INSTITUTO TECNOLOGICO Y DE ESTUDIOS SUPERIORES DE MONTERREY

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DIVISION DE INGENIERIA Y ARQUITECTURA

TECNOLÓGICO DE MONTERREY®

A KNOWLEDGE STRUCTURE TO SUPPORT MANUFACTURING TACIT KNOWLEDGE MANAGEMENT: A CHEMICAL COMPANY CASE STUDY

TESIS

PRESENTADA COMO REQUISITO ACADEMICO PARCIAL PARA OBTENER EL GRADO ACADEMICO DE:

MAESTRO EN CIENCIAS CON ESPECIALIDAD EN

SISTEMAS DE MANUFACTURA

POR:

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Dedicatoria

A mi Padre quien es mi orgullo y siempre ha sido y será el mejor ejemplo y modelo a seguir de un Hombre Integro, Leal, Apasionado en su Trabajo y sobre todo el mejor Esposo, Padre, Amigo y Compañero

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SUMMARY

Knowledge Management is a research area widely explored, researches have been leaded in diverse fields, and the Manufacture is no exception, it has emerged as one of the branches of Knowledge Management research. From the manufacture branch has been identified and defined a knowledge super class, the Manufacturing Knowledge, which has been explored by various authors proposing models, and developing systems to manage the knowledge related to the manufacturing industries of a wide range of products like metal-mechanic, pharmaceutical, electronic, automotive, chemical and petro-chemical.

The present thesis work explores a Case Study developed in a Chemical Facility located in Monterrey urban area, this facility is dedicated to the manufacturing of synthetic yarns for the textile industry. The facility object of study, is facing a problem traduced in the loss of knowledge from its employees, which is not structured and not captured, it means that exists in an intangible tacit way, this loss is either caused by the employees turnover as well as employees retirement. The problem has turned into an opportunity, since the management is interested in the development of a proposal of a tool that manages and captures the tacit knowledge related to the manufacturing activities, and that resides within employees in the form of Learning, Experiences and Skills developed.

Based on previous researches, and in complementary literature in this thesis work is presented a proposal of a Manufacturing Tacit Knowledge Model and a Knowledge Repository, which defines knowledge classes that can be easily identified by the users. The defined classes are based on common terminology of the different areas from a facility that are involved in the manufacturing process.

The final product of this thesis work, the named IK Textiles Knowledge is intended to be a tool that can capture the knowledge from the employees, also be the source for knowledge searches when required by employees to improve decision making and prevent potential events; and also provide privileges to the employees to modify and challenge the knowledge that is stored in the repository.

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1. INTRODUCTION

1.1 Context

In today's global economy, driven by intense competition, rapid innovation and short product life cycles, what an organization knows and how rapidly it learns are becoming as important as what it currently produces (Nonaka, 1994). The Global Economy has created opportunities for Companies in Emerging Economies to compete in the market; and this brought important challenges for the well established companies from the developed countries. The last century economy was mostly dominated by North-American and European Companies which provided goods and services for their own and foreign countries, but the scenario has been changing since the appearance of the emerging economies, whose are countries that are trying to attract Multi-National Enterprises (MNEs) to invest in their countries, since they are trying to offer competitive environments where the MNEs can establish their operations in pursue of more competitive manufacturing costs. Multinational enterprises (MNEs) play a pivotal role in linking rich and poor economies, and in transmitting capital, knowledge, ideas and value systems across borders (Meyer, 2004).

A solid understanding of the role of MNEs in emerging economies is vital both for policymakers and for MNEs themselves. The expectation that FDI (Foreign Direct Investment) will benefit the emerging countries economies has motivated many governments to offer attractive incentive packages to entice investors (Meyer, 2004). The rationale is that the social benefits of inward FDI would exceed the private benefits of FDI, and investors would take into account only the latter when deciding over investment locations (Oman, 2000; Blomstro¨m and Kokko, 2003).

And this went accord to the trends showed in investments done in emerging countries, Latin America and Developing Asia region, are no exceptions; until 1998 the FDI in Latin America and Developing Asia had similar amounts; accord to the "Foreign

Investment in Latin America and the Caribbean – 1999 Report by Michael Mortimore, Chief, Unit of Investment and Corporate Strategies, Production, Productivity and Management Division, ECLAC, United Nations. FDI in Mexico was attracted by the new breed of business opportunities that have emerged since 1994 in the framework of the North American Free Trade Agreement (NAFTA). In fact, NAFTA created an extraordinary incentive for United States FDI in Mexican export sectors (electronics, computers, automobiles and clothing), characterized primarily by the assembly of manufactures for export (*maquila*) (Foreign investment in Latin America and the Caribbean, 2001). However nowadays is not a secret that China and Developing Asia are attracting most of the worldwide FDI, instead of Latin America region, but it is important to mention that in the previous mentioned report, Mexico still was a focal point of the Textile Industry during the last decade, due to this particular segment of the industry demonstrated sustainable growth since the 1980s until last 1990s, but this trend has changed since Asia is attracting almost all the FDI investment, specifically in all the business related to the Textile Industry.

One market that is a good example is the Chemical Industry, and more specific the Synthetic Textile Yarn Industry; this segment ins the last century was controlled by a small number of Companies, that developed and possessed patents of highly demanded products for the textile industry; making them very profitable businesses due to the absence of important competitors. However the times have changed, and as mentioned these former companies or new ones from Emerging Economies, are making important investments mainly is Developing Asia region; turning this region into an important competitor in the textile industry.

The global garment and textile industries face changing international trade regimes, concerns with labor standards, new competitors and forms of competition. These challenges have a differentiated impact on developing country producers and workers, creating ‘winners’ and ‘losers’ (Nadvi & Thoburn, 2003). The strong competition have forced some of those former leaders Companies to retire from the market, and in some cases some of those companies are renewing their processes, philosophy and strategies, as a way to look alternatives for their business to subsist in the market and be competitive again.

Textiles and garment (T&G) represent an essential engine of industrial growth for many East Asian countries; rapid development in this cuntries has been associated with garment and textile exports. These sectors also exemplify the opportunities – and threats – from globalization. Built up under import substituting (textiles) and export-led (garments) strategies, they have had to adjust to trade liberalization and to changing global competition (Nadvi & Thoburn, 2003).

And apart from the entire Developing Asia region, China has to be taken apart; since China is the major player in the garment industry today. It accounted for 18% of total global trade in garments in 2000, up from 9% in 1990. It is the largest supplier to the EU and Japan, and the second largest (after Mexico) to the US market where it is severely restricted by the MFA. The phase out of the MFA and China's accession to the WTO (World Trade Organization) are likely to enhance China's position in the US and EU markets. China’s potential dominance is reflected in it’s nearly 75% market share of the liberalized Japanese clothing market. In contrast, its share of the US clothing market is around 13% and in the EU just under 10%. China’s ascendancy poses a challenge for the export garment industries in other developing countries. Chinese dominance is not however a foregone conclusion. Trade restrictions will continue (albeit diminishing) on China even after the MFA phase out, Chinese labor costs are rising and global buyers are nervous of relying solely on Chinese producers. Nevertheless, Chinese competition calls for upgrading by other garment and textiles manufacturers, to raise efficiency and produce higher value added items (Nadvi & Thoburn, 2003). Additional reports shows that in recent years China has become more attractive to foreign investors than any other developing country. Its accession to WTO has improved and consolidated its position in the eyes of not only Korean, Taiwanese and Japanese investors, but also the world’s leading MNEs. Owing to its FDI policy, China’s investment portfolio shifted from labour-intensive sectors in the 1980s to technology- and capital-intensive industries in the 1990s. The main investors in China today include world leaders in computers, electronics, telecommunications equipment, pharmaceuticals, petrochemicals and electricity generation equipment (Foreign investment in Latin America and the Caribbean, 2001).

However as mentioned in the last paragraph the horizon does not look discouraging for a former leader Chemical-Textile Company that still competing in the market, and has some of its operations located in Mexico. And some of the good aspects is that the Operations in Mexico started more than three decades ago, which make it a very experienced organization, and still counting with acknowledged & experienced human resources, systems and organizations, that can be the tools to maintain it a competitive company in the Textile Industry.

As mentioned in the previous paragraph, it is well known that this former leader Chemical-Textile Company has generated, accumulated and utilized through time an important amount of Knowledge. Specifically all the knowledge from the Manufacturing Processes related to Operations, Maintenance, Equipment, Materials, Product Developments and Product Quality. Part of that knowledge resides in explicit ways like manuals, procedures, instructive, specifications, etc.; but there are also part of that knowledge which resides in tacit or implicit ways, mainly on their employees, derived from their experiences & learning they have gained during their service time at a company. The single existence of all the knowledge inside this Company related to the Manufacturing Processes represents an advantage over competitor companies, however there are also some challenges in order to make useful mainly the tacit knowledge that belongs to the company, but resides within their employees.

The big crew change, which has been looming over the oil industry for years, is now upon us. The average age of offshore workers in the North Sea and North America is over 50. Cutbacks in recruitment, lack of active retention policies, early retirement, and streamlining measures all have played a part in causing chronic personnel shortages. The challenge now is, who will replace today’s workforce? (Stockwell, 2007).

Some of the main challenges are that in part of the operations of the company, did not adequately planned a generational relay since their company leaders and most experienced employees ages rank between 50 to 60 years, and between 25 to 35 for the youngest professionals. Some of their most talented and experienced employees are close to their retirement or have already left, meaning that some of the knowledge is already lost; also the company human resource structure have become smaller, the current roles now includes bigger responsibilities, and young professionals will eventually take the lead of the operations of the company. And due to all the previous challenges there is the need to retain the tacit knowledge that resides in the most experienced and talented employees, and also from the newest and youngest employees. The departure of employees causes the loss of important tacit knowledge related to the Manufacturing Processes of the company.

The Mexican Chemical Industry is no exception for the effects of the challenges of the new Global Economy. Some of them come because Mexico in the last decades used to be a preferred destination for FDI, and some of that investment came for the establishment and growth of the mentioned Company.

Those Chemical-Textile Companies located in emerging countries like Mexico are facing almost the same challenges as the mentioned in the previous paragraphs; but also they are facing their own and particular challenges. Some of the most commons are; managers are constantly asked to operate with leaner organizations, causing constant team downsizing; highly dependence in the professionals support for the decision making process and the presence of cultural patterns between the members of the organization that are not used to share their Knowledge and Experiences. These challenges have leaded the Company to optimize the Processes, Resources and Products to make them more competitive in a ferocious global economy. And that have also caused the loss of important tacit knowledge related to the Manufacturing Processes of the company.

The main source of loss, of Knowledge related with the Manufacturing Processes remains in the following, talented and experienced people leaving the company, people are not used to share their knowledge and experiences, and the absence of formal systems to retain the tacit knowledge that belongs to the company, but the loss of Knowledge could not only be interpreted as the loss of Experiences, Skills and the Know-How, Know-Why and Know-What to respond to critical situations; but also represents the loss of money due to potential wrong Decision Making Process.

And since the loss of tacit knowledge is not occurring only because people are leaving, but also due to the company is not prepared or do not have a formal process to Capture, Reuse and Maintain the tacit knowledge related to Manufacturing Processes generated by the day-to-day experience in Process Technical Support, Technology Improvement, Product Development, Process & Product Improvements, Operations, Maintenance, Product Quality and Customer Support. The opportunity is that the Company know they know how to do the things right; but they do not know how to translate it to explicit ways, retain, reuse and maintain the Knowledge, and make it easily shared and acquired by other people in the organization.

The loss of Manufacturing Tacit Knowledge can not be treated as a merely problem; it is certainly an opportunity for the Company to maintain itself and its people knowledgeable and competitive. The Knowledge is a renewable source, but just if it is generated, captured, maintained and reutilized in the correct way. The company must have the ability to recognize it, the media to Store it, the Expertise to sanitize it and the Decision to reject it when no longer required. Knowledge is constantly created inside the Company, and has the opportunity to save all the Knowledge generated by its employees. Continuous improvement in the Chemical-Textile Company often produces a large expansion of manufacturing tacit knowledge, as a consequence, employees continue using their own techniques to retain, transfer and reuse knowledge. Under these circumstances, it is difficult to obtain a competitive advantage levering what the company "knows" due to the key knowledge lost (Guerra 2004).

The work presented in this thesis provides a proposal of a Manufacturing Tacit Knowledge Management Model for the recognition, record, selection, storage, maintenance and reuse of the Diverse Types of Tacit Manufacturing Knowledge in a Company, and uses as a case study the Chemical-Textile Company located in the Monterrey, Mexico urban area.

The success obtained from this proposal could mean the opportunity to export the proposed model to the rest of the Plants that belongs to the Holding Company and that are located in North America, South America, Europe and Asia; all of them are part of the Synthetic Yarns Business from the mentioned International Holding Company.

1.2 Aim and Objectives

Aim

The aim of this research is to propose a Model to support the Manufacturing Tacit Knowledge Management.

Objectives:

- To identify key Manufacturing Tacit Knowledge.
- To provide a structure to access, store and reuse Manufacturing Tacit Knowledge.
- To provide the right formats using Manufacturing Tacit Knowledge at decision making process.
- To explore ideas about how the Manufacturing Tacit Knowledge can be kept updated.

1.3 Scope

The given research provides a model for Manufacturing Tacit Knowledge Management in a Chemical-Textile Company which produces Synthetic Yarn for the Textile Industry, being part of an International Holding Company (identified in this thesis as IK) that holds companies that Manufactures Synthetic Yarns, Chemical Intermediates, Polymers, Resins & Chemical Specialties. This thesis explores and proposes the different Manufacturing Knowledge Types that exists in a Chemical Company.

Manufacturing Knowledge has been an area of research, which has taken importance since the Knowledge Management has become a wide theme of interest for the Industry. The present research work explores the key Manufacturing Knowledge involved in the Production of a Synthetic Yarn used in the Textile Industry; and particularly in a Plant located in Monterrey, Mexico.

The processes or specialty areas considered part of this research work are all those involved in the production of synthetic yarns, and those includes from Raw Materials, Operations, Maintenance, R&D and Quality. Staff operations like finance, accounting, warehouse control and marketing are not considered part of this research work.

The research work will be extended to the employees of the referred company, including from Middle Management to Floor Shop Technicians, since the knowledge related to the Manufacturing Processes is possessed by the employees directly related to that processes.

1.4 Research Environment

This section presents a short introduction of the research environment where this work was carried out, and provides the arguments related to a previous research work done in the area of Manufacturing Knowledge Management and how they were evaluated to propose a contribution of this thesis work.

This research is a subsequent work from a previous research work related to a “Manufacturing Model to Enable Knowledge Maintenance in decision Support Systems” (Guerra, 2004) that proposed a definition of the different types of Manufacturing Knowledge, also a definition of an information and knowledge structure that enabled the knowledge Maintenance and a model of a Decision Support System based on Knowledge.

The previous research explored and grouped the different Decision Support System based on Knowledge, and concluded that supporting manufacturing decisions using systems based on knowledge requires the exploitation of information and knowledge structures, and the most compatible for this purpose are the Knowledge Based Systems (KBS), giving better information and knowledge representation (Costa 2000).

KBS based on the Manufacturing Model proposed (Guerra, 2004) are used to support manufacturing and design decisions to provide a competitive advantage and leverage using what the company knows. In the product development process important amount of knowledge are used, created and/or renewed and usually the company does not has a formal system to manage all that knowledge since it reside on peoples gained experiences and expertise; and a way to take advantage of that knowledge is to provide an efficient and systematic model to structure that knowledge.

Also the research environment aims to work with the classification of the different types of knowledge, as a way to facilitate the access of the users since the KBS could contain and share large amounts of knowledge; facilitating the creation of knowledge structures and methods for the knowledge storage, recognition, acquisition, share and measuring; and make it accessible through a computerized application.

There is also support on the different manufacturing knowledge types identified and proposed to support the decision making process; and how those types of manufacturing knowledge can be represented in easily understood models for the users. And an improvement for the knowledge maintenance in the KBS to provide the ability to deal with various types of knowledge, and a method to capture and maintain valuable new knowledge is part of the research environment field.

The knowledge maintenance framework proposed in the previous research work will be used as the basis for the proposal made on this thesis work.

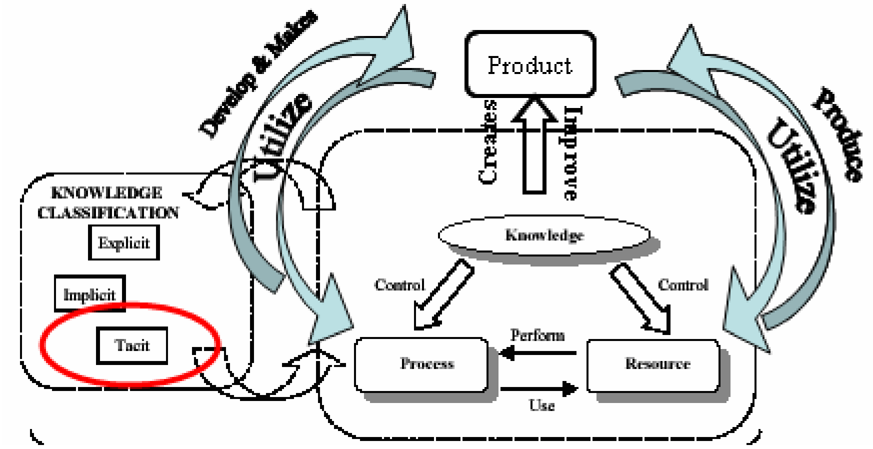


Figure 1.1 Knowledge Maintenance Framework (adapted from Guerra, 2004)

The structure proposed allows the storage and updating of the information and knowledge into a Manufacturing facility using a maintenance method; and for the maintenance of current and new information and knowledge is used a Structure applying the Knowledge Maintenance Life Cycle.

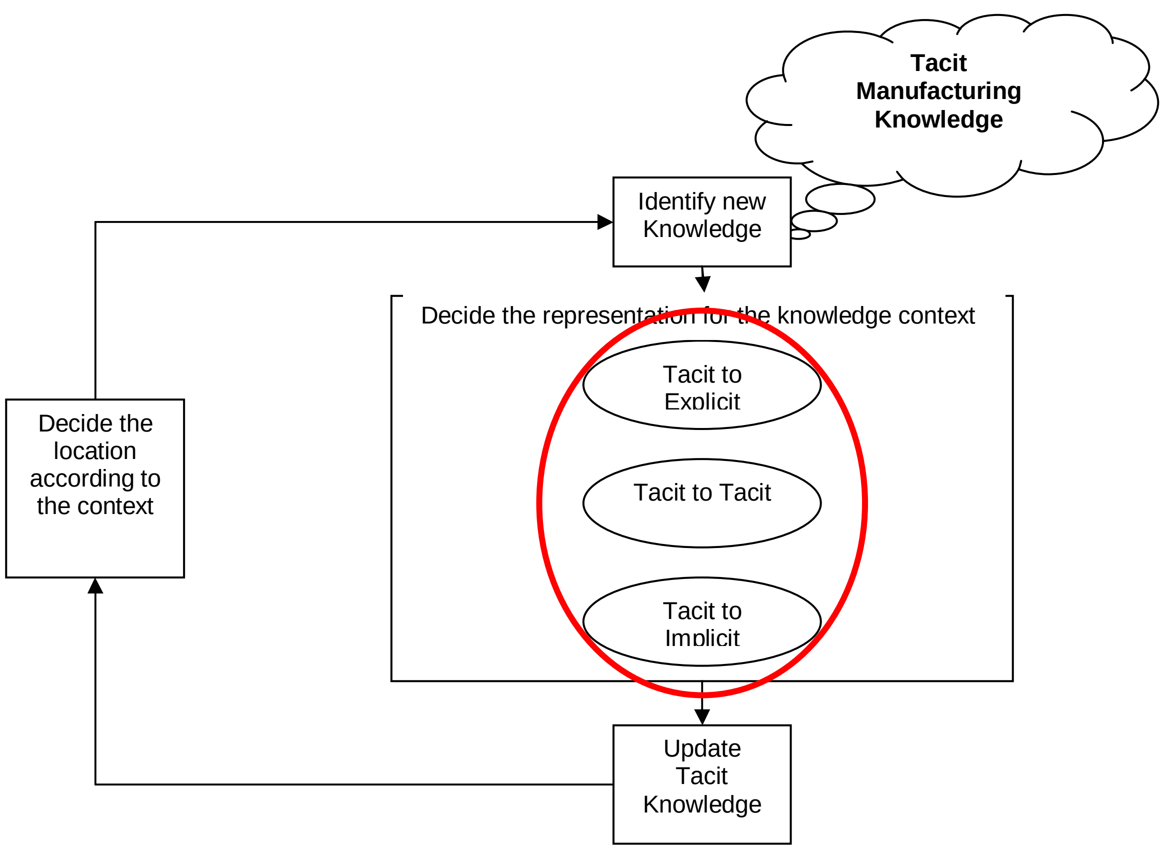


Figure 1.2 Knowledge Maintenance Lifecycle (adapted from Guerra, 2004)

The steps of Knowledge Maintenance Life Cycle are the following; new information or knowledge is created and/or identified; in the case of new information is necessary to locate the original information in the Model and replace it with the new information. In the case of knowledge follows almost the same procedure, but there is an additional step in choosing its representation, explicit, tacit or implicit. A premise for the new knowledge is that it should have a richer context and provide better ability for the user's decision making.

Knowledge creation is a synthesizing process through which an organization interacts with individuals and the environment to transcend emerging contradictions that the organization faces. Instead of merely solving problems, organizations create and define problems, develop and apply knowledge to solve the problems, and then further develop new knowledge through the action of problem solving. (Nonaka et al., 2000b).

After the Knowledge has been created and acquired, the Knowledge users must have the tools to transfer and share it. Knowledge sharing itself is organizational variable, which requires proper configuration with both strategic properties (strategic interdependence, technological linkage, and entry mode) and infrastructural conditions (knowledge encapsulation, incentive system, and intranet system).

The opportunity detected is on the creation, detection, record, renew, storage, reuse and dispose of the tacit manufacturing knowledge.

And to complete the research environment the Company chosen for this study comprehends a Chemical Plant dedicated to the manufacturing of Synthetic Textile Yarns. The referred plant belongs to the Holding Company identified as IK.

IK has as one of its top five Principles the Knowledge Systems, and have developed a philosophy about knowledge; the intention of this thesis is also to explore the topics developed by IK and apply those who fit into the proposal of this thesis work.

The Hypothesis of this thesis work is that the proposed Manufacturing Tacit Knowledge Management Model solves the problem of Manufacturing Knowledge loss in an enterprise.

1.5 Thesis Organization

The research presented in this thesis work is organized in five chapters described as follows:

- Chapter 1 – Introduction
- Chapter 2 – Research fundamentals of the thesis, summarized as:
  - Manufacturing Knowledge Types
  - Manufacturing Knowledge Management Tools
  - Knowledge Management in the Chemical and Petro-Chemical Industry
  - Manufacturing Information and Knowledge Modeling
    - Concept Maps
    - Ontologies
  - Manufacturing Knowledge Creation & Sharing
  - Manufacturing Tacit Knowledge & Organizational Learning Management
  - Knowledge as a resource in Decision Support Systems
  - Discussion
- Chapter 3 – Development of the proposed Manufacturing Tacit Knowledge Model,
- Chapter 4 – Study cases developed in the Company selected for the development of this thesis work,
- Chapter 5 – Reports, results, conclusions and further work.

2. LITERATURE REVIEW

2.1 Manufacturing Knowledge Types

Previous research works have been done about concepts of Manufacturing information and knowledge models, methods and structures; (Harding, 1999) conceptualized a model intended to function as a collector of manufacturing enterprises design information, where the information about the design stages is shared by the users; (Zhao et al. 2000) developed a method and a structure that contains relevant information obtained from the design process and the manufacturing stage of a product, proposed the basic instances in the manufacturing data structure that serve as the manufacturing information containers; (Molina and Bell 1999) presented the Manufacturing Model used to describe through general term entities the Capability of particular enterprises, the manufacturing model purpose was to support the information needs of an enterprise during the product life cycle focused on manufacturing resources and manufacturing processes, (Giachetti, 1999) visualized the fore coming interaction and collaboration between suppliers, producers and customers in the design and production of high quality products, and proposed a manufacturing process model that would increase and facilitate the information sharing among the different participants in the manufacturing stages; (Dorador, 2000) mentioned that there were available methods for the information modeling but were limited in its application, he structured a combination of two methodologies, one that modeled enterprise activities and information, a second with a capability to model information in object centered descriptions, resulting in the definition of information classes, attributes and operations later modeled using UML structure; **(**Guerra, 2004) structured a model based on the previous researches, in this model are identified instead of information, knowledge classes related with manufacturing, and with an additional capability to maintain and reuse the knowledge stored into the model; (Karacapilidis, Adamides & Evangelou, 2005) work is a knowledge system utilized to enhance the collaboration among manufacturing enterprises for the development of manufacturing and operation strategies, integrating the knowledge management, decision support and the social interactions between users; (Alizon, Shooter & Simpson, 2006) they explored the interaction between geographically dispersed peers or teams which belong to multinational enterprises, their argument is that the reuse of previous knowledge, represented by experiences in design processes could enhance standardization, quality and control of the manufacturing processes, and with the additional potential of projects costs reduction among plants or sites that reuse knowledge from peers; all of them have made important contributions for the knowledge management research area, and specifically for the Manufacturing field, since the purpose of those models was the identification, storing, reutilization and maintenance of the knowledge owned by Manufacturing Facilities and enhance the operation of those facilities; opportunities has been detected in the classification of the tacit knowledge related to the manufacturing, the way it is represented and how it can be validated prior it is made available to be shared to peers or partner organizations.

Several have been written about the main knowledge types, which are mentioned they exist within the organizations; Explicit, Tacit and Implicit Knowledge; as well as the information structures in the organizations. All of the previous research has been very important, because the main knowledge types were the basis of the development of all the theories around the knowledge management. And have also opened doors in different areas like Health Care, Education and Manufacturing to develop more specific theories of knowledge management strategies in the organizations.

One area of interest, and with wide opportunities of application of knowledge management strategies are the manufacturing companies; and this has brought the development of a research field defined as Manufacturing Knowledge.

As expressed in a previous research work, several researchers have explored manufacturing strategies organizing facility information to support decisions; however the have not explored how the manufacturing knowledge related to process and resources can be structured using different types of knowledge to support decision allowing knowledge maintenance (Guerra, 2004).

Guerra proposal consist of a super class identified as Facility Knowledge that contains the whole system inside a manufacturing facility, and from this super class derives two main classes identified as Process and Resource Knowledge respectively, and from those two comes the different manufacturing knowledge types related and defined in a specific process (see figure 2.1).

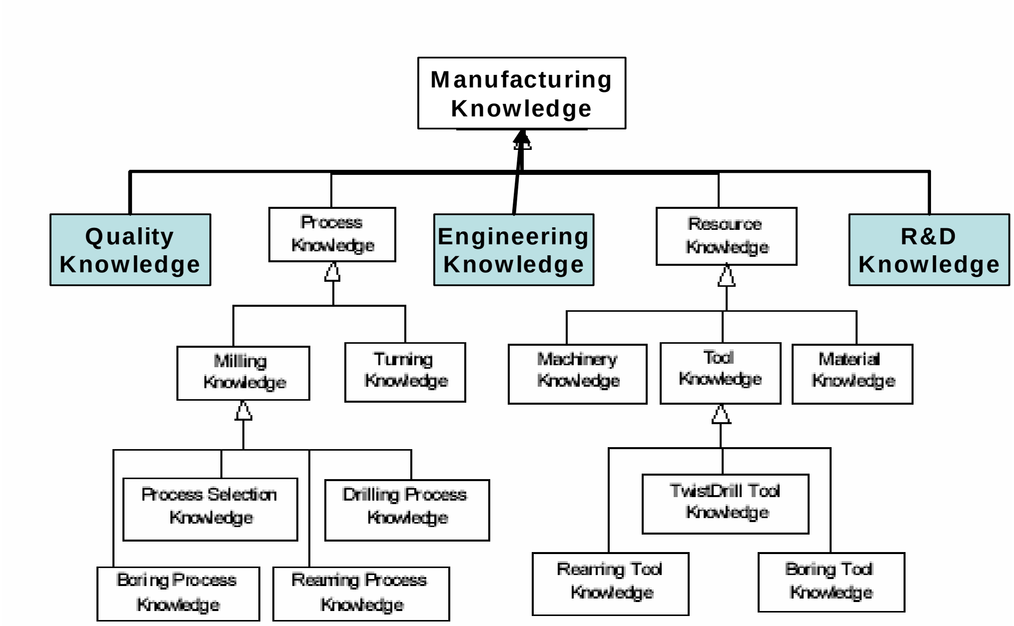


Figure 2.1 – Facility Knowledge Structure (adapted from Guerra, 2004)

An opportunity to enhance the structure proposed in the previous research has been detected, since the manufacturing knowledge classifications structure have the possibility to contain additional classifications which normally exists in manufacturing companies, and come from areas where expertise is developed within the organization; and including the consideration of make available the knowledge related to the manufacturing with users from facilities located geographically dispersed and from different cultures and spoken languages.

The types of knowledge explicit, tacit and implicit combined with the different facility knowledge classifications served to define the process and resource knowledge structure.

The previous figure shows an example of the different process knowledge classifications and the types of knowledge how they could be represented. The proposal also applies for the resource knowledge and its correlation with the types of knowledge; since resource knowledge is the other main class derived from the super class facility knowledge.

The research done to develop the structure showed in figure 2.1 provides a useful model that helps to understand how in a manufacturing facility can be identified, defined and modeled all the knowledge related to a certain process. The model stores the facility into three main structures, process knowledge, resource knowledge and the types of knowledge, and between those structures exists relationships, that enables as a consequence that the manufacturing knowledge related to processes and resources (main classes) can be represented using the basic types of knowledge (explicit, tacit and implicit). It also includes the facility areas and knowledge classifications identified for this thesis work.

2.2 Manufacturing Knowledge Management Tools

An organization has a primary goal from knowledge management, and is to identify the valuable knowledge that resides within individuals and disseminate throughout the organization (Hua Tan & Platts, 2004). Knowledge is both “raw materials” and “finished goods” in todays organizations *mentioned Leonard-Barton in 1995.* Knowledge within the organizations is a tool which is used by their members; and it is valuable since it provides an ability to make better decisions and take actions on the basis of knowledge. But the knowledge most of the time resides within organization members, and this cause that every day, knowledge essential to organizations walks out of the door, and much of it never comes back; causing drains costs to an organization, loss of time and customers (Hua Tan & Platts, 2004). But the members leaving is not the only cause of knowledge loss, additional factors like geographical distance, political squabbles, internal competition, and bad incentive systems also hinder the spread of ideas, it was referred by Hua Tan & Platts from (Building an Innovative Factory, *Hargadon & Sutton, 2000)*.

A knowledge management tool needs to have the following features (Hua Tan & Platts, 2004):

- Volume of data – capable to handle a vast amount of data on individual variables and the relationships among them;
- Structure – the information or knowledge must be structured in a meaningful content and be easy to manage by the users;
- Interpretation – Graphical displays of the information or knowledge should be easy to interpret and understand by the users;
- Ease of use – The tool must be easy to manipulate, and;
- Must be easy for the users to add, retrieve and analyze data transform data into information or knowledge with enhanced meaning for the organization,

The explicit and tacit knowledge from employees about the relationships among production variables is useful enhancing an organization's ability to solve problems and to prevent future incidents that could impact the Costs, Quality or other important metrics from an organization. Having a tool that helps a company to store its collective knowledge of the relationships between production variables and action plans, which assists the companies to develop organizational memory and use the stored knowledge to guide activities and decision making; the knowledge retained by the company can be utilized to solve similar manufacturing problems, regardless of time or geographic location (Hua Tan & Platts, 2004).

Hua Tan & Platts propose a model for the Manufacturing knowledge management based on the Burbidge (1984) connectance model for production management, the original model is a diagram which through inductive rules about directional effect of parameter changes on production variables, and predicted qualitative relationships among variables in a production scheme. Some changes were done on the connectance model, it basically consists of five levels that lead to desired actions or variables, the levels proposed contains:

- 1st level – The objective or the variable over which would be performed the analysis;
- 2nd level – Break down of the different aspects;
- 3rd level – Relevant connectance variables;
- 4th level – Actions to address the variables;
- 5th level – Management tools to address the particular variables.

An example of the proposed is showed below. The purpose of the model is to provide to the managers, or people who drives decision making processes in organizations an easy to use tool that enables them to respond to problems, or achieve objectives; the given tool is intended to capture and share the tacit knowledge that resides in a manufacturing facility.

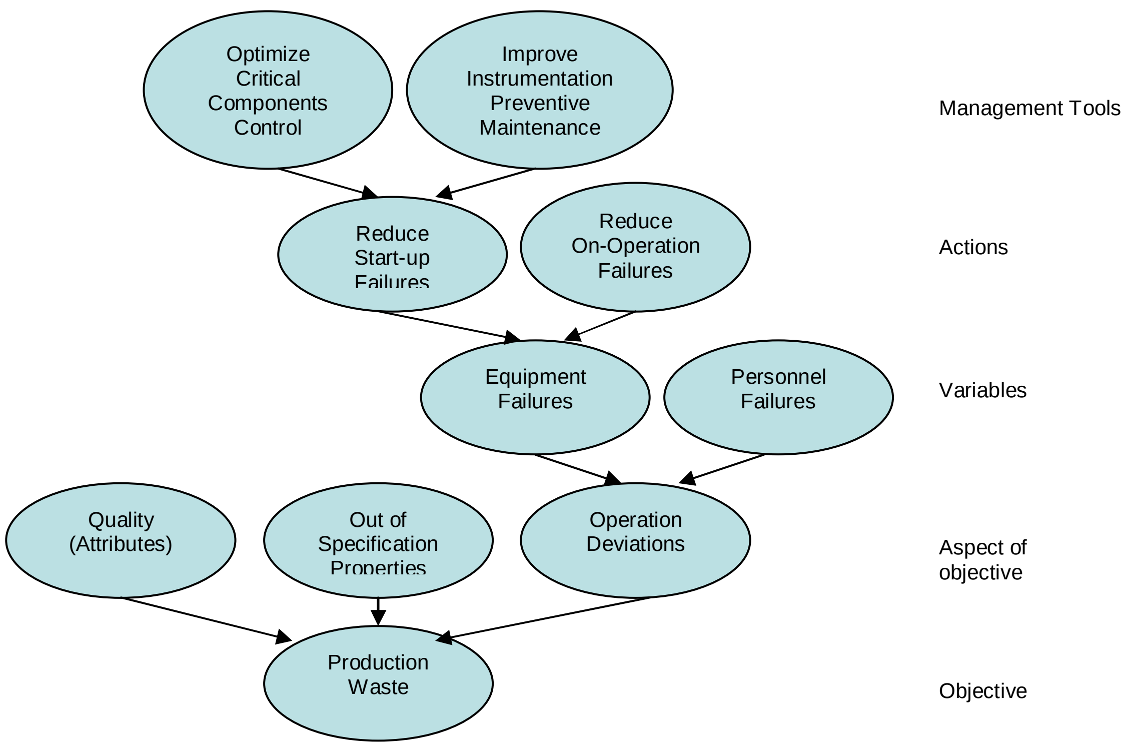


Figure 2.2 - Structure of the Network diagram (adapted from Hua Tan & Platts, 2004)

The core processes are defined as those that make the organization what it is. For a manufacturing organization, the manufacturing process—often called manufacturing operations—will certainly be one of the core processes. And from the manufacturing process is derived one of its core resources, the knowledge owned by the organization related to all the activities that surround the manufacturing of goods. Another research reported that any improvement in, or addition to the organization's core knowledge should produce a corresponding improvement in the organization's performance (Shaw & Edwards, 2006), this can be interpreted as a two way improve of the knowledge and operations within an organization.

A research study developed over two manufacturing companies encompassed had an strategy followed that delivered different types of knowledge (formal or informal) in different formats (written, oral, and electronic) (Shaw & Edwards, 2006).

The top level categories proposed for the content of the knowledge in a manufacturing organization are: manufacturing operations, manufacturing strategy (subdivided into structure and infrastructure) and corporate strategy.

Previous research on knowledge management in manufacturing organizations, that best relates with Shaw & Edwards work were Collinson (1999), this author examined the process transfer of best practices between two manufacturing organizations, the goal of this transfer was to improve manufacturing processes in both organizations the one that shares and the one that receives and utilizes the shared knowledge reflected in best practices; the improvement of work practices in the recipient company mean improvement in process control, quality monitoring, process enhancement groups, cross-functional working, improved communication and customer focus.

The implementation of a knowledge management initiative will involve process change in the organization, it is a challenge for the organizations that are not familiarized with these terms, but will also require some culture or perspective change: the top-down initiative needs to be matched with the bottom-up commitment and enthusiasm, it means that the initiative from the management must show commitment from the top of the organization to be capture and well received by the rest of the employees, this is based on (Knowledge Management Sans Frontieres, research done by J.S. Edwards & J.B. Kidd, 2003b).

While informal (in particular, oral) knowledge sharing usually happen in organizations, between members whose constantly develop these kind of tasks, most of the time without a pattern or an established process, but there was some disagreement in the companies selected by Shaw & Edwards over whether it should be encouraged the knowledge sharing. The opposition to knowledge management processes is mainly based on what is constantly shared is gossip, personal views, or rumors which will be mistaken for fact. The support for knowledge management processes felt that: enhanced personal relationships will make for more effective working; members will share knowledge in a more relaxed setting and not necessarily in formal meetings; another example of knowledge sharing are spontaneous innovative thoughts that might be found in a corridor conversation.

Information and knowledge should stay current through constant up-dating; encouraging individuals to take the ownership of processes which produce the information and knowledge. However (Collinson, 1999) found that people empowerment can be difficult and a cultural change is a slow process. To enhance this process this author proposed the establishment of a role of Champion of Knowledge Management, who actively promotes the collectivistic culture and encourages the free sharing of knowledge and information (Shaw & Edwards, 2006).

Shaw and Edwards mentions also that even the commitment was present, and leadership taken, there were some limitations and barriers; like people felt that knowledge communication sometimes were ineffective (long meetings, wrong people involved, abuse of the e-mail, and briefings were not of the right information); or a feel of frustration and despair due to the enormity of the task. The barriers can be removed with the gradual change in people’s culture about the peer to peer sharing of their knowledge obtained from learning and experiences. A limitation of Shaw and Edwasrds study is that it only took two organizations to develop the study, and also a limited number of participants.

The collaborative work occur either through face-to-face interactions between participants on a project, or indirectly between geographically and temporarily dispersed individuals or teams. In the second case collaboration is facilitated by the reuse of previous knowledge (i.e. experiences, design processes, etc.) (Alizon, Shooter & Simpson, 2006).

A research work was developed by Alizon, Shooter and Simpson on the International Group Renault-Nissan, with the purpose to develop a method for the systematical reuse of experiential knowledge created during new car models designs processes and for the current manufacturing processes. The researchers mentioned that at the individual level, process designers try to reuse manufacturing information, but in most cases it only takes them to recent models, this can be explained as the inexistence of formal systems that retains and structures previous knowledge makes the search a long and ineffective process.

The reuse of processes information and knowledge offers opportunities to improve manufacturing traceability, standardization, quality and control as well as enables potential decreases in manufacturing costs (Alizon, Shooter & Simpson, 2006). They also argued that knowledge reuse can facilitate the collaborative product development, due to the use of previous experiences in designs or manufacturing processes.

The opportunities found during the traditional design process at Renault-Nissan include:

An interesting part of the proposal for Renault-Nissan is the method to search and reuse existing design information; for this to be accomplished it is essential that manufacturing characteristics of existing product is available for the process designers. The way the search and reuse is done consist basically in that the designer enters the desired characteristics for the product to be developed, which are used as request; those are then matched with the existing characteristics, the information inside the repository is filtered and the relevant designs are delivered.

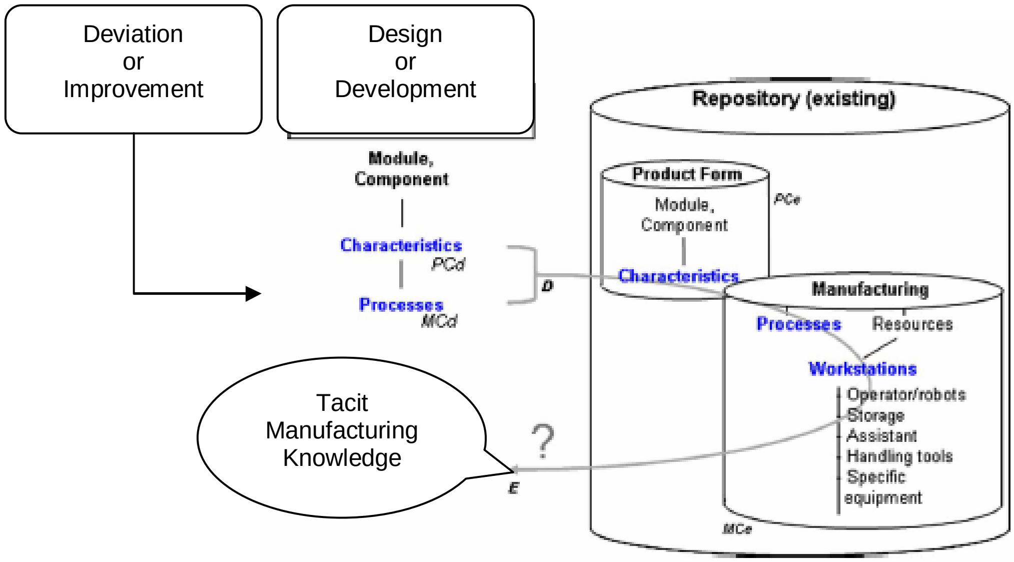


Figure 2.3 - Structure of the proposed method at Renault-Nissan (adapted from Alizon, Shooter & Simpson, 2006)

The manufacturing strategy development within an organization is a complicated task that is undertaken by a group of managers (Karacapilidis, Adamides & Evangelou, 2003). The maximum exploitation and enhancement of the organizational knowledge are ubiquitous requirements; since such knowledge resides in an evolving set of assets including the employees, structure, culture and processes referred the mentioned authors based on a previous research done by (Van der Bent, Paauwe & Williams, 1999).

The manufacturing strategy refers to the accumulation and combination of tangible (facilities, processes, etc.) and intangible (knowledge, routines, etc.) assets/resources which are an important part for defining the competitive position of the manufacturing function within an organization. Intangible assets, like the knowledge, are accumulated in an organization, and many resides on its personnel experiences; many organizations have those assets, but they do not know how to identify, record, validate, reuse and renew that knowledge. (Karacapilidis, Adamides & Evangelou, 2003).

The proposal made by Karacapilidis, Adamides & Evangelou is an electronic system, intended in this case to be used by the managers from an organization who's had the objective to develop a manufacturing strategy. The system is supposed to enhance the collaboration among managers, giving them access to a system where they can add proposals and/or comments that can be read, evaluated, and feed backed by their peers; this system is a discussion board, that keeps track of the discussions, and allows the users to ask and respond to comments or questions from other users. The system is a kind of knowledge repository, where knowledge graphs are constructed and stored; those graphs contains codified knowledge, that can be connected to other interrelated graphs trough nodes . The system maintains the knowledge graphs with their specific information (node type, subject, submitter, date of submission, associated articles or white papers, etc.), and can be accessed any time by other users, applying queries for specific subjects.

- Deviation → Quality problem
  - **Problem →** Physical streaks over fabric (Critical Customer)
    - **Position →** Improve current product
      - **Connected Activities**
        - » Modify Heat Profile *submitted by Technical Manager*
        - » Increase heat water mass flow rate *submitted by Process Engineer*
      - ***Connected Resources***
        - » Change critical components *submitted by Area Supervisor*
    - **Position →** Develop a new product with different parameters
      - **Connected Activities**
        - » Product with less mass flow rate *submitted by Process Engineer*
      - **Connected Resources**
        - » Product with different raw materials *submitted by Area Supervisor*

Figure 2.4 - Placement of positions and their associated elements in Co-MASS (adapted from Karacapilidis, Adamides & Evangelou, 2005)

The advantage observed in this proposal is that it provides a tool useful to retain specific manufacturing knowledge about decision making processes; and in this way discussion about problems or opportunities founded and uploaded, does not need to be taken person-person, and the information can be retained and accessed any time. It can be a good system for a decision making process, and also can be extended to other areas rather than management; like Product Development, Operations, Maintenance, Raw Materials, Quality, etc.

There is an assumption that the manufacturing knowledge can be gathered, qualified and codified by a single person, mainly by managers; but in practice it involves people from different disciplines from marketing to product development since the manufacture of a product requires the participation of all levels in an organization, trying to cover from the very voice of the customer to the expertise from the technicians or operators whose are the directly related to the manufacturing of the goods offered by an organization (Karacapilidis, Adamides & Evangelou, 2005).

The system proposed, were evaluated on one of the largest third-party pharmaceuticals manufacturers in Europe, located in Greece and other Western Europe countries. The individuals selected to evaluate the operation of the knowledge management system were mainly mangers from different disciplines (Manufacturing, marketing, purchase, etc.); the study could is not completely representative of a manufacturing organization, since it does not include people from different levels in the organization; however for the previously mentioned authors it provided interesting results. The system is intended to assist the manufacturing strategy development and the capturing and stimulates knowledge elicitation. It is reported that the system has been tested for more than a year, and the results of a survey applied to the selected user’s shows that in general at least people had a neutral position about the usage a web-bases knowledge management system.

The researches about information and knowledge sharing have shown how methods of structuring information can provide a basis for information sharing. However, these have two significant limitations: the users of these structures must be willing to agree on a common structure for the information needed; the system developers and users must share a common understanding of the semantics, or meaning, of the structural elements to be captured (Gunendran and Young, 2006). These authors have made an alternate proposal for the knowledge sharing process among the organizations, and this is the use of ontologies.

But what is ontology and what is useful for? A definition that clarifies is; ontology is a formal, explicit specification of a shared conceptualization. A definition given by Young et al., explained in simple terms ontology is a medium that provides a basis for a shared meaning.

Ontology is a medium to share information/knowledge within and between boundaries between persons from the same and from different organizations (Gunendran & Young, 2006). Further, ontology building is a process that turns knowledge from tacit and internal into explicit and external (Nonaka, and Takeuchi, 1995).

Gunendran and Young refers that in the case of manufacturing models must capture the available information related to manufacturing processes, resources and strategies, and their function is to be the repositories from the information manufacturing related activities, and be able to share the required information between many users. Ontologies have also the capability to define meanings of concepts that can be shared across boundaries or different environments, allowing the integration of multiple contexts, which exists in manufacturing environments like Operations, Maintenance, Research & Development, Quality, etc.

2.3 Knowledge Management in the Chemical and Petro-Chemical Industry

Some Chemical Companies have worked on the establishment of Knowledge Management Programs as tools in the realization of post-merger integration processes and new product developments wrote Bo Glasgow, Chemical Market Reporter Editor in an article called "Knowledge Management is finding its way into Chemical Industry". Calvin Cobb, vice-president of chemical practice Cap Gemini Ernst & Young (CGEY) pointed that for Chemical Companies, Knowledge Management is a function of people, processes and technology, where entrenched corporate culture often presents more of a challenge than does the viability of high tech solution sets.

A key concept of Knowledge Management most recommended for the Chemical Companies is the “virtual community”, which means to count with functional expertise on real-time and spread out throughout the company. The idea would be to form different communities, engineers, scientists, and other networks regardless of which business units they work for or where they reside geographically. However sharing information freely is often perceived as a doubled-edged sword since the knowledge repository might still be stuck in the “knowledge is power” mindset, was also commented by Calvin Cobb.

An important observation done to the Consultant firm CGEY defined the cumulative knowledge as a critical asset, and for that purpose this firm has established metrics to measure its employees in knowledge creation, reuse and sharing; monitor the traffic in the databases, record creators, users, submissions to best practices, methodologies or techniques.

Another incentive that leads Chemical Companies into the implementation of Knowledge Management Programs is the aging of middle management and senior technical people, with a sizable number close to their retirement age, and the challenge is clear for this industry, “How can their knowledge be captured, preserved and positioned for reuse before it walks out of the door?”, accord to Calvin Cobb interview for the Chemical Market Reporter.

Oil and Gas companies are increasingly recognizing Knowledge Management as a core corporate competency. It is defined as “an integrated approach to identifying, managing and most importantly sharing an organization’s information assets, including databases, documents, policies and procedures, as well as undocumented expertise resident in individual workers.” **(***Capgemini Expertise in Upstream Information Management and Electronic Document Report Management Systems, 2004).*

The latent knowledge held by individuals is becoming a major issue for many E&P companies, whose workforces are rapidly approaching retirement age. This makes the knowledge capture and transfer process critical to sustaining daily operations. A study done on 2003 by the Society of Petroleum Engineers, stated that *"…the E&P industry will experience a 44% attrition rate among petroleum engineers by 2010, and 231,000 years of cumulative experience and knowledge will be lost to the industry in the next 10 years due to retirement."* The challenge will become bigger with the E&P industry's trend towards increased use of remote operations, centralized decision-making, reduced staffing and numerous data sources; the main goal as mentioned in the previous paragraphs is to develop the tools to retain the cumulative experience and knowledge that resides in their employees.

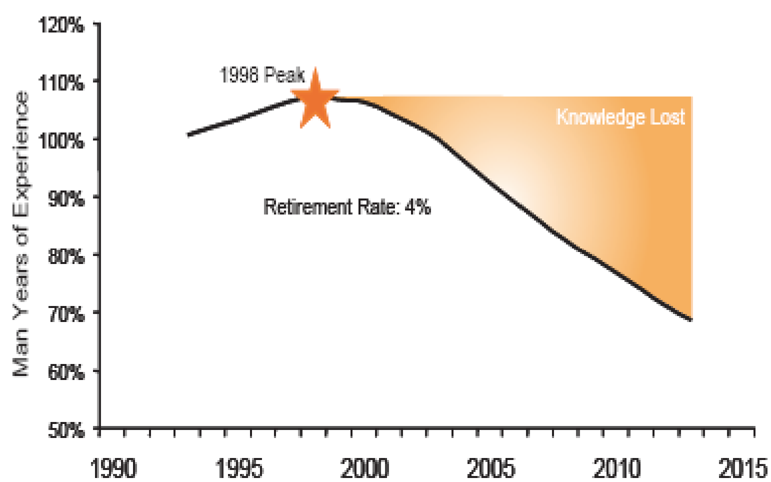


Figure 2.5 - Loss of Knowledge based on the Society of Petroleum Engineers 2003 age distributions

Some organizations have turned to storytelling and anecdotal success stories to show the value of the investments made in KM. Stephen Denning of the World Bank wrote a book about storytelling from companies like Xerox, Chevron, and Schlumberger all have worked to create a virtual coffee bar where success stories are told. The result is a story that people can relate to and numbers that people can believe (Vestal, 2002). Following is showed a table that summarizes some of the successful cases from global Chemical or Petro-Chemical companies that made important bets on knowledge management tools implementation.

Organization	Target Value Proposition	Approach	Results
ChevronTexaco	Reduce operating costs, improve operational excellence, improve safety	CoPs, facilitate transfer of best practices, People finder	• Two billion dollar reduction in annual operating costs (1991 v. 1998) • $670 million came from refining best practices. • **Total investment of more than $2 million (total figure unknown)**
Dow Chemical	Provide faster access to information, improve information management, improve sales leads	Content management, communities of practice	• Increase number of sales leads • Increase in new product sales • Improved customer satisfaction scores • **CM investment of over $3 million for start up, $8 million annually.**
GE Plastics	Decrease customer service costs	Customer portal, customer knowledge repository	• Number of test chips created decreased from 4.2 to 2.7 • Average reduction of 4.5 hours per color match • Savings of $2.25 million per year • **Total investment unknown**
Shell	• Create a single, global company • Reduce cycle time • "Too Fast to Follow"	• Global Networks (CoPs) • New ways of working • Letting the new guys into "Old Boy" networks • Transfer of best practices	• $200 million/yr cost savings • Reduced number of wells • Increased facility uptime • Reduced design and planning errors • **Total investment of approximately $4 million**
BP	***Know-how:*** A brand attribute; ability to innovate and execute faster and smarter than competitors	Networks, Peer Assist, AARs, Retrospects, Technology VP support, Operations Value Process	• $260 million cost savings/yr cost savings • Reduced number of wells • Increased facility uptime • Reduced design and planning errors • **Total investment unknown**
Schlumberger	Knowledge in the hands of employees and customers	CoPs, InTouch KM system, intranet, extranet, content management	• $200 million cost savings • 95% reduction in time to resolve technical queries • 75%reduction in updating modifications • **Total investment of approximately $20 million**

Figure 2.6 - Measuring Knowledge Management (Vestal, 2002)

Some of mentioned Global leader companies have implemented Knowledge Management tools like:

- ***Shell Global Solutions***, has a Knowledge Centre on its webpage with access to Shell customers where is kept up-to date knowledge about Shell's technology developments and use of technology; customer testimonials of joint projects in different fields like refining, chemicals, gas and LNG, etc.; and a Customer Wide Web (CWW) which offers a direct connection to a worldwide knowledge base through a web-enabled channel; it is a resource that enables customers to read technical and business reports, participate in discussion forums and run various applications, a virtual workspace.

- ***BASF,*** created a space dedicated for the Occupational Medicine and Health Knowledge Management, called Centers of Excellence where the company make available all the knowledge related with health protection for its employees and customers.

- ***BAYER,*** states that knowledge is one of the most important resources in a company. To ensure that the valuable know-how and experience accumulated over the years is not lost through fluctuation or restructuring, they count with and can develop for its customer knowledge management system (KMS). The services offered extend from consulting and concept development to process support and the implementation of a customized knowledge management system to collate, manage and make available to others the knowledge that exists within a company, Organization of workshops, Establishment of and support for communities of practice, process-oriented performance support system (knowledge warehouse).
- ***DOW CHEMICAL COMPANY,*** has launched an Answer Center, an online tool that leverages Dow's expertise in liquid separation technology to increase customer service and business efficiency. The Web-enabled knowledge base pools decades of experience and information about FILMTEC™ reverse osmosis (RO) and nanofiltration (NF) elements and DOWEX* ion exchange resins in a user-friendly interface; it provides a searchable base of answers to hundreds of

questions. If the system is unable to answer a question, the issue is sent via e-mail to a Dow technical expert.

2.4 Manufacturing Information and Knowledge Modeling

Models are tools that help to appreciate and understand systems with complexity, and this is done enabling them to look at particular areas of the system, models also are intended to facilitate the communication between members in an organization, they capture and decompose essential features of systems, which are converted into more manageable parts that are easy to understand and to manipulate. In more practical and condensed terms it is said that "*A model is a simplification of reality*" (Abdullah, Benest, Evans & Kimble, 2002). Even that knowledge is an abstract concept, for an organization that has the interest in the retention of essential knowledge from its members; work has to be done to structure a model that can capture this knowledge, a model must break down from the general to the particular knowledge; and must give the opportunity to the organization members to easily identify the knowledge types or classes they are familiar to.

Some of the knowledge modeling tools that are commonly used is the Concept maps and the Ontologies.

2.4.1 Concept Maps

Concept maps are a result of Novak and Gowin's (1984) research into human learning and knowledge construction. Novak (1977) proposed that the primary elements of knowledge are *concepts* and relationships between *concepts* are *propositions*, defining concepts as "records of events or objects, designated by a label", this means that concepts are visual, graphic, textual or other media representations of common events or objects in an organization. Propositions consist of two or more concept labels connected by a linking relationship that forms a semantic unit. The conjunction of concepts and proposition leads to the development of concept maps, those are defined as graphical display of concepts.

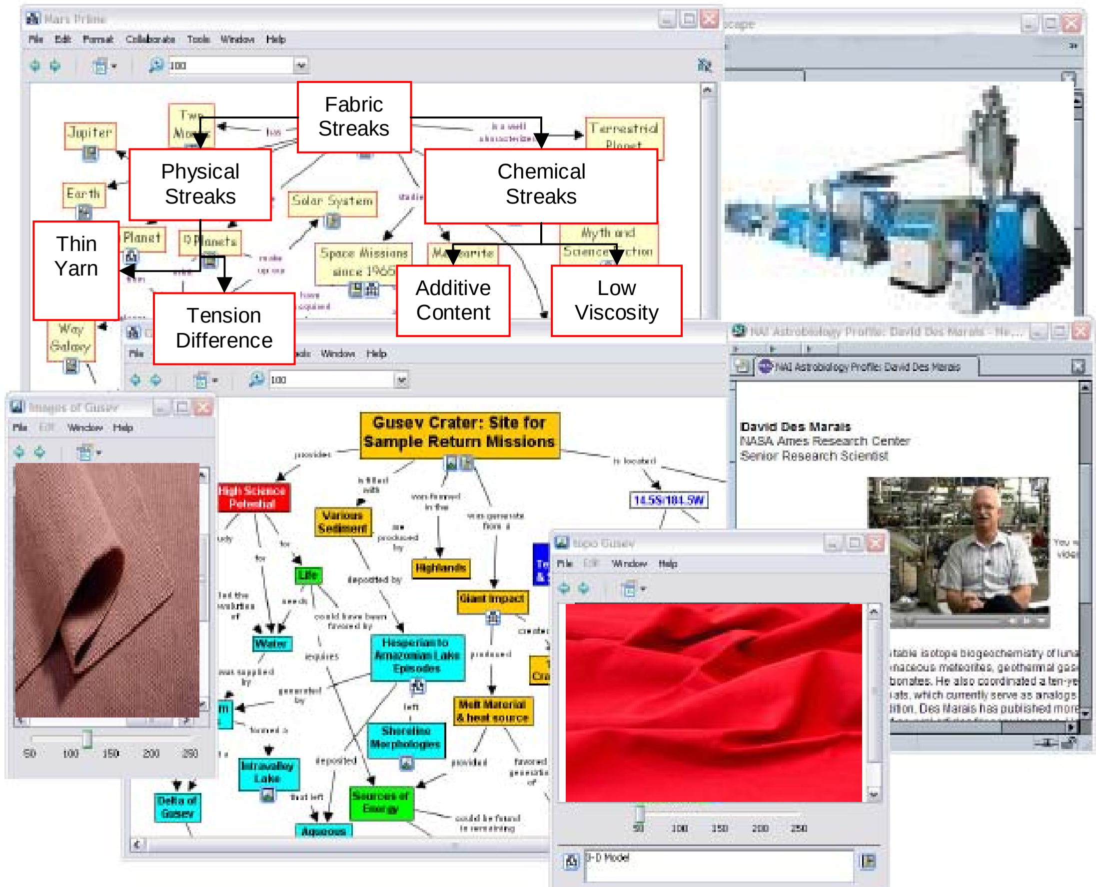


Figure 2.7 - A knowledge model (adapted from Cañas et al., 2004)

Concept maps are told to be a way of representing what a person understands or know of a certain field of knowledge. The use of Information Technology makes easier the construction and modification of the knowledge representation, and to allow groups of people to share in the construction of the concept maps (Cañas at al., 2004). The purpose of concept maps is to empower users, individually or collaboratively, to represent their knowledge, to share them with peers and colleagues, and to publish them, concept maps are also linked to related concept maps and to other types of media (e.g., images, videos, web pages, etc.). The collaboration between users enables them to participate in the construction or renovation of concept maps, promote comments, criticism, and peer review. The public repositories results in a collection of knowledge models, constructed by users in a variety of domains of knowledge and from different physic locations.

At the Institute of Human & Machine Cognition (IHMC) at the US, the research efforts had its origins in the use of concept mapping for knowledge elicitation. At the IHMC was developed a toolkit for knowledge acquisition and the development of expert systems. One of the particular developments is a nuclear cardiology expert system NUCES (Ford, Cañas, Andrews et al., 1991; Ford et al., 1996); the mentioned authors wanted to extend the use of concept maps beyond knowledge representation, and serve as a browsing interface to a domain of knowledge. NUCES used a concept map-based browser as the interface for the explanation subsystem of the expert system. This concept mapbased interface provided a way of organizing and browsing knowledge about any domain included in the map (Cañas, Ford, & Coffey, 1994), the concept maps provides access to diverse knowledge representation tools like images, videos, audio, texts, etc. (See figure 2.7).

2.4.2 Ontologies

Knowledge is scattered throughout various documents within organizations, and is possible that organization's knowledge is stored without the opportunity of being retrieved and reused, since is not adequately structured by the use of guides or maps; causing that this knowledge will not be shared and possibly forgotten after it has been invented or discovered. It has become important for "learning organizations" to make the best use of information gathered from various sources, like documents, practices, users inside the organizations and also from external sources like suppliers, customers. Organizations are concerned with preserving knowledge within (Marian, Tomas, Jan & Robert, 1998). The authors referred three stages in the information life cycle: finding (acquisition), organizing and sharing.

The research work done by the mentioned authors was based on the theories of ontologies representation for knowledge modeling. The ontology represents formal terms with which knowledge can be represented and individual problems within a particular domain can be described. Marian, Tomas, Jan and Robert argued that there two purposes for which ontologies may be used:

- to define most commonly used terms in a specific domain, thus building a skeleton that contains common knowledge identifications for an organization,
- to enable knowledge sharing and re-using both spatially and temporally, giving privileges to the users that owns and creates knowledge within the organization;

Ontology allows a group of people to agree on the meaning of some basic terms, from which many different individual instantiations, assertions and queries may be constructed. Once there is a consensus on understanding what particular ‘words’ mean, knowledge represented by these words can be adapted for particular purposes. Knowledge must be defined unambiguously because different people in the organizational structure of an organization need to use them with the same meaning. Thus, it is possible to reuse and share the knowledge once people reached an understanding of the representations made by the ontologies used.

The purpose of the knowledge model proposed by Marian, Tomas, Jan and Robert (see figure 2.8) is to provide a graphic representation of the knowledge that resides in an organization, using ontologies, which can be related either for operations, developments, researches, etc.; one advantage that can be identified of this model is the linkage of general subjects to particular documents, records or multimedia files, and this could facilitate the search done by a user who is making a query in the system. What can imply a certain degree of complication would be the construction of the domain models and ontologies, since it can not be easy for all the users in an organization to construct that kind of domains using ontologies; but a good point could be that the usage of ontologies, and the privileges of the users to modify an existent domain model and ontologies, is that a first trial will be subsequently improved either by its creator or other users; the challenge then would be to encourage the members within an organization to use a knowledge system like the proposed. It is certain that the use of ontologies condensate and ease the use of terms to identify knowledge fields in an organization, and that there are also a certain degree of complexity in how to develop the ontologies useful for an organization, however the model proposal must be made by a knowledge expert or an expert team designed by the organization, whose own a high level of expertise within the

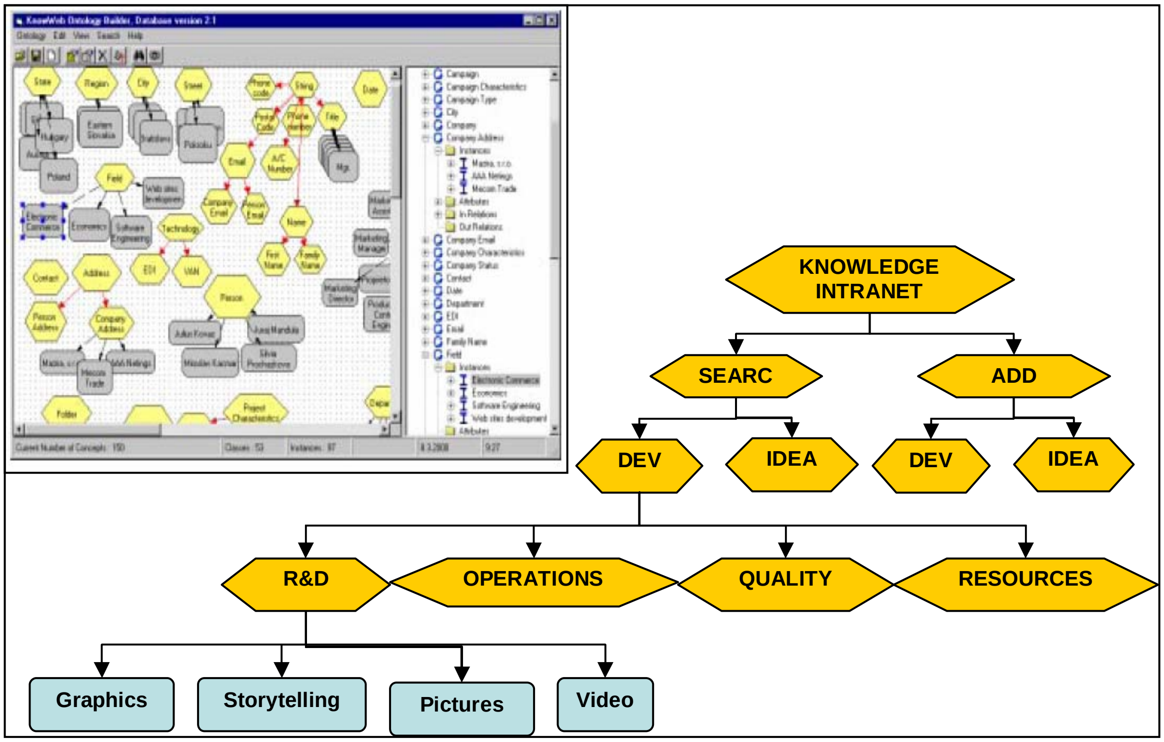


Figure 2.8 - Sample of a Domain Model (adapted from Marian, Tomas, Jan & Robert, 1998)

Organization and can provide ontologies terms easily identified for the rest of the members, which will be only the users and not the designers of the model that will store the knowledge from the organization members.

With increasing pressure on top executives to deliver results, they acknowledge that today's business environment is fueled by a resource called knowledge, however some still perceive knowledge networks as just another flavor-of-the month management fad, as well as communities of practice, are considered as another 'in thing' in knowledge management have been dismissed by managers as a an activity that is beyond their control and of no real benefit to the organization, the previous is argued by Costa and Young, 2001. It is also argued that knowledge networks increase innovation and improve organizational efficiency, and can have greater benefits if they are structured and receive management guidance.

A commonly used tool for the ontologies-knowledge modeling is the Unified Modeling Language (UML), it is considered a vehicle for the object oriented design and analysis of the manufacturing information and knowledge structures by obtaining a set of class diagrams, describing the relationships between classes in the MFIKM. This choice was made because UML has become recognized as an accepted language to support the design and modeling of multiple perspectives of information Systems (Costa and Young 2001).

2.5 Manufacturing Knowledge Creation and Sharing

It has turned more important the knowledge management than the knowledge creation within an organization (Von Krogh, Ichiro and Nonaka, 1999). The knowledge creation is not only a process of data compilation, which is transformed into value creator knowledge; it is a process for the building of truth, based on approved certainties. These authors proposed the existence of five factors that facilitate the knowledge creation; 1) promote in the organization a knowledge view, 2) lead conversations between the employees, 3) develop knowledge promoters, 4) create an adequate context, and 5) local knowledge globalization. The importance from the previous statement done by the mentioned authors, is that the organizations should not only focus in the implementation of tools, systems, metrics and design a responsible of the knowledge management, but the development from the top management to the engineers, technicians of a philosophy or key strategy to promote and convince people about the importance of the knowledge that resides within them, and also the importance of transform that knowledge into a form that can be shared and utilized by their peers.

Researchers and consultants have recommended to the organizations to consider the knowledge creation as a source for competitive advantage, and to generate a learning environment which satisfies the information economy demands.

However, even that an organization promotes the knowledge creation as a key strategy, the employees can not be forced to be creative and to share knowledge, it should not be an obligation, and also there should be compensations and promotions strategies that encourage the employees to be active participants in a knowledge creation environment.

An efficient knowledge creation depends also on the existence of an appropriate context, a common space which can be physical or virtual. If the knowledge creation is stimulated in an organization, it is suggested to occur in an environment where the employees have the motivation to implement and apply the ideas from their peers, the previous statements were agued by these authors (Von Krogh, Ichiro and Nonaka, 1999). Also explained that knowledge-based view of a firm, considering a firm as a knowledge-creating entity, argued that knowledge and the capability to create and utilize such knowledge were the most important source of a firm's sustainable competitive advantage.

A critical step rather than create the knowledge, is to recognize it, and know how to translate it from a tacit to an explicit form; part of the knowledge that resides in the employees can be represented in manuals, instructions, graphics, drawings, etc; however there are another knowledge that is not easy to transform like the personal experiences accumulated, individual perceptions and intuitions.

Nonaka and Takeuchi proposed five steps for the knowledge creation; 1) share the tacit knowledge, 2) create concepts, 3) justify concepts, 4) develop a prototype, and 5) assign a level to the knowledge.

Without active knowledge sharing, employees and their leaders have little input on how to improve or revolutionize the way they create value. This is one of the factors of loss of competitive advantage, since the environment in which it operates is dynamic, caused by high levels of employees turnaround with the consequent loss of the knowledge acquired by employees which leaves the organization. Knowledge is considered essential to profitability. Successful companies use knowledge of their businesses, their customers, their competitors, and their environment to create valuable and difficult to imitate products (MBM, 1999).

If employees do not share knowledge in ways that allow them to capitalize on this change, the company will eventually perish. In order to avoid this fate, we strive for two goals:

1) Proactive knowledge-sharing: This means breaking down barriers between businesses so that employees from different units can ask one another questions, seek and offer advice, and provide constructive criticism. This requires the recipient of advice to exercise humility and acknowledge that he can learn from others, be they supervisors or subordinates.
2) Integration: This involves recognition that the value chains which comprise IK are not separate entities, but an evolving interactive network. If an employee has an idea that he think might add value to his particular work, he should also consider its impact on the work of others. What may seem like a barely significant byproduct of one production process may turn out to hold enormous potential value to other value chains.

The goal of IK is to create knowledge systems that promote proactive knowledge sharing and integration among all its businesses and capabilities (MBM, 1999).

The preceding paragraphs show the intention of the Company IK that holds the related Chemical Plant which produces Synthetic Textile & Personal Care Yarns to support the existence of Knowledge Systems that could enhance the performance of its different businesses, and the related Plant in this thesis work is no exception, this is one of the main reasons why a model for the tacit knowledge related to manufacturing was chosen to be developed and proposed in the search for add value to the business with a better management of its Knowledge.

Approaches to information and knowledge sharing have been researched, and those approaches have shown how methods of structuring information can provide a basis for information sharing. However, these have two significant limitations: the users of these structures must be willing to agree on a common structure for the information needed; the system developers and users must share a common understanding of the semantics, or meaning, of the structural elements to be captured. The latter appears to be particularly difficult to achieve and has led to a wide range of ontology based research (Gunendran & Young, 2006).

As the 21st century unfolds, organizations regard the strategic management of knowledge resources as one of the key factors for sustainable competitive advantages. In particular Knowledge Sharing is perceived to be an essential process for knowledge management. However, sharing knowledge is not a natural process developed by people inside organizations; people are not commonly committed to share their knowledge as they think their knowledge is valuable and important, and an instrument that preserves them in an organization. Hoarding knowledge and looking suspiciously upon knowledge from others are the natural tendency. This natural tendency is difficult to change, and takes time to promote and reach a cultural change. And rather than just encouraging or mandating knowledge sharing, fostering the motivation to share knowledge must precede (Bock & Kim, 2002). Should also be considered to compensate employees for their contributions obtained by the sharing of their knowledge when it has been adequately validated and reused by others within the organization, and it contributed to solve or prevent potential issues that could have cost time, money or impacted other important metrics from the organization.

Knowledge sharing is a kind of social interaction among people. Two principal theories which explain the social interaction of people are economic exchange theory and social exchange theory. According to the economic exchange theory, individuals will behave by rational self-interest, this is explained based on the theory knowledge sharing occurs when its rewards exceeds its costs, and is referred not only to costs for the organizations but for the employees also (Bock & Kim, 2002). And the expected rewards could mean that people will receive benefits such as monetary rewards, promotion or educational opportunity, and that way the will develop a positive attitude toward knowledge sharing.

On the other side the social exchange theory engenders feelings of personal obligation, gratitude, and trust. Expected associations assume that if employees believe they could improve relationships with peers by offering their knowledge, they would develop a more positive attitude about knowledge sharing (Bock & Kim, 2002).

The results obtained from the study taken on four Korean enterprises, showed that contrary to think that the economic benefits were the main engine that drive the knowledge sharing, they discouraged the formation of a positive attitude toward sharing. This study developed by Voelpel and Han is explained on the reasoning that rewards can have a punitive effect; due to diverse reasons like not receiving an expected reward is indistinguishable from being punished; rewards can break off relations, for each person who wins, implying a feel of fear of loose their connections with their peers; others feels they will loose; since if there is a limited number of incentives, people will begin to look at each other as competitors and to consider themselves as incapable to reach an incentive; or if employees develop a feeling of being constantly controlled to measure the contribution they are making to the organization, to provide them a large reward, they lose interest in what they are doing, or another cause of loss of interest in the knowledge sharing process is that if the rewards programs has limited number of prizes or recognitions, once the rewards run out, people returns to their normal behavior, and they became discouraged to share their knowledge. It is certainly a delicate subject to be discussed within the organizations, since people has different personalities and behaviors, and the management must look to a knowledge sharing-rewards proposal that will be comfortable if not for all at least for the majority of the employees.

In some cases the most experienced employees learned through the time they have spent within an organization that they should share their knowledge which was acquired from their work and training they received from former experienced employees; and they perceive knowledge sharing as a normal activity. Research has been done in multinational companies that are practicing knowledge management through their globally dispersed subsidiaries, however very little is known about particularities of practicing knowledge management in the context of a specific country. Beyond studies focusing mainly on the triad regions of the USA, Japan and Western Europe, there are barely research works within other geographical contexts, even though the relocation of industries from developed countries to low-cost developing countries will continue in the long term (Voelpel & Han, 2005).

Even that the research case does not refer to a new facility transferred from a developed country, it does belong to a Multi-National Company (MNC), and it certainly must operate under the same management strategy as the rest of the companies that belong to IK, and one of the structures as mentioned before are the Knowledge Systems; and as the past paragraph mentions, the study cases are developed in a plant located on a developing country with different cultural aspects as the company origin country, which in this case are the United States.

On a research developed between 2003 and 2004 in a MNC facility located in China, were identified some differences along with the ones located in the developed country referred to Knowledge Management, and Knowledge Sharing; those differences were classified into four dimensions technical skills, organizational capabilities, marketing knowledge and environmental familiarity; some of them represents advantage for the Chinese peer, and some other disadvantages. The research also showed that Chinese people were opener toward knowledge sharing in contrast with the USA partners, due to a higher degree of collectivism. Other finding is that by that time knowledge management theory was basically leader-oriented, and not institutionalized. An author referred by Voelpel and Han proposed four main reasons for the gap in the Knowledge Management theory across Chinese companies, inadequate planning and a lack of resources, insufficient accordance with the company's core business, a shortage of knowledge management specialists and a lack of appropriate management tools (Voelpel & Han, 2005).

Even that the plant where this research project was chosen to be developed are located in Mexico, it is important to note that as in Chinese companies, Knowledge Management theory is not well known by this organization, and the research has the possibility to face cultural aspects that can show reluctance to the proposal and possible implementation of a model for the tacit knowledge related to manufacturing retention by a system provided to the employees.

The research study also involved the evaluation of the implementation and success of a system specifically designed for the Knowledge-sharing across the facilities located world wide. This system belongs to the German company Siemens, and It is called "Siemens ShareNet"; and that system integrates components such as knowledge library, a forum for urgent requests and platforms for knowledge sharing in order to gain not only explicit, but specially tacit knowledge – which is considered by this company as the more important source of innovation – the purpose of this system is to go beyond and improve the traditional knowledge repositories developed until then (Voelpel & Han, 2005). The structure of the Siemens Sharenet is showed in figure 2.9, it is integrated by a committee for the global management of this system and rewards assignation to the contributors considered that created value for the company; this committee counts with the support of an Editor that filters the knowledge added to the sharenet, information technology for the correct operation of the system, a hotline were users can direct their questions. The next level is conformed by the sites Sharenet Managers, whose manage the local systems and encourage their peers to contribute to the sharenet; and the last level is conformed by all the users with access to the sharenet.

The system used by Siemens as the tool to share tacit knowledge among its employees across the world, has local structures for its facilities that are spread across the world with the existence of local Sharenet Managers, whose first task is to promote the use of this system, also supervise the network and scanned the contributions for quality, and bid feedback; an addition of the Siemens Sharenet are the incentives to motivate the employees to use the Sharenet, it is mentioned that the introduction of the incentives boosted the number of contributions significantly (Voelpel & Han, 2005).

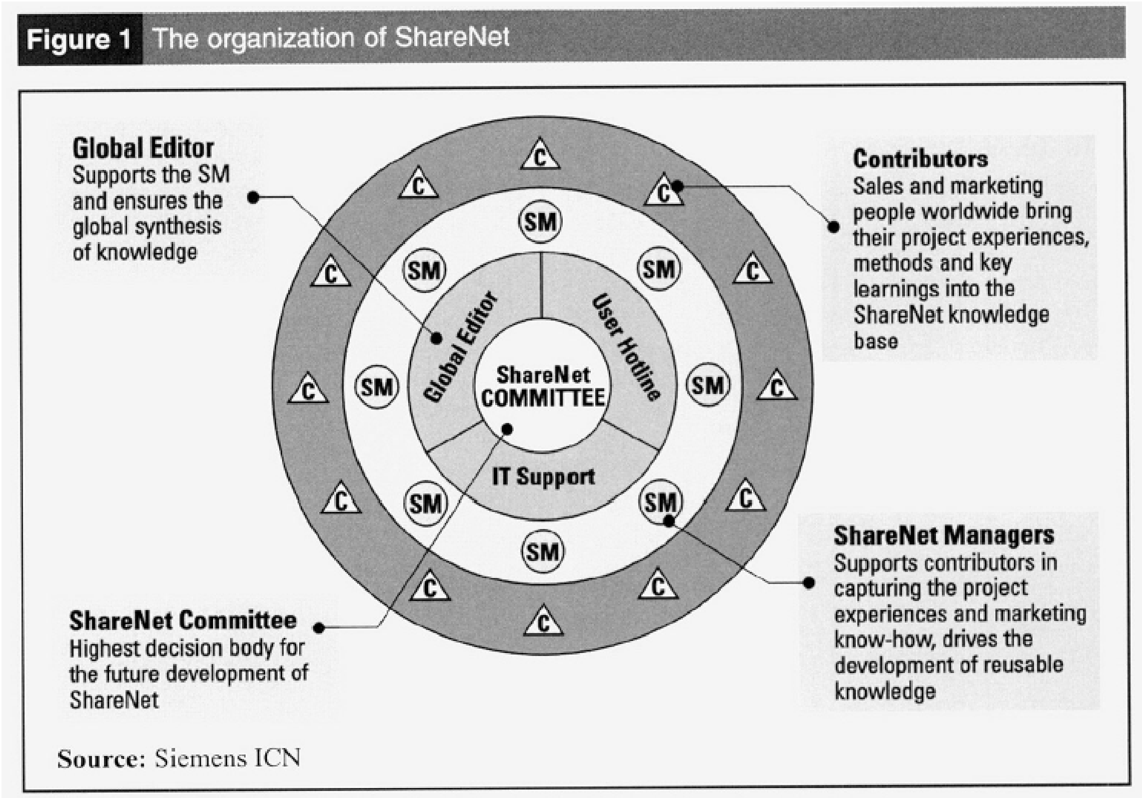


Figure 2.9 – Siemens Sharenet structure (Voelpel & Han, 2005)

Motivations for knowledge sharing are mentioned to be complex and multifaceted in China. From the knowledge receiver's point of view the use of Sharenet can save considerable time and enhance productivity, and provides solutions based on the experiences of colleagues and experts, derived from the best practices of projects in other regions of the world. Also the users manifested that if the answer to urgent requests was not satisfactory, they had the opportunity to contact the right people that can provide a high-quality answer. From the contributor's point of view, the factors that motivate Chinese employees to share their knowledge are Incentives and the Culture. There is not a published formal study about the implementation of knowledge management-sharing tool in Mexican companies; however it can be argued that culture of Mexican employees differs from the Chinese employees, this means an opportunity to be developed, measure the level of acceptance, usage and contribution of companies, contributor and user employees in Mexican companies.

However there were also barriers that decreased the level of contribution of employees to the Siemens Sharenet, and two main were identified; the company decided to stop the program of incentives due to the global economy contraction at 2001, and this caused a huge decrease in the participations; and the second is that when the company decided to give material incentives instead of monetary, they found that the higher the level of an employee the less interest in participate in the sharenet. This can be considered as a global factor, people is more encouraged by monetary than material incentives, that is why the implementation of a knowledge sharing culture must emerge from the rewarding until it reaches a cultural change when the sharing process is considered a normal process and part of the normal performance of an employee.

Ontologies are widely used across a range of applications such as knowledge engineering, artificial intelligence and computer science, knowledge management applications, natural language processing, e-commerce, medical applications, intelligent information integration, data base design and integration, information retrieval and semantic web, previous researches argued that the ontology applications are to support information and knowledge sharing. The activities of product development and manufacturing require several contexts of information and knowledge related to the product as well as to manufacturing capabilities such that the modeled information and knowledge can be used to support the product development (Gunendran & Young, 2006).

Gunendran and Young also aimed that product/manufacturing models are the sources and repositories for the information and knowledge of product development and manufacturing activities, and must be able to share the required information between many users; and the structures they have need to be understandable and capture concepts, concept taxonomies, axioms, rules, functions, procedures as well as relationships.

2.6 Manufacturing Tacit Knowledge & Organizational Learning Management

With the ending of the single-job-for- life culture, businesses lose much of that knowledge when an individual leaves the organization. Knowledge management (KM) is emerging as a discipline that provides the mechanisms for systematically managing the knowledge that evolves with the enterprise. Most literature on KM classifies knowledge into two main categories: explicit knowledge and tacit knowledge. Explicit knowledge can be defined as things that are clearly stated or defined, and are tangible documents, images, etc., while tacit knowledge can be defined as things that are not expressed openly, but implied, it means are abstract objects, like concepts, ideas, skills, learning, etc. (Abdullah, Benest, Evans & Kimble, 2002). Both basic knowledge types exists within an organization, and in the case of manufacturing organizations is no exception, part of the knowledge from the organization can be stored and classified in documents like procedures, instructive, practices; but the tacit is definitely important part that resides within the employees, and is not easily captured and translated.

Explicit knowledge can be defined as knowledge that can be seen, shared and communicated with others, and exists in tangible ways like manuals, procedures, instructions, etc. Tacit knowledge on the other hand is that which is embedded in a person's memory and which is difficult to extract and share with others, is the knowledge of "how-to solve the problem" and constitutes actually an employee's ability, knowledge and skill. While the techniques for problem solving can be learnt in the classroom, how they are used in a particular solution is a personal skill and the solution created by one employee will differ from that of another. These variations are attributable to the differences in the tacit knowledge.

A recent study has gone to develop indexes to manage the intellectual capital of the organizations, and the intellectual capital is referred as the tacit knowledge from the employees, measuring the effect of tacit knowledge on an organization performance, resulting in that organizations with higher degree of tacit knowledge usage had also better financial and innovation metrics; and it also permitted in an indirect way to measure their competitive advantage based on the tacit knowledge that resides and are utilized in the company. This research study was developed in more than 100 US and Canadian firms that currently used knowledge management tools (Harlow & Imam, 2006).

Another study was leaded intended to define if approaches for tacit or explicit knowledge separately had more benefit for an organization, and the conclusions lead to define that the alternative to combine both knowledge types in the knowledge management strategies retrieves the greater benefits. The proposal of the right combination and balance vary with a number of factors like the technology the organization uses, the market conditions it faces, the "knowledge intensity" of its strategies and operations, the current attitudes of its key knowledge workers toward the organization, the degree of geographical dispersion of its knowledge workers, the resources available to the organization to invest in developing infrastructure and processes for its knowledge management practice (Sanchez, 2000).

Organizations that have not implemented systematic knowledge management approaches are suggested by this author (Sanchez, 2000) to begin with tacit knowledge management practices, since they argued that tacit knowledge management approaches often create surprising organizational interest in and energy for developing more extensive knowledge management practices. The achievement of initial organizational successes through use of tacit knowledge practices helps to build confidence that the knowledge management practices will be worth the effort. He stated that organizations that manage to implement effective knowledge approaches not only will be more effective at leveraging their knowledge, but will also become better learning organizations.

Stenmark commented that even that tacit knowledge constitutes the major part of what people know, it is difficult for organizations to fully benefit from this asset. This is because tacit knowledge is inherently elusive, and in order to capture, store, and disseminate, it first has to be turned into explicit. But the conversion from tacit into explicit is not exactly easy, and is expressed to often fail due to three reasons:

3. People is not necessarily aware of our tacit knowledge,
3. On a personal level people do not need to make it explicit in order to use it, and this applies for tacit knowledge that is not utilized by a person itself, and that is not necessary shared with others, and
3. People do not want to give up a valuable competitive advantage (Stenmark, 2000).

2.7 Knowledge as a resource in Decision Support Systems

Good Decision Making is imperative for organizations to survive. In order for good decision making, the proper steps must be taken to ensure accurate information is used, it can also be applied to knowledge for decision making. Traditional Decision making phases takes the Decision Maker through knowledge gathering, alternative formulation and finally a selection of the alternative. These phases indicate that the Decision Making is considered a Knowledge intensive activity. Not only is Knowledge a requirement for making a decision, but the decision itself then becomes a piece of knowledge (Jones, 2006).

Some models of KM activities have been developed; one is the Knowledge Chain Model. This model describes five primary and four secondary activity classes which were noted to contribute to competitiveness (see Figure 2.10).

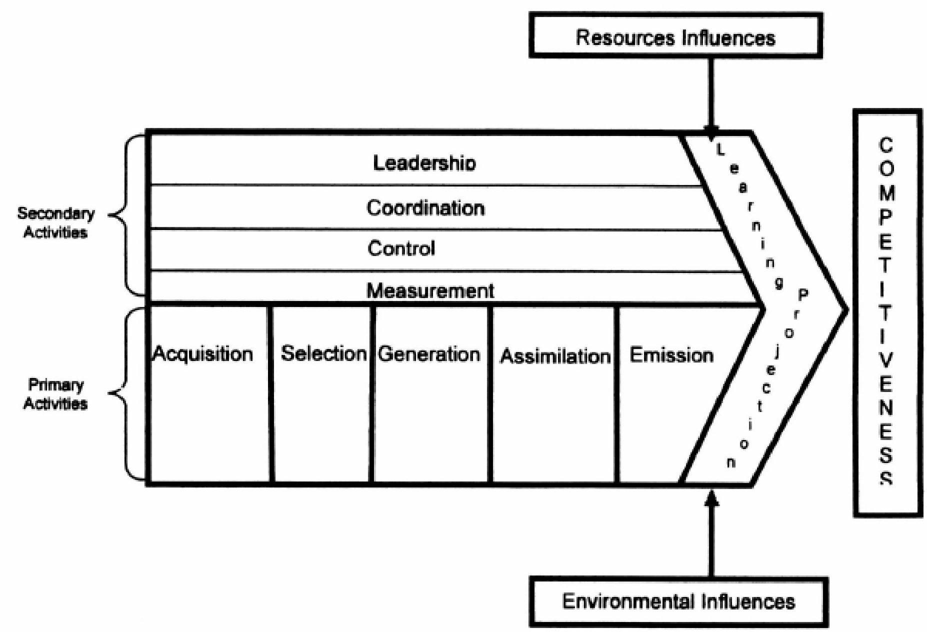


Figure 2.10 – Knowledge Chain Model (Lee, 2000)

The Decision Making Process has been proposed to de divided in four phases;

3. Intelligence – The decision maker is aware of the need for a decision making, and collects the knowledge surrounding, that can enhance the potential decision;
4. Design – Alternative courses of action are formed, speculates the possible outcomes;
5. Choice – The decision maker choice one of the alternatives, however this stage could not be easy to take since similar outcomes could give similar results, or none outcome could give the expected results, the decision maker requires a certain level of expertise to ponder the different knowledge gathered and supports his/her decision on the ones that are expected to retrieve the greater benefit;
6. Implementation – Apart from the implementation, it may imply alert the effected individuals.

Each one of the Decision Making Process Phases needs knowledge to be completed. Poor quality decisions could result if the required knowledge is not present, is incomplete or the decision maker does not has the skills required to run the decision making process (Jones, 2006). Decision Making is the "process of selecting from a set of options the alternative(s) that are most likely to lead to desired outcomes". In order to select a set of options, the decision maker must first obtain information regarding each possible alternative. Once this information is gathered and culminated in an alternative it is considered a new piece of Knowledge; and the Knowledge surrounding not chosen alternatives can be considered as by-products.

A survey taken by Kepner-Tregoe at Princeton, New Jersey, showed that employees are having to take more decisions and in less time than in the past. By making decisions quickly, decision makers in some cases are sacrificing quality, productivity and customer service; and on the other hand Business today requires taking better quality decisions to help the organization succeed (Goldwasser 2001).

The Knowledge Activities showed in the Figure 2.10 and the Decision Making Phases mentioned in the prior paragraphs have similarity (see Figure 2.11).

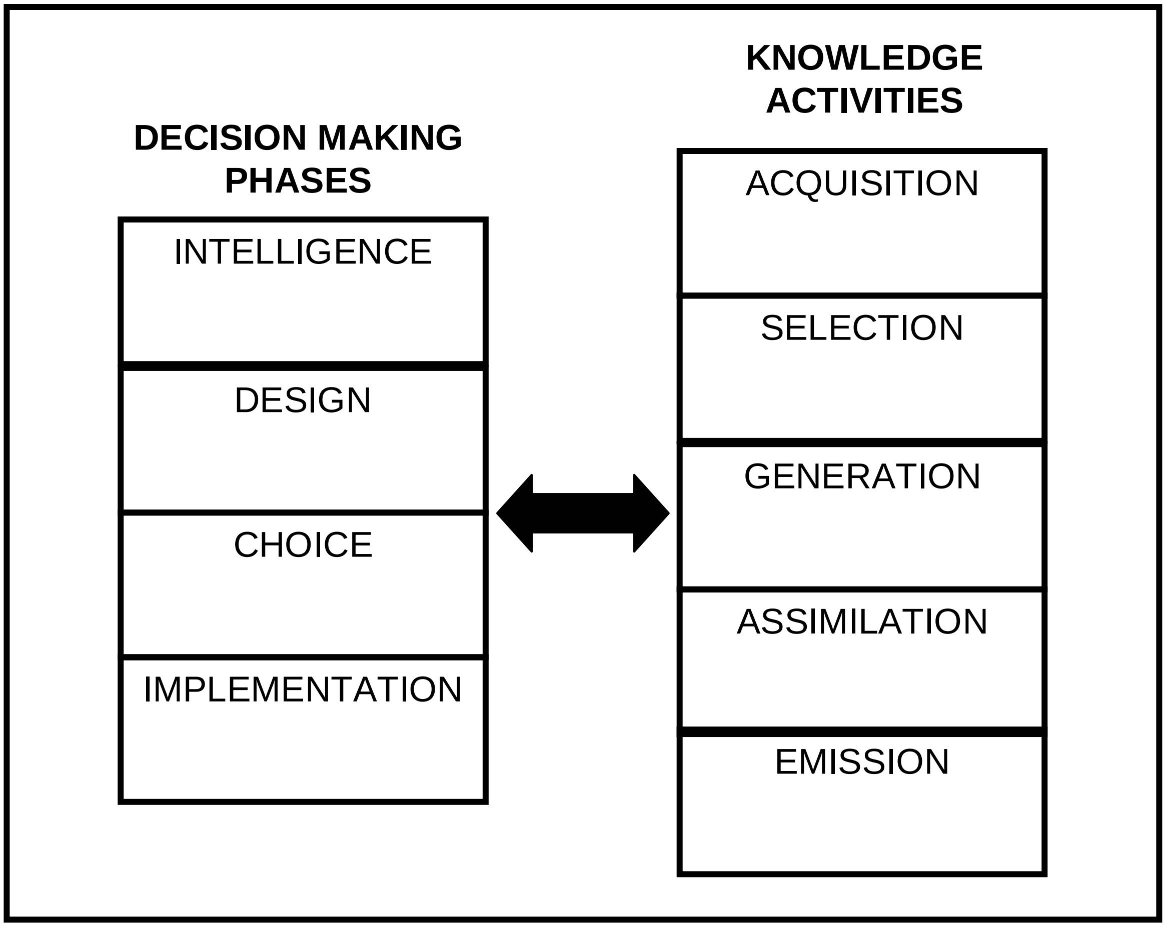


Figure 2.11 – Decision Making Phases vs Knowledge Activities (Adapted from Jones, 2006)

In order to effectively and efficiently practice decision making, decision support systems (DSS) have been used in some of the phases of the decision making process. If those similarities between the KM activities in the Knowledge Chain Model and the Decision Making Phases are better understood those mean that better DSS can be built to help organizations improve their Decision Making Processes.

2.8 Discussion

- The Manufacturing Knowledge is a research field that has reached a degree of importance in the Knowledge Management, the researches developed by different authors demonstrate the interest to provide to the manufacturing companies models or structures were those companies can store, reuse and renew the tacit knowledge acquired and developed by the employees. The types of manufacturing knowledge are not a complete developed branch since the diversity of industry areas, companies; languages provide difficulty in defining common keywords for classes and attributes.

- It has been also demonstrated that individual efforts of some researches and companies like Renault-Nissan and a Pharmaceutical Company have worked on the development of models and subsequent systems intended for the capture and management of knowledge related to their manufacturing processes, but mainly from their employees. Either databases, discussion boards, intranet pages, etc. but all with the same purpose retain the knowledge that is not currently retained.

- The Chemical and Petro-Chemical Industry is no exception of moving to knowledge management approaches, it is certain that the high degree of complexity of Chemical or Petro-Chemical Plant Operations can represent a difficulty in the structuring of a general model adapted for all the vast type of operations worldwide, however the importance of have found information about this industry provides an impulse to work on a proposal for a Chemical Textile Plant.

- Models are intended to be simplifications of reality, but has the complexity of how to select the tool that best fit to model the Knowledge from a Manufacturing Facility, it means it is complex the Knowledge Modeling, since knowledge in its tacit way is abstract and is difficult to be expressed, however with the combination of the tools encountered like Concept Maps, Ontologies and tools like UML diagrams, previous researches and the selection of adequate keywords that interpret the Tacit Knowledge type of interest exist the possibility to work on a proposal for the problem stated in this thesis work.

- Knowledge Creation is constant and inherent process developed within the manufacturing facilities, since they are dynamic organizations that are constantly renewing process, equipment and/or products; and this knowledge creation is basically developed within their employees. Employees are the basic structure of a facility and they are the owners of the knowledge related to the manufacturing; the need in the thesis problem is how to identify the knowledge created. The other challenge that has been faced by other researchers and is not discarded in this thesis work is the knowledge sharing, and how to achieve the convincement of the employees to share what they know and that is not structured in procedures, instructive, images, etc; and a challenge is bigger since the previous studies refers to case studies from different companies, different countries and different cultures.

- The same challenges can be faced on the development and implementation of a DSS for a Manufacturing or Chemical Plant, since the developer, and not necessarily the Information Analyst; has to deal with diverse point of views of the different roles played in the Company, from the Manager to the Technicians, whose are intended to be the final users; it is important to take in account the challenges mentioned once a proposal for the DSS is done and approved.

3. MANUFACTURING TACIT KNOWLEDGE MANAGEMENT MODEL

This chapter contains the author's research idea of a Model for the Manufacturing Tacit Knowledge Management. It proposes a Model based on UML class diagram for the structure and management of the Tacit Knowledge resident in a Manufacturing Facility. The model includes general terms for the manufacturing knowledge classes explored, and it was developed in a Manufacturing Facility (Chemical-Textile Company); and the purpose is that the model structure and knowledge classes defined can be exported to other facilities in the same industrial sector, or also exported to different industry areas, and be a tool for the management of Manufacturing Knowledge existent in Tacit ways.

The model was developed using UML (Unified Modeling Language), since it allows the creation of classes that represents the Manufacturing Knowledge types, and their particular attributes. UML allows a complete visualization of the model.

The chapter is divided in three sections, in the first the structure of the Manufacturing Facility (Chemical-Textile Company) which is the base to conform the model is presented; second contains the Manufacturing Tacit Knowledge definition and the Manufacturing Tacit Knowledge types that exists within the Manufacturing Facility (Chemical-Textile Company); and fourth section contains the Manufacturing Tacit Knowledge Model

3.1. Manufacturing Facility (Chemical-Textile Company)

The development of a Model for the Management of the Tacit Knowledge that resides within a Manufacturing Facility, first requires to recognize the areas within the facility that are part of the manufacturing process, meaning the different areas of expertise that exists in the facility; the areas served to create a schematic to recognize where the Manufacturing Tacit Knowledge resides.

This research work was done on a Manufacturing Facility described in section 1.1, the facility produce synthetic yarns for the textile industry; the structure of this facility served as the basis for the development of the concepts and model proposed in this research.
As previously seen in chapter 2, the tacit knowledge is that which is embedded in a person's memory and which is difficult to extract and share with others. For example, how a senior manager uses a particular decision theory to solve certain problems. The knowledge of "how-to solve the problem" is actually the manager's ability, knowledge and skill. While the techniques for problem solving can be learnt in the classroom, how they are used in a particular solution is a personal skill and the solution created by one employee will differ from that of another (Abdullah, Benest, Evans & Kimble, 2002).

To identify and select where the Manufacturing Tacit knowledge resides, first has to be explained the organization of the company, as well as to identify the employees that creates and owns the knowledge (see figure 3.1).

For the purposes of this research work general terms are used to describe the Facility areas and employees roles, to facilitate the understanding of the structures and the model proposed.

The areas in the Manufacturing Facility that participates in the creation of Manufacturing Tacit Knowledge are those related with the production of the products/goods, and are defined as follows (figure 3.1 shows a proposed schematic of the areas within a Manufacturing Facility):

- Operations – Is the area that includes all the tasks and employees dedicated to the operation of the manufacturing equipment in the production lines;
- Maintenance – Area that includes all the tasks and employees dedicated to the routine maintenance and increase the reliability of the manufacturing equipment;

- R&D (Research & Development) – Area that includes all the tasks and employees dedicated to the development and improvement of raw materials, products and processes;
- Quality – Area that includes all the tasks and employees dedicated to the Management of Quality Systems to guarantee the compliance of Products and Raw Materials quality specifications;
- Engineering – Area and employees dedicated to the design and improvement of manufacturing equipment.

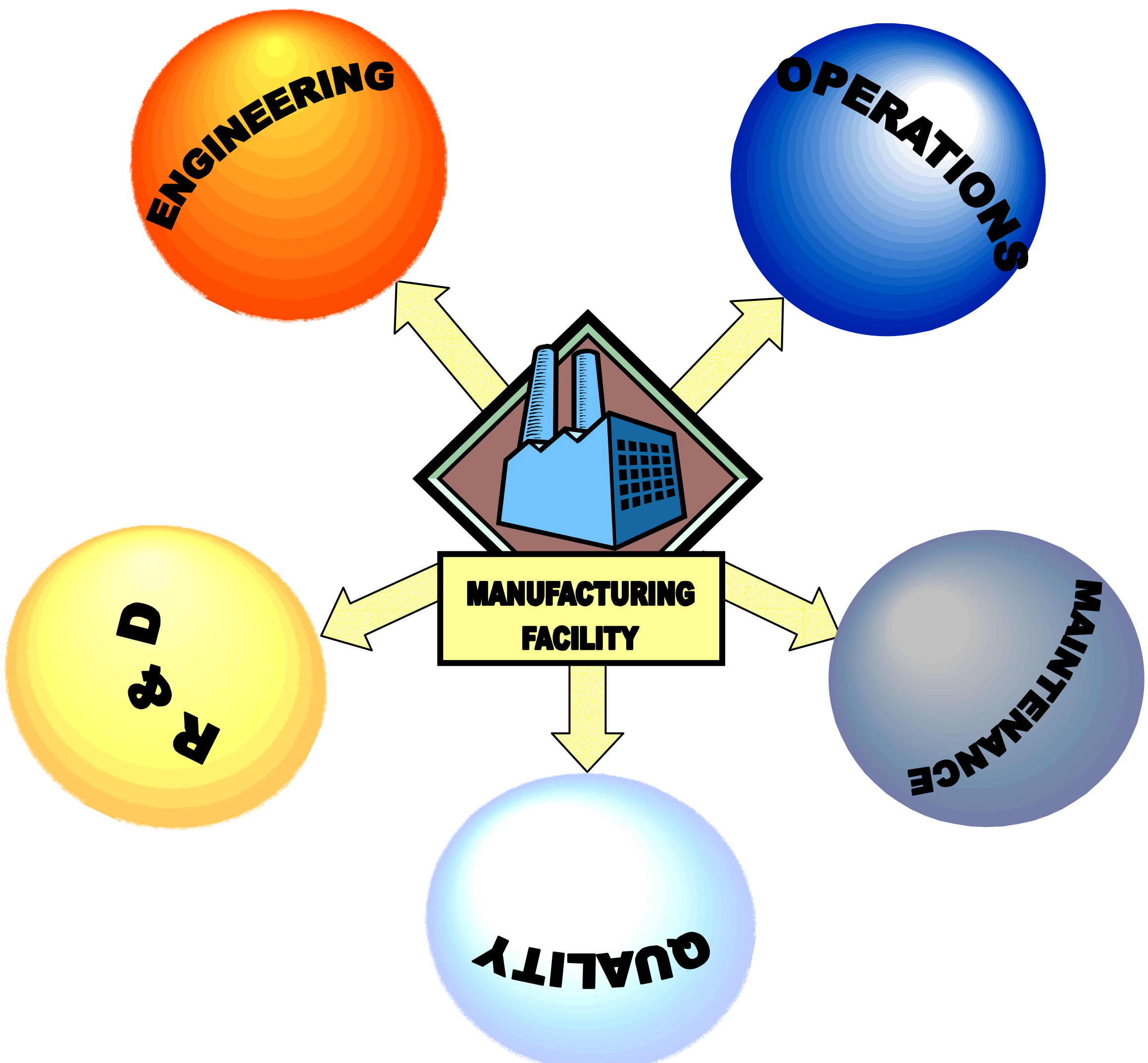


Figure 3.1 Manufacturing Areas in a Manufacturing Facility

The definition of the areas existent in the facility, serve as the basis for the definition of the Manufacturing Tacit knowledge types and for the Manufacturing Tacit knowledge model construction. In the research work done by Guerra (Guerra, 2004) was explored how different types of knowledge can be used and maintained in a manufacturing knowledge structure, making an important contribution on the Manufacturing Knowledge research, since it provides definitions of the knowledge types within a manufacturing facility and a model for the manufacturing knowledge maintenance. For this research work were found opportunities to extent the research in the Manufacturing Knowledge field, and those opportunities are:

- the definition of Manufacturing Tacit Knowledge Types;
- the detection of the Manufacturing Tacit Knowledge creators and owners;
- and the proposal of a Model for the Manufacturing Tacit Knowledge Management that will be the base for the development of a Knowledge Based System (KBS) as the tool to recognize, capture, reuse and maintain the knowledge of interest.

The Manufacturing Knowledge on the research done by Guerra (Guerra, 2004) is the knowledge structured to support machining process-planning decisions and is related to process and structures within a Manufacturing Facility; in this research work the proposal is for the management of the knowledge that is not structured, and that knowledge is considered an important resource for the achievement of the facility metrics. Figure 3.2 describes that the Manufacturing Facility is the owner of the Manufacturing Knowledge.

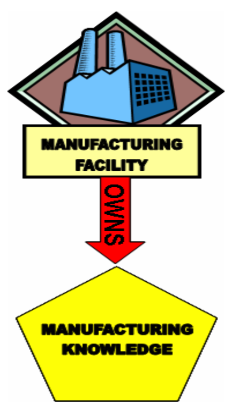


Figure 3.2 - The Manufacturing Knowledge in the Manufacturing Facility

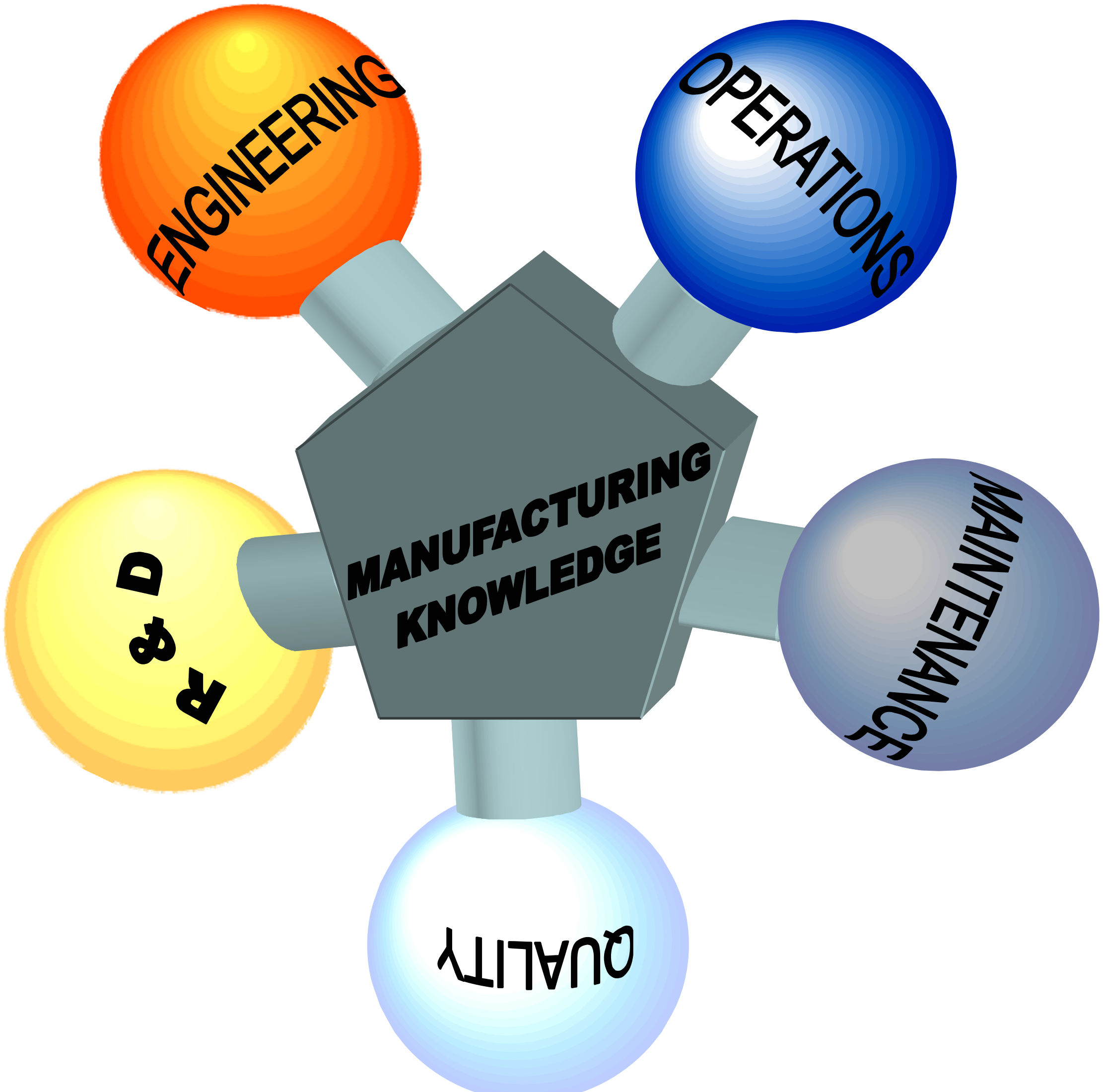


Figure 3.3 - Manufacturing Areas and Manufacturing Knowledge

The Manufacturing Knowledge utilizes the same structure from Figure 3.1, and Figure 3.3 describes that the Manufacturing Knowledge is decomposed also in the Manufacturing Areas.

It is recognized that manufacturing knowledge exists in the Manufacturing Facility, in both explicit ant tacit ways; the explicit knowledge exists as mentioned in the previous chapter in formats like manuals, procedures, handbooks, etc.; and there are systems dedicated to store, update and keep them available for the employees. On the other hand the tacit knowledge, is the knowledge related to the manufacturing of the products, and resides within the facility employees; the tacit knowledge has been accumulated through learning, experiences and skills developed in the manufacturing areas (see figure 3.3); the opportunity is to propose a model for the management of the Tacit Knowledge from a Manufacturing Facility, which is defined as Manufacturing Tacit Knowledge. The contribution of the manufacturing tacit knowledge management is that it enrich the intellectual and economic assets, if the media are given to translate it to explicit ways that can increase the intellectual capital of the Manufacturing Facility; figure 3.3 shows how the tacit and explicit knowledge types represents the Manufacturing Knowledge.

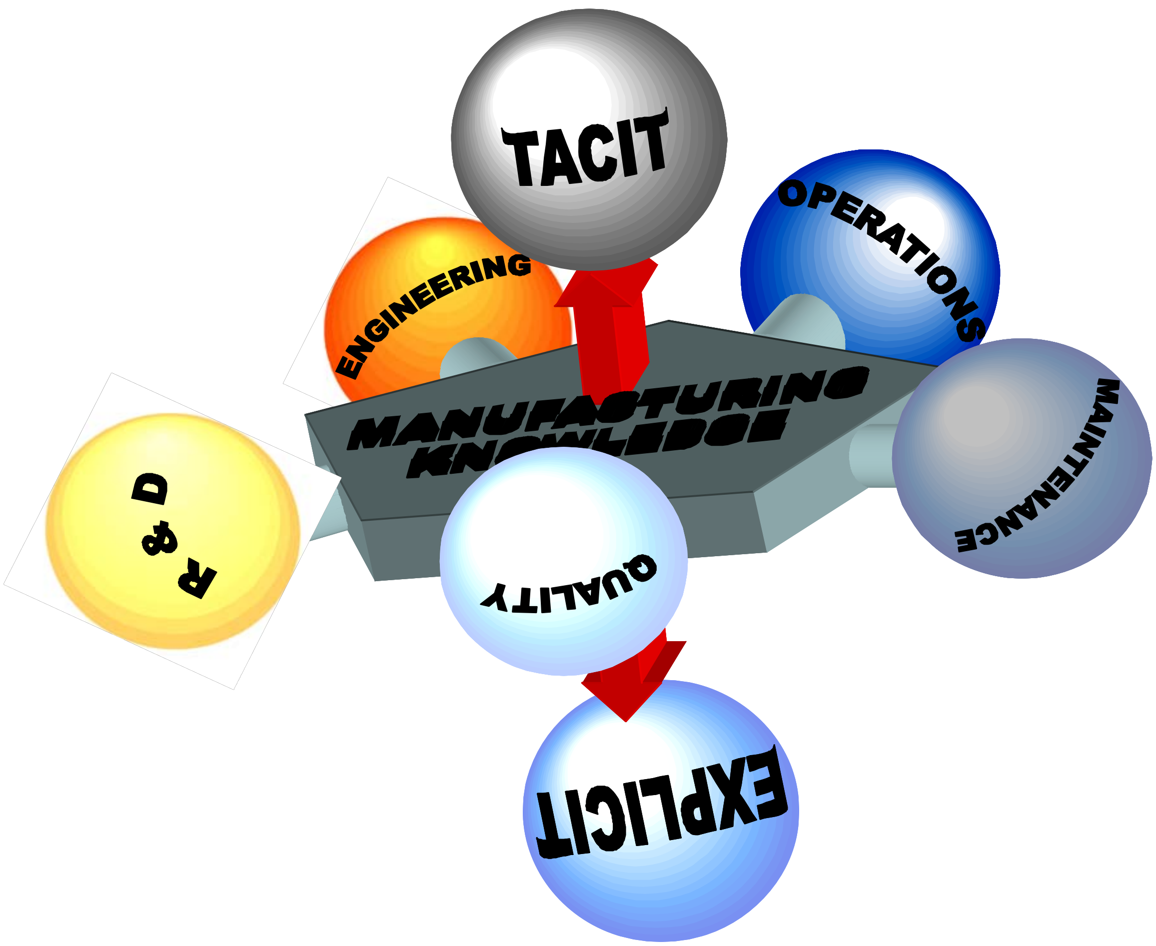


Figure 3.4 Tacit & Explicit knowledge relation with Manufacturing Knowledge pentagon

3.2. Manufacturing Tacit Knowledge definition & types within the Manufacturing Facility (Chemical-Textile Company)

Previous research works have been done about concepts of Manufacturing Models; with important contributions for the knowledge management research area, and specifically for the Manufacturing field, since the purpose of those models was the identification, storing, reutilization and maintenance of the knowledge pertaining to Manufacturing Facilities and enhance the operation of those facilities. The author's research idea is to provide an extension of the previous research works and explore the proposal of a Model intended to manage the Manufacturing Tacit Knowledge that resides in the company employees.

Manufacturing knowledge is defined as the knowledge in a Manufacturing Facility related to the activities for the manufacture of products/goods; this knowledge is a facility asset, and resides either in explicit and tacit ways. As mentioned in section 3.1 there are knowledge that actually resides in formal systems available in the facility; however there are an opportunity, this is the management of the knowledge that resides in the employees and this is intended to be done with the model proposed taken as the basis for the development of a KBS.

The Manufacturing tacit knowledge exists as learning, experiences or skills (LES); it is not formally and physically stored in the facility; it is available as long as the employees work at the facility, but it can be lost once the employees leave. Every day, knowledge essential to organizations walks out of the door, and much of it never comes back; this organization drains costs organization time, money and customers (Hua Tan & Platts, 2004).

The Manufacturing Tacit Knowledge is defined, as the knowledge created, owned and gained by the facility employees from the learning and experiences achieved and skills developed (LES) in the manufacturing areas described in figure 3.1; much of this knowledge is not formally recognized, captured, reused, maintained and available to other employees in the facility. The manufacturing knowledge as well as its tacit representation is an asset that belongs to the facility, the next figure shows the way to locate the Manufacturing Tacit Knowledge in a Manufacturing Facility.

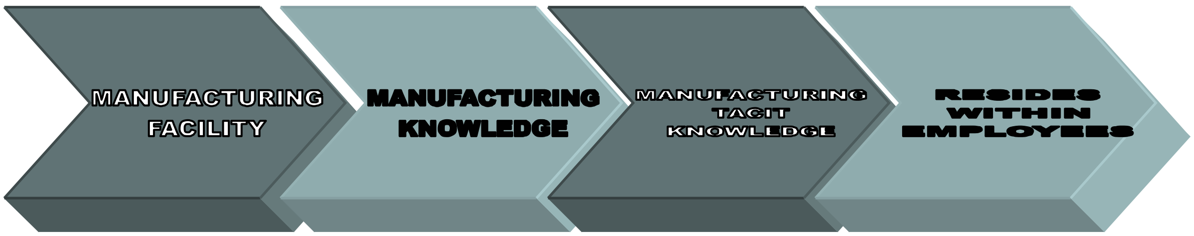


Figure 3.5 Manufacturing Facility, Manufacturing tacit knowledge location

The employees, who own the Manufacturing Tacit knowledge in a facility, are:

- Technicians
- Supervisors
- Engineers
- Managers

Besides from identifying the knowledge owners and creators in the company and the development of the model; it must be recognized that none model and KBS, even if is developed in a friendly software, that is easy to access and to work over, and can save important amounts of knowledge; it will not work adequately if the employees are not convinced that the management of the manufacturing tacit knowledge of the facility is a useful tool, also that the model is not intended to take from them personal their personal LES, but enrich the company assets and give themselves and other employees the opportunity to learn from other LES shared by other employees. The inclusion of the different roles in the company that owns and creates the knowledge, helps in the detection of the exact locations where the knowledge resides, this in combination with the areas involved in the manufacturing process, will be the guides to propose the knowledge model.

3.3.Manufacturing Tacit Knowledge Structure

Previous research work done by Guerra (Guerra, 2004) explored the understanding and definition of the different types of knowledge that resides within a Manufacturing Facility, as well as how that knowledge can be structured and maintained; this work represent an important contribution to the Knowledge Management strategy of a manufacturing facility. However this research work found an opportunity to enhance the structure proposed by Guerra (Guerra, 2004), exploring other knowledge types identified in a manufacturing facility, giving an alternate Manufacturing Knowledge Model, focused on the Manufacturing Tacit knowledge Management. According also with Guerra (Guerra, 2004) Costa (2000) and Kakabadse (2003) defined that both information and knowledge can be represented using models, which are intended to capture the essential features of a real system, separating them in small parts to be better manipulated and understood.

3.3.1. Manufacturing Tacit Knowledge Structure development

Amongst the many techniques used to model knowledge, the most common are CommonKADS and Protégé 2000, the Unified Modeling Language (UML) with its attendant Object Constraint Language (OCL), and Multi-perspective modeling Knowledge-based systems can be deployed as the technological means for capturing and managing both explicit and tacit knowledge as part of an organization's knowledge management initiative. But, before these can be built, the knowledge that pervades the organization must be identified and modeled using appropriate acquisition, representation and modeling techniques. (Abdullah, Benest, Evans & Kimble, 2002). Knowledge modeling techniques are widely adopted for designing knowledge-based systems (KBS) and these systems are important for knowledge management. KBS are developed using knowledge engineering (KE) techniques that are often similar to software engineering (SE), and both domains emphasize the use of conceptual models in designing software systems. Most of these knowledge models heavily rely on modeling notations used in software engineering; UML is widely adopted. UML can be formally tailored for knowledge modeling by creating a UML profile for knowledge modeling (Abdullah, Paige, Benest & Kimble, 2005). Since UML is a common language used for the knowledge modeling, the proposed model is constructed using UML Class diagram to offer a presentation based on common structures.

The product development process, within a typical manufacturing company, utilizes large amounts of knowledge related to manufacturing and design activities. However, due to the significant volume of knowledge generated in the manufacturing and design stages, there is a need for an efficient and systematic approach to structure this knowledge (Guerra, 2004). This will enable the knowledge to be readily maintained (Rezayat 2000); assuring the long-term use of these systems (Sainter et al. 2000).

The proposed structure in this thesis research is based on figure 3.4 (Tacit & Explicit knowledge relation with Manufacturing Knowledge pentagon) which shows the Facility Manufacturing areas and the relation of the Manufacturing Knowledge with the basic types of knowledge representation (tacit and explicit). This model propose the structuring of tacit knowledge from each of the manufacturing areas, the Model contains classes based on the Manufacturing Areas within a facility; providing the users a way to recognize the knowledge repository, where they can store as well as request the learning or experiences they want to share or to leverage from.

The basic structure is shown on figure 3.6; as mentioned in the previous paragraph the knowledge classes also serve as the knowledge repositories that will contain the Learning, Experiences and Skills (LES) from the facility employees which are translated into knowledge representations. The LES are the subjects of interest, since are difficult to capture and transfer between employees in a structured way; as mentioned the lack of management of this knowledge can imply an important economic and intellectual loss for the facility, once an employee leaves a facility or his or her responsibilities are different. It is worth to mention that no matter the role an employee plays in a manufacturing facility, from technicians to managers, they have tacit knowledge that has retrieved benefits to the facility, but can extent its contribution if it can be captured, structured and shared with peers.

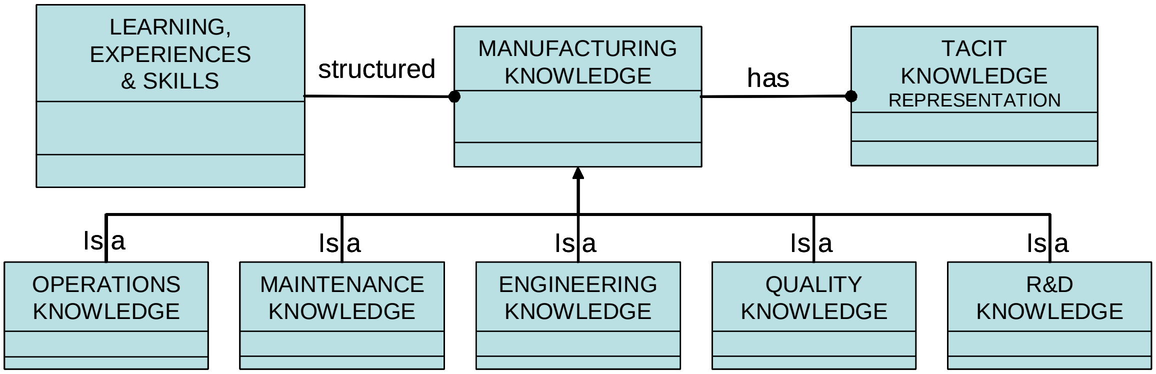


Figure 3.6 Manufacturing Tacit Knowledge structure (adapted from Guerra, 2004)

One of the purposes of the structure is that employees from the different manufacturing areas can easily identify the repository where they can capture and access the knowledge they want to share or retrieve.

The manufacturing tacit knowledge that resides within the employees, once an employee recognize it and intends to share it, will be represented in explicit ways that can make it available to be utilized by his/her peers. The knowledge representation are the ways the Manufacturing Tacit Knowledge will be stored and shown, using media tools that can transform the tacit knowledge into explicit ways. The manufacturing knowledge classes were selected and defined based on a terminology common for Manufacturing facility Areas.

The Figure 3.7 shows the detailed Manufacturing Tacit Knowledge Structure, with the attributes for the main class as well as for the knowledge classes identified; and the tools to represent the Manufacturing Tacit knowledge.

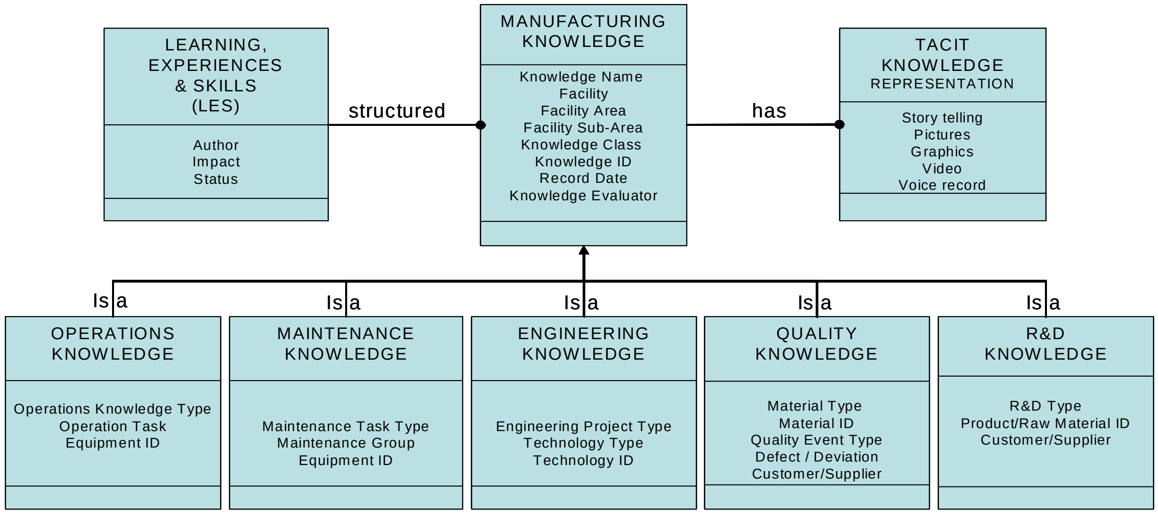
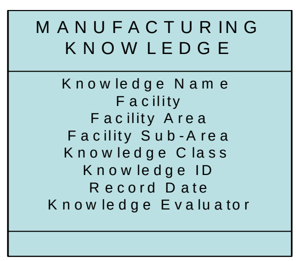


Figure 3.7 Manufacturing Tacit Knowledge detailed structure (adapted from Guerra, 2004)

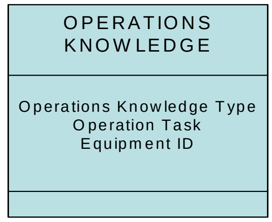
3.3.2 Manufacturing Tacit Knowledge Structure



The Main Class (Manufacturing Knowledge) contains basic attributes for the capture, as well as basic attributes for the search in the knowledge repository.

Knowledge Name is the identification given by the author to his/her knowledge captured. The Facility is the identification of the Plant; Facility Area & Sub-Area refers to the different sections in a Manufacturing Process; Knowledge class is used to select the manufacturing knowledge repository; the knowledge evaluator is the person who validate the knowledge captured in the repositories, the knowledge evaluator can be a knowledge champion as well as an expert from the manufacturing area related to the knowledge class; Knowledge ID and Record date are attributes given by default from the repository to maintain an order of the knowledge records. The previous attributes serve to locate the Manufacturing Tacit Knowledge in the structure. Each of the manufacturing knowledge classes has additional attributes to differentiate them from other repositories in the model.

3.3.2.1 Operations Knowledge



Operations Knowledge is a manufacturing tacit knowledge that resides within employees related to the Manufacturing Operations in a Facility. This knowledge represent the LES acquired in the Manufacturing Facility operation tasks, mainly from LES about Operation Deviations or Improvement Ideas or Proposals; these knowledge can be exported to other Manufacturing Operations and prevent deviations or provide ideas for improvements. The skills developed by the employees in the operation tasks, can be utilized to enhance the skills of their peers. All of the previous represent the Operations Knowledge Sources. Task and Equipment ID are attributes to identify the specific location of the Operation Task where the LES was recognized. The benefit from save, maintain and reuse the knowledge generated from the Operation LES is to prevent future operation deviations making available past experiences to the employees and apply the knowledge stored; and also the utilization of valid operation improvement ideas that can be extended to other facility areas as well as to other facilities.

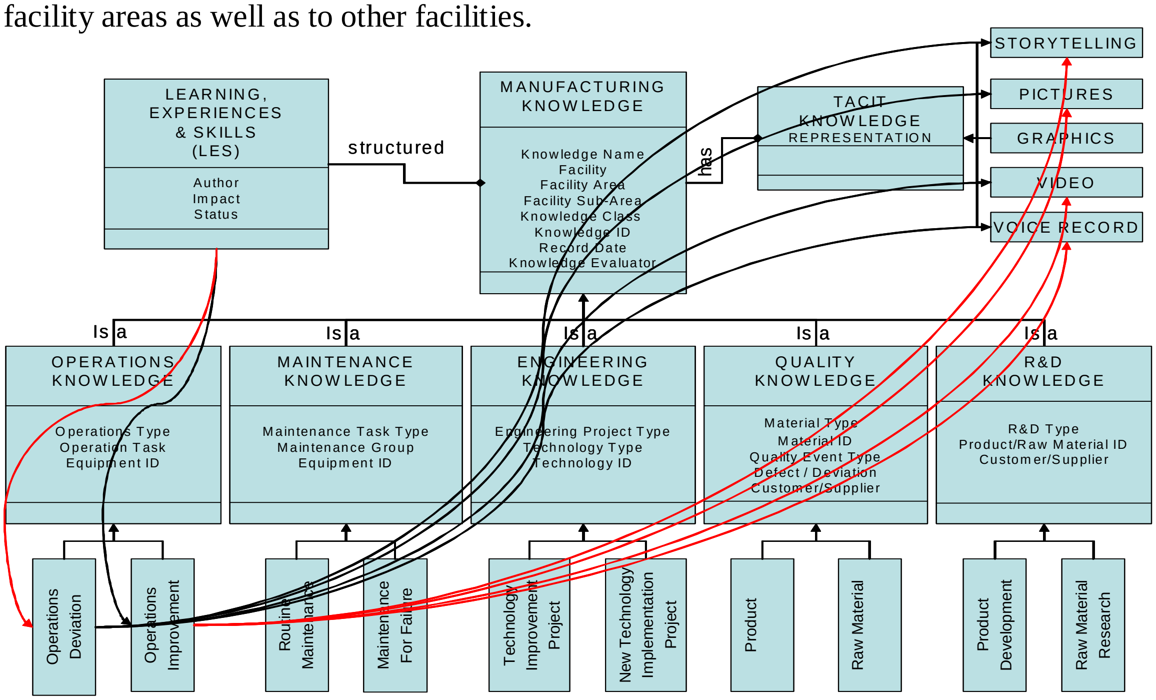
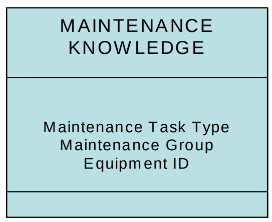


Figure 3.8 Operations Knowledge Structured

Figure 3.8 shows how the Operations Knowledge is structured according to the Operations Type from Deviations to Improvement Ideas into various tacit knowledge representations. As shown in figure 3.8 an operations deviation improvement idea is structured using tools as video, pictures, voice records and/or storytelling which can be combined to provide a complete knowledge representation. The tools to represent an Operations Knowledge permit the contained knowledge to be utilized by all organization levels, since it mainly solve or improve tasks from the Manufacturing areas which will be used by the Facility Technicians.

3.3.2.2 Maintenance Knowledge



Maintenance Knowledge refers to the tasks performed by the Maintenance Area employees; like Maintenance of Process Equipment, Measuring or Control Instruments. The attributes to separate these LES are the Maintenance Task Type; it defines if the knowledge comes from a Routine Maintenance or Maintenance for Failures. The Maintenance Group refers to the Specialty involved in the related knowledge like Mechanic, Electric or Electronic Specialists. Equipment ID relates to the facility equipment identification, where is contained the Process Equipment, Measuring or Control Instruments to represent the exact location of the equipment related to the Maintenance Knowledge. This knowledge has been separated from Operations Knowledge to provide an easier identification for the Operations and Maintenance Areas employees, since usually are independent organizations in a facility that performs different activities. The purpose of a repository for the Maintenance Knowledge from the maintenance specialists is to retain, maintain and reuse the knowledge from Maintenance area employees from their maintenance tasks; and make it available for improve other maintenance tasks, train new maintenance employees or retrain employees.

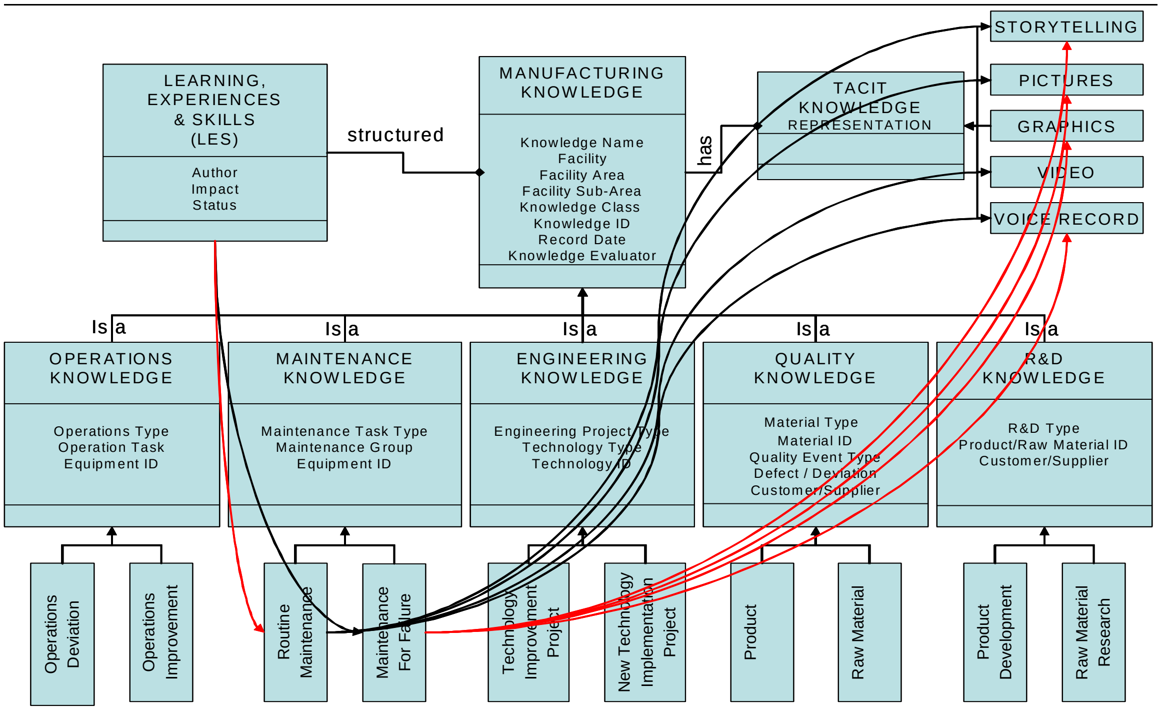
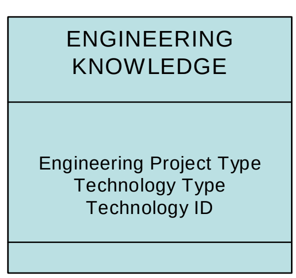


Figure 3.9 Maintenance Knowledge Structured

Figure 3.9 shows how the Maintenance Knowledge is structured based on the Maintenance Task type, which can be Scheduled Maintenances or Failure Maintenance, those tasks can then be structured in video, pictures and/or storytelling. The purpose is to capture the expertise of the maintenance specialists, that resides in tacit ways and transform it into explicit ways, and the media that most fit to accomplish this goal are the ones targeted in figure 3.9.

3.3.2.3 Engineering Knowledge



This knowledge class contains the knowledge related with Engineering Projects developed in a facility. The first attribute is the classification of the Projects divided into Improvement Projects of the existent Process Technology, or the Implementation of new Technology; the attribute Technology Type are the equipment for the Process Operation and Control, and the ID is an identification given by the facility for the referred technology. This knowledge class has been defined as a single class, due to it involves a higher level of expertise, like engineering and managing level; is not related with day-to-day improvements, it refers to long term and high impact benefits in a facility. It is important to retain the LES from engineering projects, due to the experiences derived from projects helps the engineering area to better plan and to execute future projects utilizing the knowledge retained in the engineering knowledge repository.

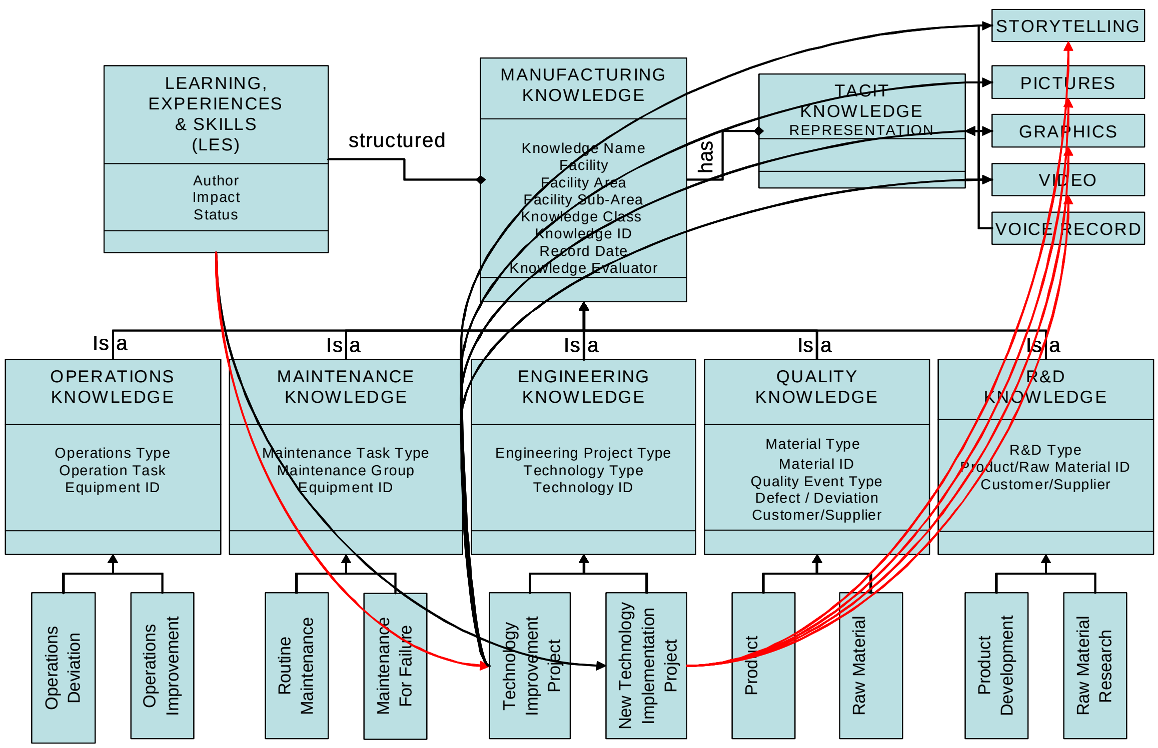


Figure 3.10 Engineering Knowledge Structured

The engineering knowledge is an important knowledge source for a facility since it represents the expertise from the employees who are experts in process and control technology; part of this manufacturing tacit knowledge is exported to other manufacturing areas to enhance operation tasks, the maintenance of the equipment or the quality of the products. The structure is intended to capture the knowledge derived from engineering projects which can be applied as best practices for future similar or different projects. These knowledge are LES in tacit ways since represents the experience gained by the project developers, which can be captured into explicit media like video, pictures, graphs and/or storytelling (see figure 3.10).

3.3.2.4 Quality Knowledge

This knowledge class (See Figure 3.11) stores the knowledge acquired from Quality incidents related to Raw Materials or Finished Product, which is the first attribute, Material Type; the Quality event type classifies the Claims from the Customers related to the quality of finished products, Claims allocated to the facility raw material suppliers, or Internal Quality reports related with quality events that derived in poor quality of finished products or affections caused to the raw material; the attribute Defect or Deviation is to select the type of affection; an attribute to specify either the Raw Material or Finished Product and a one to select the Customer or Supplier if required. The LES related to Quality can generally come from the Quality Leader in a Facility, but can also be shared by the Technicians or other employees. The LES from Quality incidents translated to explicit ways to represent the quality knowledge are important tools for the prevention of future incidents, since help in the definition and selection of effective corrective and preventive actions for the facility or for the suppliers.

The quality knowledge resides mainly within the employees related with the Facility Quality Management, Customer Support, Raw Materials Quality but is not limited to other facility employees; employees contribute to enrich the Quality Knowledge by sharing theirs to improve the Quality of the products and prevent quality incidents related with raw materials or products that can affect customer's satisfaction. It is also part of the quality knowledge the knowledge acquired from complaints of the customers related with the quality and performance of the products.

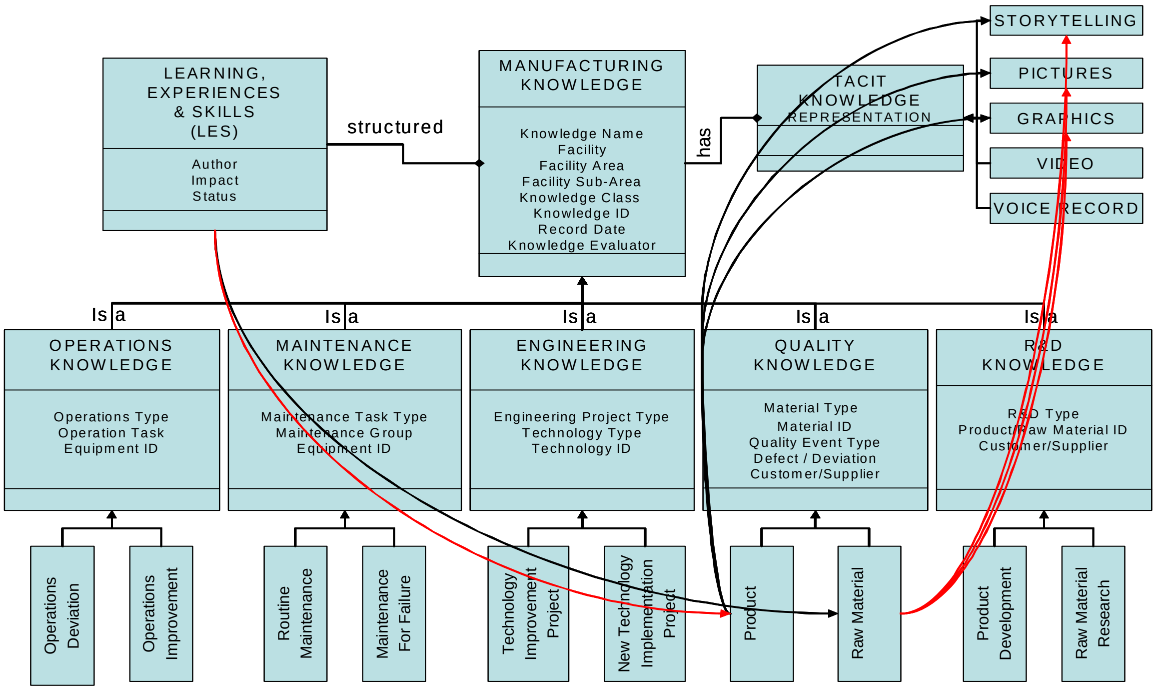
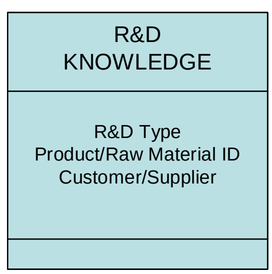


Figure 3.11 Quality Knowledge Structured

3.3.2.5 R&D Knowledge



This Knowledge Class (see figure 3.12) contains the manufacturing tacit knowledge related with Projects for the Development of New Products or the Research of New Raw Materials, represented in the attribute R&D Type. Product/Raw Material ID is an attribute to select the description of a Product or Raw Material, the next attribute is for the selection of the Raw Material Supplier or the Customer which will consume the developed product. The importance of the retention of this knowledge is to improve the setup and run of future R&D projects developed in a facility or that can be shared with peers from different facilities who can utilize the retained knowledge in similar projects to improve their projects.

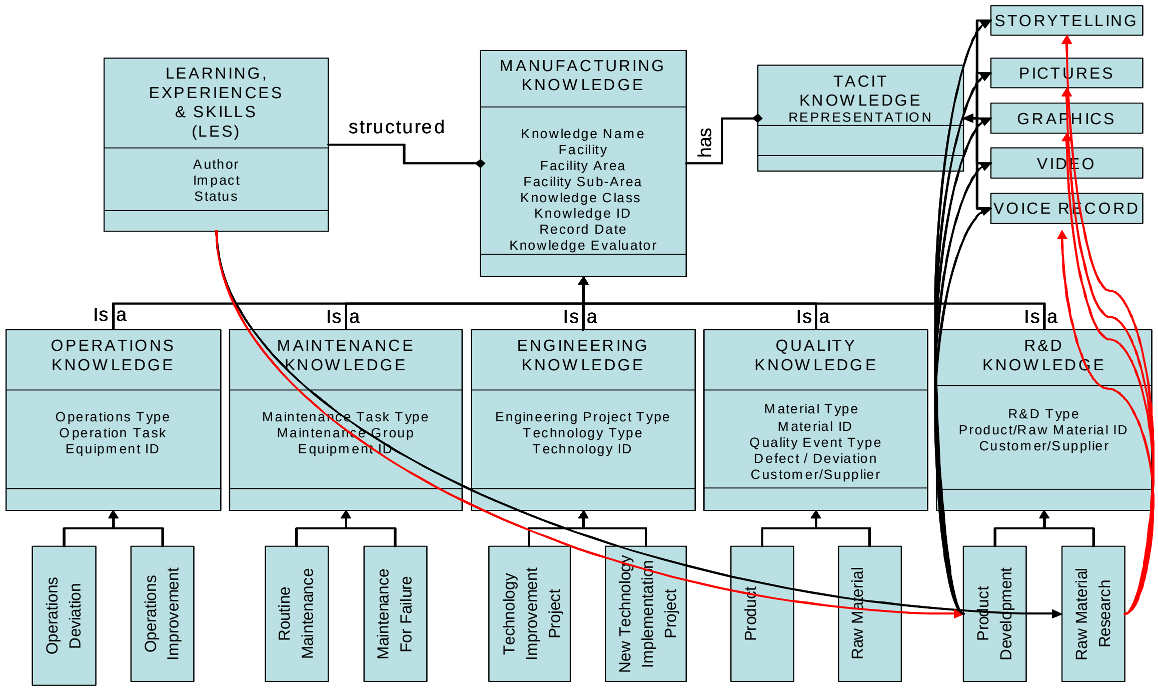


Figure 3.12 R&D Knowledge Structured

R&D knowledge is an essential part of the manufacturing tacit knowledge, since it represents the expertise gathered by the technical experts in a facility about the product developments and the research done for the implementation of new raw materials to improve the performance of the products and/or optimize the manufacturing costs. This knowledge class resides in the R&D area employees; without the existence of a structured repository the knowledge does not has the opportunity to be saved, structured and later utilized by them or by their peers to improve future R&D Projects. It is critical for a facility to manage the LES from R&D since represent an important knowledge source that can be exported to the rest of the manufacturing areas.

4. CASE STUDIES

4.1 Background

The chapter 4 includes three case studies that supports and demonstrates the operation of the MTK structure proposed in chapter 3 (see figure 3.7), the validation of the MTK classes and sub-classes and instances proposed; each of the case studies includes examples of MTK selected to store, share, and reuse MTK and to be transformed from tacit into explicit representations. The case studies are developed in the Manufacturing Facility, dedicated to the production of Synthetic Textile Yarns; the particular cases presented in this chapter are taken from actual experiences. The purpose of the development of the case studies is as mentioned to demonstrate the operation of the MTK structure, transforming this knowledge from tacit to explicit representations; the complete MTK cycle creates value for the facility, keeping relevant MTK from its employees and giving them the opportunity to gather stored MTK and use it to achieve better decision making processes.

The particular case studies are:

o 1st Case Study

The 1st case contains an example that demonstrate the operation of the MTK structure, the knowledge captured in this example, comes from a learning derived from an Operations Improvement Idea occurred at the facility, the deviation came from a specific product which presented variability in the control of a critical property (Yarn Additive Content) causing product degradation, waste and the risk of a potential quality claim from the customers. Based on his learning and experiences the Supervisor of the affected Area proposed a change of a component used to drive the product into the Additive feed section; the change implied the use of a different material that could reduce the variability of the mentioned property. The test driven for this purpose leads to an important improvement over the Additive content over the yarn; eliminated the waste generation attributed to it and prevent a potential claim. The knowledge derived from this idea is required from the management to be captured, make it available and shared within the facility and to peers from other facility as a tool to learn to prevent future incidents and to demonstrate the existence of opportunities to improve processes performance.

- 2nd Case Study

It contains an example that demonstrates the identification, representation and structuring of a MTK derived from a serious incident occurred within the facility. The incident was related with repetitive failures of process equipment, its failures caused unscheduled facility outages, which contributed to waste generation, production loss, facility unavailability and loss of potential sales; the incident was qualified as a serious business incident with great economic losses. The investigation and consequent solution of the incident has been asked to the Maintenance Manager to be retained, contained in media tools and to be shared to other facilities as a way to prevent business incidents in other operations. The purpose of this example is to demonstrate the possibility to retain the MTK of a serious incident where various areas were involved in the investigation of the root cause and the solution to the issue; and the potential loss of the knowledge acquired from this experience; the existence of the MTK structure using a media repository will give to other employees the opportunity to retain and reuse MTK; and also improve the decision making process for future events were experience and skills will be required.

- 3rd Case Study

It comprises an example that demonstrates the process to retain MTK acquired, such knowledge is provided by an Engineer; this example reflects the usage of the current knowledge and how the employee identifies the opportunity to enhance the related MTK; the process to make available the Engineer’s knowledge has to follow the representation, structuring and the appropriate validation. The objective of this case study is also to provide a demonstration of the operation of the MTK structure, avoiding the loss of MTK. The MTK resident within the employees is considered a Manufacturing Facility asset, retrieved during employees service years; the existence of the MTK structure modeled with a software tool also enhances the decision making process for future events within the manufacturing facility.

The Facility has IT systems that contains manuals, instructive, procedures; such documents represent an important source of information and knowledge useful for all the company; however the retention and sharing of the MTK from the employees is not formalized; situations has occurred when knowledge has walked out of the door and could not be retained, implying a new learning curve for the employees and the facility. The loss of that knowledge has meant in some cases loss of money given by inadequate decision making process due to the lack of LES.

Nowadays the company is about to face a critical situation with organizational changes and close retirements; Facility Management is interested in the proposal of a tool that can serve as the media to retain, reuse and renew the MTK from its employees; giving the opportunity to develop better decision making processes in future events and a comparative advantage for the company, avoiding long learning curves when employees take new roles.

4.2 Specific Objective

The specific objective of this thesis chapter is:

- Demonstrate that the proposed MTK structure is a useful tool for the identification, retention and reuse of Manufacturing Tacit Knowledge within a Facility, and that the existence in a structured manner of the MTK gives to the facility the possibility to improve its decision making processes.

4.3 Demonstration scope of the structure and methodology

The manufacturing facility human resources are structured in the areas defined in MTK structure. The IT systems available in the facility, which contains the information and knowledge currently retained in those systems, are not part of this thesis scope.

4.4 Case Study 1 – Supervisor's Operations Knowledge capturing (Learning from Operation Deviation solution)

The Case Study 1 has the purpose to demonstrate through an example the operation of the MTK structure proposed in chapter 3. The example is taken from a real case within the manufacturing facility; where an Operations Supervisor using his Learning, Experiences and Skills solved a Deviation on the control of a product specification that was causing the generation of waste, production delays, loss of potential sales and also potential quality incidents on the trade.

This example demonstrates how the employee will identify and select the MTK Class, Sub-Class, attributes and the MTK representation where he will store and structure the MTK that he will retain and make available for the facility.

The MTK structure contains five knowledge classes which correspond to the manufacturing areas within the facility. The knowledge classes functions as the basis to select the correct location of the MTK retained by an employee. The employee identifies the MTK classes and the knowledge-subclasses or type as showed in figure 4.1.

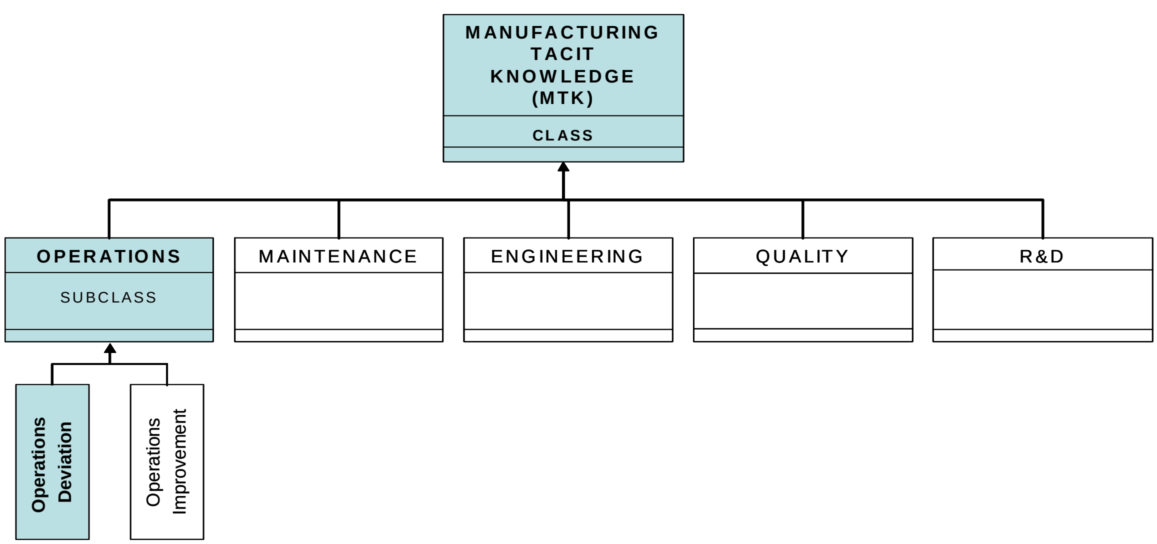


Figure 4.1 - MTK Structure – identifying and storing Operations knowledge

The employee stores the tacit knowledge derived from the learning related with an "Operations Deviation" on a manufacturing process of a specific product; the capture of the related knowledge will give the opportunity to extend the learning to other processes as well as to other facilities, the MTK structure gives that possibility.

The MTK Structure presented for this thesis research has been named "IK Textiles Knowledge Repository" (See figure 4.2), it has been developed using html format; it is conformed by various intranet pages containing the different knowledge classes as repositories, the indexes used to structure the knowledge, and the tacit knowledge captured with their representations; in the main page are included the access buttons to:

- The index which contains the fields used for the Knowledge Structuring; those are Task selection, Knowledge Class & Sub-Class, the Facility, Area and Sub-Area;
- The specific Knowledge Repositories derived from the Knowledge Classes defined;
- And a list of the most recent Knowledge added to the "IK Textiles Knowledge Repository".

When an employee access the "IK Textiles Knowledge Repository" proceeds with the following steps:

1. Select the button "GO TO ADD NEW KNOWLEDGE" (see figure 4.2), to access the index page to select the attributes of the knowledge he/she will add and send to be evaluated.

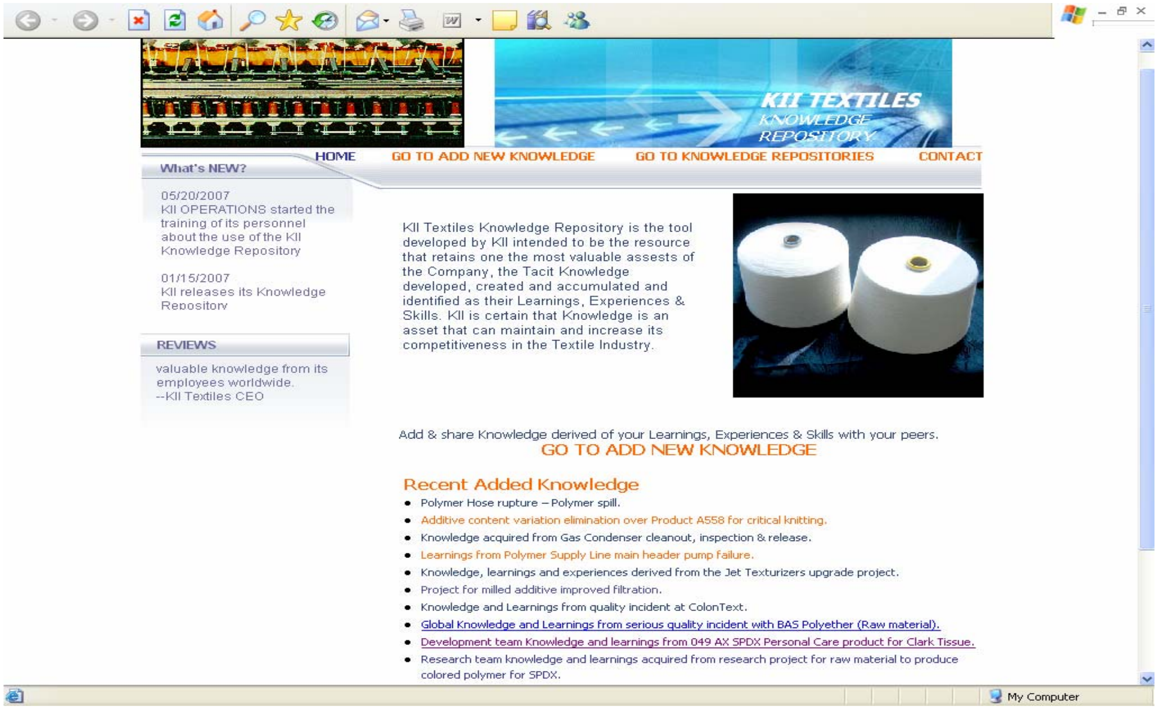


Figure 4.2 - MTK structure "IK Textiles Knowledge Repository" main page

2.On the ADD NEW KNOWLEDGE INDEX page the employee selects the attributes correspondent to the knowledge which will be added to the knowledge repository; the attributes will give the location in the particular repository related to the knowledge class where the added knowledge belongs, the employee follows the steps as shown in figure 4.3; figure 4.4 shows the attributes selection for the 1st Case Study in the Knowledge Repository. Once the attributes are selected, the employee clicks on "ADD".

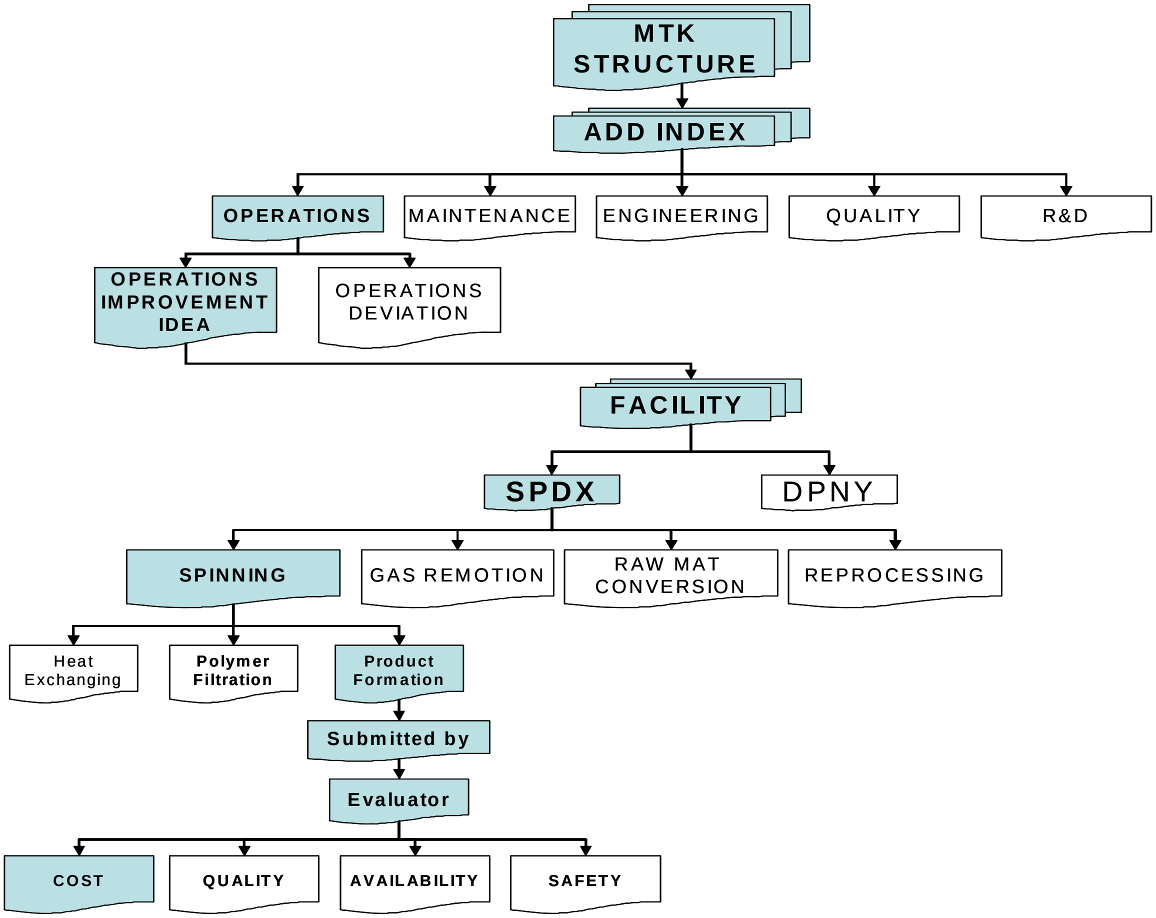


Figure 4.3 - Operations Knowledge attributes selection steps

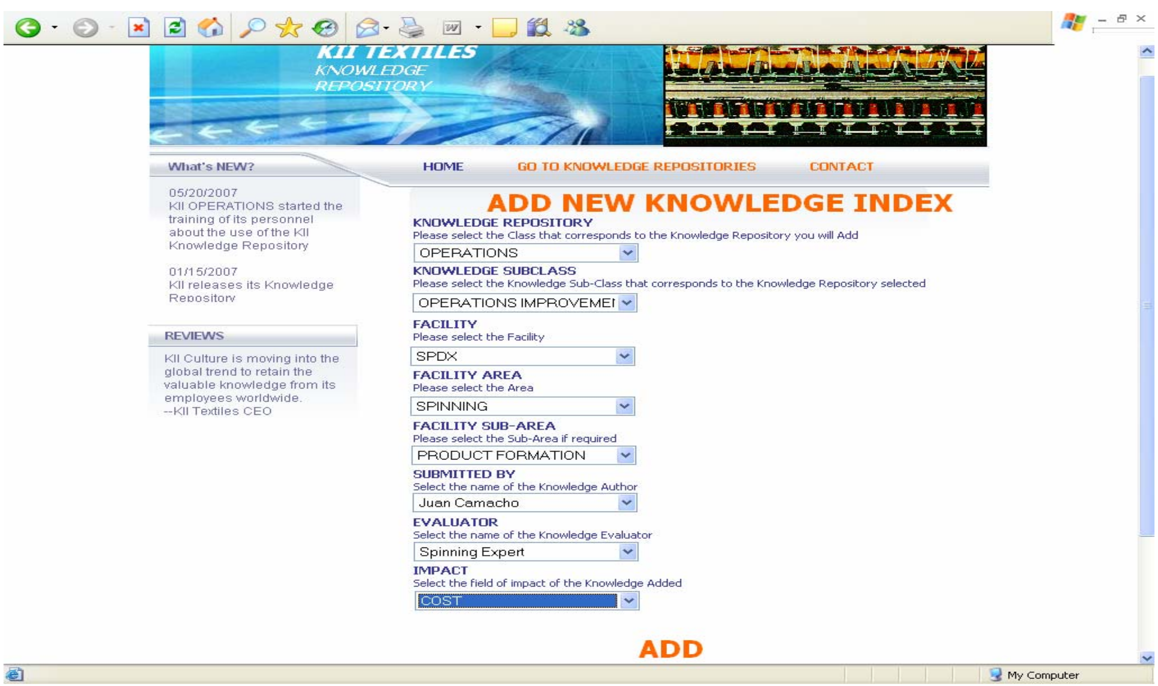


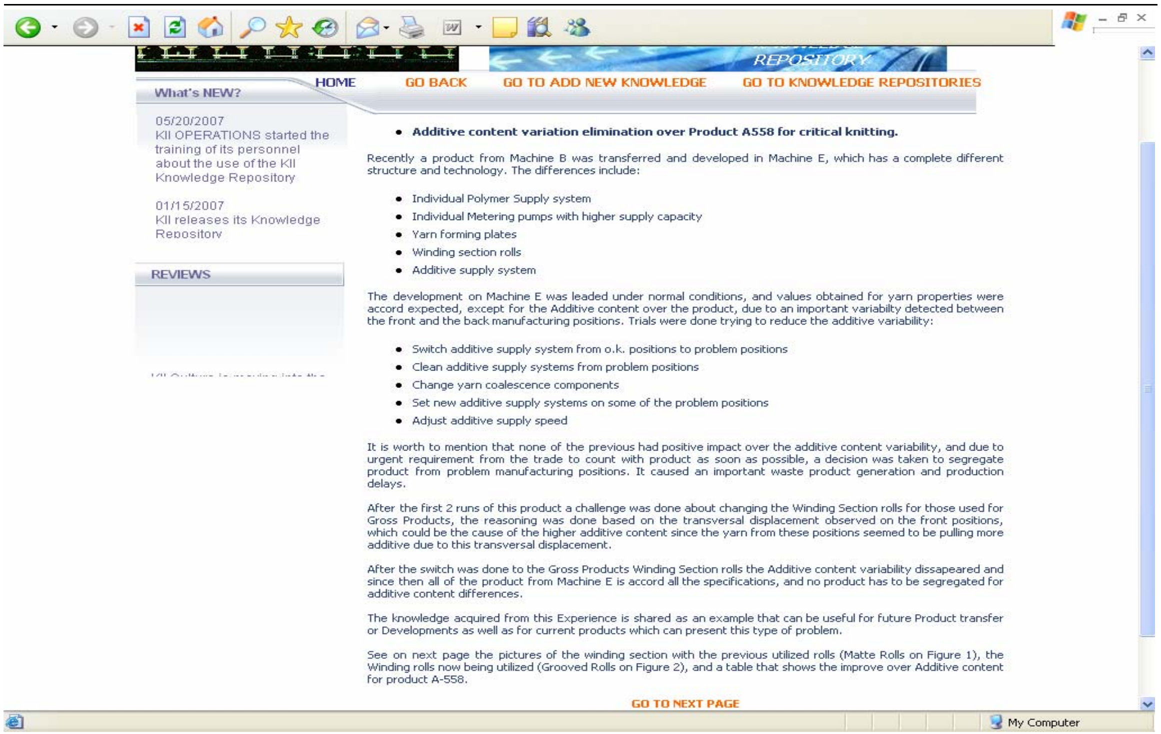
Figure 4.4 – Case Study 1 attributes selection steps

3. When the employee finish the attributes selection, clicks on the button "ADD" (SEE FIGURE 4.4), and is transferred to the page where the knowledge is added, and selects the Knowledge Representation Tools (see figure 4.5).

Figure 4.5 – Case Study 1 knowledge addition

The employee has the option to move through the pages he/she has registered, add more pages if required and finally send the added knowledge to the selected evaluator, the knowledge is saved and placed available into the repository until it has been validated (see figure 4.5) by the evaluator selected by the author.

4. Once the knowledge has been saved and validated by the selected evaluator, it looks like the figures 4.6 & 4.7.



- **Additive content variation elimination over Product A558 for critical knitting.**

Recently a product from Machine B was transferred and developed in Machine E, which has a complete different structure and technology. The differences include:

- Individual Polymer Supply system
- Individual Metering pumps with higher supply capacity
- Yarn forming plates
- Winding section rolls
- Additive supply system

The development on Machine E was leaded under normal conditions, and values obtained for yarn properties were accord expected, except for the Additive content over the product, due to an important variabilty detected between the front and the back manufacturing positions. Trials were done trying to reduce the additive variability:

- Switch additive supply system from o.k. positions to problem positions
- Clean additive supply systems from problem positions
- Change yarn coalescence components
- Set new additive supply systems on some of the problem positions
- Adjust additive supply speed

It is worth to mention that none of the previous had positive impact over the additive content variability, and due to urgent requirement from the trade to count with product as soon as possible, a decision was taken to segregate product from problem manufacturing positions. It caused an important waste product generation and production delays.

After the first 2 runs of this product a challenge was done about changing the Winding Section rolls for those used for Gross Products, the reasoning was done based on the transversal displacement observed on the front positions, which could be the cause of the higher additive content since the yarn from these positions seemed to be pulling more additive due to this transversal displacement.

After the switch was done to the Gross Products Winding Section rolls the Additive content variability dissapeared and since then all of the product from Machine E is accord all the specifications, and no product has to be segregated for additive content differences.

The knowledge acquired from this Experience is shared as an example that can be useful for future Product transfer or Developments as well as for current products which can present this type of problem.

See on next page the pictures of the winding section with the previous utilized rolls (Matte Rolls on Figure 1), the Winding rolls now being utilized (Grooved Rolls on Figure 2), and a table that shows the improve over Additive content for product A-558.

GO TO NEXT PAGE

Figure 4.6 – Case Study 1 knowledge representation (1st page)

ROLL TYPE	ADDITIVE CONTENT SPECIFICATION (%)	AVERAGE ADDITIVE % ON FRONT POSITIONS
Smooth	3.0 to 6.0	6.15
Rough	3.0 to 6.0	4.50

Figure 4.7 – Case Study 1 knowledge representation (2nd page)

4.5 Case Study 2 – Maintenance Manager Knowledge editing (Learning and Experiences from Process Equipment Maintenance for failures)

The Case Study 1I has the purpose to demonstrate through an example the operation of the MTK to access previous added knowledge within the repository. The example is taken from a manufacturing facility case; where a series of critical failures occurred within the facility brought some unscheduled facility outages with consequences in waste generation, production delays and loss of potential sales, as some of the most important impacts. Once the investigation process is finished and the information regarding to the failure is available; the management has requested the Maintenance Manager to retain the knowledge acquired by the organization about how it was solved the chronic problem of the recurrent failures of a process equipment which caused various facility outages; the opportunity remains in the capturing of the learning obtained with this experience and make it available for the facility as well as for the other sites, the potential of the knowledge retention is to provide a useful repository that could prevent similar incidents in similar operations.

This case study demonstrate how an employee will access to the IK Knowledge Repository and identify and select the MTK Class, Sub-Class, attributes and the MTK representation stored which refers to Maintenance for Failures of Process Equipment within the DPNY Facility, the exemplified case study shows the representation tools selected to capture the referred knowledge.

For the case study 2 from the MTK structure is selected the knowledge class which corresponds to the maintenance area within the DPNY facility (see figure 4.8).

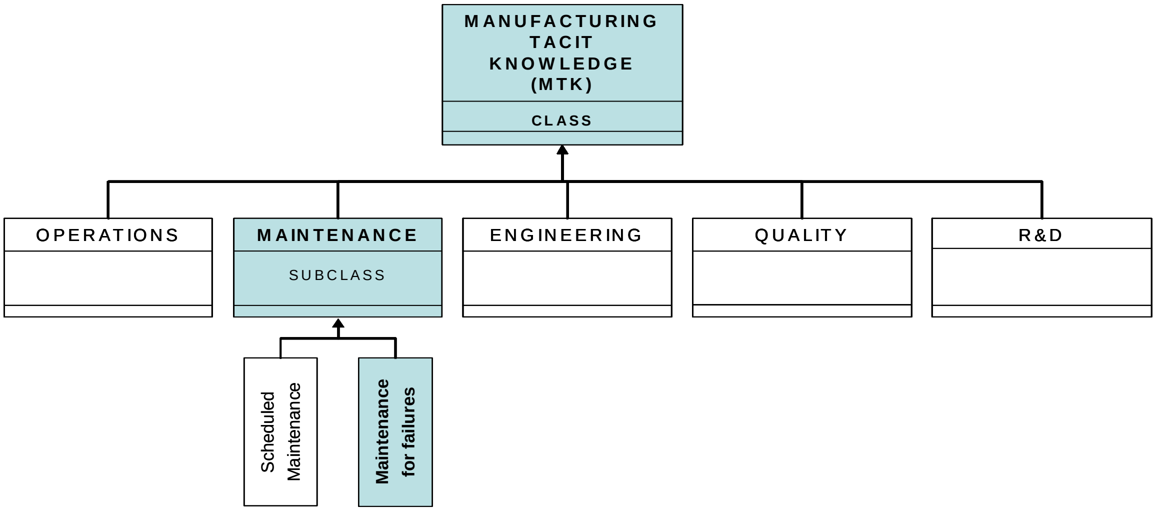


Figure 4.8 MTK Structure – Case Study 2 knowledge subclass selection

The structured tacit knowledge from Case Study 2 is related to "Maintenance for Failures" within the DPNY Manufacturing facility. The steps required to follow up the search of the knowledge attributes from Case study 2 is demonstrated in figure 4.9, trough the selection of the main task (Class Repositories search), the knowledge class, sub-class, facility, area, sub-area & the maintenance group.

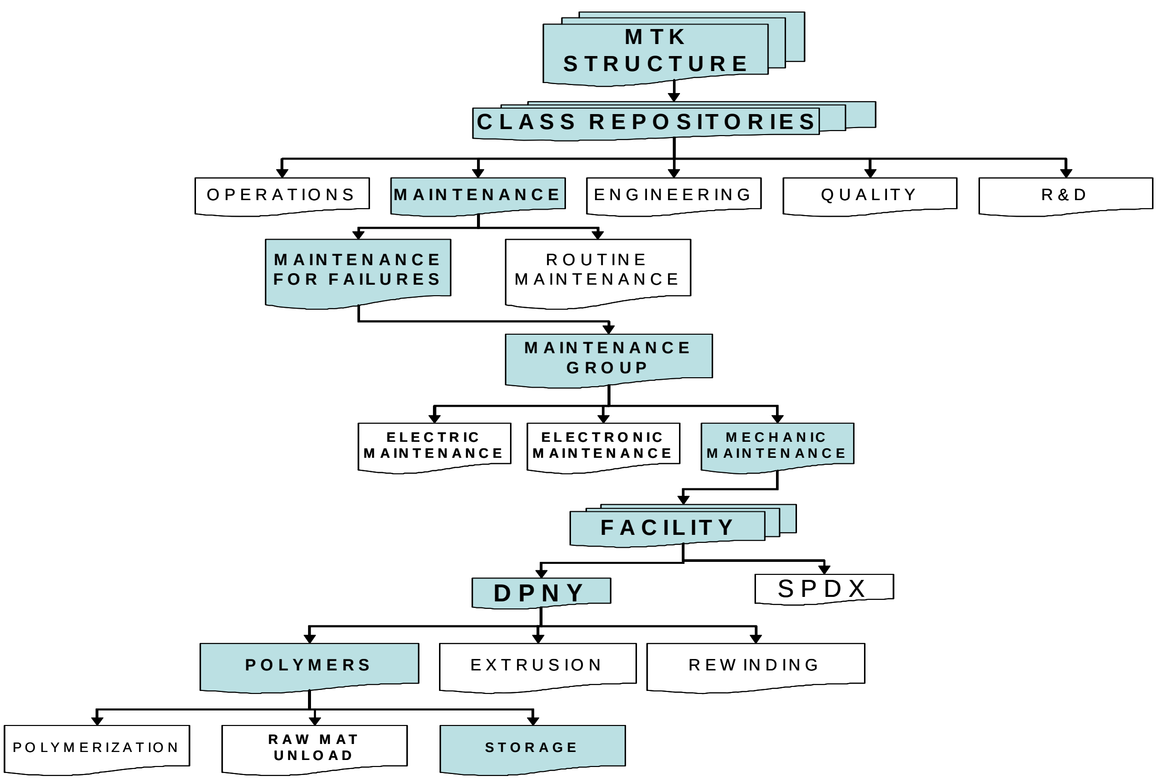


Figure 4.9 - Case Study 2 attributes selection steps

The steps an employee follows in the IK Textiles Knowledge repository to search within the repositories are:

1. From the IK Textiles knowledge repository main page selects "GO TO KNOWLEDGE REPOSITORIES" (see figure 4.2), the user is taken to Knowledge classes repository index,
2. For the Case Study 2, which is a knowledge acquired from the failures from and the maintenance given to a process equipment the employee selects the "MAINTENANCE TEAM REPOSITORY" (see figure 4.10),

Figure 4.10 – Knowledge Classes repositories – MAINTENANCE KNOWLEDGE

3. The employee is taken to the Maintenance Team Repository search engine, where selects the attributes given to the search engine to run the search into the repository and display the results of the stored knowledge that approaches to the request done by the employee (see figure 4.11),

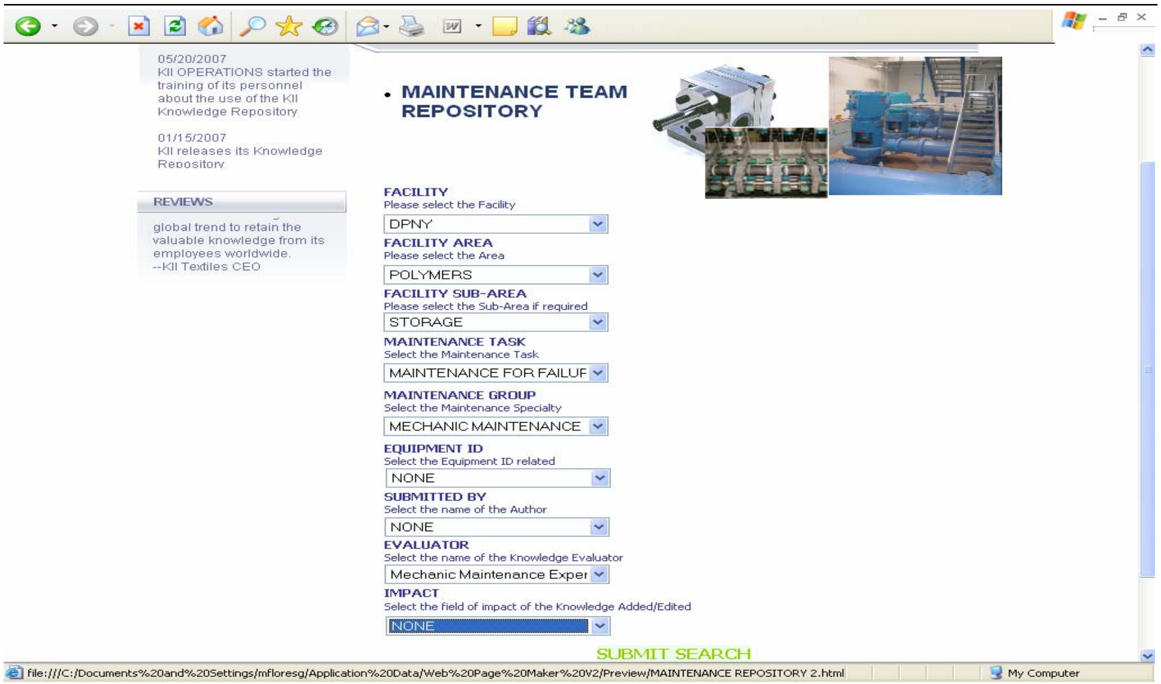


Figure 4.11 – Maintenance Knowledge Repository search engine display

4. From the results displayed by the search engine, the employee selects the knowledge the user is interested, clicking either "GO TO" (read) or "EDIT" (modify), Case Study 2 shows an example of reading a knowledge stored (see figure 4.12),

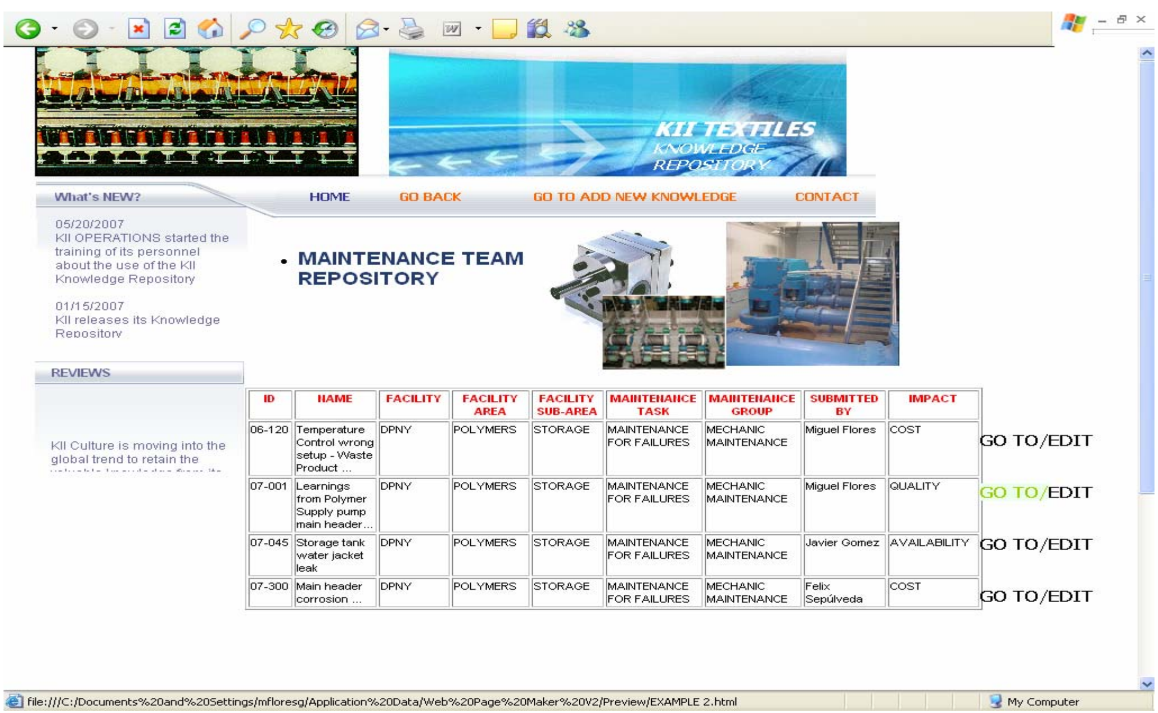


Figure 4.12 – Maintenance Knowledge Repository submitted search list

5. From the Maintenance Team Repository search engine is displayed the knowledge selected by the user, this Case Study contains the different tacit knowledge representations, for this example the storytelling format, graphics and pictures (see figures 4.13, 4.14 & 4.15).

Figure 4.13 – Case Study 2 Maintenance Knowledge representation (1st page)

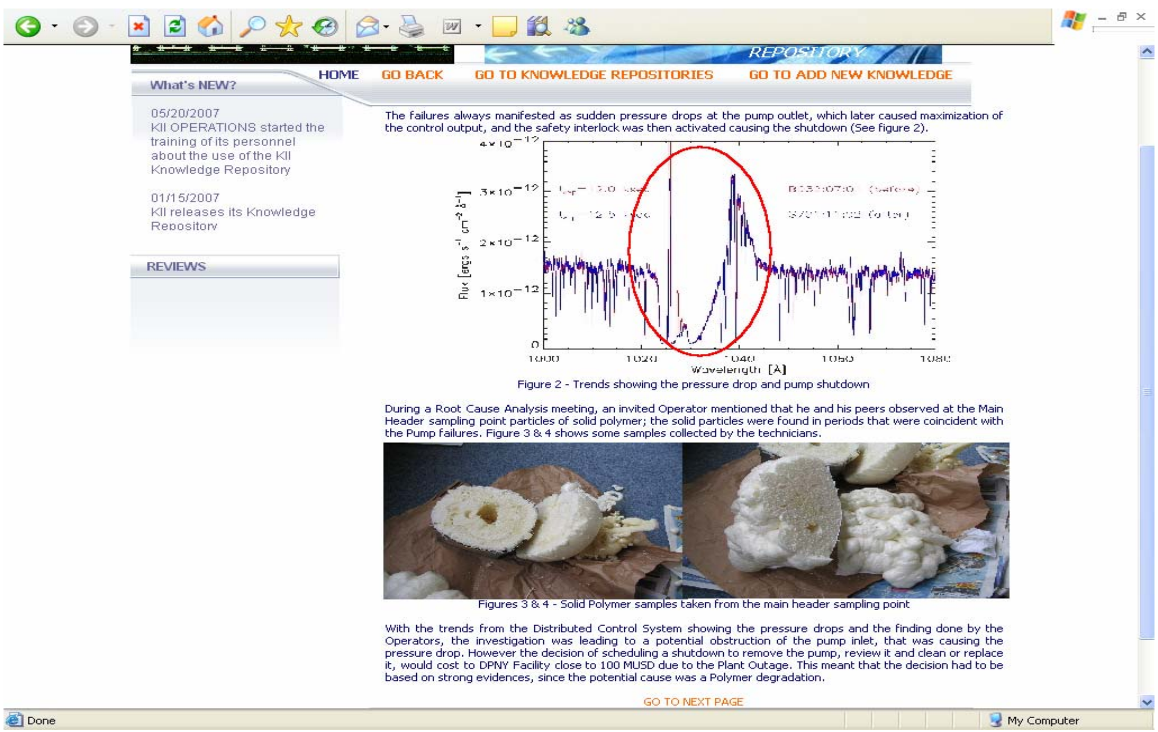


Figure 4.14 - Case Study 2 Maintenance Knowledge representation (2nd page)

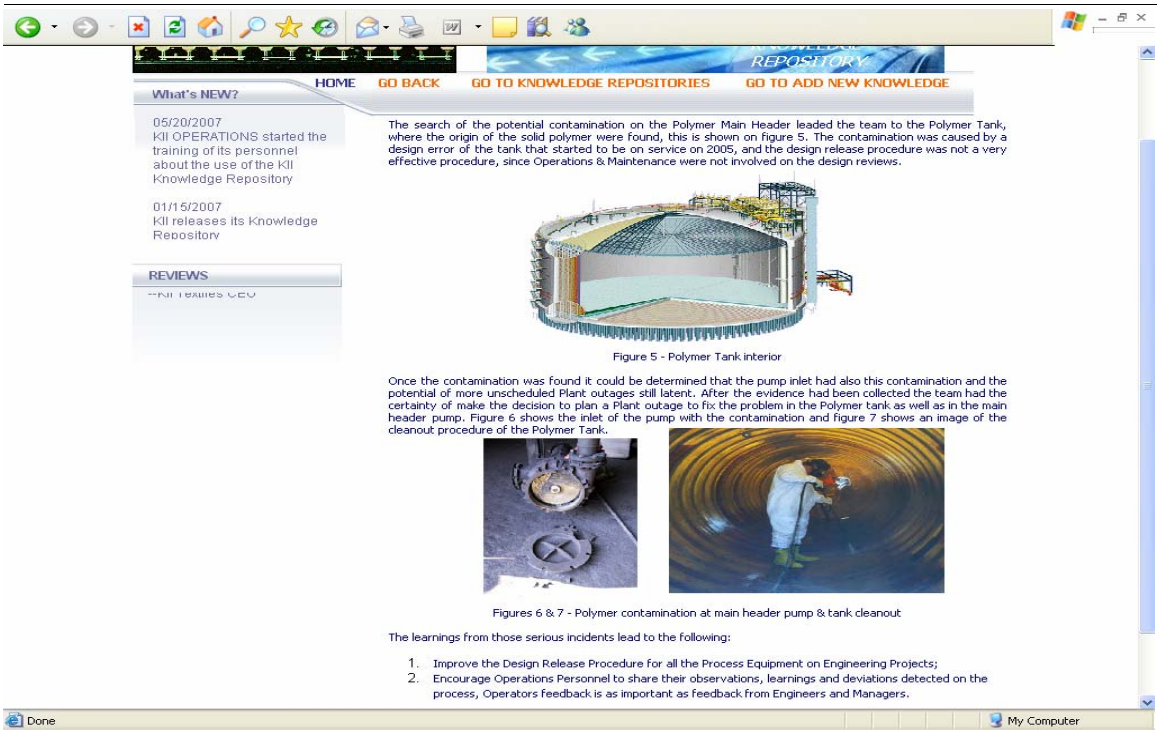


Figure 4.15 - Case Study 2 Maintenance Knowledge representation (3rd page)

4.6 Case Study 3 – Development team Knowledge and learning from 049 AX SPDX product for Clark Tissue.

The Case Study 3 demonstrates the operation of the IK Textiles Knowledge Repository to modify an already captured knowledge related to a Product Development. The example is taken from an actual case within SPDX manufacturing facility; the Project Leader Engineer and the rest of the Development acquired important learning from a product development process. This project is the first part of a global project, SPDX is the facility which ran the first trials and the results derived from those derived in a successful development; and an opportunity surged about that if the knowledge achieved by this proves is shared and applied by the rest of the facilities worldwide that belong to IK this R&D Knowledge will benefit either in reducing their implementation process, reducing the waste generated by the product manufacturing process, reduce the time to have product available in the market and avoid potential quality claims from customers. The idea of having this R&D Knowledge based on the structure proposed in chapter 3, is that the learning derived from the operation of the machine and the best way to capture, explain it and share to the peers is using tacit knowledge representation media, which will facilitate the understanding from other engineers worldwide that are from regions like North America, Europe and Asia, where the language differences could mean barriers to transmit the knowledge in a simple instructive without tacit knowledge representations and also a common language.

This case demonstrates how the employee identified and ran the MTK Class, Sub-Class and attributes search; and the selection of representation tools to modify the stored R&D Knowledge by a peer from other facility, with new learning that he/she will retain and make available in the IK textiles knowledge repository.

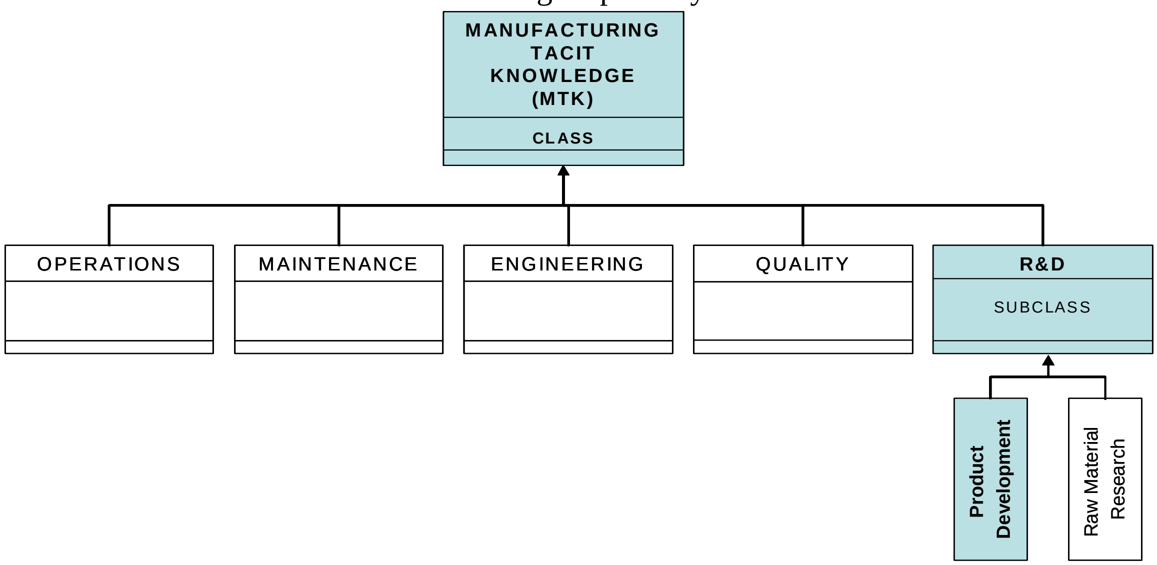


Figure 4.16 MTK Structure – R&D Knowledge → Product Development

The employee will store a learning traduced to tacit knowledge about a “Product Development”. During the process developed into the facility the Leader Engineer and the team assigned to the Product Development had several issues with the product manufacturing, specifically in the begging of the individual runs, the leader engineer asked other sites for knowledge related to solve the transition problems, however none site had experience in manufacturing of the related products. During the trials the team found the solution to the product transition problems and the product development became a success; the Global R&D supervisor asked him to share the knowledge acquired with the rest of the facilities, since the knowledge from SPDX will improve the implementation of the same project in other facilities, and also provides a guide to follow for similar product developments in SPDX as well as in other facilities; however the learning would not be easy expressed in an instructive since he knows the best way to describe the task done would be trough tools like videos and/or pictures; and can also contain part of storytelling in a common language, in this case all the peers are English spoken. The possibility to capture the knowledge into a video or pictures also brings the opportunity to have an easy understandable material for the Technicians.

The knowledge from Case Study 3 is assigned to "Product Development" knowledge subclass and belongs to SPDX Manufacturing facility. The steps required to run the search of the knowledge attributes from Case Study 3 to find the knowledge which is to be modified is showed in figure 4.17, trough the selection of the Class Repositories index, the knowledge class, sub-class, facility, area & sub-area.

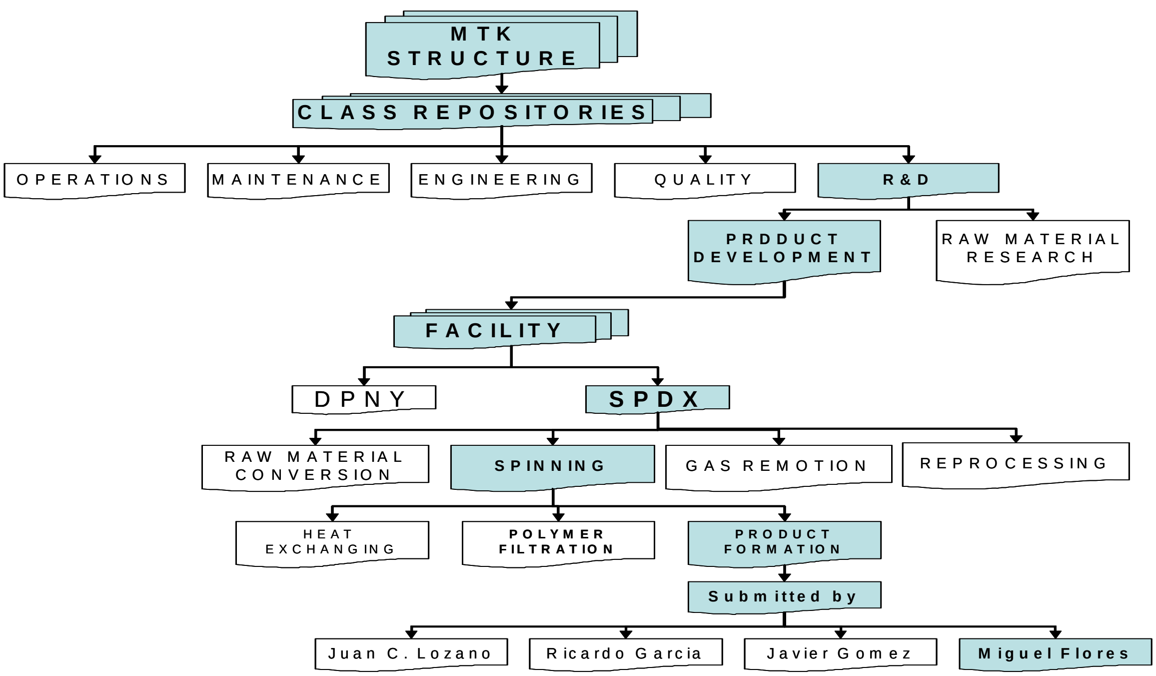


Figure 4.17 – Case Study 3 attributes selection

In the knowledge repository the user employee proceeds as described in the next steps to access to a currently stored knowledge that he/she will modify, by including additional knowledge acquired by its own experience related to the same knowledge.

1. The user selects the "GO TO KNOWLEDGE REPOSITORIES", and the system takes him/her to the Knowledge Class index, then is selected the R&D Repository, where the search is to be requested (see figures 4.2 and 4.10),
2. On the R&D Team Repository search engine the user employee, selects the attributes that gives the closest description of the knowledge that will be modified (see figure 4.18), and the list with the knowledge that describes the submitted request is displayed,

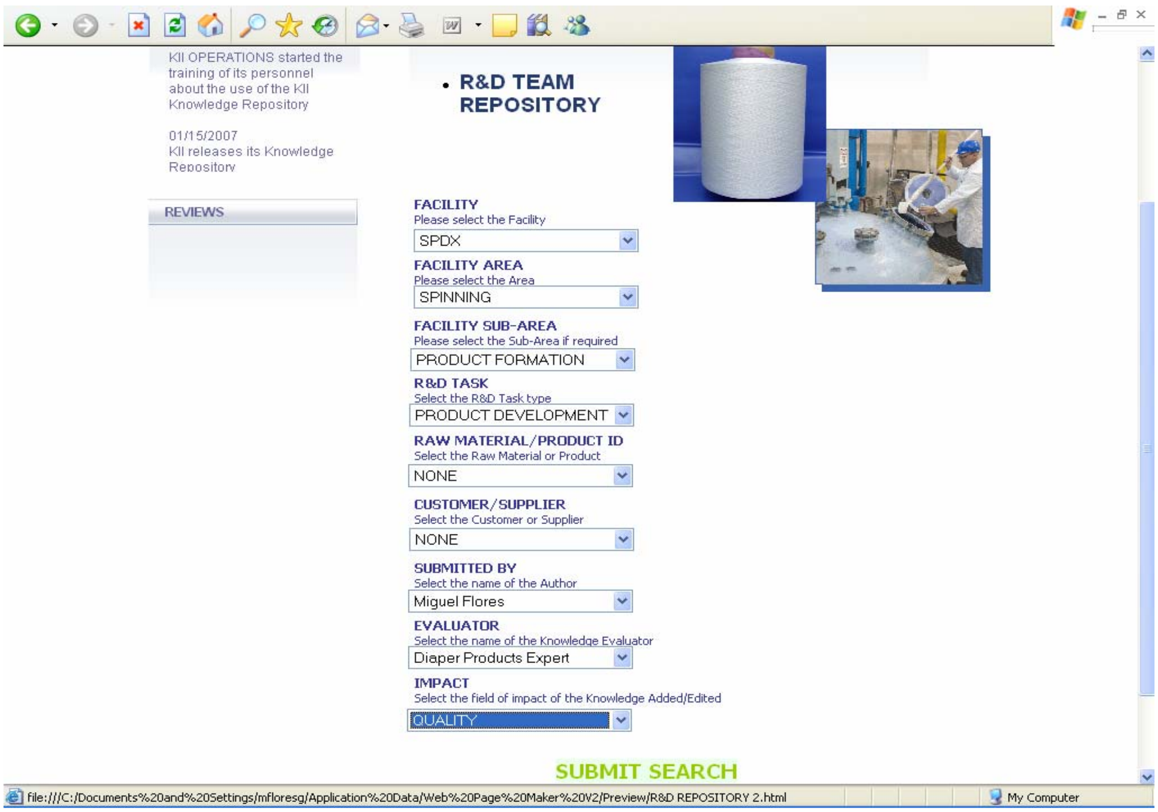


Figure 4.18 – R&D Knowledge Repository search engine display

3. From the displayed list with the results most approximate to the attributes selected for the search developed, the user employee clicks the "EDIT" option to modify the selected knowledge (see figure 4.19),

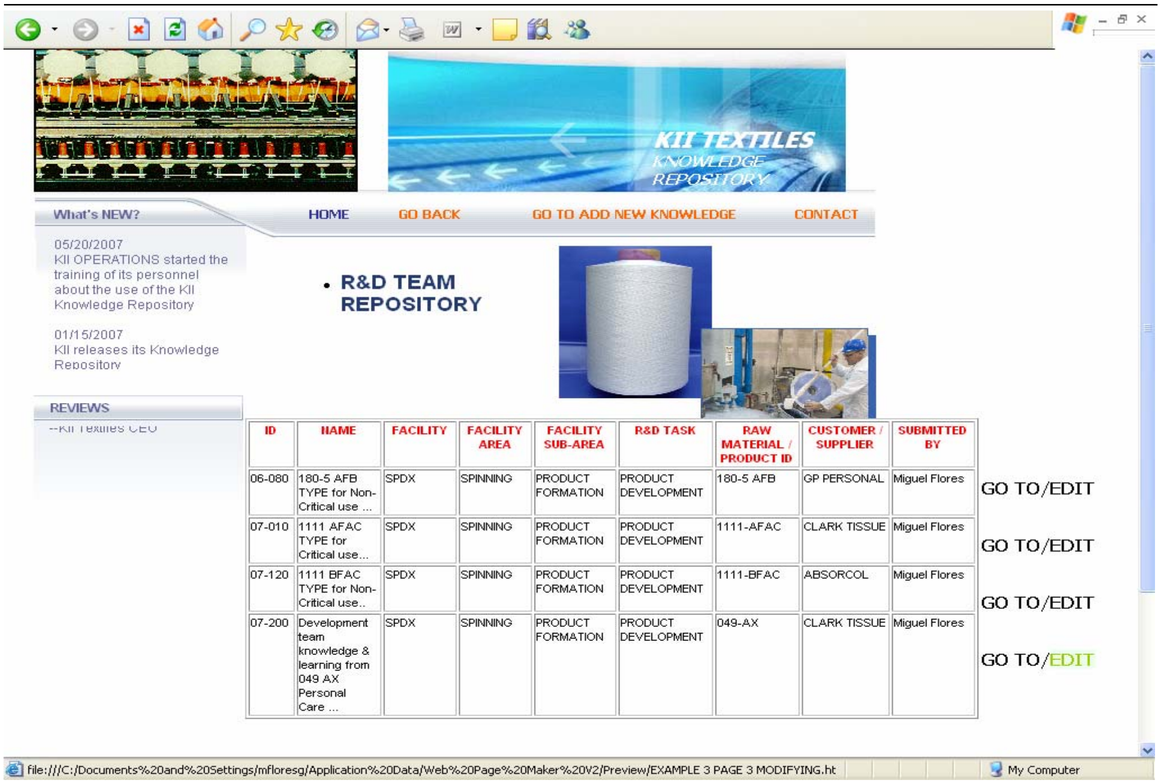


Figure 4.19 – R&D Knowledge Repository submitted search list

4. On the edited knowledge the user employee has the capabilities to modify the text from the story telling; modify, remove and/or add pictures, videos, graphics and voice records previously stored in the repository; also add or remove entire pages (see figure 4.20). Once it has been modified, is sent to the original evaluator whose validates the proposed modifications prior it is placed available in the repository. The system recommended to count with limited access for its first stage of implementation, the modifications proposed to stored knowledge is authorized just for Supervisors, Engineers and Managers.

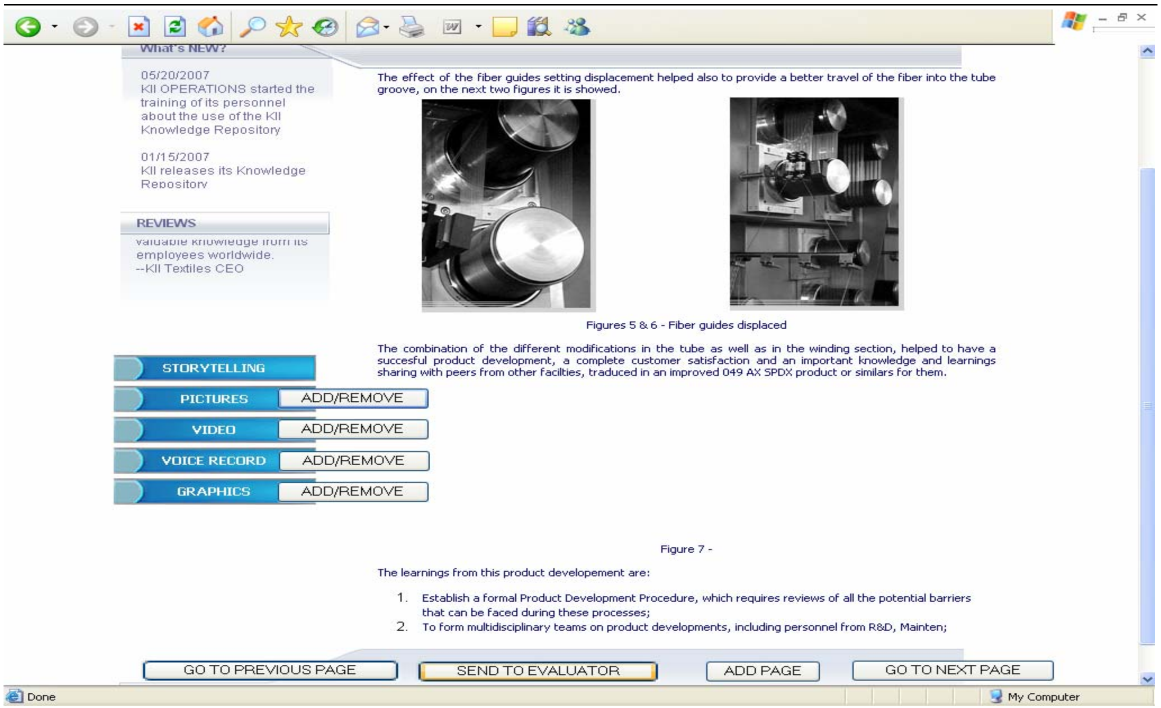


Figure 4.20 - R&D knowledge modification options for Representation Tools

5. When the modified knowledge is authorized and set available into the repository, it is presented in the same format as other stored knowledge (see figures 4.21, 4.22 & 4.23).

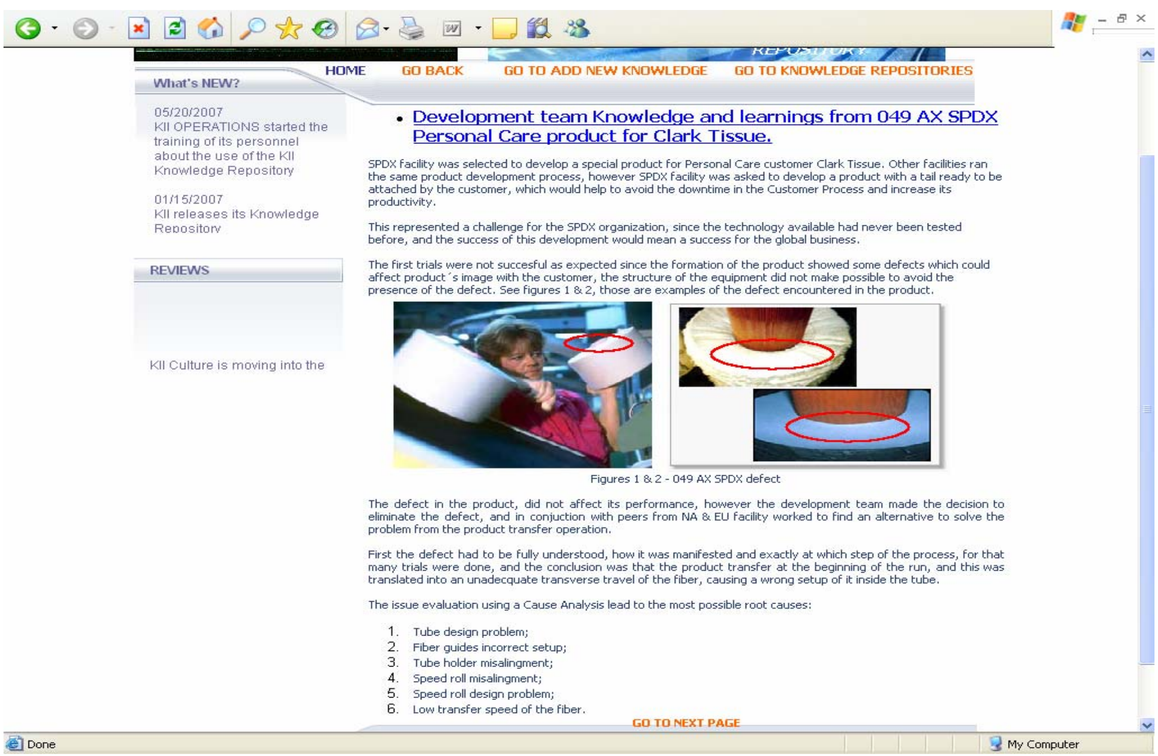


Figure 4.21 - Case Study 3 R&D Knowledge representation (1st page)

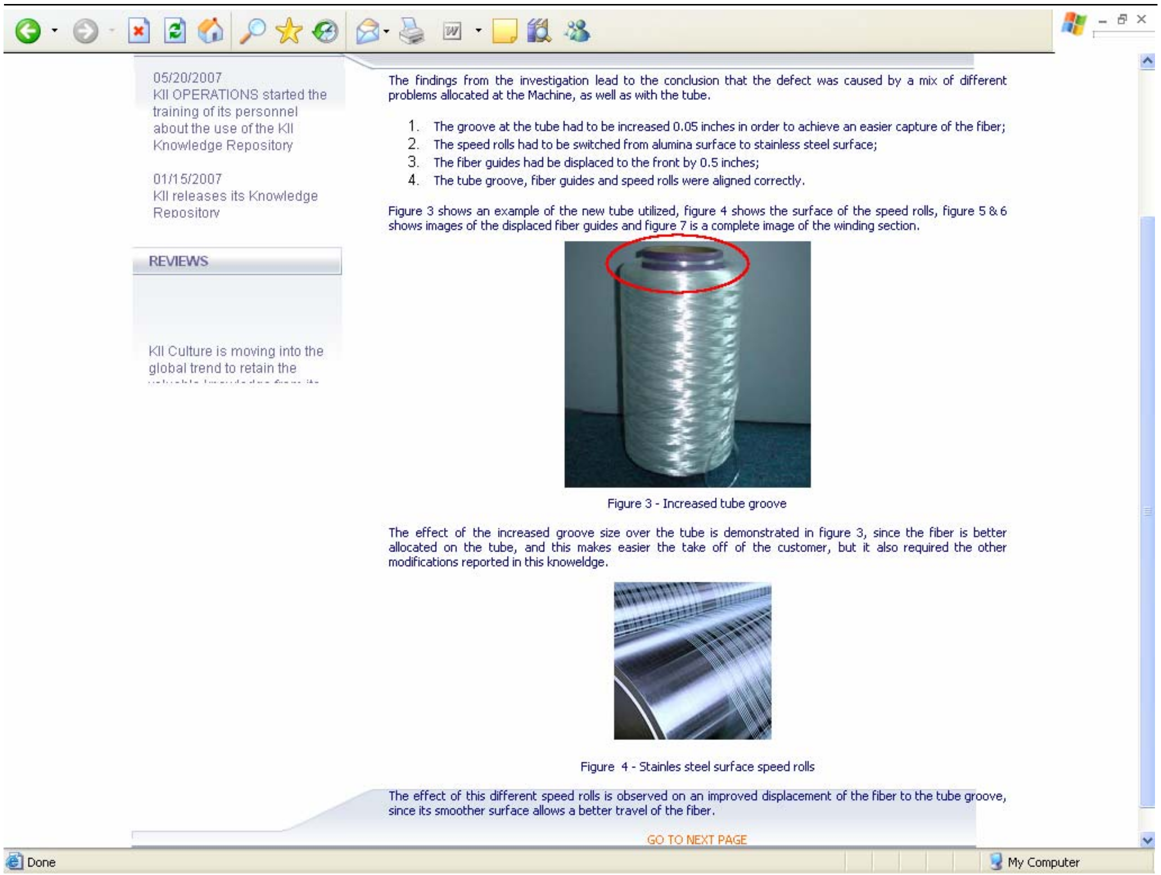


Figure 4.22 - Case Study 3 R&D Knowledge representation (2nd page)

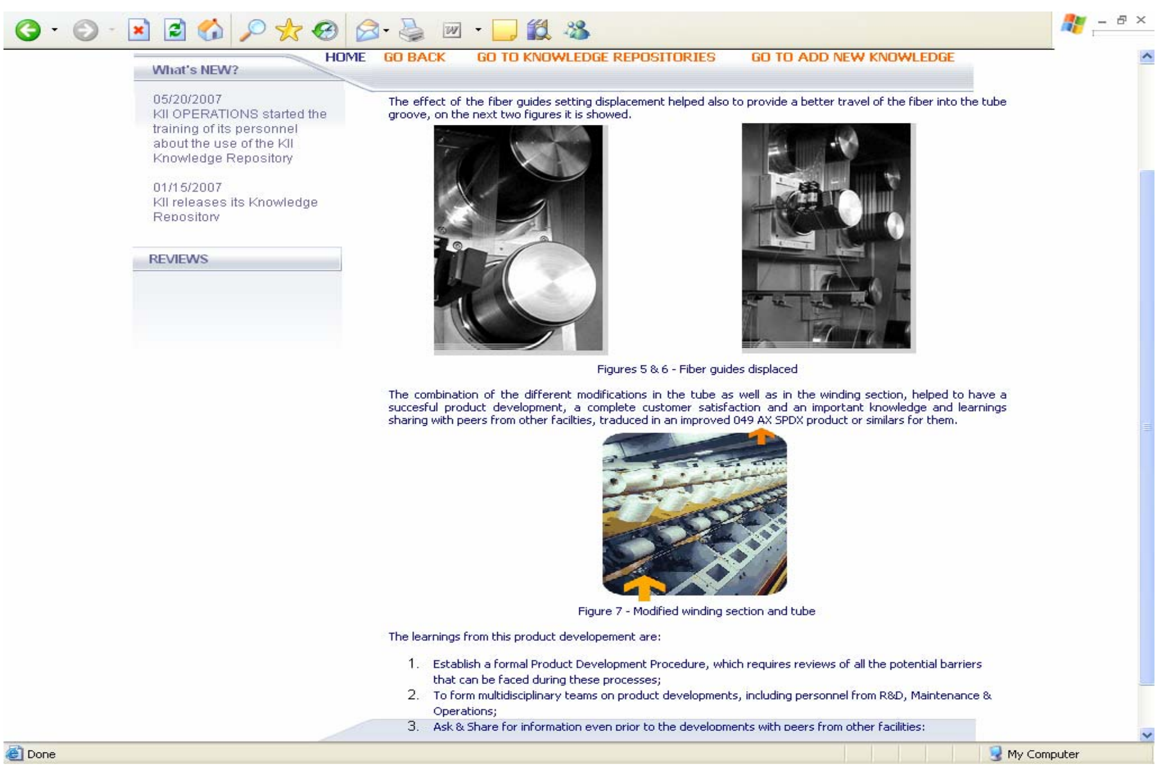


Figure 4.23 - Case Study 3 R&D Knowledge representation (3rd page)

4.7 MANUFACTURING TACIT KNOWLEDGE MODEL AND IK TEXTILES KNOWLEDGE REPOSITRY CONTRIBUTION

The problem stated in this thesis work, the loss of manufacturing tacit knowledge caused by the employees turnover and the retirement of expert employees, can be mitigated with the existence of the solution presented “IK Textiles Knowledge Repository”.

This tacit knowledge represented as learning and experiences acquired and skills developed by the employees has now been classified under keywords intended to be common for employees usage of the Knowledge Repository and to other facilities rather than the subject to the research study which detects added value from the structure proposed in this thesis work that derived in the Knowledge Repository developed.

The main contributions of this Thesis work are:

- Detect and define the problem, the Loss of Manufacturing Tacit Knowledge at the Chemical Facility selected, and the potential that this problem exists in other Facilities that belongs to the IK Textiles;
- The definition of Knowledge Classes related to the Manufacturing Process of Chemical Facilities,
- The structuring of a model with the main knowledge classes and the attributes that describes the knowledge classes and sub-classes,
- The development of a tool, named IK Textiles Knowledge Repository, based on the Model for the Manufacturing Tacit Knowledge,
- The demonstration with real cases of the operation of the Manufacturing Tacit Knowledge Model as well as the operation of the Knowledge Repository,
- The opportunity to implement the Knowledge Repository in all the IK textiles facilities, and similar proposals in other companies.

5. RESULTS, CONCLUSIONS AND FURTHER RESEARCH

5.1 RESULTS

The following results have been achieved in this thesis work:

- The identification of the loss of tacit knowledge related to the Manufacturing Process in the subject to study facility, and the potential problem extended to other facilities of the Company;
- The definition of Knowledge Classes derived from a super class defined as Manufacturing Knowledge; the knowledge classes were defined based on the major organizations that conforms the facility, which are common terms in other facilities;
    - Operations Area,
    - Maintenance Area,
    - Engineering Area,
    - Quality Area,
    - R&D Area

- The development of the Model with instances and attributes that serve as the identification tools of particular knowledge (see figure 3.7);
- The demonstration through real cases of how to develop the structuring, capturing, search, modification and validation process of Manufacturing Tacit Knowledge within the IK Textiles Knowledge Repository;
- The mitigation of the loss of knowledge within the Chemical Facilities through the capturing of the Knowledge Repository;
- The potential decrease of Manufacturing problems related with lack of experience, learning or skills through the possibility for the users accessing to captured knowledge of similar incidents;
- The possibility for the users to edit and modify stored knowledge to enhance it.

5.2 CONCLUSSIONS

- Even that knowledge is an abstract concept, the utilization of terms similar or equal to the departments or areas from an organization, helped to define the keywords that identifies the knowledge classes associated with the super class "manufacturing knowledge";
- The knowledge subclasses defined are associated with common incidents that occurs within the facility, these terms however does not necessarily apply to other type of Manufacturing facilities, but can serve as guides to other facilities;
- The tool developed for this thesis work, the IK Textiles Knowledge Repository demonstrated the capability to store, modify or read the employees tacit knowledge;
- The metrics proposed to measure the effectiveness of the Knowledge Repository are:
  - The number of Knowledge added;
  - The number of Knowledge modified;
  - The number of Knowledge validated;
  - The number of Knowledge rejected;
  - The number of Knowledge read;
  - The number of Knowledge utilized by the users;
  - The number and classification of events prevented with the utilization of Knowledge from the Repository;
  - The magnitude of the events prevented.

5.3 FURTHER RESEARCH

- This thesis work has the limitation of only been developed on two local facilities, there is the opportunity to extend the application of the Knowledge repository globally to all the facilities that belongs to IK Textiles, and measure the effectiveness of the Knowledge Repository in different countries.

- The thesis work has also the limitation of being applied to a single branch of the Chemical Industry, it has to be validated its applicability on other fields like Petro-Chemical industry.
- The number of Case Studies is limited and would be required to increase the number of cases to validate the usefulness of captured knowledge,
- Explore also if the concept proposed has applicability to other fields rather than industrial, e.g. medicine, academic, marketing, etc.;
- No studies have been reported about cultural impact of knowledge management approaches implementation in Mexican industry, this to prevent potential reluctance of the employees to the utilization of knowledge management tools and to share their tacit knowledge (learning, experiences or skills) it is not intended by this thesis work to explore the psychology of the employees about the knowledge management, it is an opportunity to explore the organizational psychology of Mexican workers about the utilization of knowledge management tools.

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APPENDIXES

- 4th Case Study

Contains an example about a Deviation in the Operations at DPNY facility; the deviation is defined to have an impact in Safety, since it involved the damage of a flexible metallic hose used to transport a polymer, the damaged derived into a spill of material, and this is considered as a safety incident. It is intended to capture the knowledge acquired from this experience, which contains learning about the wrong set up of the hose, the inadequate selection of hose material; and pictures were saved to serve as testimonials of the incident. The management is interested also in have available the knowledge and share it to other facilities, to help them to learn from this incident and those facilities through the use of pictures can easily identify the equipment involved.

Figure A1 – Operations deviation addition into Operations Team Repository

Figure A2 – Operations Team Repository – Operations Deviation example

- 5th Case Study

A scheduled maintenance of the process equipment identified as Gas Condenser at SPDX was carried out recently, this task has never been operated before, since the equipment started operations three years ago. The engineer leader of the maintenance has considered the importance of the retention of the experiences achieved during this maintenance, this due to it is not a frequent task developed at the SPDX facility and the learning acquired from this event have the risk to be forgotten by the employees involved, or lost in case people leave or changes its responsibilities. The learning stored and utilized in future scheduled can improve the time scheduled for the maintenance activities including the release of the equipment to be set in operations again. Here is exemplified the search of this equipment and how it is stored in the repository.

Figure A3 – Routine Maintenance knowledge search within Maintenance team repository

Figure A4 – Routine Maintenance search results selection

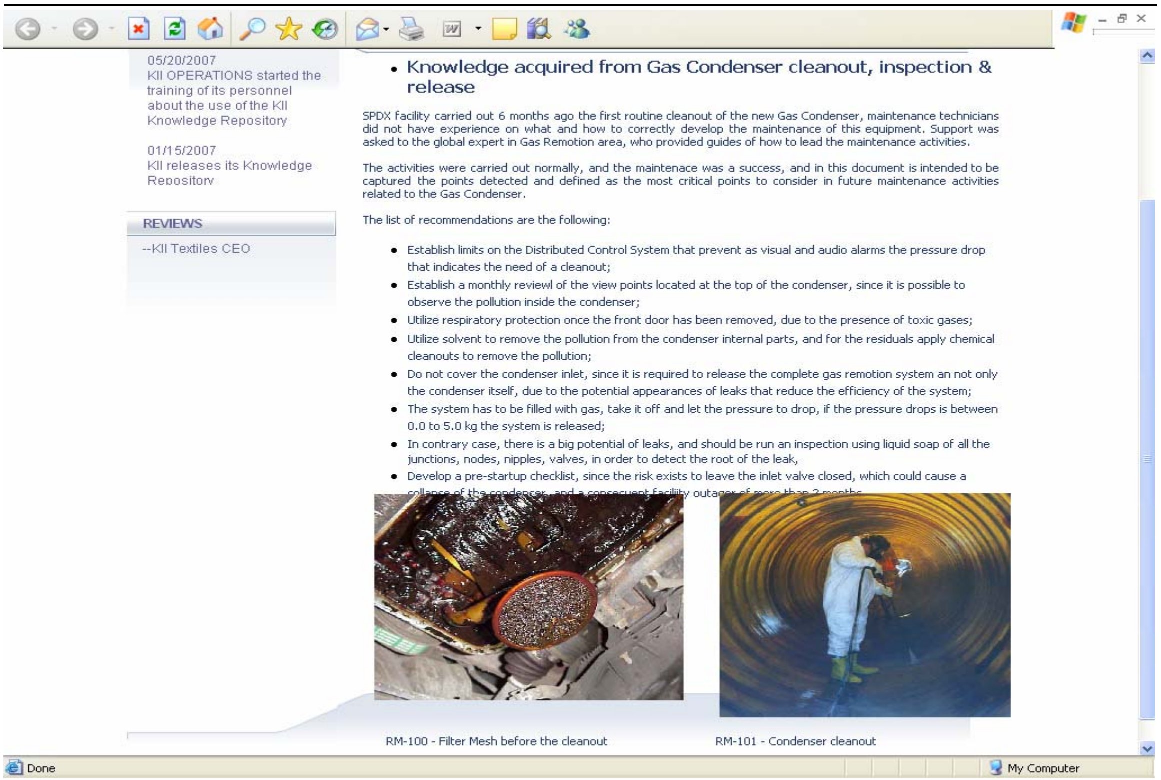


Figure A5 – 5th Case Study knowledge representation

o 6th Case Study

This case study was identified by the Engineering Manager at SPDX facility, after the implementation of a project for the set up of a raw material storage tank with different technology, meaning higher capacity, different construction material, different temperature control strategy, different mixing strategy and higher material pumping capacity. The project was considered as a success, since the equipment had been in operation for almost two years, this until an operator reported the presence of solidified material over the mixers. The resolution of this problem was reached until the system was scheduled for a shutdown, clean the internals of the tank and modify the supply line to avoid the accumulation of material over the mixers. It is intended to develop a document, like a best practice for future engineering projects, and prevent potential incidents if all the points recommended by the derived knowledge document are considered.

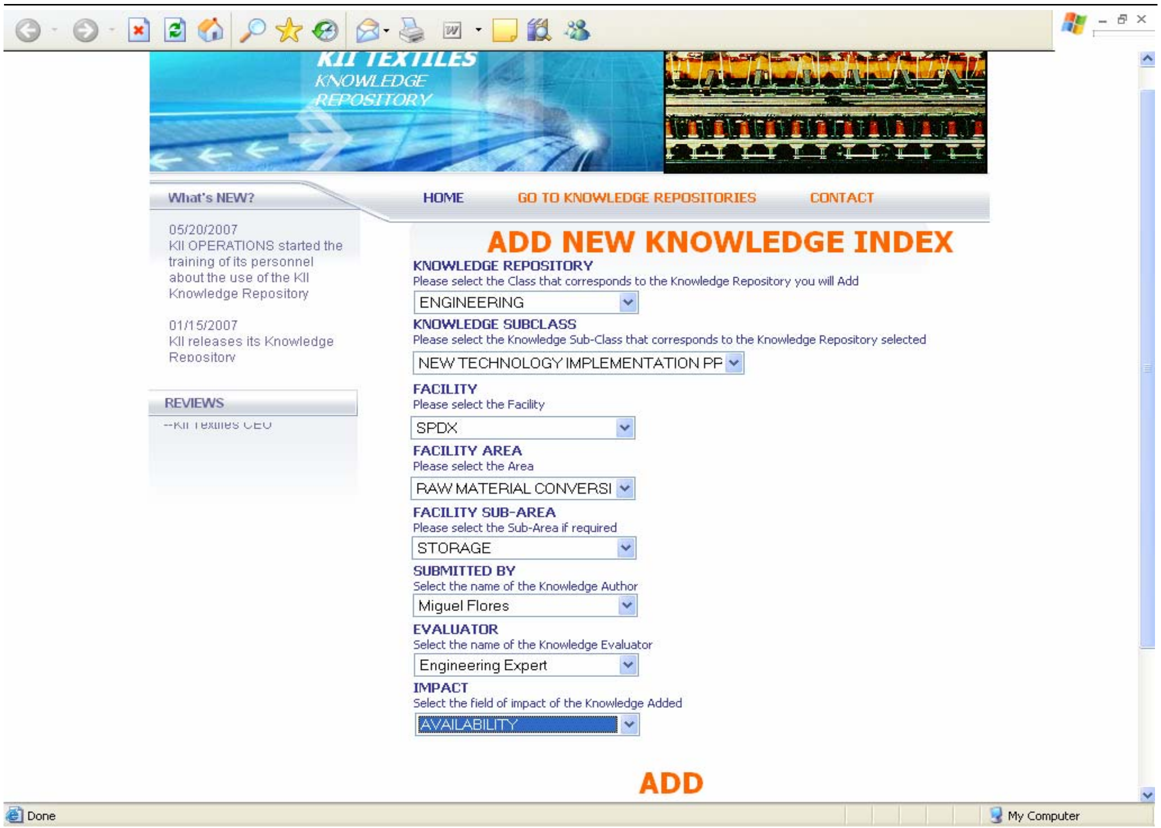
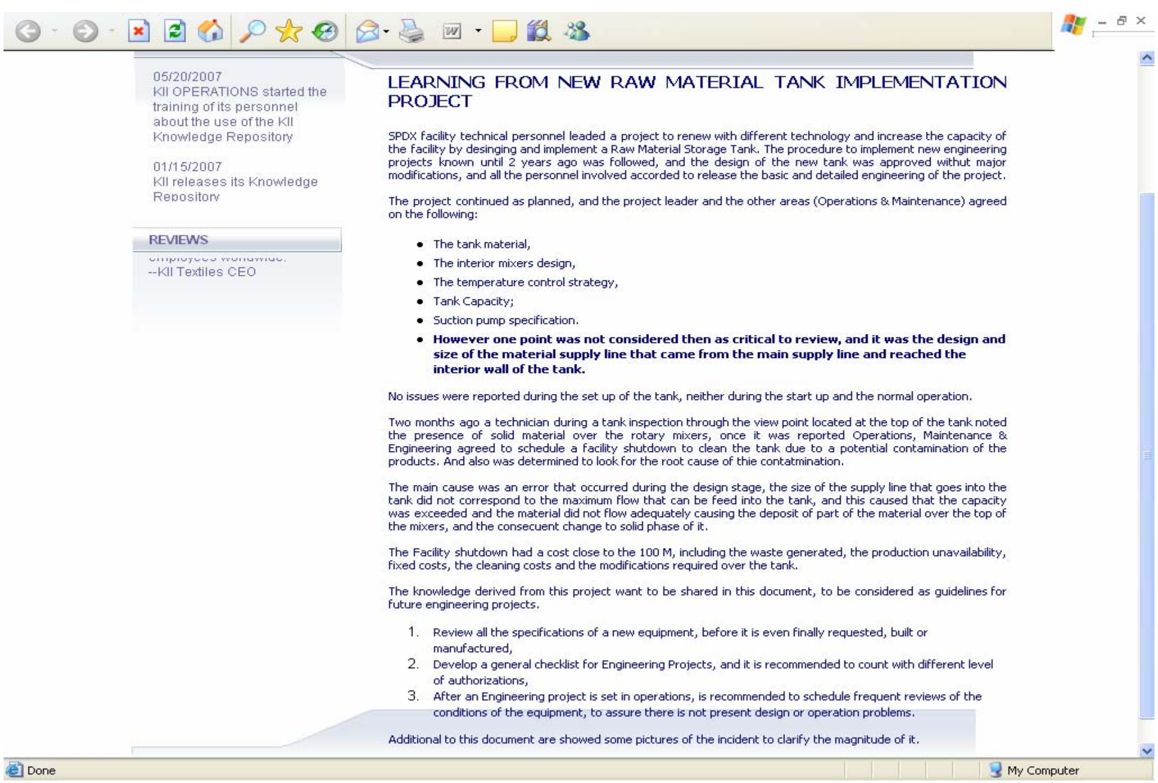


Figure A6 – 6th Case Study attributes selection in Add New Knowledge Index



LEARNING FROM NEW RAW MATERIAL TANK IMPLEMENTATION PROJECT

SPDX facility technical personnel leaded a project to renew with different technology and increase the capacity of the facility by desinging and implement a Raw Material Storage Tank. The procedure to implement new engineering projects known until 2 years ago was followed, and the design of the new tank was approved withut major modifications, and all the personnel involved accorded to release the basic and detailed engineering of the project.

The project continued as planned, and the project leader and the other areas (Operations & Maintenance) agreed on the following:

- The tank material,
- The interior mixers design,
- The temperature control strategy,
- Tank Capacity;
- Suction pump specification.
- **However one point was not considered then as critical to review, and it was the design and size of the material supply line that came from the main supply line and reached the interior wall of the tank.**

No issues were reported during the set up of the tank, neither during the start up and the normal operation.

Two months ago a technician during a tank inspection through the view point located at the top of the tank noted the presence of solid material over the rotary mixers, once it was reported Operations, Maintenance & Engineering agreed to schedule a facility shutdown to clean the tank due to a potential contamination of the products. And also was determined to look for the root cause of thie contatmination.

The main cause was an error that occurred during the design stage, the size of the supply line that goes into the tank did not correspond to the maximum flow that can be feed into the tank, and this caused that the capacity was exceeded and the material did not flow adequately causing the deposit of part of the material over the top of the mixers, and the consecuent change to solid phase of it.

The Facility shutdown had a cost close to the 100 M, including the waste generated, the production unavailability, fixed costs, the cleaning costs and the modifications required over the tank.

The knowledge derived from this project want to be shared in this document, to be considered as guidelines for future engineering projects.

1. Review all the specifications of a new equipment, before it is even finally requested, built or manufactured,
2. Develop a general checklist for Engineering Projects, and it is recommended to count with different level of authorizations,
3. After an Engineering project is set in operations, is recommended to schedule frequent reviews of the conditions of the equipment, to assure there is not present design or operation problems.

Additional to this document are showed some pictures of the incident to clarify the magnitude of it.

Figure A7 – 6th Case Study Knowledge representation (1st page)

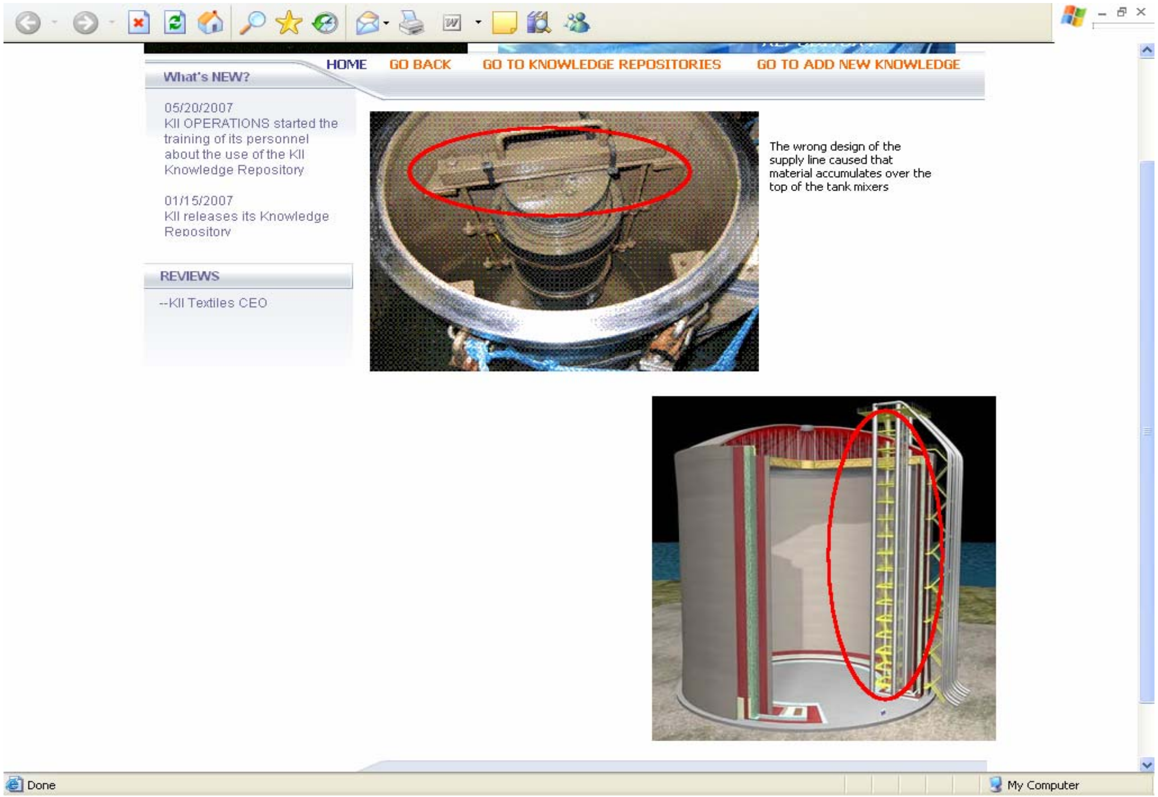


Figure A8 – 6th Case Study Knowledge representation (2nd page)

- 7th Case Study

This example contained is a particular case of a project for the research of a new raw material which modifies a property of the products manufactured in the facility, improving the product performance with the customers. A R&D project generates important amount of knowledge that are not formally structured and are just kept within the employees involved in the project. The purpose of the case showed is to demonstrate that the knowledge derived from R&D projects can be identified, captured and reused in future projects to develop best practices and improve the development of projects R&D projects, and it will also contribute to conform a repository for the training of future employees dedicated to the R&D area. The example demonstrates how an employee will proceed with a search, to find the document the employee is interested in modify it, adding new learning acquired from the research process, with its subsequent validation process by the knowledge evaluator.

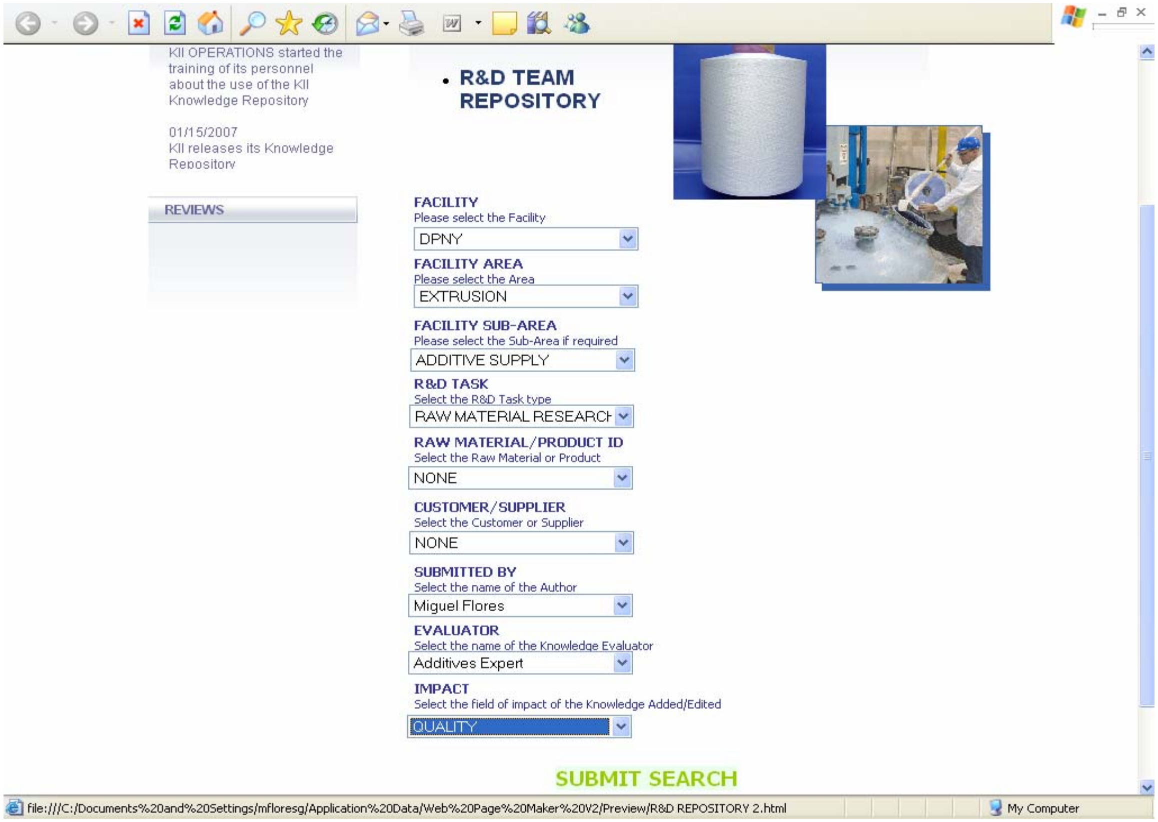


Figure A9 – 7th Case Study Search index

Figure A10 – 7th Case Study Search results, and EDIT selection

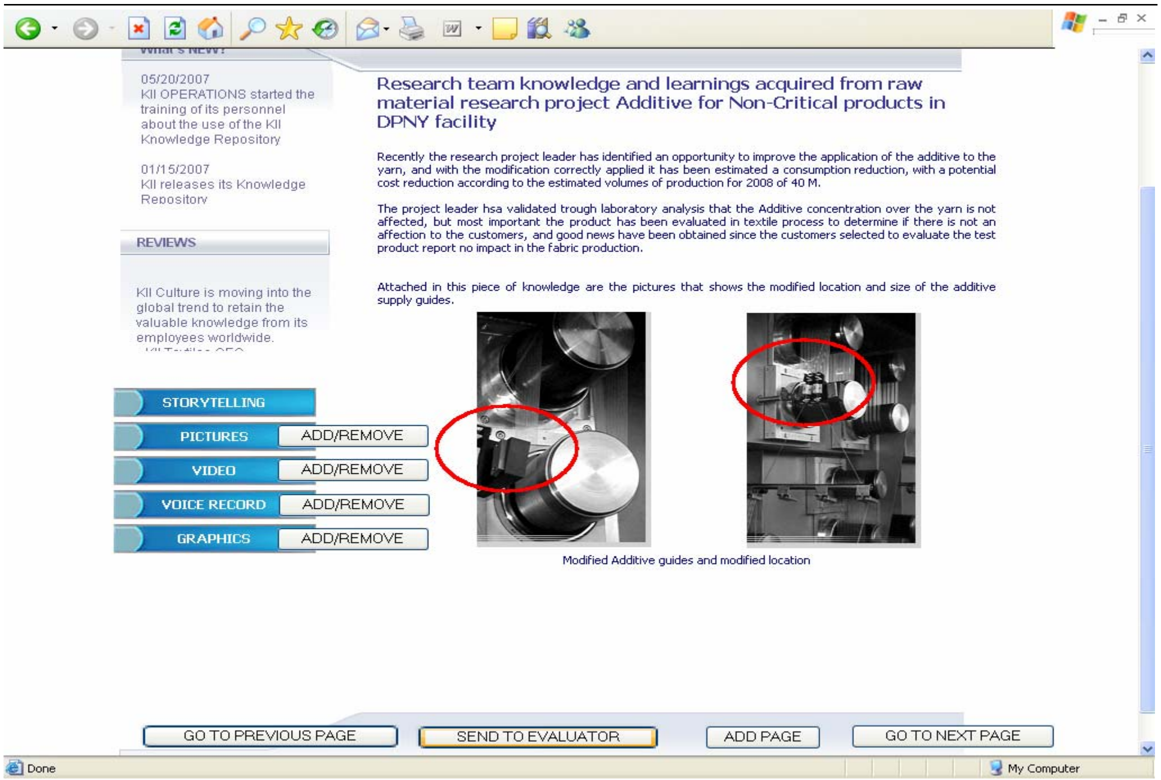


Figure A10 – 7th Case Study Search results, and EDIT selection

- 8th Case Study

Contains a case related to the Quality Knowledge; the example is based on a Quality incident reported by a customer; the purpose of this case is to identify, capture and reuse the knowledge acquired by the employees involved in the investigation and resolution of the quality incident and the development of best practices that prevent future quality incidents and maintain the customer satisfaction. The employee in charge of the investigation to determine the cause of the quality incident, in this case a customer claim, wants to save the learning from the investigation, as evidence of the defect, the claim, the corrective as well as the preventive actions that will avoid a similar incident with this and with other customers.

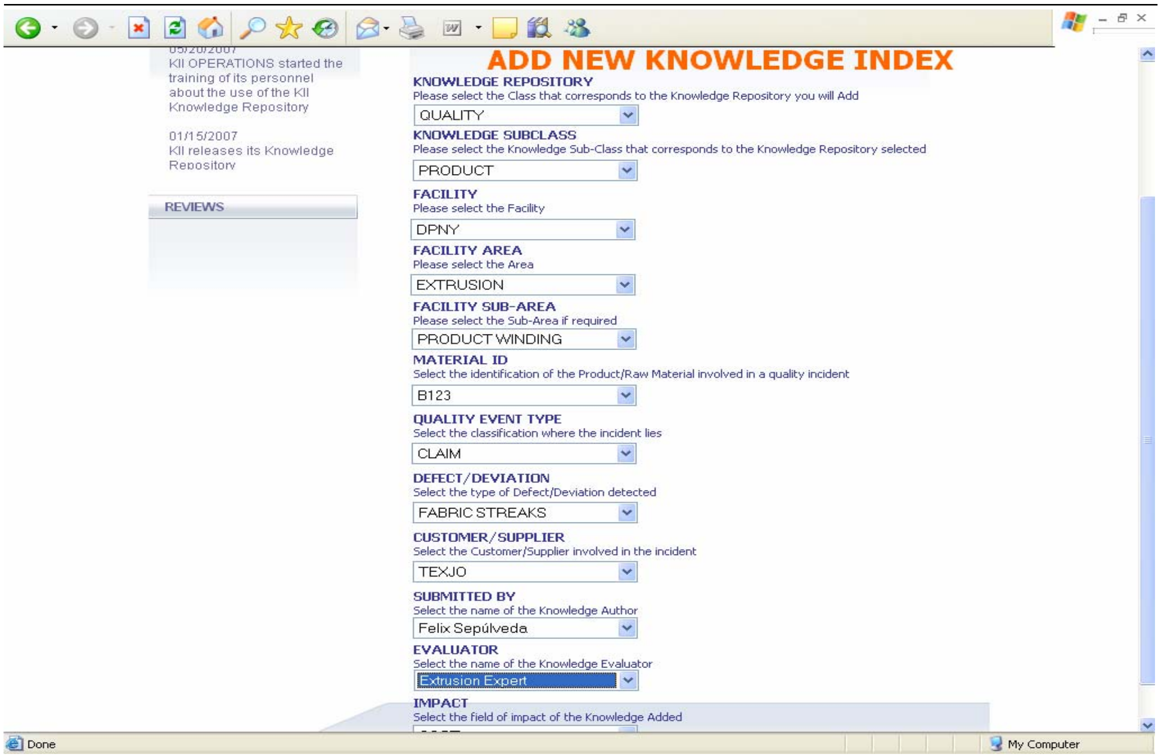


Figure A11 – 8th Case Study, Quality Knowledge → Add new knowledge attributes selection

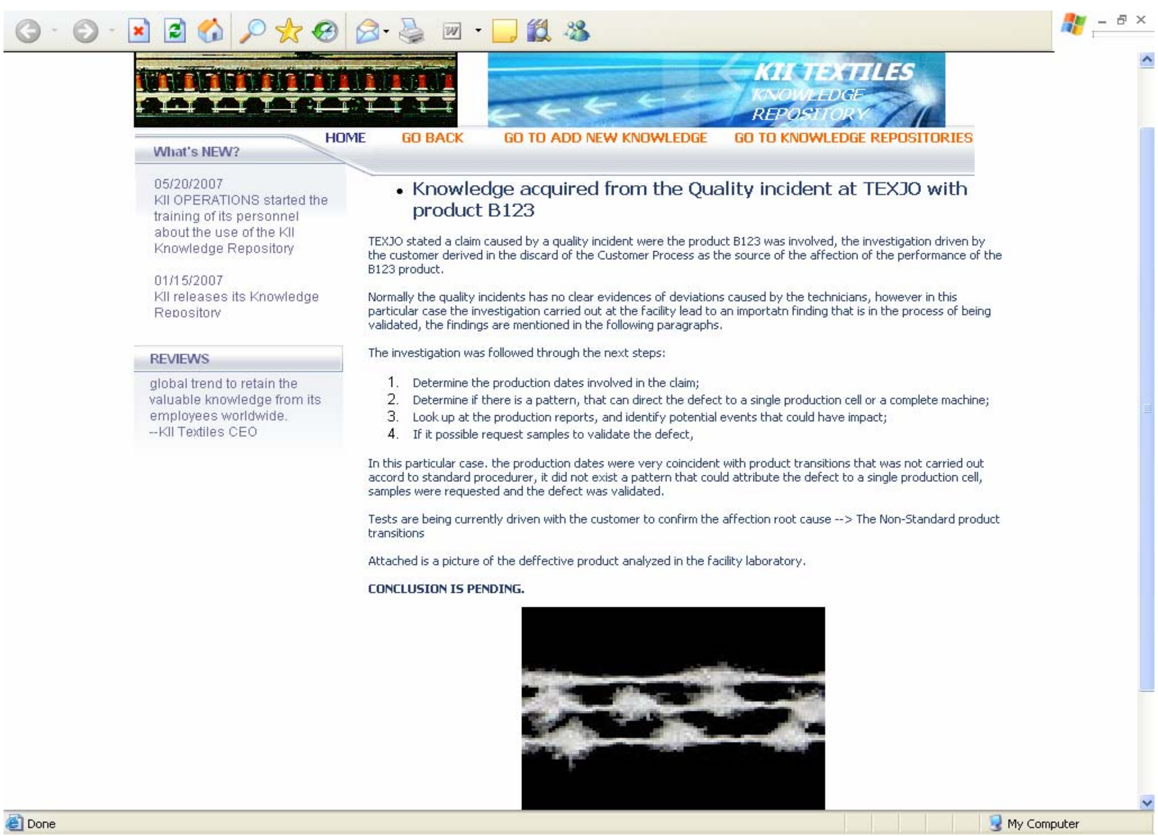


Figure A12 – 8th Case Study, Quality Knowledge → Knowledge representation to be validated