure the company and the shareholders that the intangible asset that is knowledge is being properly looked after, much as a financial audit provides reassurance that money is being properly managed.

Some of the questions addressed during a knowledge audit are as follows:

- What are the organization's knowledge needs?
- What knowledge assets or resources does it have and where are they?
- What gaps exist in its knowledge?
- How does knowledge flow around the organization?

- What are the blockages that prevent knowledge from flowing across the organization (people, procedures, technology)?

Once you start asking these questions, a clear picture of your organizations knowledge structure will start emerging, and using these results can help you establish processes and systems to tackle certain shortcomings.

Some of the key benefits of a knowledge audit are as follows:

- It helps the organization clearly identify what knowledge is needed to support overall organizational goals and individual and team activities.
- It provides evidence of the extent to which knowledge is being effectively managed and indicates where improvements are required.
- It provides an evidence-based account of the knowledge that exists in an organization, how that knowledge moves around in, and is used by, that organization.
- It provides a map of what knowledge exists in the organization and where it exists, as well as revealing gaps.
- It reveals pockets of untapped knowledge.
- It provides a map of knowledge and communication flows and networks.
- It provides an inventory of knowledge assets, giving a clearer understanding of the contribution of knowledge to organizational performance.
- It provides vital information for the development of effective knowledge management programs and initiatives that are directly relevant to the organization's specific knowledge needs and current situation.

Most often, the deliverable for a knowledge audit is a detailed report documenting the current state of knowledge management within an organization, an analysis and summary of themes from conversations with staff, and a presentation to management and/or a project team summarizing findings.

Knowledge audits are usually conducted as part of the planning phase to develop and implement knowledge management initiatives. Within this framework, a completed knowledge audit should be used to inform decision makers about how/where to proceed and which areas should be prioritized.

4.2 Knowledge Acquisition and Storing

Knowledge audit reveals the knowledge needed by firm, the next step is to identify knowledge sources and acquire the knowledge accordingly. Firm's knowledge ranging from technology knowledge and organizing knowledge to product knowledge and market knowledge, in general, may come from either internal source or external source. Internal knowledge is the knowledge located within the internal source, which is associated with the internal staff, technical information, database, business processes, the daily work process, system and organization culture. The external knowledge is the knowledge from the outside which might be generated through interactions with customers, suppliers, competitors, and personal or professional

networks. Acquired knowledge from the internal resource is favorably to form the competitive advantage of the enterprise and cannot be imitated by competitors easily although it may spend much time and high cost.

Knowledge acquisition is a process by which knowledge is obtained through widely scanning of the internal and external sources. It details how people experience new knowledge, how that knowledge is stored in the brain, and how that knowledge can be recalled for later use.

The firms' knowledge can be gained in various ways depending on which type of knowledge is needed, such as:

- Through staff training to acquire internal knowledge. Staff training can be conducted in some ways, such as sending people outside for training, hiring outsiders for internal training and education, establishing regular knowledge teaching and communication system.
- Through leasing, joint venture, licensing trade, purchase, talent introduction and knowledge alliance to obtain the external knowledge.
- Through books, journals, intranet postings and social media to acquire codified knowledge.
- Through the internet to gather related knowledge.
- Through data mining techniques to discover new knowledge.

Along two dimensions of knowledge nature (experiential or objective) vs. knowledge sources (internal or external), knowledge acquisition can be divided into four types, i.e. direct experience, indirect experience, external search, and internal information (Fletcher and Harris, 2012).

Direct experience concerns experiential knowledge that is developed by the firm. The indirect experiential knowledge refers to learning from the others. Firms can acquire indirect experiential knowledge by incorporating other units into the organization as well as imitating the behavior of other, established firms which has the potential to improve firm operations. Likewise, firms can gain objective knowledge that is external and internal to the organization. Objective knowledge refers to knowledge that is explicit or codified. External information concerns focused search for objective knowledge from external sources such as chambers of commerce, trade publications, newspapers etc. Internal information, on the other hand, refers to codified explicit experiential knowledge that is made accessible in the firm's internal systems for knowledge sharing.

For some knowledge on the basic theory as well as the knowledge related to the public interest, they are the common wealth of humankind which belong to the whole society. Such knowledge can be acquired without much payment or with little cost for knowledge carriers.

For the Internet knowledge, 'Witkey' is a new way to collect such knowledge. The so called 'Witkey' is a web-based system whereby users can exchange and purchase services and information, share knowledge and experience in order to save time and money. By using 'Witkey', people can obtain their required knowledge with a little pay.

Acquired knowledge should be stored in organization memory (OM). Memory as a long-term repository is defined as a system of knowledge and skills that preserves and stores perceptions and experiences beyond the moment when they occur, so that they can be retrieved at a later time. One form of OM in a team setting is the transactive memory system (TMS). TMS is a collective system that is used by individuals in close relationships to encode, store, and retrieve knowledge in different domains (Wegner, 1987). In a TMS, individual knowledge is shared with other team members, which can be retained and recalled collectively. Individual knowledge is embedded into the collective knowledge of the team through a TMS, providing a repository of knowledge for team members. As Wegner indicated a TMS has two components: a structural component, which shows how TM links individual memories to a collective knowledge network; and three transactive processes that can occur during the encoding, storing, and retrieval of information in the team memory. The structural component in the TMS, just as many researchers suggested, is a cognitive structures built upon a shared conception of one another's expertise which is developed in the team in order to integrate members' distributed skills and expertise. The computer network metaphor is often used to identify three processes related to the development and application of TMSs as directory updating, information allocation, and retrieval coordination.

For codified knowledge, it can be retained in the knowledge repository of the firm. Knowledge repository is an online computer-based system which is used to store professional knowledge, experiences and documents. Knowledge structure in the knowledge repository may take one of the following forms:

- Dictionary including definition, concept and vocabulary of nouns in the knowledge domain.
- Image database including digitalized image and video files.
- Textual database including books, journals, manuals and instructions, etc.
- Database including various kinds of databases.
- Case base including typical cases on decision-making and problem-solving.
- Rule base including definitive knowledge as well as rules on decision-making and problem-solving.
- Script library including events, processes and typical behaviors.
- Object base including concepts, entities, and objects.
- Process base including working processes.
- Model base including causality model, etc.

4.3 Knowledge Transfer and Knowledge Sharing

Knowledge in the repository of the organization should be activated by a number of ways for its future use and value creation. Knowledge transfer and sharing among employees can enable the firm to make the best use of its knowledge.

Knowledge transfer (KT) is regarded as the process by which an organization makes available knowledge about routines to its members, and is a common phenomenon that can be an effective way for organizations to extend knowledge bases and leverage unique skills in a relatively cost-effective manner. The transfer of knowledge is a multifaceted and dynamic process. It encompasses the more overt structured knowledge transfer as well as the more difficult to observe but equally crucial absorption and building of tacit knowledge in unstructured knowledge transfer. There are two types of KT processes (Chen and McQueen, 2010): structured knowledge transfer and unstructured knowledge transfer. Structured knowledge transfer is a formal, planned and intentional transfer process, such as trainees in a classroom listening to an expert giving a presentation. Unstructured knowledge transfer is an informal, unplanned and spontaneous transfer process, which occurs during daily work.

Persons from different institutions often communicate at a deep level and transfer knowledge. Knowledge flows are essential when knowledge is transferred to a person or to an organization. The flow of knowledge is an important concept for understanding collaborative innovation. People often understand knowledge as a process, and the knowledge management is based on knowledge flows and the processes of creating, sharing, and distributing knowledge.

Knowledge transfer occurs at various levels: between individuals, from individuals to explicit sources, from individuals to groups, within groups, between groups, and from the group to the whole organization. Communication processes and information flows together build up those knowledge flows for transferring knowledge from one place or format to another. The receiver relates it to his/her own mental model and creates his/her own interpretation of the original knowledge that he/she received.

New knowledge is formed when the receiver relates the received knowledge to his/her own understanding – his/her mental model – and forms his/her own interpretations from this knowledge.

The nature of the transferred knowledge is often addressed as an important factor. For instance, the more tacit and complex, the more difficult it becomes to accomplish transfer. The more ambiguous the causes and effects of the knowledge, the more difficult it is to transfer. Besides the knowledge transferred itself, the cognitive abilities of both the source of knowledge and the recipient are key factors. Absorptive and retentive capacity of the recipient, i.e. how well equipped they are to take in, absorb, and apply the knowledge, is of course central in transfer situations. Furthermore, the value of the stocks of knowledge at the source is a potential factor. The more valuable it is, the more likely it is that the recipient will attempt to use it. The absorptive capacity will determine whether it will work or not. Another factor, related to competitive advantage, is the uniqueness and inimitability of the knowledge. If knowledge transferred internally can also be transferred externally to competitors, for instance through personnel migration or intelligence activities, there is a risk that the effects, say on costs, can be duplicated by competitors. This can lead to cost reductions across the industry, meaning there is a risk that price and profit levels are reduced overall. Here, the commonalty of knowledge across actors

will determine the risks of failure. Another risk refers to drawbacks that result from the articulation of knowledge necessary in order to be able to transfer it. Articulation requires simplification, which means that finer aspects of the knowledge might have to be removed or be unintentionally lost. Some argue that the risks associated with articulating and transferring tacit knowledge are so high that it is more effective to avoid transferring such knowledge and accept the higher costs associated with coordinating a diverse set of organizational skills. However, it has also been argued that organizations must try to diffuse knowledge, otherwise it will be difficult to reap the leveraged benefits of knowledge.

During knowledge transfer, there is another issue addressing transfer will. Given that it is people who actually create, share, and use knowledge, an organization cannot effectively exploit knowledge unless its employees are willing and able to share their own knowledge and assimilate the knowledge of others. It implies a voluntary act by individuals who participate in the exchange of knowledge even though there are no compulsory pressures.

Knowledge sharing (KS) involves at least two persons, groups, or organizations: the sender, who is willing and able to share knowledge, and the receiver, who is willing and able to combine this new knowledge with his or her existing knowledge and use it. KS can be people-oriented which emphasizes the importance of tacit knowledge, the social infrastructure and the business performance, or technology oriented, i.e. concentrating on the technology infrastructure and the ways, in which explicit knowledge is codified, stored and interrogated.

KS is a critical activity for managing knowledge in organizations, as it improves the knowledge asset by adding to the organizational knowledge, since individuals' knowledge becomes part of organizational knowledge. KS can occur among individuals, among groups, among organizational units, and among organizations. KS in organizations occurs in two channels, one inside the organization and the other between the organization and its environment. Knowledge-sharing forums are examples of KS inside the organization. These sharing forums provide an environment where both explicit and sticky tacit knowledge can be shared. Sharing does not mean that one person's knowledge is transferred to another, but rather it provides an environment where different actors contribute within a context and, based on the absorptive capacity of the recipients, a flow of knowledge occurs. Barriers to KS include the absorptive capacity, relationships between employees, time, cultural differences, etc.

4.4 Knowledge Conversion

Shared knowledge in a firm contains both tacit and explicit knowledge. One of the challenges is what to convert to explicit knowledge, so that it more easily transferable. Nonaka and Takeuchi (1995) defined four types of conversion processes which they describe as 'fundamental to creating value'. There are four combinations of conversion of explicit and tacit knowledge:

1. Tacit-to-tacit (socialization) – individuals acquire knowledge from others through dialogue and observation;
2. Tacit-to-explicit (externalization) – the articulation of knowledge into tangible form through elicitation and documentation;
3. Explicit-to-explicit (combination) – combining different forms of explicit knowledge, such as that in documents or databases; and
4. Explicit-to-tacit (internalization) – such as learning by doing, where individuals internalize knowledge into their own mental models from documents.

The above four processes form the SECI (Socialization – Externalization – Combination – Internalization) spiral. The SECI spiral is the interplay between tacit and explicit knowledge starting at the individual level. Individuals' knowledge is the basis of organizational knowledge creation. The dynamic interaction between individuals and their environment facilitates the four modes of knowledge conversion.

- *Socialization* is the process of transferring tacit knowledge to another through shared experience. The tacit knowledge is acquired through building a field of interaction to share experiences and mental models, such as spending time together or living in the same environment, or informal social meetings outside of the workplace. Mental models refer to deeply held internal images of how the world works, which have a powerful influence on what we do because they also affect what we see.
- *Externalization* is a process of concept building involving the conversion of tacit knowledge into explicit knowledge. In other words, tacit knowledge is articulated into explicit concepts. Tacit knowledge is shared by a self-organizing group through dialog and reflection. Using appropriate metaphors or analogies the group members articulate their hidden tacit knowledge. Tacit knowledge is converted to explicit knowledge in the form of a new concept.
- *Combination* is a process of systemizing concepts into a knowledge system, by combining it with external knowledge. This involves combining various forms of explicit knowledge such as documents, meetings, telephone conversations, or messages on computerized communication networks by sorting, adding, combining and categorizing them into new knowledge, a new product or new service.
- *Internalization* is a process of embodying explicit knowledge into tacit knowledge. The knowledge conversion process of 'learning by doing' triggers internalization. New concepts created by individuals or the group need to be justified through bodily experience.

Nonaka and Takeuchi (1995) emphasizes that organizational knowledge building is a spiral process, starting at the individual level and moving up through expanding communities of interaction that cross group, departmental, divisional, and organizational boundaries. At the same time, there is the feedback of organizational level of knowledge to the group level and then back to the individual level. The four modes of knowledge conversion enable organizational knowledge to become externalized and amplified, and organizational knowledge building to become larger in scale and faster in speed.

The foundation of the above four basic processes is 'Ba', a rather fuzzy concept proposed by the Japanese philosopher Kitaro Nishida, and further developed by Shimizu. 'Ba' is defined "as a context in which knowledge is shared, created, and utilized, in recognition of the fact that knowledge needs a context in order to exist" (Nonaka et al., 2001). This context can be tangible, intangible or any combination of tangible and intangible elements. In this perspective, the concept of knowledge is strongly related to a given material and cultural context, beyond the fact that it is has been considered a personal belief. Knowledge belonging to given person may be shared, recreated or amplified when that person is an active actor in 'Ba'. To make things even more confused, Nonaka et al. (2001) consider that "'Ba' as an interaction means that 'Ba' itself is knowledge rather than a physical space containing knowledge or individuals who have knowledge". In our understanding, 'Ba' is suitable to create an innovative atmosphere.

According to Nonaka and Takeuchi (1995), the four 'Ba' phases correspond to the four phases of the SECI spiral:

1. *Originating 'Ba'* corresponds to the *Socialization* phase of SECI spiral. People share feelings, emotions, and mental models in it.
2. *Interacting 'Ba'* corresponds to the *Externalization* phase. Here individual 'know how' and mental models are converted into common terms and concepts.
3. *Cyber 'Ba'* corresponds to the *Combination* phase and technology which is used to present the explicit knowledge.
4. *Exercising 'Ba'* corresponds to the *Internalization* phase. In this phase, explicit knowledge is converted into tacit knowledge.

Although the SECI spiral model has been widely used in knowledge management research, it has some limitations. Glisby and Holden (2003) have argued that all four modes of knowledge conversion are culture-dependent, where Japan-specific cultural factors are tacitly embedded in the model. They, however, suggest that understanding Japanese social and organizational cultures and related value systems might enable this model to be used successfully in Western or other cultural settings.

The Japanese organization style is rooted in the tradition of groupism (Hayashi, 1990). Groupism is the individual identity with a group to the extent that their individuality is not completely repressed, but it is submissive to the group (Graham, 2003). The group in Japanese organization is the foundation for loyalty, belonging, and family. The Japanese employee has a deep cultural system that defines their altitude toward the head of the group and to the members of the group. It is quite natural that SECI spiral is relevant to the Japanese organizational system. On the other side, the culture of some Western developed countries like Unite States itself is rooted on individualism in contrast to Japanese. The American employees were less loyal to the organization and more focused on their individual need. The Japanese culture capture group knowledge and Americans capture individual knowledge.

There are some dissenting theories refuting the SECI spiral as a foundation and tool for understanding knowledge conversion (Gourlay et al., 2003). But the overwhelming consensus shows that Nonaka's SECI spiral is useful and relevant for the conversion of tacit knowledge to explicit.

4.5 Knowledge Integration and Creation

As knowledge is transferred and shared from one to another, the knowledge is then combined and creates new knowledge. This process of transferring and combining knowledge is known as knowledge integration (KI). KI is a process of transferring knowledge, both tacit and explicit, across organizational boundaries and sharing it with individuals and teams at recipient sites.

Knowledge integration can be thought of the integration of specialist knowledge to perform a discrete productive task. Where this description emphasizes the output, others focus on the knowledge component, e.g., the integration of different types of component knowledge. Other descriptions focus on the integration component, e.g., the synthesis of individuals' specialized knowledge into situation-specific systemic knowledge; or the integration of complementary assets and knowledge. In some cases, the integration component is presented as a social process, e.g., an ongoing collective process of constructing, articulating and redefining shared beliefs through the social interaction of organizational members.

The term 'Integration' now is one of the most often used words in the industry and academia. It is a universally accepted necessary process in the constitution and development whatever integration is. The essential feature of innovation is knowledge integration and creation. The function of innovation system is production, diffusion and use of new and economically useful knowledge to value-creation.

The industry academia government relations are emerging from different institutional starting points of knowledge integration, which perform different knowledge functions.

In the epistemological dimension, there are two kinds of knowledge: explicit and tacit. The explicit knowledge can be codified, stored and easy to excess. On the other hand, tacit knowledge is knowledge that people possess but cannot be easily codified.

Recently scholars of knowledge management in different countries pay more attention to the tacit knowledge and its role in the innovation process. One of the important factors in the learning, absorption and innovation is the crucial effects of tacit knowledge. In knowledge application and creation the emphasis is on tacit knowledge, which is in the form of know-how, skills, common knowledge, and practical knowledge of organizational members and closely associated with real life. The tacit knowledge is acquired by and stored within individuals.

In the ontological dimension, there are two kinds of knowledge: individual and organizational (collective). Innovation is a kind of social activities and organizational knowledge is necessary. The collaborative innovations are based on the knowledge integration and knowledge sharing. Academia, enterprise, and government share information and knowledge across institutional spheres to generate new innovation opportunities. The most important and difficult tasks are communication and interaction of tacit knowledge for the knowledge integration since they are on the base of mutual empathy and understanding.

Knowledge integration is the process of synthesizing multiple knowledge modules from different sources into a common knowledge module. It focuses more on synthesizing the understanding of a given subject from different perspectives. Integration of knowledge includes integrating the knowledge of:

1. Technology and business;
2. Explicit and tacit;
3. Individual and organizational, etc.

From the strategic view, knowledge integration of collaborative innovation refers to the integration of knowledge (intellectual) assets including human assets, structural assets and social assets.

It is widely accepted that knowledge integration improves firm performance. High knowledge integration creates superior product innovation performance in industry networks and across functional boundaries. One knowledge integration activity, co-development with customers, directly improves product performance.

Knowledge creation (KC) refers to how new knowledge is created in organizations. This new knowledge could be generated at each level:

- job/individual;
- team;
- organization; and
- industry.

The goal of any knowledge management and knowledge enabling program is to link its newly created knowledge to other people even other generations of people. The act of knowledge creation is dynamic and includes what individuals possess through their experiences, learning, and talents. All this forms the basis of tacit knowledge. Once it is expressed in any form (such as words, and sounds), the knowledge becomes static and explicit (Conway and Sligar, 2002). For example if you have a new idea of design a business mode, your creation remains a dynamic one until you write it down. This is the key to knowledge generation and innovation The knowledge worker might come up with a solution to a problem and have moved knowledge from the dynamic state to static state, thus becoming an author of new ideas.

Within knowledge creation process, knowledge created by an individual is shared by team members, which is then transferred to the team and codified into written or digital format, and finally becomes part of the organization's knowledge system, supporting the knowledge processing and management process.

The organization can increase the members' participation in this authorship process by motivating them. If the organization requires knowledge workers to become authors, allocate time in the schedule so that authoring is a priority. The more empowered a knowledge worker feels to publish authored materials, the more likely he or she will do it. If a knowledge worker comes up with an idea to solve a particular problem in the group, a committee can be formed to collaboratively discuss and come up with even more solution to the problem. If the organization's author participation is low, the culture or the infrastructure should be changed to improve it.

4.6 Knowledge Absorption and Using

In the present competitive and dynamic business environment, organizations strive to identify and assimilate new knowledge in order to gain first mover advantage and enhance their performance and profitability. Thus, the ability to absorb new knowledge has become crucial for organizations willing to achieve sustainable competitive advantage.

Absorptive capacity (ACAP) as an organizational capability enables the firm to benefit from external knowledge. ACAP is defined as one of the firm's key learning processes with regard to identifying, assimilating, and exploiting knowledge available in the environment. Organizational ACAP builds on the individual ACAP of its members, although it is not the sum of these individual capabilities. ACAP uses external knowledge to foster internal innovation. It is widely accepted that ACAP develops cumulatively, is path-dependent, and builds on existing knowledge. ACAP requires an understanding of how to work with other specialists. This is referred to as shared understanding, or complementarity between the recipient and source knowledge.

ACAP is a dynamic capability pertaining to knowledge creation and utilization. This is what causes the differences in a firm's ability to ensure a competitive advantage: According to the dynamic capability theory, ACAP is an ability that requires investments in order to be advanced.

With high ACAP, the firm could timely response to technological change by utilizing the knowledge and technology generated into new products and processes.

When the organization has assessed the potential value that a knowledge project can create for itself and seen the framework, the leader needs to evaluate whether the organization is ready for such a change. He may do it by weighing the value that the knowledge management solution brings against it risks (Conway and Sligar, 2002). A team that is considering starting a KM effort should take into consideration the potential areas of risk. There are nine main areas that might influence even impair the success of KM solution:

1. *Cost of solution*: A new solution places considerable risk and financial strain on the organization. The cost contains two parts, the upfront investment (hardware, software, and people costs for development, etc.) and operating cost (technical and non-technical).
2. *Organizational competencies*: Organizations need to balance their KM programs across three competencies: customer satisfaction, product leadership, and organizational operations. Outstanding performance in one dimension might lead to prosperity, but falling short in another dimension might threaten the organization's survival.
3. *Proving success*: The organization need to align the objectives of the knowledge management program with business success criteria, to develop a set of evaluations reflecting this alignment.
4. *KM adoption*: KM solutions involve two groups of persons: knowledge creators and knowledge users. Knowledge creators view KM as a threat to their prestige,

perhaps even their livelihood. As the only person who truly understands how to solve particular technical issues, why should he be interested in sharing this knowledge? Knowledge users may also lack enthusiasm. To address this risk, the true innovative problem solvers must appreciate that not only does their worth to the organization increase the more they share their knowledge of existing problems and move on to solve new issues, but equally important, their managers understand their value. Likewise, the knowledge user can be given new challenges that don't rely on repeating known solutions to problems.

5. *Executive sponsorship*: The role of sponsor involves much more than authorizing the expenditure for the initiative. Executive sponsorship for a new KM project is critical if the program is to be a success. Special challenges arise if the KM sponsor leaves the organization or moves to a new position. If the KM initiative was founded on a clear business case that was aligned with the key business goals, the new sponsor can rapidly appreciate the initiative's value.
6. *KM tools*: KM systems typically make life easier either or for the contributor or the knowledge re-user, but not both. It involves the responsibility for indexing and metadata. The contributor would prefer to simply submit material into the system without codifying metadata, entering keywords, and so on. On the other hand, knowledge users need to be able to find the most appropriate information as rapid as possible, so they want to enter the minimum amount of information necessary to retrieve the most appropriate knowledge. The solution to this problem may put more work on the contributor or on the knowledge user. It may introduce a third party to codify the knowledge or use the automated tools to help.
7. *Culture change*: When organization introduces a system-based approach, the group dynamics that made a community-based approach viable may be destroyed. Organizations fail when they adopt a KM strategy that straddles both a document-centric strategy and a collaboration strategy.
8. *Inflexibility*: Although a disciplined approach to understanding the goals and performance metrics of a KM initiative can reduce the uncertainty of creation value, KM remains inherently unpredictable. In addition to the uncertainties of the business environment and the capabilities of the technology itself, which affect all IT applications, KM depends on a change in working behavior. As a result, few KM initiatives are likely to follow their original plan exactly.
9. *Solution delivery process*: The final implementation risk involves the methods used to deliver the IT solutions. Implementation teams should look closely at the methods that their technology solution uses, whether in-house or external, to see how well they support the specific needs of this type of work.

Since there are such a wide range of risks, a disciplined approach to risk management becomes essential. But overspending on the managing uncertainties will reduce the value created by the initiative and underspending may threaten the ability to achieve the goal.

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