CHAPTER 2 - LITERATURE REVIEW

2.1. Data, Information, Knowledge & Wisdom

According to [2], the content of the human mind can be classified into five categories: data, information, knowledge, understanding, and wisdom. Ackoff indicates that the first four categories relate to the past; they deal with what has been or what is known. Only the fifth category, wisdom, deals with the future because it incorporates vision and design. With wisdom, people can create the future rather than just grasp the present and past. But achieving wisdom isn't easy; people must move successively through the other categories.

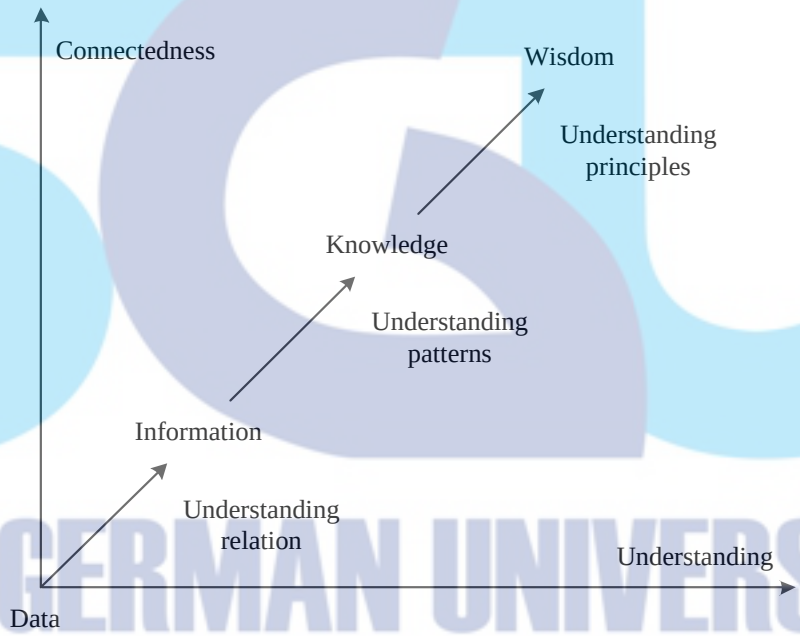

Figure 2.1. Data to Wisdom [3]

2.1.1. Data

Data is defined as raw. It simply exists and has no significance beyond its existence (in and of itself). It can exist in any form, usable or not. It does not have meaning of itself. In computer parlance, a spreadsheet generally starts out by holding data. Data represents a fact or statement of event without relation to other things [3].

2.1.2. Information

Information is defined as data that has been given meaning by way of relational connection. This "meaning" can be useful, but does not have to be. Information embodies the understanding of a relationship of some sort, possibly cause and effect [3].

2.1.3. Knowledge

Knowledge is defined as the appropriate collection of information, such that its intent is to be useful. Knowledge is a deterministic process. When someone “memorizes” information, then the knowledge has to be collected. This knowledge has a useful meaning to them, but it does not provide for, in and of itself, it’s an integration such as would conclude further knowledge. For example, elementary school children memorize, or collect knowledge of, the "times table". They can tell you that "3 x 3 = 9" because they have collected that knowledge (it being included in the times table). But when asked what is "1910 x 247", they cannot respond correctly because that entry is not in their times table. To correctly answer such a question requires a true cognitive and analytical ability that is only encompassed in the next level, which is understanding [3].

2.1.4. Understanding

Understanding is defined as an interpolative and probabilistic process. It is cognitive and analytical. It is the process by which we can take knowledge and synthesize new knowledge from the previously held knowledge. The difference between understanding and knowledge is the difference between "learning" and "memorizing". People who have understanding can undertake useful actions because they can synthesize new knowledge, or in some cases, at least new information, from what is previously known (and understood). That is, understanding can build upon currently held information, knowledge and understanding itself [3].

2.1.5. Wisdom

Wisdom is defined as an extrapolative and non-deterministic, non-probabilistic process. It calls upon all the previous levels of consciousness, and specifically upon special types of human programming (moral, ethical codes, etc.). It beckons to give us understanding about which there has previously been no understanding, and in doing so, goes far beyond understanding itself. It is the essence of philosophical probing. Unlike the previous four levels, it asks questions to which there is no (easily-achievable) answer, and in some cases, to which there can be no humanly known answer period. Wisdom is therefore, the process by which we also discern, or judge, between right and wrong, good and bad. Bellinger [3] believes that computers do not have, and will never have the ability to possess wisdom. Wisdom is a uniquely human state, wisdom requires one to have a soul, for it resides as much in the heart as in the mind. And a soul is something machines will never possess.

2.2. Knowledge Management

Knowledge Management (KM) is the process of gathering, managing and sharing employees' knowledge capital throughout the organization. Knowledge sharing throughout the organization enhances existing organizational business processes, introduces more efficient and effective business processes and removes redundant processes. It is a discipline that promotes a collaborative and integrated approach to the creation, capture, organization access and use of an enterprise's knowledge assets. KM has now become a mainstream priority for companies of all sizes. Capturing a company's most valuable knowledge as assets and distributing it across the enterprise is a business critical issue for many help desk, customer support, and IT departments [4].

Aligned with the definition of KM by Davenport [1] in chapter 1, KM is defined as the process of capturing, distributing, and using knowledge effectively in an organization.

Broadbent [5] defines KM as a form of expertise management which draws out tacit knowledge, making it accessible for specific purpose to improve the performance of organization; about how the organization's 'know-how' should be structured, organized, located, and utilized to provide the most effective action at that point time.

The Gartner Group in Bhojaraju [4] defines Knowledge management as a discipline that promotes an integrated approach to identifying, capturing, evaluating, retrieving, and sharing all of an enterprise's information assets. These assets may include databases, documents, policies, procedures, and previously un-captured expertise and experience in individual workers. Knowledge management issues include developing, implementing and maintaining the appropriate technical and organizational infrastructure to enable knowledge sharing.

2.2.1. History of Knowledge Management

The field of knowledge management has received increasing amounts of attention in recent years; however, the roots of the field can be traced back many years. In fact, the concept of knowledge management is nothing new. Corporations have always had some process to synthesize their experience and integrate it with knowledge acquired from outside sources (e.g. inventions, purchased patents) [6].

In particular, firms have long employed various knowledge management techniques. Communities of practice, for instance, have been in existence for a great many years. In ancient Rome, 'corporations' of metalworkers, potters, masons, and other craftsmen had both a social aspect and a business function. In the middle ages, guilds fulfilled similar roles for artisans throughout Europe. Firms have also long invested in training, mentoring and other educational and knowledge sharing programs [6].

However, recent advancements in technology have enabled the knowledge management field to make dramatic improvements in its ability to store, retrieve, capture and transfer knowledge from one area of the firm to another. These recent technological developments have enabled firms to institutionalize their knowledge management function and integrate the knowledge management techniques mentioned above with new technologies in order to create integrated knowledge management programs. This development has enabled the field of knowledge management to take off. This example of "technological specification" explains how advances in technological development often occur in rapid "bursts of evolutionary activity" after a small improvement in a technology opens the door to a wider range of applications. For example, consider the effects that the relatively small development of the web browser had on the development of the Internet. Once Netscape developed a user-friendly HTML interface, the web browser brought about rapid advances in the mass-market penetration of the Internet [6].

In this manner, technological speciation can also be used to analyze the development of the knowledge management field. Recent developments in information technology have an important role for the sudden emergence of knowledge management. Information technology has provided new tools to better perform the activity of building knowledge capital. Specifically, the knowledge management field witnessed substantial “evolution” after the introduction of Lotus Notes, which was one of the earliest integrated email, database and document management applications. This software for the first time allowed users to access, share information and communicate with employees across a global organization [6].

2.2.2. Components of Knowledge Management

Based on actual experiences of the leading global KM case studies, the components for KM can be broadly categorized into three classes - People, Processes, and Technology (see Figure 2.2.). While all three are critical to build a learning organization and get business results from KM, a majority of organizations worldwide implementing KM have found it relatively easier to put technology and processes in place, whereas the "people" component has posed greater challenges [4].

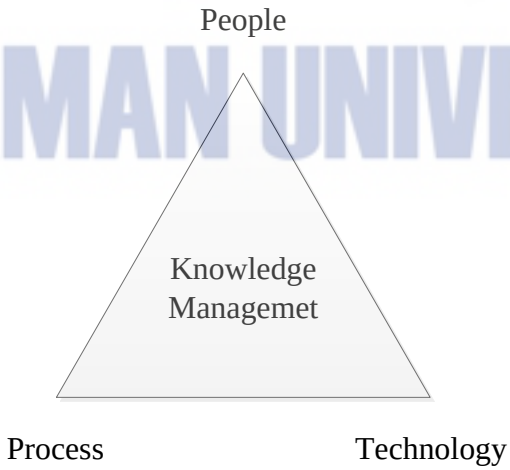

Figure 2.2. Components of Knowledge Management [4]

The biggest challenge in KM is to ensure participation by the people or employees in the knowledge sharing, collaboration and re-use to achieve

business results. In many organizations, this requires changing traditional mindsets and organizational culture from “knowledge-hoarding” (to keep hidden or private) to “knowledge-sharing” (share among team members) and creating an atmosphere of trust. This is achieved through a combination of motivation / recognition and rewards, re-alignment of performance appraisal systems, and other measurement systems. A key to success in Knowledge Management is to provide people visibility, recognition and credit as “experts” in their respective areas of specialization - while leveraging their expertise for business success [4].

The Process component include standard processes for knowledge-contribution, content management (accepting content, maintaining quality, keeping content current, deleting or archiving content that is obsolete), retrieval, membership on communities of practice, implementation-projects based on knowledge-reuse, methodology and standard formats to document best-practices and case studies, etc. It is important for processes to be as clear and simple as possible and well understood by employees across the organization [4].

KM technology solutions provide functionality to support knowledge sharing, collaboration, workflow, document-management across the enterprise and beyond into the extended enterprise. These tools typically provide a secure central space where employees, customers, partners and suppliers can exchange information, share knowledge and guide each other and the organization to better decisions. The most popular form of KM technology enablement is the Knowledge-Portal on the Corporate Intranet (and extranets where customers, partners and/or suppliers are involved). Common technologies used for knowledge portals include standard Microsoft technologies or Lotus Notes databases. A company must choose a technology option that meets its KM objectives and investment plan. While technology is a key enabler to KM, it is important to ensure that the technology solution does not take the focus away from business issues and is user-friendly and simple to use. Many companies have made the mistake of expending a disproportionately high portion of their KM effort and resources on technology - at the cost of people-involvement or strategic commitment - resulting in zero or very limited business results. It is

also important to remember that users of the KM system are subject-matter experts in their respective areas of specialization and not necessarily IT experts [4].

2.2.3. Type of Knowledge

According to Morrissey [6], knowledge can be thought of as information combined with experience, context, interpretation, and reflection is highly contextual. It is a high-value form of information that is ready for application to decisions and actions within organizations.

There are two types of knowledge, tacit knowledge and explicit knowledge.

- **Tacit knowledge**

  Tacit knowledge can be defined as knowledge that is subconsciously understood and applied, difficult to articulate, developed from direct experience and action, and usually shared through highly interactive conversation, storytelling and shared experience. Examples of tacit knowledge include "best practice" performed in an organization, management skills, technologies, customer, market, and competitor intelligence. Tacit knowledge is, by definition, hard to codify and store [6].

- **Explicit knowledge**

  Explicit knowledge, on the other hand, is more precisely and formally articulated, although removed from the original context of creation or use. Explicit knowledge includes, for example, the content of spreadsheets, management reports, procedural and training manuals. In other words, explicit knowledge is any knowledge that can be codified and documented [6].

Table 2.1. Comparison Properties of Tacit vs. Explicit Knowledge [7]

Properties of Tacit Knowledge	Properties of Explicit Knowledge
Ability to adapt, to deal with new and exceptional situations	Ability to disseminate, to reproduce, to access and re-apply throughout the organization
Expertise, know-how, know-why, and care-why	Ability to teach, train
Ability to collaborate, to share a vision, to transmit a culture	Ability to organize, to systemize, to translate a vision into a mission statement, into operational guidelines
Coaching and mentoring to transfer experimental knowledge on a one-to-one, face-to-face basis	Transfer knowledge via products, services, and documented processes

There is also somewhat of a paradox at play here: highly skilled, experienced, and expert individuals may find it harder to articulate their know-how. Novices, on the other hand, are more apt to easily verbalize what they are attempting to do because they are typically following a manual or how-to process. Table 2.1 summarizes some of the major properties of tacit and explicit knowledge [7].

Typically, the more tacit knowledge is the more valuable it tends to be. The paradox lies in the fact that the more difficult it is to articulate a concept such as story, the more valuable that knowledge may be. This is often witnessed when people make reference to knowledge versus know-how, or knowing something versus knowing how to do something. Valuable tacit knowledge often results in some observable action when individuals understand and subsequently make use of knowledge. Another perspective is that explicit knowledge tends to represent the final end product whereas tacit knowledge is the know-how or all of the processes that were required in order to produce that final product [7].

2.2.4. Model of Knowledge

An organization creates knowledge through the interactions between explicit knowledge and tacit knowledge. The interaction between the two types of knowledge is called knowledge conversion. Through the conversion process, tacit and explicit knowledge expands in both quality and quantity. Nonaka and Takeuchi [8] has identified that there are four modes of knowledge conversion (see Figure 2.3). They are:

- Socialization: from tacit knowledge to tacit knowledge
- Externalization: from tacit knowledge to explicit knowledge
- Combination: from explicit knowledge to explicit knowledge
- Internalization: from explicit knowledge to tacit knowledge

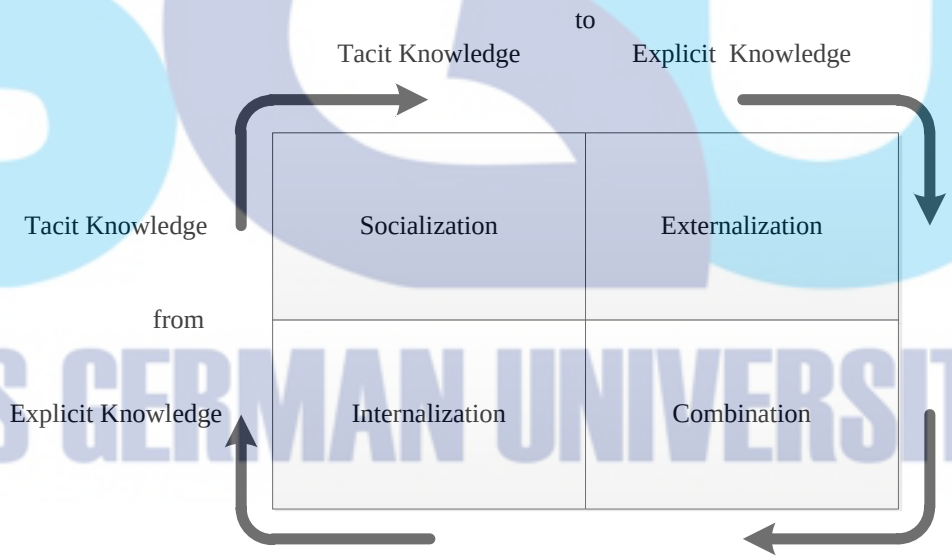

Figure 2.3. Model of Knowledge [8]

When knowledge is internalized to become part of individuals' tacit knowledge bases in the form of shared mental models or technical know-how, it becomes a valuable asset. This tacit knowledge accumulated at the individual level can then set off a new spiral of knowledge creation when it is shared with others through socialization [9].

2.2.4.1. Socialization

Socialization is the process of converting new tacit knowledge through shared experiences. Since tacit knowledge is difficult to formalize and often time- and space-specific, tacit knowledge can be acquired only through shared experience, such as spending time together or living in the same environment. Socialization typically occurs in a traditional apprenticeship, where apprentices learn the tacit knowledge needed in their craft through hands-on experience, rather than from written manuals or textbooks. Socialization may also occur in informal social meetings outside of the workplace, where tacit knowledge such as worldviews, mental models and mutual trust can be created and shared. Socialization also occurs beyond organizational boundaries. Firms often acquire and take advantage of the tacit knowledge embedded in customers or suppliers by interacting with them [9].

2.2.4.2. Externalization

Externalization is the process of articulating tacit knowledge into explicit knowledge. When tacit knowledge is made explicit, knowledge is crystallized, thus allowing it to be shared by others, and it becomes the basis of new knowledge. Concept creation in new product development is an example of this conversion process. Another example is a quality control circle, which allows employees to make improvements on the manufacturing process by articulating the tacit knowledge accumulated on the shop floor over years on the job. The successful conversion of tacit knowledge into explicit knowledge depends on the sequential use of metaphor, analogy and model [9].

2.2.4.3. Combination

Combination is the process of converting explicit knowledge into more complex and systematic sets of explicit knowledge. Explicit knowledge is collected from inside or outside the organization and then combined, edited or processed to form new knowledge. The new explicit knowledge is then disseminated among the members of the organization. Creative use of computerized communication networks and large-scale databases can facilitate this mode of knowledge conversion. When the comptroller of a company collects information from throughout the organization and puts it together in a context to make a financial report, that report is new knowledge in the sense that it synthesizes knowledge from many different sources in one context. The combination mode of knowledge conversion can also include the `breakdown' of concepts. Breaking down a concept such as a corporate vision into operationalized business or product concepts also creates systemic, explicit knowledge [9].

2.2.4.4. Internalization

Internalization is the process of embodying explicit knowledge into tacit knowledge. Through internalization, explicit knowledge created is shared throughout an organization and converted into tacit knowledge by individuals. Internalization is closely related to `learning by doing'. Explicit knowledge, such as the product concepts or the manufacturing procedures, has to be actualized through action and practice. For example, training programs can help trainees to understand an organization and themselves. By reading documents or manuals about their jobs and the organization, and by reflecting upon them, trainees can internalize the explicit knowledge written in such documents to enrich their tacit knowledge base. Explicit knowledge can be also embodied through simulations or experiments that trigger learning by doing [9].

2.2.5. Knowledge Management Assets and Processes

Typically, there are six knowledge assets in an organization [10], namely: stakeholder relationship (includes licensing agreements; partnering agreements, contracts and distribution agreements), human resource (skills, competence, commitment, motivation and loyalty of employees), physical infrastructure (office layout and information and communication technology such as databases, e-mail and intranets), culture (organizational values, employee networking and management philosophy), practices and routines (formal or informal process manuals with rules and procedures and tacit rules, often refers to "the way things are done around here"), and intellectual property (patents, copyrights, trademarks, brands, registered design and trade secrets).

Knowledge management processes maximize the value of knowledge assets through collaboration, discussions, and knowledge sharing. It also gives value to people's contribution through awards and recognitions. Process includes generation, codification (making tacit knowledge explicit in the form of databases, rules and procedures), application, storing, mapping, sharing and transfer. Together these processes can be used to manage and grow an organization's intellectual capital [4].

2.2.6. Challenges for Managing Knowledge

Most often knowledge lies within an organization implicitly, out of sight, undervalued and underused. Often, it leaves the building when the employees walk out of the company along with them. Managing the flow of knowledge around an organization is a challenge. The Knowledge management process normally face six challenges at each stage of the process flow [11], and failing to meet any of these challenges can derail an organization's ability to use its knowledge assets to its best advantage. The six challenges are as follows:

2.2.6.1. Knowledge Acquisition

The challenge here is to get hold of the information that is around, and turn it into knowledge by making it usable. This might involve, for instance, making tacit knowledge explicit, identifying gaps in the knowledge already held, acquiring and integrating knowledge from multiple sources (e.g. different experts, or distributed sources on the WWW), acquiring knowledge from unstructured media (e.g. natural language or diagrams) [4].

2.2.6.2. Knowledge Modeling

Modeling bridges the gap between the acquisition of knowledge and its use. Knowledge model structures must be able to represent knowledge so that it can be used for problem solving. One important knowledge modeling idea is ontologies, which are specifications of the generic concepts, attributes, relations and axioms of a knowledge base or domain. Ontologies can act as placeholders and organizing structures for acquired knowledge, while also providing a format for understanding how knowledge will be used [4].

2.2.6.3. Knowledge Retrieval

When a knowledge repository gets very large, finding a particular piece of knowledge can become very difficult. There are two related problems to do with knowledge retrieval. First, there is the issue of finding knowledge again once it has been stored, understanding the structure of your archive in order to navigate through it efficiently. And second, there is the problem of retrieving the subset of content from the repository that is relevant to a particular problem. This second problem, the dynamic extraction of knowledge from a repository, may well set problems for a knowledge retrieval system that alter regularly and quickly during problem-solving [4].

2.2.6.4. Knowledge Reuse

One of the most serious impediments to cost-effective use of knowledge is that often knowledge bases or systems are constructed afresh. It is unusual for problem-solving experience or domain content to be acquired and then reused, partly because knowledge tends to require different representations depending on the problem-solving that it is intended to do. Understanding the use and application of knowledge would enable more leverage to be gained from the knowledge already at hand, thereby increasing the returns on the investment in those knowledge assets [4].

2.2.6.5. Knowledge Publishing

The challenge of publishing or disseminating can be described as getting the right knowledge, in the right form, in the right place, to the right person, at the right time. Different users will require knowledge presented and visualized in different ways, and the quality of such presentation is not merely a matter of preference, but can radically affect the value of the knowledge to the user. Getting presentation right will involve understanding the different perspectives of people with different agendas, while an understanding of knowledge content will help to ensure that

important related pieces of knowledge get published at the appropriate time [4].

2.2.6.6. Maintenance

The last challenge is to keep the knowledge repository functional. This may involve the regular updating of content as content changes (e.g. as price lists are revised). But it may also involve a deeper analysis of the knowledge content. Some content has a considerable longevity, while other knowledge dates very quickly. If a repository of knowledge it to remain active over a period of time, it is essential to know which parts of the knowledge base must be discarded and when. Other problems involved in maintenance include verifying and validating the content, and certifying its safety [4].

2.2.7. KM techniques & technologies

According to Morrissey [6], there are wide ranges of knowledge management tools in use today by firms seeking to implement a knowledge management solution. These tools can be broadly classified into two distinct categories, knowledge management techniques and knowledge management technologies.

2.2.7.1. Knowledge Management Techniques

Knowledge management techniques are most effective at capturing employees' tacit knowledge, although many of the management techniques below also provide an explicit knowledge capture component. These management techniques are particularly effective at capturing tacit knowledge because many of the knowledge management techniques detailed below involve human interaction where contextual knowledge can be transferred. Under ideal circumstances, this type of contextual knowledge can be codified in a general form and shared with larger populations [6].

The more common knowledge management techniques, in increasing order of sophistication, include:

- Mentorship programs;
- After action reviews / project summaries;
- Regular intra-office (or intra- division) meetings;
- Storytelling;
- Communities of practice, and
- Centers of excellence.

Each of these management techniques is discussed in greater detail below.

- **Mentorship programs**

One of the least sophisticated and easiest to implement forms of knowledge management is a mentorship program. A mentorship program allows experienced senior employees to share their knowledge and experience with junior employees. Junior employees can seek advice and counsel of their mentors when encountering a particular challenge, which the mentor may have dealt with previously. Mentoring programs are an inexpensive way to inspire future leaders, improve management and staff relationships and prepare people to succeed an aging workforce [6].

- **After-action reviews / project summaries**

Originally developed and used extensively by the U.S. Army, an after action review is a discussion of a project or an activity that enables the individuals involved to learn for themselves what happened, why it happened, what went well, what needs improvement and what lessons can be learned from the experience. The spirit of an after action review is one of openness and learning - it is not about problem fixing or allocating blame. Lessons learned are not only tacitly shared on the spot by the individuals involved, but can be explicitly documented and shared with a wider audience [6].

- **Regular intra-office or intra-division meetings**

The purpose of these meetings is to bring together employees from different offices or different areas of the firm. Such interaction between disparate areas of the firm allows employees to exchange ideas and experiences and thus transfer knowledge between areas of the firm. In fact, off-site meetings are a great way to get people together, away from the office, to discuss important topics and share information. They can prove really valuable for networking with colleagues and learning about what's going on in other areas within the organization [6].

- **Storytelling**

Storytelling is another management technique, which has been used to facilitate the exchange of knowledge between members of an organization. Robert McKee, a prominent screenwriting coach, says, “The best way to persuade people is by uniting an idea with an emotion.” By telling a compelling story you not only weave a lot of information into the telling, but you also arouse your listener's emotions and energy. Steve Denning, a leading advocate of storytelling, states: “storytelling relinquishes a straightforward journey from A to B, and in the end provides a vehicle for conveying unseen tacit knowledge.” Storytelling draws on deep-flowing streams of meaning, and on patterns of primal narratives of which the listeners are barely aware, and so catalyzes visions of a different and renewed future [6].

- **Communities of practice**

Communities of practice are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis. Communities of practice are formed around a common sense of purpose and a real need to know what each other knows. These communities may have many different purposes. They may create a forum for group members to document lessons learned or help create a standardized set of “best

practices". Alternatively, a community of practice may help to initiate new employees into a group or trade, serve as a source of advice to help solve common business problems, or function as a sounding board for new ideas [6].

- **Centers of excellence**

Centers of excellence, or knowledge centers, are formal centralized organizations whose job also consists of synthesizing and distributing the firm's knowledge (these knowledge centers) continually digest the firm's experience. These centers of excellence can help to centralize knowledge codification and help relieve some of the burden of knowledge capture from operating units [6].

2.2.7.2. KM Technologies

In addition to the above knowledge management techniques, there are also a host of knowledge management technologies. In contrast to knowledge management techniques, knowledge management technologies excel at capturing employees' explicit knowledge, but have difficulty capturing tacit or contextual knowledge [6].

According to Morrissey [6], there are 4 categories of knowledge management technologies: knowledge storage tools, search and retrieval tools, collaboration tools and communication tools. These categories of knowledge management technologies are discussed below:

- **Knowledge Storage Tools**

Knowledge storage tools, also known as content databases, allow a firm to electronically collect and store information. Examples of such storage tools include knowledge databases (Lotus Notes) as well as corporate intranets, which serve as a repository of, project files and other knowledge created by users. The latest knowledge storage tools differ from earlier database or file systems in that these newer tools have more sophisticated organizational structures, which allow users to more easily identify and

locate desired information. In addition, the Internet has allowed for global access to such knowledge databases so that employees can store and retrieve information on a worldwide basis [6].

- **Search and Retrieval Tools**

The second category of tools is the search and retrieval tools. These tools allow the user to easily search for and locate information within a knowledge database or other knowledge repository. These tools also include tools which allow users to locate specific expertise within (or external to) a firm. For example, an employee may be working on a project which deals with a specific challenge. Using an expertise locator tool, the employee could query the expertise database and identify other employees (internal or external to the firm) who may have experience or expertise in this particular field. These tools are particularly useful in helping employees locate others within a dispersed organization who may possess valuable knowledge relevant to their work [6].

- **Collaboration Tools**

Collaboration tools allow employees to create a virtual, web-based workspace in which they can share files and interact in an electronic environment. Such tools can provide a collaborative workplace which can enable distributed teams to work together to accelerate and improve development and delivery of products and services, optimize collaborative business processes, and improve innovation, problem-solving, and decision-making. These tools allow for the separated project teams to exchange electronic files, discussing topics on-line, as well as store, retrieve and organize project work in a centralized location [6].

- **Communication Tools**

Various communication tools can also help firms address their knowledge management issues. These communication technologies can be classified into asynchronous and synchronous tools. Asynchronous tools include

technologies, which allow communication between two or more users on a sequential basis. Examples of such technologies include email, wikis and weblogs. Synchronous tools are those technologies, which facilitate communication between users on a real-time basis. Discussion and chat technologies and videoconferencing are examples of synchronous communication tools. Both asynchronous and synchronous tools help to improve the knowledge sharing, interaction and transfer of information between employees in an organization [6].

2.2.8. Knowledge Importance

Dalkir [7] has identified that the major business drivers behind today's increased interest and application of KM lie in four key areas:

- Globalization of business
  Organization today is more global, multisite, multi-lingual, and multicultural in nature [7].

- Leaner organization
  The employees today are doing more and faster, but the employees also need to work smarter as knowledgeable workers, working in increased pace and workload [7].

- Technological advances
  The employees are more connected. Information technology advances have made connectivity not only ubiquitous but also have radically changed expectations: the employees are expected to be on at all times and the turnaround time in responding is now measured in minutes, not weeks [7].

2.2.9. KM-IRIS Methodology

In order to successfully carry out a KMS development and implementation project, while at the same time reducing the degree of complexity, it would be a great aid to be able to use a stage-based methodology that defines the whole creative process in each phase. This would involve defining, among other things, the tasks to be performed, the techniques to be used, the modeling languages for representing the knowledge and the technological infrastructure that allows knowledge to be stored, processed, and distributed, depending on the roles that have been defined [12].

With a view to solving this problem of a lack of such knowledge management methodologies, since 2003, the IRIS Group (Grupo de **I**nvestigación en **I**ntegración y **R**e-**I**ngeniería de **S**istemas / Research Group in Systems Integration and Reengineering) at the Universitat Jaume I in Castelló (Spain) has been working on a project entitled "Methodology for Knowledge Management." The objective was to develop and validate a useful, practical methodology that can be used to guide the process of developing and implementing a system for gathering, managing, applying, and transferring the knowledge that is generated both inside an enterprise and in the relations it has with the different organizations it works with. At the same time, it must also ensure the quality, security, and authenticity of the knowledge supplied. The general methodology is divided into five phases [12]:

- Analysis and identification of the target knowledge
- Extraction of the target knowledge
- Classification and representation
- Processing and storage
- Utilization and continuous improvement

Each phase that make up the methodology will be discussed in the next sub-chapter in more detail, which is, the activities involved in each step, the techniques and tools that can be used to support the process, and the main results that are to be expected (see Table 2.2.).

Table 2.2. KM-IRIS Methodology for Knowledge Management in an Organization [12]

PHASES	ACTIVITIES	TECHNIQUES	EXPECTED RESULTS	COMPUTER SUPPORT TOOLS
PHASE I. Identification	• Identify the conceptual blocks of knowledge • Classify into ontological categories • Define the target knowledge (knowledge requirements)	• Templates and questionnaires to identify blocks of knowledge • Reference models concerning the target of knowledge	• Conceptual blocks of knowledge • Target knowledge • Categories	• Office automation tools • Modeling tools
PHASE II. Extraction	• Extract knowledge from sources in order to define the input variables and categorize it • Define the extraction and calculation procedures	• Templates to define the input variables • Reference models for extracting and calculating target knowledge	• Set of input variables • Extraction and calculation procedures	• Office automation tools • Modeling tools
PHASE III. Representation	• Establish the relations within the target knowledge • Draw up the knowledge map	• Metamodelling (UML) • Ontologies • Conceptual maps	• Model of the Knowledge map	• Modeling tools • Ontology engin-eering tools
PHASE IV. Processing	• Develop the technical infra-structure supporting the knowledge map by following an object-oriented methodo-logy for the development of computer systems	• BPM techniques • ETL techniques • Document / DBMS • Data warehouse • OLAP • Data mining	• Knowledge portal (Executable knowledge map)	• BPM techniques • ETL techniques • Document / DBMS • Data warehouse • OLAP • Data mining
PHASE V. Utilization	• Establish training and conti-nuous improvement mecha-nism among the member of the organization • Carry out maintenance and the feedback process on the knowledge management system	• e-Learning • Groupware • TQM • ISO standard of quality	• Efficient use of knowledge within the organization	• Office automation tools • Modeling tools • Learning tools

2.2.9.1. PHASE I (Identification)

One of the aspects that usually generate most confusion in KM is the difference between knowledge and information. This uncertainty is increased by the fact that KM relies on information technologies for support instead of a set of specific technologies that could be called "knowledge technologies." If information and knowledge are not the same, then there seems to be something strange about the fact that knowledge can be handled using technologies that were designed for processing information [12].

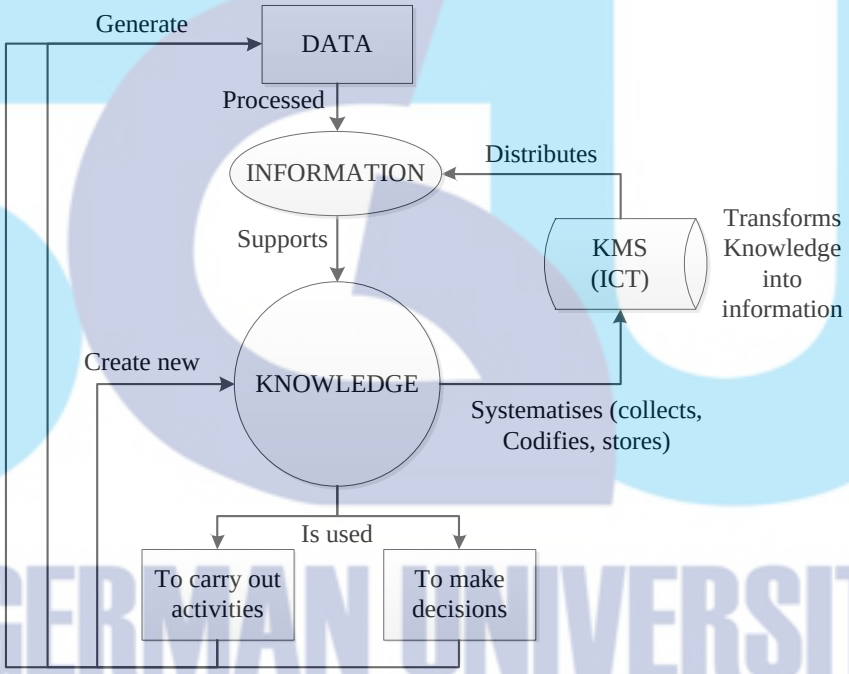

Figure 2.4. KMS Relation with Information & Knowledge [12]

Figure 2.4 attempts to unravel this paradox. As it is seen, knowledge and information are different. The individual who possesses knowledge needs to analyze and assess information so that in a given situation, they can make the right decisions or carry out the activities that have been proposed. In this context, the goal of the KMS is to identify existing knowledge and extract, collect, and codify it as information so that it can be stored and distributed using a computer system. Thus, the KMS transforms the organization's knowledge into information that will later be

utilized by individuals to make better decisions or to better perform their tasks and duties. The quantity and quality of information that is used by the individuals in the organization to make decisions based on their knowledge therefore increases because now it is not only produced by processing data but also come from already existing knowledge. Moreover, the KMS helps to generate new knowledge because having more information available means that when faced with the same situation, individuals are more likely to make a different kind of decision or to solve problems in a more efficient way, which, in turn, is a source of feedback for the system. In this context, the organization's knowledge that will be extracted, processed, and codified in KMS (thereby converting it into information) is called target knowledge [13].

Therefore, the aim of this first phase of the methodology is to identify the knowledge that is going to be managed by the system, that is to say, the target knowledge. In order to identify this knowledge using a pragmatic vision is needed by us by directing the search towards the knowledge that is useful to the organization and will provide an added value when utilized. To make it easier to identify in an organized fashion, it is better to begin by defining blocks of knowledge, which are understood as being any elements belonging to the organization or to its surroundings that contain a particular type of knowledge. These conceptual blocks of knowledge are different for each type of organization, and they may even differ within the same kind of organization because such blocks can only be defined by taking into account the strategic objectives of the organization and its core activities [12].

Once the desired elements of the organization (conceptual blocks of knowledge) have been defined, the target of knowledge must be identified to enable to be extracted, represented, and utilized in each of these conceptual blocks [12].

Finally, after identifying the knowledge in each block, a detailed description of the knowledge that has been defined as target knowledge and, depending on the volume, perhaps build up an ontological classification so that it can be represented, processed, and utilized at a later stage must be provided. Valuable aids to carry out this phase include resources, such as templates, questionnaires, and reference models, that help organizations of the same type or sector to define their conceptual blocks of knowledge, as well as to identify, describe, and classify the target knowledge [12].

2.2.9.2. PHASE II (Extraction)

The aim of this phase is to define suitable mechanisms with which to obtain the target knowledge that was identified in the previous step. To achieve this, first the input variables that will be used in order to obtain the target knowledge must be defined. These input variables may be data or documents that are in the organization's information system, that is to say, in sources of explicit knowledge, in which case they will be called explicit input variables. On the other hand, they might consist of information or knowledge held by people related to the organization, that is; they lie in sources of tacit knowledge, in which case they will be labeled tacit input variables [12].

Another source of variables will be the actual KMS itself because one or several input variables could be target knowledge generated by the KMS that has been implemented in the organization and which can be used to create new knowledge. So, it must therefore be capable of providing itself with feedback. Once the variables have been defined, the sources of knowledge must be identified, which are understood to mean any

components within or outside an organization that supply those variables [12].

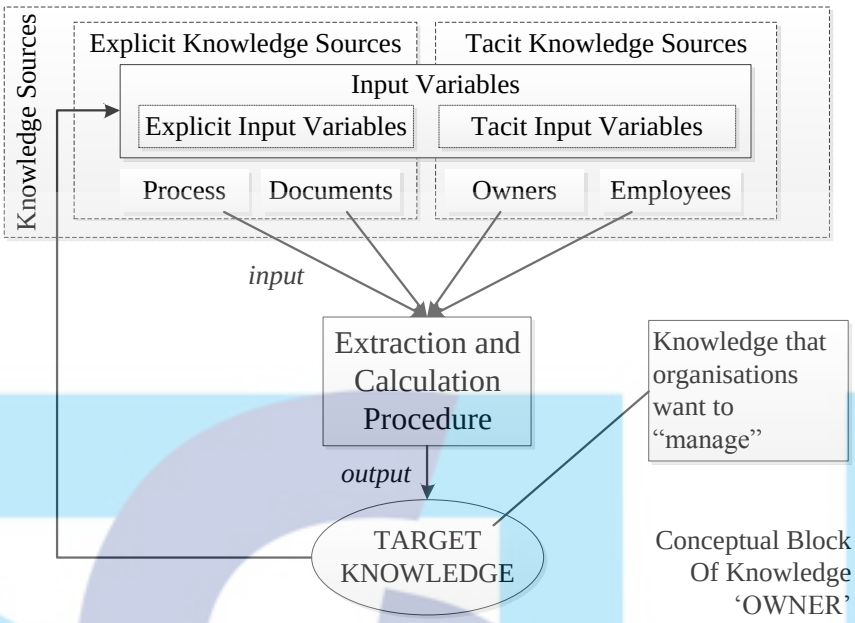

Figure 2.5. Phase II of the KM-IRIS Methodology for KM [5]

The final step then is to define the procedure that is going to be used to extract the variables from the sources and also the method of calculation—the algorithm—that allows target knowledge to be obtained by combining the input variables. These procedures will vary according to the conceptual block of knowledge that is being dealt with and the input variables that have been defined (see Figure 2.5.) [12].

Table 2.3. Example of Phase I & II of the KM-IRIS Methodology after tailoring it to the needs of an enterprise [12]

Conceptual Block	Employee	Process	Customer	Product
Phase I.				
Ontological category	Satisfaction	Sales	Profit	Cost
Target knowledge	Economic satisfaction	Receive an order	Economic profitability customers	Economic profitability of product
Description	Extent to which the employee is satisfied with the salary he/she is paid	Best practices in accepting orders	Classification of customers according to their economic profitability	Classification of customers according to their economic profitability
Phase II.				
Input variables	• Opinion about employees and immediate bosses • Average salary in the sector	• Information (Documents+ Data) that is needed or generated to carry out the task, and identification of its origin / destination • Human & technological resources that are involved Control or associated regulations	• Annual sales turnover • Average price of products acquired • Average quality of products acquired • Number of claims lodged • Average length of payment period in days • Customer's behavior patterns	• Average cost of the raw materials and labor used to manufacture product • Average profit obtained from sale of the product • Average cost assigned to the product as advertising costs • Average cost deriving from financial expenses arising from marketing the product
Knowledge source	Employee consultancy firms, business associations, trade unions in the business sector	Employee	Databases and document databases data warehouses	Databases and document databases data warehouses
Calculation procedure	Statistical calculation	Detailed description of the procedure for running task using the IDEF0 modeling language	Statistical calculation	Statistical calculation
Extraction procedure	Questionnaires and personal enquiries	Templates for defining profiles of work positions drawn up by the IRIS group	ETL, OLT, and OLAP techniques data mining techniques	ETL, OLT, and OLAP techniques data mining techniques

Table 2.3 shows an example of the results obtained in Phase I and Phase II of the KM-IRIS methodology after tailoring it for knowledge management in an enterprise. Employee and process deal with tacit sources of knowledge, and customer and product are concerned with explicit sources [12].

2.2.9.3. PHASE III (Representation)

In the third phase of the methodology, after identifying and extracting the knowledge, the target knowledge will be represented in such a way as to provide us with a model of the knowledge map of the organization [14].

In line with the Model Driven Architecture (MDA) approach proposed by the Object Management Group [15], in the KM-IRIS methodology, the knowledge map is represented at different levels of abstraction. Initially, a model of the knowledge map is created at the Computation Independent Model (CIM) level, that is to say, independent of the computation. Later, transformation mechanisms are used to obtain the corresponding model at the Platform Independent Model (PIM) level. Modeling of the knowledge map at both the CIM and the PIM level is performed by means of the set of profiles developed for this purpose using the extension mechanisms provided by the latest version 2.0 of Unified Modeling Language [12].

The CIM model of the knowledge map must include the conceptual blocks of knowledge that have been identified within the organization, the target knowledge of each block, their location, and the way they interrelate with the other elements on the map, as well as what input variables are required to obtain them and the procedure for calculating or obtaining them. At this level, the CIM model is aided by the use of conceptual and ontological maps as a step prior to setting out a common framework of the concepts inherent to the organization [12].

The PIM model will result from the transformation of the model of the CIM level knowledge map. This phase involves determining what part of the CIM model is worthwhile computerizing and then running the previously defined transformation mechanisms [12].

2.2.9.4. PHASE IV (Processing)

Once the PIM model of the knowledge map has been obtained, the next step is to generate an executable model for it that can be run on a certain technological platform. This model, called a Platform Specific Model (PSM) in the MDA approach, is produced as the result of processing the knowledge map on a specific computer platform in order to allow the enterprise to obtain and utilize the knowledge wherever and whenever it is requested [12].

The activities to be carried out in this phase are similar to those proposed in any other object-oriented methodology for developing a computer system, but they are based on the previously obtained PIM models. The final result will be a knowledge portal that shows the knowledge map of the enterprise and offers different tools with which to locate and access it [12].

2.2.9.5. PHASE V (Utilization)

The last phase is the utilization of the knowledge, which involves not only making a knowledge portal available to the organization but also providing it with the mechanisms it needs to make efficient use of the KMS that has been developed [9]. This involves performing different types of tasks related to training, evaluation, continuous improvement, and maintenance. Some of the most notable tasks are as follows [12]:

- Establish policies and procedures to allow self-maintenance of the system [16]. In order to achieve this objective, the knowledge portal must be integrated with the different computer systems used in the enterprise. In this way, all the explicit input variables will be extracted automatically. It is also important to introduce organizational changes so that tacit technical knowledge is codified and stored in such a way as to make it automatically available from the portal. For example, templates and forms must be defined for storing know-how, skills, experience, and so forth so that what was previously kept inside

people's minds, in specific documents or was jotted down on a piece of article, is now integrated within the portal.

- Establish a system of interrelated indicators that keep us permanently informed about the status of the KMS at both the strategic, technological and organizational levels [12].

- Consideration of cultural aspects to facilitate the participation and cooperation of all members of staff at the organization, as well as all the stakeholders involved in the organization's objectives, that is, interactions with customers, suppliers, administration, trade unions, and so forth [12].

The adaptation of the general methodology to the specific case of enterprises can be seen in Figure 2.6. The methodology was applied to a large textile enterprise so as to be able to validate and refine it [12].

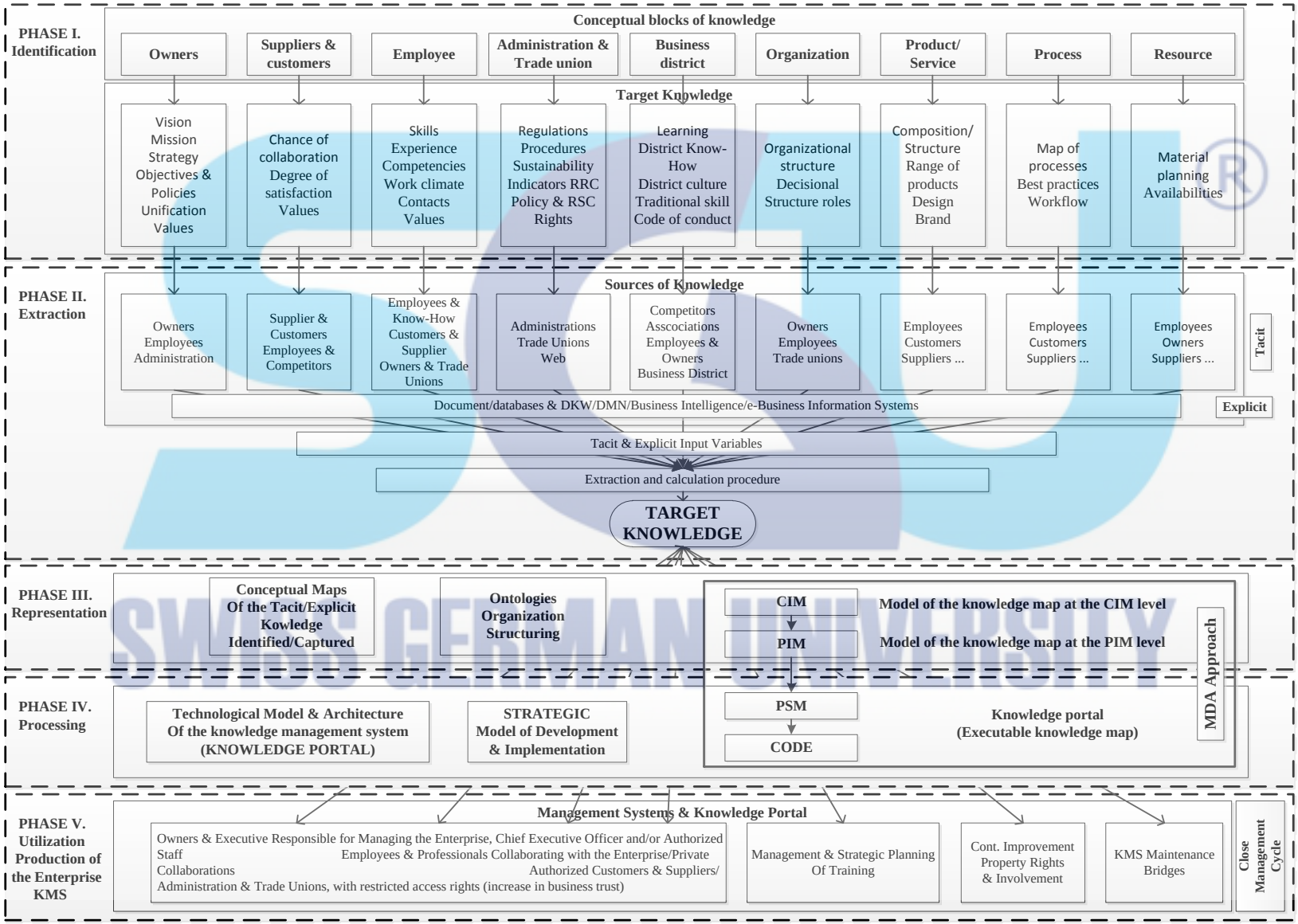

Figure 2.6. Specialized Version of the KM-IRIS Methodology for Knowledge Management in an Enterprise [12]

2.3. Production Process

According to the Oxford Dictionary, the definition of industry is economic activity that gives value added to raw material and processes it into finished good. There are several classifications in industry [17], including:

- Primary Industry: Cultivate and exploit natural resources, such as agriculture and mining
- Secondary Industry: Take the output of the primary industries and convert them into consumer and capital goods. Manufacturing is the principal activity in this category, but construction and power utilities are also included
- Tertiary Industry: Constitute the service sector of the economy.

The beginnings of machine tool technology occurred during the Industrial Revolution. During the period 1770-1850, machine tools were developed for most of the conventional material removal processes, such as boring, turning, drilling, milling, shaping, and planing [17].

Groover [17] has identified that the final products made by the manufacturing industries can be divided into two major classes, which are consumer goods and capital goods. Consumer goods are products purchased directly by consumers, such as cars, mobile phone, clothes, shoes, laptop, and bags. Capital goods are goods that purchased by companies to produce goods and / or provide services, such as: aircraft, communication equipment, trucks and buses, railroad locomotives, machine tools, and construction equipment. Most of these capital goods are purchased by the service industries.

In addition to final products, other manufactured items include the materials, components, and supplies used by the companies that make the final products. Example of these items include steel, bar stock, metal stampings, machined parts, plastic molding and extrusions, cutting tools, dies, molds, and lubricants. Thus, the manufacturing industries consist of a complex infrastructure with various categories of layers of intermediate suppliers with whom the final consumer never deals [17].

2.3.1. Process Planning

According to [17], process planning involves determining the most appropriate manufacturing processes and the order in which they should be performed to produce a given part or product specified by design engineering. If it is an assembled product, process planning includes deciding the appropriate sequence of assembly steps. The process plan must be developed within the limitations imposed by available processing equipment and productive capacity of the factory. Part or subassemblies that cannot be made internally must be purchased from external suppliers. In some cases, items that can be produced internally may be purchased from outside vendors for economic or other reasons.

In traditional process planning, the process planning has been accomplished by manufacturing engineers who are knowledgeable in the particular processes used in the factory and are able to read engineering drawings. Based on their knowledge, skill, and experience, they develop the processing steps in the most logical sequence required to make each part. In process planning of parts, the processes needed to manufacture a given part are determined largely by the material out of which it is to be made. The material is selected by the product designer based on functional requirements. Once the material has been selected, the choice of possible processes is narrowed considerably [17].

A typical processing sequence to fabricate a discrete part consist of a basic process, one or more secondary processes, operations to enhance physical properties, and finishing operations as illustrated in Figure 2.7. Basic and secondary processes are shaping processes, which alter the geometry of a work part. A basic process establishes the initial geometry of the part. In most cases, the starting geometry must be refined by a series of secondary processes. These operations transform the basic shape into the final geometry. There is a correlation between the second processes that might be used and the basic process that provides the initial form [17].

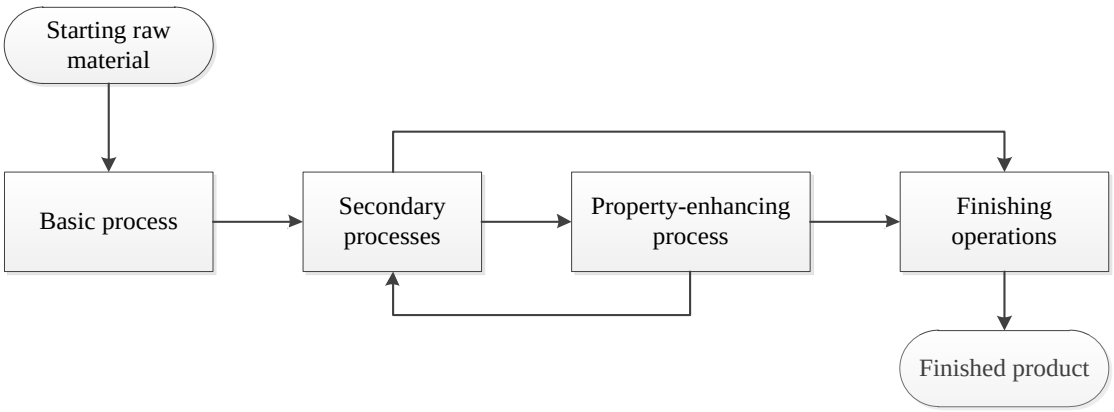

Figure 2.7 Typical Sequence of Processes Required in Part Fabrication [17]

Shaping operations are generally followed by operations to enhance physical properties and/or finish the product. Operations to enhance properties include heat treating operations on metal components and glassware. Finishing operations are the final operations in the sequence; they usually provide a coating on the work part (or assembly) surface. In some cases, property-enhancing processes are followed by additional secondary operations before proceeding to finishing, as suggested by the return loop in Figure 2.7 [17].

2.4. Machine Elements

All the machines are made up of elements or parts and each element may have to be designed separately and in assembly. The machinery elements are classified in two main types: general purpose elements like nuts, bolts, bearing, couplings, gears, and special purpose elements like piston, shafts, crankshaft etc. [18].

The general purpose elements, which are common in all types of machines, are classified into two types: fasteners and elements of rotary motion drive. The fasteners are the machine elements that connect or join various part of machine into one part. The joint can be permanent or temporary type. The examples of fastener elements are nuts, bolts, rivets, eyelets, and by welding. The elements of rotary motion drive help transmit motion or power to or from the machine. For example belt connected to the motor and pump helps running the pump. Other examples elements of rotary motion drive are rope, chains, worm drives, shafts, axles, coupling, gears etc. [18].

2.4.1. Gear

According to Groover [17], gears are machinery components used to transmit motion and power between rotating shafts. The transmission of rotational motion is achieved between meshing gears by teeth located around their respective circumferences. Depending on the relative numbers of teeth of the two gears, the speed of rotation can be increased or decreased from one gear to the next, with corresponding decrease or increase of torque. Gears come in many form, according to shaft position, gear speed, and gear teeth position (See Figure 2.8., 2.9., and 2.10.) [19].

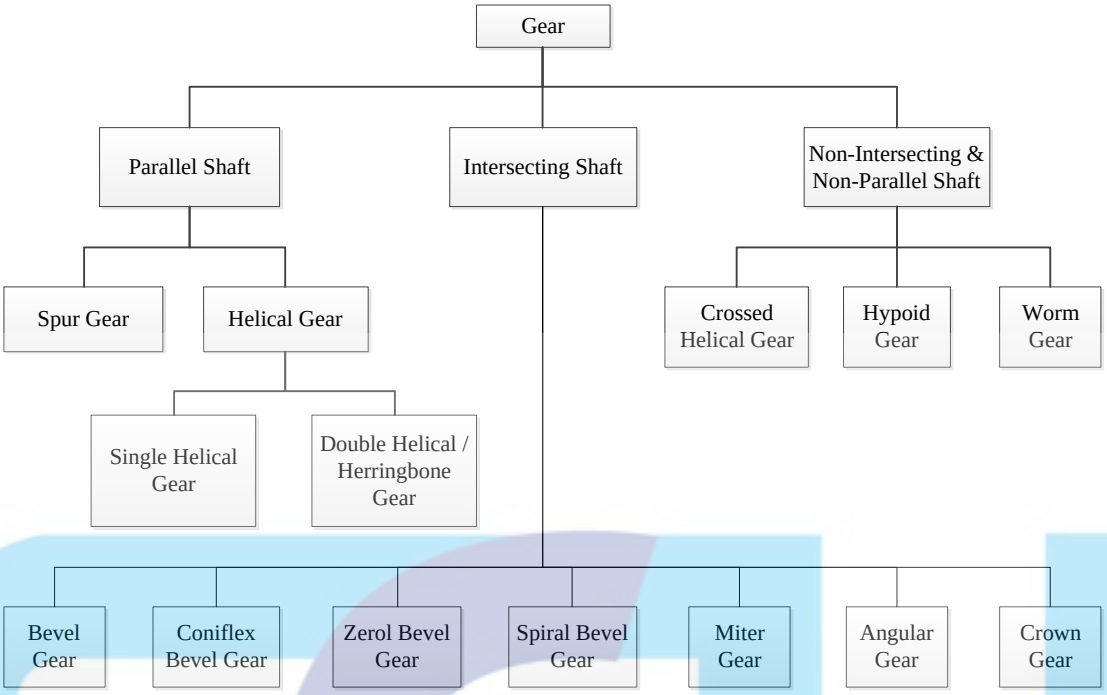

Figure 2.8. Gear Classification According to Shaft Position [19]

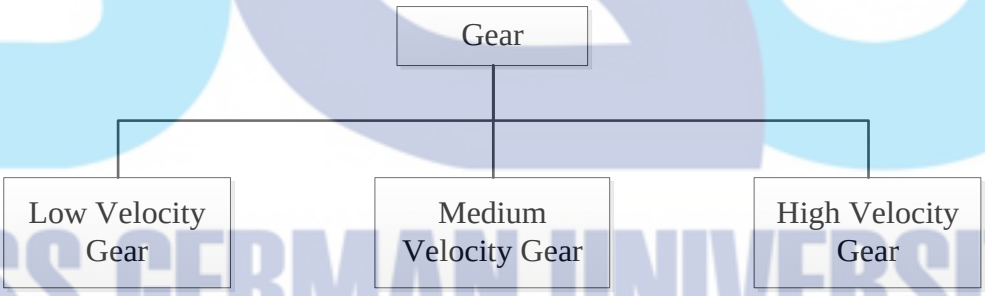

Figure 2.9. Gear Classification According to Gear Velocity [19]

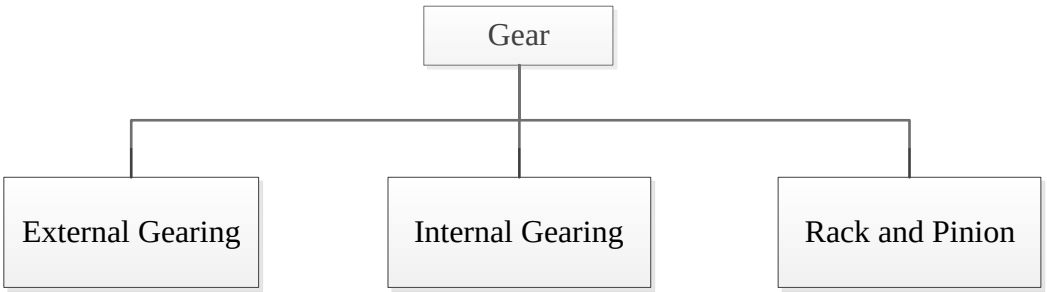

Figure 2.10. Gear Classification According to Gear Teeth [19]

2.4.2. Gear Manufacturing Process

According to [19], gears can be manufactured by most manufacturing process such as casting, forging, extrusion, powder metallurgy, and blanking. But as a rule, machining is applied to achieve the final dimensions, shape, and surface finish in the gear. The initial operations that produce a semi finishing part ready for gear machining as referred to as blanking operations; the starting product in gear machining is called a gear blank.

There are two principal methods of gear manufacturing, gear forming and gear generation.

2.4.2.1. Gear Forming

In gear form cutting, the cutting edge or the cutting tool has a shape identical with shape of the space between teeth. Two machining operations, milling and broaching can be employed to form cut gear teeth [19].

2.4.2.2. Gear Generation

In gear generating, the tooth flanks are obtained (generated) as an outline of the subsequent positions of the cutter, which resembles in shape the mating gear in the gear pair. Therefore, two machining processes are employed, shaping and milling. There are several modifications of these processes for different cutting tool used [19],

- Milling with hob (gear hobbing)
- Gear shaping with a pinion-shaped cutter
- Gear shaping with a rack-shaped cutter

Cutters and blanks rotate in a timed relationship; a proportional feed rate between them is maintained. Gear generating is used for high production runs and for finishing cuts [19].

2.4.2.3. Gear Finishing

Some metal gears can be used without heat treatment, while those used in more demanding applications are usually heat treated to harden the teeth for maximum wear resistance. Whether heat treated or not, some type of finishing operation is generally required to improve dimensional accuracy and surface finish of the gear after machining. Finishing processes applied to gear that have not been heat treated include shaving and burnishing. Finishing processes applied to hardened gears include grinding, lapping, and honing [19].

2.5. Standard Operating Procedure (SOP)

One of the most useful systems to streamline a business is having a Standard Operating Procedures (SOP) manual. It is a working document (accessible to all staff) that provides detailed instructions on specific recurring work processes. It communicates who will perform the task, what materials are necessary, where the tasks will take place, when the task must be performed, and how the person will execute the task [20].

Standard operating procedure is defined by Stup [21] as a means to remove variations in work performance caused by people completing the same work processes in different ways. A process is a set of actions that a person or group of people must perform in order to complete a job. A standard operating procedure describes the steps that people should use to complete a process.

Standard operating procedure forms the backbone of an organization. Standard Operating Procedures should be designed to achieve specific results. Management must decide what business goals will be achieved through better management with SOPs and how those goals will be measured [22].

A standard operating procedure is a living document, which is subject to change. (It is good to review it quarterly). It is therefore useful to have it in electronic format on a web-based collaborative system so that all employees have access to the latest version [20].

According to Vorster [22], there are 5 benefits from using the SOP which are:

- Reduced learning curve / training time for new employees

  When someone is new on the job, the well-written and researched SOP can be a lifeline to them to be able to know how things work. For instance, the manager or the supervisor can ask the new employee to make all the arrangements for both the manager or the supervisor and the new employee to organize and attend a workshop in another city. By referring to the SOP, the new employee will know exactly which travel agency we use with their contact details, which type of car to hire / service to use, how many quotes to get regarding the venue, how to communicate with the workshop delegates, etc. without having to ask the manager or the supervisor about it all. It's a great time-saver and confidence booster for the new employee [22].

- Ensured business continuity

  When a key staff member is on leave or not in the office for some reason, work does not have to stand still. By referring to the SOP someone else can take over the urgent tasks and do them correctly the first time [22].

- Standardized processes

  The SOP makes it easy to find out what policies and procedures are in place to handle repetitive situations / tasks [22].

- Ensure that the clients are getting the best possible experience with the company

  Because there is a standard way of dealing with client queries, refunds, promotions, follow-up etc., the employees can make sure that each client is treated fairly and equally, enhancing their interactions with the company, which provide the best possible service for the clients [22].