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**SEMANTIC BASED APPROACH FOR KNOWLEDGE
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**SEMANTIC BASED APPROACH FOR KNOWLEDGE
MANAGEMENT**

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ABSTRACT

Keywords: Semantics; Ontologies; Concepts; Rules; Knowledge Representation;

Companies are beginning to understand the importance of the management and maintenance of knowledge resources. One of the main constraints that have hindered the solution to resolving technical problems has been the efficient access to knowledge and expertise. Currently, the problem of ‘understanding’ has been one of the main limitations that have hindered the robustness of conventional systems due to lack of ‘semantics’ in knowledge representation. Therefore, there is need for enhancing the management and maintenance of knowledge through a semantic based approach. Semantics is defined as the study of meaning in communication and it aims to identify relationships between syntactical elements through the use of ontologies.

The aim of this thesis is to develop prototype tools utilising semantic based approach for knowledge management in order to demonstrate and quantify the potential capability of these technologies within the defence equipment support market. The development of these semantic based prototypes are based upon accomplishing certain objectives: (i) transform an existing Excel based cost model into a semantic based application (ii) capture complex knowledge about maintenance and diagnosis of equipments in one central knowledge base, (iii) incorporate within the prototype a two way dialogue to help in diagnosing a problem and allow for rapid discovery of appropriate solutions, (iv) evaluate and validate use of semantic based approach to manage knowledge within the defence equipment support market, (v) use of multiple cases to demonstrate the benefits of semantic technology. The aim and objectives of this research project was achieved by adopting a qualitative research approach and a five-phase research programme methodology.

The research project has highlighted that the use of semantic technology enhances the reusability, flexibility and maintainability of knowledge and its management. The ability to represent functionalities graphically reinforces understanding and makes functionality editing easier. Semantic technology can also be deployed gradually which means it can mature with the problem. The definition of synonyms and ontologies gives semantic technology an advantage over other computer based knowledge representation techniques. This research project successfully demonstrates and quantifies the benefits of semantic technology.

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GLOSSARY OF TERMS

G&A	General and Administration
HLU	High Level Unit
KBS	Knowledge Based System
LSM	Lightning Strike Mesh
WSDL	Web Service Description Language
WWW	World Wide Web

CHAPTER 1:

INTRODUCTION

1.1 Background

Cost modelling has become an influential factor in determining the success of organisations' as they realise that in order to remain competitive, they need an effective means and platform for estimating and predicting the cost for an undefined project. Most cost modelling platforms are usually developed using Microsoft Excel with additional help from macros. However, a better medium is required that will aid cost modelling and improve the efficiency and effectiveness of cost prediction. Currently, queries on data cannot be implemented on Excel platform effectively and Excel could sometimes become confusing. A slicker and better approach will be to introduce the use of semantics in cost modelling. The outcome of this research project will demonstrate the effectiveness of applying semantics (linguistics) to cost modelling.

Maintenance of knowledge has always been an essential factor that has contributed to the success of organisations' as they realise that their most valuable resource and asset is the knowledge of its people. However, one of the main constraints that have hindered the solution to resolving technical problems has been the efficient access to knowledge and expertise due to experts that are bound by their geographical location or the sudden departure of experts. A common solution has been the use of knowledge based systems which allows for knowledge reproduction. However, KBS lacks meaning in communication which means a more efficient and effective way is needed for managing and maintaining knowledge in order to correct defects and improve system performance.

This research project has been conducted with the industrial sponsor and Cranfield University, with the outcome of quantifying a semantic based approach for managing knowledge. The structure of this chapter is as follow: section (1.2) demonstrates the research motivation and need for the project, section (1.3) demonstrates the problem statement, the industrial sponsor will briefly be introduced in section (1.4) the breakdown structure of this research project will be captured in section (1.5) and finally section (1.6) will state the aim and objectives of the research project.

1.2 Research Motivation

The revolution of the Internet has changed the way in which companies communicate. However, the biggest issue faced with the Internet is the lack of meaning in language. The Internet is currently described as ‘Syntactic Web’ meaning its core foundation is solely based on syntax. The term ‘Semantic Web’ has been widely dispensed in Industry. Semantic is described as the study of meaning in communication. Research has demonstrated that semantic web will be the evolution of the current World Wide Web, an Internet whereby, machine understands language due to the definition of ontologies. Majority of industry do not understand the potential benefits of the application of semantics, not only for the WWW, but for also managing and maintaining knowledge for conventional software applications.

1.3 Problem Statement

The majority of cost modelling development is usually implemented using Microsoft Excel with additional help from macros. However, a better medium is required that will aid cost modelling and improve the robustness of cost prediction. One of the core issues with using an Excel based cost model is that the excel platform itself is non-relational except for reference commands such as VLOOKUP. Excel based cost model are also complicated and can be easily confusing when modification is required. A prototype is therefore needed that will transform an existing excel based cost model into a fully operational semantic based cost model utilising ontologies and declarative rules. The prototype will quantify the use of semantics in cost modelling.

Contracting for availability has become a key strategy for the UK MoD. By contracting for availability, the UK MoD must incorporate ‘Value for Money’ within its contracts with working groups. Previously, industry earned more money if a greater amount of components failed. The reason is because demand for spares and repairs would have been much higher. By contracting for availability, the UK MoD can place the risk of supporting these components on Industry. However, one of the main constraints that have hindered the solution to resolving technical problems has been the efficient access to knowledge and expertise. Very often, experts that are required to demonstrate this competency in problem solving are related to a specific domain and distributed geographically. Another unforeseen circumstance that occurs is that subject matter experts could suddenly decide to leave or be

redeployed. As a result of this, current engineers end up spending large amount of time to find a solution to previously resolved problems. This leads to increased time-to-fix, downtime, and substantial unnecessary cost increase.

A potential solution to this problem is the use of a knowledge based system which will reproduce knowledge from human experts utilising latest technologies such as semantics, declarative rules & ontologies. A prototype demonstrator is then needed that will quantify the use of semantic technology within this field. The aim of this thesis is then derived from the problem definition.

1.4 Industrial Sponsor

TechModal was founded in 2005 by PhD students researching semantic technology and cost engineering techniques within the aerospace sector. The company was formed to utilise the latest web technologies for practical solutions within decision support. Having researched the field of Semantic Technology at PhD level and implemented semantic technology applications in industry, TechModal have selected Ontoprise semantic technology as the most efficient framework on which to build semantic applications. TechModal are also software resellers and are partners with companies such as Microsoft, Plexus, Fast and Ontoprise.

TechModal are PhD level consultants providing cost engineering consultancy services to clients such as MoD, BAE Systems, Rolls-Royce, Air Bus, etc.

1.5 Aim and Objectives

The aim of the research project is to develop prototype tools utilising semantic based approach for knowledge management in order to demonstrate and quantify the potential capability of these technologies within the defence equipment support market.

The objectives of this research project are to:

- Transform an existing Excel based cost model into a semantic based application.
- Capture complex knowledge about maintenance and diagnosis of equipments in one central knowledge base.

- Incorporate within the prototype a two way dialogue to help in diagnosing a problem and allow for rapid discovery of appropriate solutions.
- Evaluate and validate use of semantic based approach to manage knowledge within the defence equipment support market.
- Use of multiple cases to demonstrate the benefits of semantic technology.

1.6 Thesis Structure

Figure 1.1 illustrates the thesis structure which suggests the various stages for the research project and the proposed method used to successfully accomplish these stages. As presented in this section, Chapter 1 describes the project background and identifies the research motivation and problem statement, industrial sponsor, aim and objectives and the thesis structure.

In chapter 2, an extensive state of the art literature review is carried out in order to gain a better insight into the context of the project. The literature review focuses on knowledge management, knowledge capture techniques, knowledge based systems, maintenance support, cost modelling and more importantly, the current use of semantic technology in industry in order to highlight the research gaps.

Chapter 3 identifies the different existing approaches and the adopted methodology during this research project. In Chapter 4, the AS-IS model of the Excel based cost model is presented in order to illustrate how cost for a composite part is currently being represented.. The AS-IS model for the maintenance of a part is also documented. After understanding the limitations of the AS-IS model, Chapter 5 aims to capture and represent knowledge for the prototypes that are to be developed using various computer based knowledge representation techniques. Chapter 6 then illustrates the steps taken to develop these semantic based prototypes and validation of the TO-BE through the already validated AS-IS models. Chapter 7 discusses the results of the project, methodology, conclusion and more importantly the contribution to knowledge.

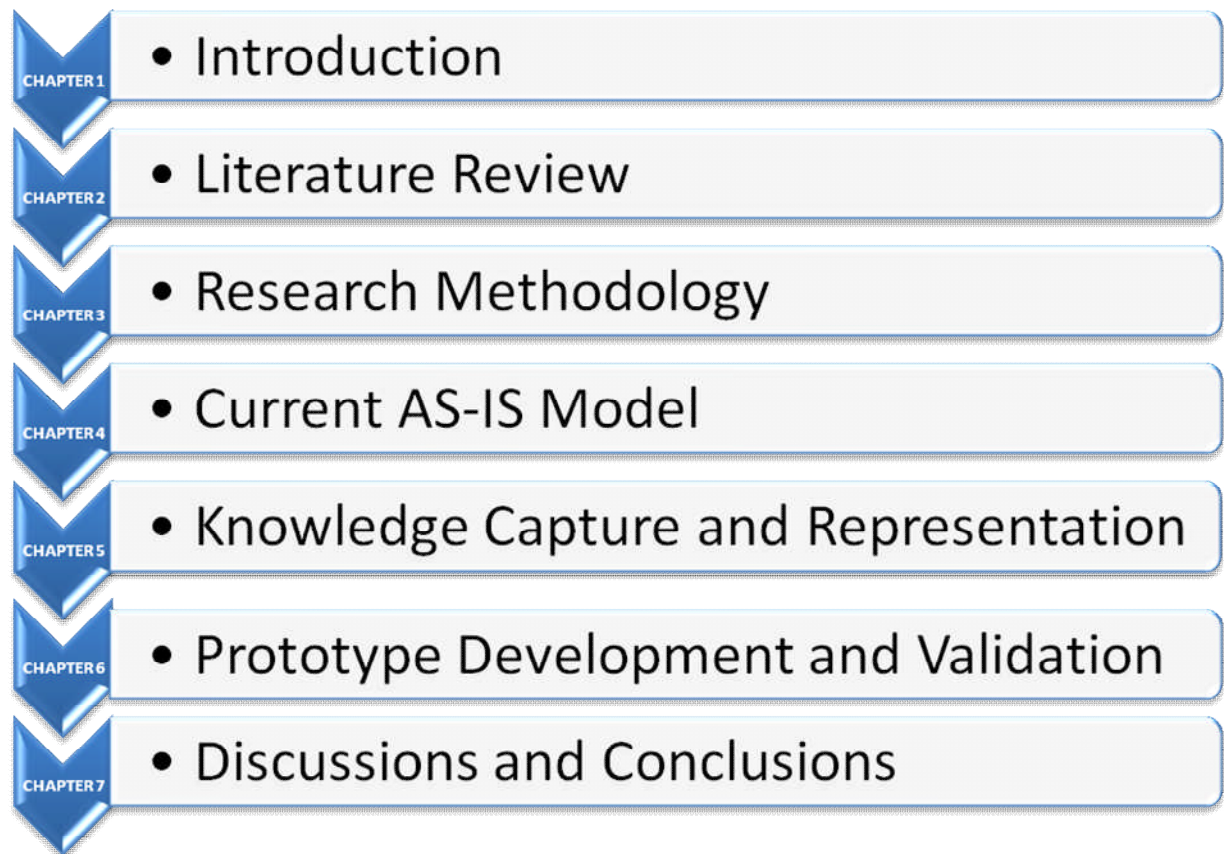


Figure 1.1- Thesis Structure Overview

1.7 Chapter Summary

This chapter has presented an overview of the project. Cost modelling is usually developed using Microsoft Excel platform, the use of semantics will aid in improving some of the limitations and difficulties with Excel based cost models. After the development of a cost model for a composite part, the next step is the maintenance and diagnosis of equipments which has been a common problem within the defence equipment support market (Ministry of Defence) due to lack of risk sharing with Industry. However, the use of semantic based technology will aid in offering intelligent diagnostic functionalities and define ontologies which will improve system performance and incentivise decisions made. The next chapter focuses on carrying out a literature review that will identify current advancements in the use of semantic technology and other critical areas.

CHAPTER 2:

LITERATURE REVIEW

2.1 Introduction

The following chapter gives a state of the art literature review on which this thesis is based, providing the reader with an overview of the development of knowledge based systems, including external factors that affect the performance of KBS. Factors such as understanding general knowledge management techniques, knowledge capture, technological advancements like the semantic web, semantic based knowledge representation techniques (ontology), and computer based knowledge representation techniques are all essential concepts that should be considered and used appropriately in order to develop successful knowledge based systems. A state of the art literature review on maintenance support and cost modelling will also be carried out in order to understand the current work that has taken place in these fields.

Figure 2.1 describes the breakdown structure of the literature review. The literature review commences with an overview of knowledge management in section (2.2) and the means of utilising the appropriate technique to capture various dimensions of knowledge. Section (2.3) reviews the use of knowledge based systems and the techniques currently being utilised by KBS. Section (2.4) concludes the use of computer based knowledge representation techniques and a detailed literature will describe the use of semantic based knowledge representation techniques and technologies in industry. A review on maintenance support is also carried out in section (2.5) in order to understand the current techniques adapted by these maintenance systems. Section (2.6) presents the need of cost modelling and advanced technologies that could aid in cost estimating and cost management.

The literature review will conclude with the scope of the present work in section (2.8) which will introduce a summary of the previous research work in section (2.9) in order to understand the outcome of the project undertaken and highlight the research gaps.

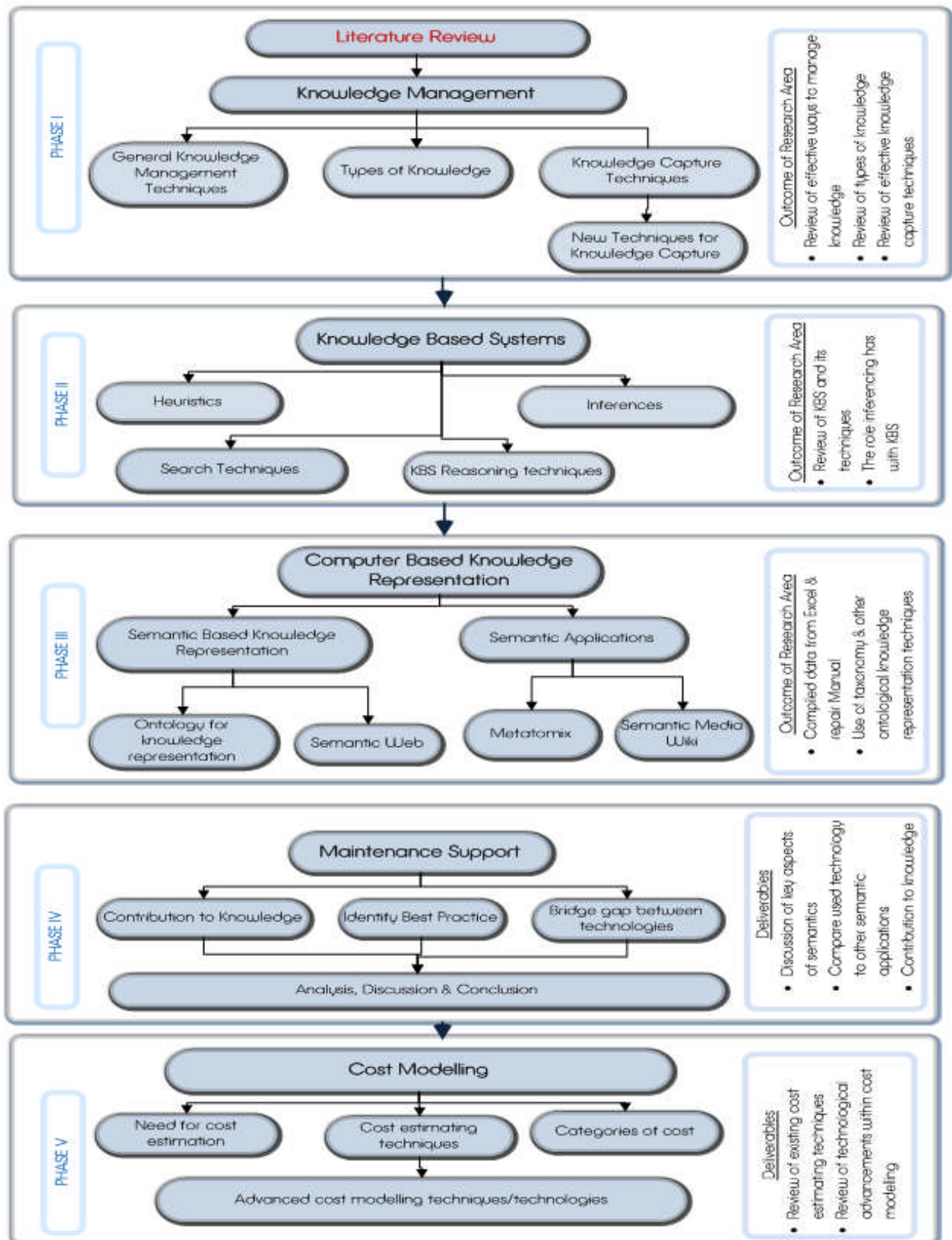


Figure 2.1 – Breakdown Structure of Literature Review

2.2 Knowledge Management

Knowledge management is now quickly becoming an important business activity for many organisations as they realise that in order to remain competitive, there is need for effectively managing intellectual resources. Grover and Davenport (2001), argues that rather than having knowledge management as a standalone business phenomenon that becomes popular for a short period of time, the management of knowledge is best accomplished by integrating it with other business functions and processes.

In today's world, any discussion of knowledge leads to understanding how knowledge is defined. In practice, knowledge is defined as starting at data, encompassing information and ending at knowledge. Typically, data is refined, classified and corrected in order to add value. This leads to information once it is put in context. This type of conversion is relatively mechanical and has been supported by various technologies such as storage, communication and processing mediums (Grover and Davenport, 2001). According to Grover and Davenport (2001) knowledge is known to have the highest value in human contribution. It is the greatest relevance to making decisions and actions and it is also the most difficult content type to manage because it exists in people's mind. Liebowitz, (2003) defines the relations between data, information, knowledge and wisdom as illustrated in Figure 2.2.

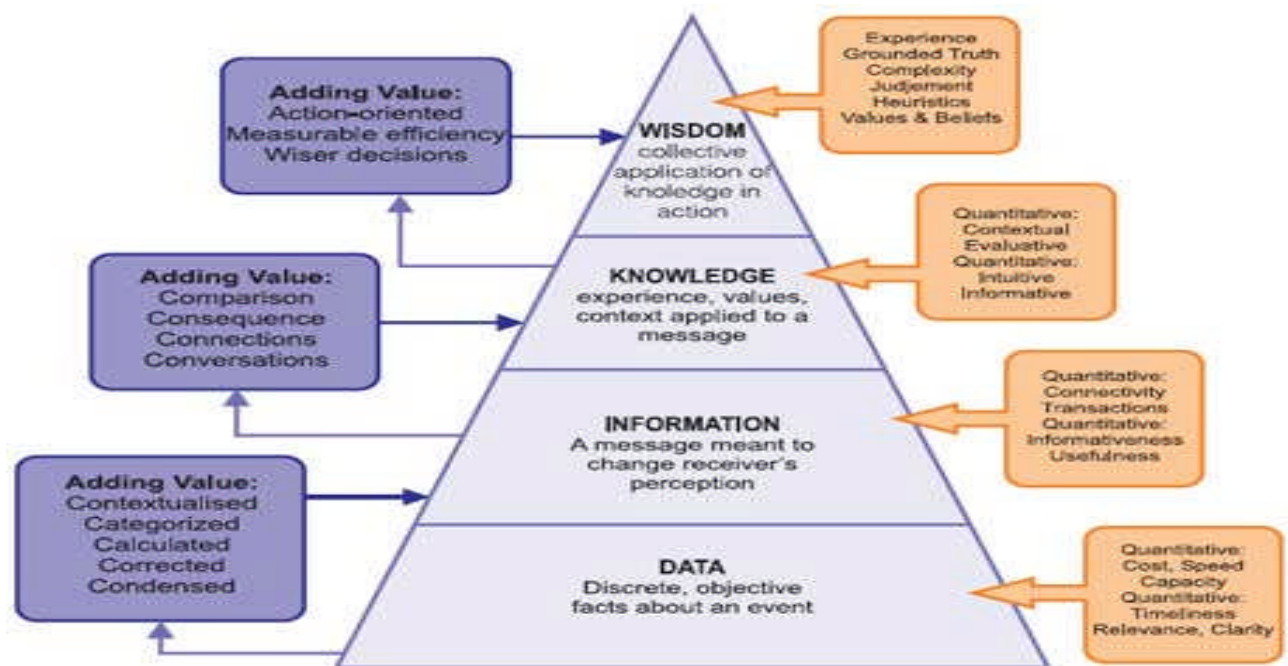


Figure 2.2 - Relations between data, information and wisdom (Liebowitz, 2003)

According to Bellinger et al (2001), “*Knowledge represents a pattern that connects and generally provides a high level of predictability as to what is described or what will happen next*”. Servin, (2005) argues that any knowledge management technique/tool will not be successfully if it is not used in a manner that is sensitive to the ways people feel and operate. According to most researchers, knowledge management is composed of three components. These are people, processes, and technology.

People: knowledge management is a people’s issue. This view has been supported by Grover and Davenport (2001), and Nonaka et al (2000), knowledge management cannot exist if the culture of the organisation does not support ongoing learning and knowledge sharing.

Processes: Servin (2005) suggests that an organisation needs to make changes to the structure of their internal processes in order to improve knowledge sharing which will enforce knowledge management.

Technology: knowledge management is not IT. However, technology is a crucial enabler for managing knowledge. It is imperative to understand that technology itself does not create shared knowledge. “It needs to be supported by and integrated with, relevant people and processes” (NHS Evidence, 2002) (Servin, 2005).

There are two main types of knowledge. These are tacit and explicit knowledge. This view has been supported by all authors.

Tacit Knowledge: tacit knowledge is hard to articulate and less concrete than explicit knowledge. The concept of tacit knowledge was adopted from scientist and philosopher Polanyi (1958). It is imperative to understand that he spoke about a process (**tacit knowing**) and not a form of knowledge. However, his phrase has been used to represent a form of knowledge. Organisations are realising the importance of acquiring and maintaining the tacit knowledge of their employees and tacit knowledge is considered more valuable than other types of knowledge because its foundation is based on experience. It requires **trust** in order for it to be shared effectively (Servin, 2005), (Nonaka et al 2000).

Types of Tacit Knowledge: According to O’Hara and Shadbolt (2001), tacit knowledge comes in different forms. Firstly, there is a technical dimension of tacit knowledge. Polanyi (1958) stated that this includes crafts and skills. This type of tacit knowledge is very difficult

to formalise and pass on and in general a long apprenticeship background is a necessity in acquiring this type of tacit knowledge. Callahan, (2004) describes this type of tacit knowledge as “*things that are not said because nobody fully understands them*”. Secondly, Collins, (1974) stated that the second type of tacit knowledge is a background knowledge that forms the foundation of use of any specific knowledge. Callahan, (2004) describes this type of tacit knowledge as “*things that are not said because everyone understands them and takes them for granted*”. Finally, there is tacit knowledge that is in some sense distributed about an organisation in little bits of know how. People within the organisation have or may not have access to this codified form of tacit knowledge. This type of tacit knowledge is connected to distributed knowledge sources in order to produce reasoning or inference process (O’Hara and Shadbolt, 2001). Callahan, (2004) describes this type of tacit knowledge as “*things that are not said because, although some people understand them, they cannot costlessly articulate them*”.

Explicit Knowledge: explicit knowledge is knowledge that can be easily articulated and accessible from documents, databases, etc. Examples of such knowledge include manuals, best practices, etc. Explicit knowledge can represent structured or unstructured knowledge. Structured knowledge is organised in a way that can be easily retrieved in the future if needed. Example of structured knowledge includes documents, database, spreadsheet, etc. Unstructured knowledge includes e-mails, audio-video selections, images, etc. They are unstructured because the content of information is not referenced for future retrieval (Servin, 2005), (Nonaka et al 2000). Figure 2.3 illustrates the dynamic interactions of both types of knowledge.

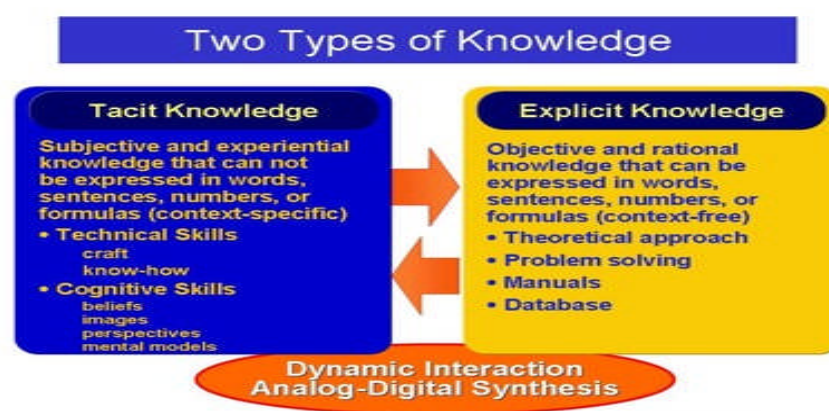


Figure 2.3 - Dynamic interactions of both types of knowledge (NHS Evidence, 2002)

According to Nonaka (God father of knowledge management), he states that “*knowledge creation is a continuous, self-transcending process by means of which one transcends the boundary of the old self into a new self by acquiring a new context, a new view of the world and new knowledge*”. Figure 2.4 proposes a model developed by (Nonaka et al, 2000), which represents the organisational knowledge creation/conversion process.

Socialisation: this type of knowledge is where tacit knowledge is converted into tacit knowledge by means of discussions, informal meetings, communications, etc. The key theme of this paper suggests that this type of knowledge occurs traditionally in apprenticeship (Nonaka et al 2000). Apprentices learn the tacit knowledge required in order to master their craft using hands on practical experiences rather than documented mediums.

Externalisation: tacit knowledge is converted into explicit knowledge by means of knowledge based systems, documentations, instruction manuals, etc. When tacit knowledge is made explicit, this enforces knowledge sharing which becomes the basis of new knowledge. In order to successfully convert from tacit to explicit knowledge, one must adopt the sequential use of metaphor, analogy and models which is crucial for the development of KBS (Nonaka et al, 2000).

Combination: explicit knowledge is converted into a different type of explicit knowledge. An example of this is uploading the contents of a document into a database so that it can be easily accessible (Nonaka et al, 2000).

Internalisation: explicit knowledge is then converted back into tacit knowledge. This is closely related to “*learning by doing*”. For example, trainees can enrich their tacit knowledge base by reading documents and manuals (Nonaka et al, 2000).

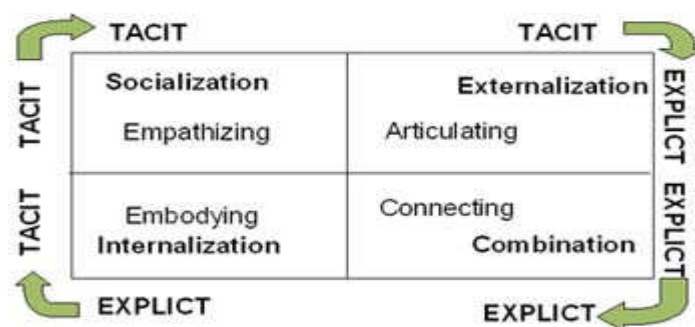


Figure 2.4 - SECI knowledge conversion model (Nonaka et al, 2000)

2.2.1 General Knowledge Management Techniques

Below are a list of the most common tools and techniques used for knowledge management within an organisation.

2.2.1.1 After Action Review (AAR)

An after action review is sometimes known as “**lessons learnt**”. It is a discussion of an activity that allows the involved individuals to assess for themselves the results of what happened, why it happened, how well it went, potential improvements and what lessons can be learnt. The key strength of this paper suggests that this technique is not about allocating blame but it is about understanding the spirit of learning (Collison and Parcell, 2001). AAR was originally developed and extensively used by the US Army (NHS Evident, 2002).

2.2.1.2 Communities of Practice (CoP)

CoP are considered as people who come together and share a set of problems/passion about a particular topic and who also enhance their knowledge in this area by continuous interaction on an ongoing basis (Lyle et al, 2005). Etienne Wenger is responsible for establishing the term “*community of practice*”. According to Wenger (2002), “*without communities of practice, there can be no knowledge management*”.

2.2.1.3 Conducting a knowledge audit

This paper suggests that a knowledge audit is a representation into an organisation’s knowledge health. Knowledge audits looks into organisation’s knowledge needs, gaps existing in knowledge, knowledge flow within the organisation and knowledge assets/resources and their location within the organisation. The result of the knowledge audit identifies the knowledge management efforts focus. (Servin, 2005)

2.2.1.4 Developing a knowledge management strategy

A KM strategy is a plan that suggests how an organisation will improve its knowledge management. This paper suggests that knowledge management strategy should be incorporated within the organisation’s overall strategy and objectives. (Servin, 2005)

2.2.1.5 Exit Interviews

Recently, exit interviews have been expanded as an effective knowledge management tool (Servin, 2005). The interviews aim to capture valuable knowledge on what it takes to do the job efficiently and effectively. The strength of this paper suggests that a successful exit interview becomes a win-win situation for both the employee and organisation because the employee unique contribution leaves a mark on the organisation and the organisation retains a portion of the employee's knowledge (Skyrme, 2001),

2.2.1.6 Identifying and sharing best practices

The sharing of practice is an essential aspect of knowledge management initiative. A best practice is a methodology that suggests the best way of achieving a specific objective. This paper suggests that the term **“best practice”** is often referred to as **“good practice”** seeing as it is debatable whether there is a best approach in achieving an objective. According to Servin, (2005), much of best practices knowledge is tacit. The best way to share best practices is on the job (Servin, 2005).

2.2.1.7 Knowledge Centres

Knowledge centres are an improved version of a library. This enhancement focuses more on knowledge rather than information. A knowledge centre focuses on collecting, organising and sharing knowledge and information. This paper suggests that the main benefit of knowledge centres is that core knowledge management responsibilities can be integrated together under one framework rather than having it dispersed around the organisation (Servin, 2005).

2.2.1.8 Knowledge harvesting

Knowledge harvesting is a way of capturing the know-how tacit knowledge of experts. The captured know-how knowledge can then be made available to others through mediums such as manuals, best practises, training programmes, etc. Knowledge harvesting is all about trying to codify and articulate the tacit knowledge that exists within the expert's minds in order to capture an expert's decision-making processes (Servin, 2005).

2.2.1.9 Peer Assists

A peer assist is a term pioneered by British Petroleum (BP). It is a process whereby a team of people working on a project arranges a meeting or workshop in order to seek insights and knowledge from other teams (Collison et al, 2001). The formal use of this process as a knowledge management tool was also established by BP. BP calls this ***“learning before doing”*** which means gathering knowledge before undertaking a project. (Collison et al, 2001)

2.2.1.10 Social Network Analysis (SNA)

SNA is the mapping and measuring of relationships that consists of people, computer systems or other form of entities (Krebs, 2002). In knowledge management, SNA identifies and captures the relationships between people in order to represent a map of knowledge flows. The key strength of this paper is that it suggests that an SNA is an organisational X-ray seeing as it shows the real networks that operate within the organisation. Benefits of NSA include the identification of isolated individuals/team members and detection of information bottlenecks, (Servin, 2005)

2.2.1.11 Story telling

Story telling is the use of stories within organisation to share knowledge. Story telling uses a language that is more effective. Story telling for knowledge management can make organisational communication more human and telling stories are usually memorable and are known to be an excellent vehicle for true learning (Denning 2002). The strength of this research is that it suggests that the technique is more effective when something new or unexpected or different happens in a situation.

2.3 Knowledge Capture

The NHS Evidence (2002) paper suggests that the main purpose of knowledge capture is to acquire an expert’s decision making process in great detail so that someone else could repeat the same set of process and establish the same results/conclusions. Knowledge capture can also be defined as a process by which one captures the expert’s thoughts and experience by knowing what the experts know (Rhem, 2006). The key strength of the NHS Evidence, (2002) paper concludes that there is no set formula for capturing knowledge or knowledge

harvesting. However, there are some guidelines that will aid in the process. This paper successful states the foundation of knowledge capture but it fails to address specific knowledge capture techniques. The first step as stated in this paper for knowledge capture is that one must **focus** on capturing the knowledge that is most important to the success of the organisation. The second step states that one must **understand end users** by ensuring that the knowledge is captured at the right level.

The third step suggests that the **identification** of finding experts is essential; it also suggests that background information should be collected about these experts once they are identified. The fourth step suggests that the success of knowledge capture is based on the ability of the interviewer to capture the right type of knowledge from the experts. This view is also supported by Neve (2003) and Milton (2003). Helping people communicate what they know effectively and capturing that is a valuable skill.

According to NHS evidence (2002), one of the best ways to capture tacit knowledge is using one-to-one, face-to-face interviews with experts. However, Milton (2003) suggests other effective techniques. The last step suggests asking the experts to talk about what they know (**knowledge harvesting**) and describe specific scenarios when they have applied their “know how” knowledge. In order to capture knowledge effectively, a tape recorder will be needed in order to transcribe the interview. This view is supported by most authors.

The purpose of having so many knowledge elicitation techniques remains in the fact that experts possess various forms of tacit knowledge. It is essential to utilise the appropriate technique in order to access and capture the various types of knowledge (Hara and Nigel Shadbolt (2001), Collins (1974)). This process is referred to as the “*differential access hypothesis*” and has been implemented in real world settings with supporting evidence (Milton, 2003)

Milton (2003) suggests the various techniques for capturing knowledge. As illustrated in Figure 2.5, the appropriate knowledge capture techniques to use for process, concept, explicit and tacit knowledge are presented.

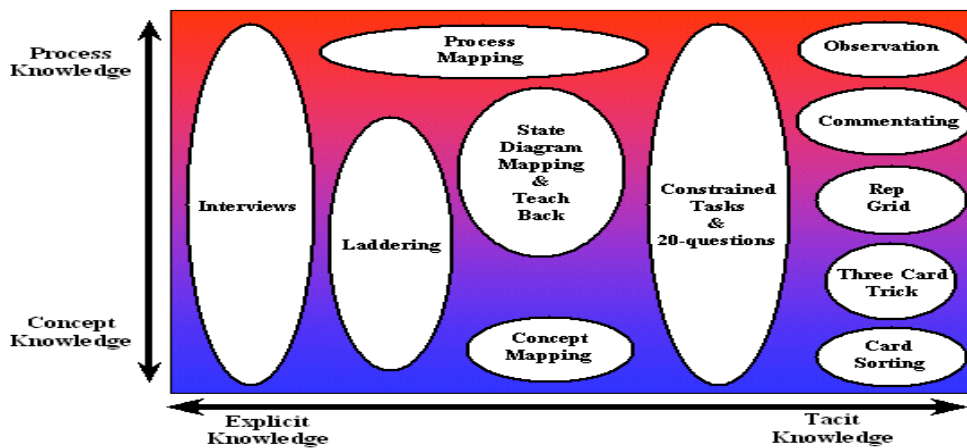


Figure 2.5 - Knowledge acquisition techniques (Milton, 2003)

The key theme of this research by Milton (2003) successfully describes multiple knowledge elicitation techniques and how one could use these techniques to capture various dimensions of knowledge. However, this research fails to address the foundation of knowledge capture which could be detrimental if left out within the process of capturing knowledge. The first knowledge capture technique has suggested in this paper is the protocol generation technique. The overall aim of this technique is to establish a record of behaviour. Interviewing falls under this technique, in structured interviews, the questions and responses are definitive. This is used when specific information is needed. In unstructured interviews, neither questions nor answers are specified in advance (Milton, 2003).

Neve (2003) stated that an effective way of capturing knowledge from an expert is to begin with a central starting point. For example, “*what is the most important aspect to you in your working life*”. The opening phase should be very general so that the expert will not be misled but it should also be specific enough to attract the expert’s attention.

Another knowledge capture technique as suggested by Milton (2003) is the idea of **commentary** which utilises self-report technique. Self-report is achieved when the expert provides a running commentary of their thought processes as they solve a problem. Experimental evidence on real world settings have proved that self-reports can access cognitive processes that cannot be fully recalled or biased after a certain task is completed. The “**teachback**” technique also allows the knowledge engineer to describe part of the knowledge that has been captured in previous sessions. The expert then comments on what the knowledge engineer is describing in order to reveal any gaps or misunderstandings.

Milton (2003) also suggested that simply **observing** and note-taking as the expert performs daily activities can be useful. This process is however time-consuming and is rarely used as they are an inefficient means of capturing tacit knowledge from an expert.

Another technique for knowledge capture is the **protocol analysis** technique which involves the identification of knowledge objects within a protocol. This paper suggests that concepts are entities within a domain. Attributes are generic properties or features belonging to a concept and values are specific properties or actual Figureure Milton (2003).

Hierarchical techniques for knowledge capture are also used to create, review and modify hierarchical knowledge in form of ladders (tree structure). In this knowledge capture technique, the domain expert and knowledge engineer refer to a ladder presented on paper or computer screen. This will allow the human expert to add, rename, delete or re-organise various nodes as appropriate.

Milton (2003) also suggested the idea of **matrix based** technique for knowledge capture which involves the development and filling of a two dimensional matrix. This can be tabulated within a table and useful examples includes having a two dimensional matrix representing concepts v properties, attributes v values, problems v solutions, tasks v resources, etc. This paper suggests that this technique is effective for validating previously captured knowledge.

Sorting techniques are also known to be KA techniques and are powerful and well known methods for capturing the way experts compare and organise concepts. The power lies in the revelation of new knowledge about concepts, classes, attributes, properties (attributes and values) and priorities. One of the simplest form of sorting techniques is **card sorting**. This technique helps in identifying similarities and differences between the various classes of concepts in a specific domain (Milton, 2003)

Most authors argue that the **3 card trick** for knowledge elicitation helps in determining the attributes of classes. Bechhofer (2006) suggests that there will always be 2 cards that are more related to each other. This process allows the human expert to identify which 2 cards are most similar and what is the difference from the 3rd card. The 3 cards are chosen

randomly and the effect of this technique allows the definition of hidden attributes that are not immediately articulated by the human expert (Milton, 2003).

2.3.1 New Techniques for Knowledge Capture

Research has shown that there have been new advancements for knowledge capture techniques. Rosenschein (2003) suggested in a conference that PowerPoint is usually the presentation medium of choice. He spoke about the “Quindi solution” which emphasizes on the collaboration of two primary media of knowledge exchange which are the live event and document/data based content. The “Quindi” solution works by taking the expanded live event of a meeting and turning it back into an explicit document. The “Quindi” solution records the audio and video in a synchronised way and uses the speed of PowerPoint presentation. This solution offers both instantaneous and after the meetings conclusion and also uses flexible playback loop.

Researchers (Leake, Maguitman, Reichherzer, Alberto, Carvalho, Arguedas, (2005), suggests a more effective method of capturing knowledge from experts. The use of electronic concept mapping tools empowers experts in order to take on a more active role within the process of knowledge elicitation. The advantage of this technique is that a medium for building richly interconnected knowledge models concept maps about a particular domain can be established. The main goal of this technique is to allow experts to build their own concept maps and link their maps to others. The Institute for Human Machine Cognition has designed and implemented CmapTools (electronic concept mapping tool) which can generate concept maps, link multiple concept maps and multimedia resources and access concept maps. This new technique could provide an open world perspective of the problem domain seeing as various experts could add their insights and thoughts within the Cmap tools. The key theme of this paper suggests that the main goal of this tool is to provide a framework for experts as they develop their own concept maps and link it to others and make decisions on how to extend their knowledge models (Ca.nas 2001, Leake, 2002).

2.4 Knowledge Based Systems (KBS)

KBS are part of AI applications seeing as they emulate the “thinking processes” taken by humans in order to solve broad classes of problems (Darlington, 2000). Feigenbaum et al (2008) argues that in order for KBS to perform competently over certain tasks, they will need

much more specific knowledge which will bring forth new generation of KBS that will utilise larger knowledge bases. Researchers have stated that expert systems owe their origin to artificial intelligence. Marvin Minsky, one of the pioneers of AI defined AI as “*The field of study that is attempting to build systems which if attempted by people would be considered intelligent*” Figure 2.6 illustrates many applications of artificial intelligence. Most researchers believe that KBS are one of the largest applications of AI.

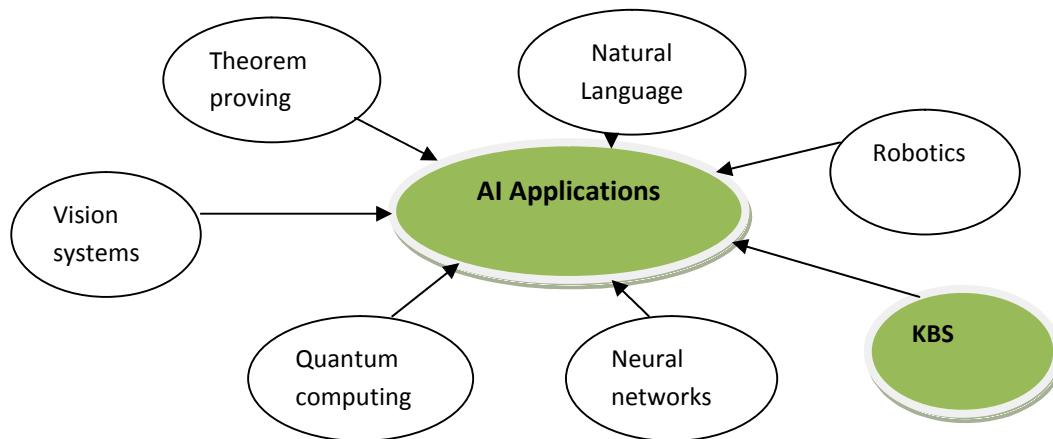


Figure 2.6 - Applications of artificial intelligence (Darlington, 2000)

Most research states that the main difference in which expert systems differs from conventional systems is the approach taken to solve a problem. Conventional systems solve problems via algorithms, whereas expert system uses **heuristics** which is intended to increase the probability of solving a problem. An algorithm uses a step by step approach to solve a problem whilst heuristics uses trial and error which is guided by a reference to a preordained goal (Giarratano and Riley, 1994). Darlington, (2000), explained heuristics by using an analogy of a motorist searching a car park for car parking space. The key theme of this paper successful articulates the idea behind heuristics but fails to address how this technique could be utilised in industry to solve a particular problem.

The **state space search** is a technique utilised by KBS. Darlington, (2000), suggested that the solution to a particular problem is found from knowing how to move from an initial state, to a final state, or goal state. The success of reaching the goal destination is based on knowledge of the correct sequence of moves to arrive at the final state. This technique defines the nature

of most AI problems. Most researchers (Marshall et al, 1990) suggested that a tree hierarchical structure is often used to represent the resulting search space.

As the number of nodes increases, the search space will grow enormously. Most researchers argue that this has always been a major stumbling block to large AI problems such as the chess game. This problem is known as “combinatorics explosion”. In order to deal with this problem, a number of heuristic techniques have been developed. These techniques are known as blind search and heuristics search (Rich, 1992).

With the blind search technique, the depth-first and breadth-first procedures are used. The breadth-first procedure uses level by level search paradigm rather than depth. It looks for the level that consists of the required goal node whilst the depth-first procedure goes deeper into the lower level nodes to look for the solution. (Rich, 1992) (Darlington, 2000). Darlington (2000) argues that the main problem with the blind search is that it does not make use of any specific knowledge to guide the search. However, heuristics searches use domain-specific knowledge to extend the search space. This is typically different from blind search techniques that use brute force methods to search for a solution.

2.4.1 Overview of existing approaches in KBS

2.4.1.1 Case Based Reasoning

The idea behind CBR is to solve new problems based on the solutions used for the previously solved problems. This approach works by retrieving the most similar cases and then reusing the knowledge in that case in order to solve the problem. The proposed solution is then revised and then the useful parts of the new experience are retained in order to aid future problem solving. However most researcher argues that to achieve viable results in large settings, a large amount of cases is needed in order for the solution to be excellence (Agnar, et al 1994).

2.4.1.2 Model Based Reasoning

The MBR explicitly documents the representation of the internal functionalities of a system in order to predict and simulate the behaviour of the system. The first step of the MBR is developing a precise representation model of the system. Once this is validated, one can acquire solutions from the model based on a set of inputs (Ulises et al, 2003). The MBR

offers a sense of completeness within the defined framework. However, recent research has suggested that modelling is difficult because it is time consuming and expensive.

2.4.1.3 Rule Based Reasoning

Ulises et al (2003) and Darlington (2000) suggests that the majority of expert systems are developed using rules. The creation of the rules in a collective manner is commonly known as the knowledge base. This paper suggests that most researchers believes that the RBR systems have the advantage of being just as accurate like the MBR, however a major disadvantage is that the RBR can only be designed on instance level.

2.4.1.4 Inference

Most researchers believe that the real capability of an expert system is its capacity to make inferences (Darlington, (2000), Ignasi et al, (2003)). This technique is exactly what makes a KBS intelligent (Marshall, 1990). Inference is known as the drawing of conclusions from a problem domain. The inference engine is a program that interprets the rules within the knowledge base in order to draw conclusions. Research has shown that the 2 main strategies used are the backward chaining and forward chaining. An inference engine might utilise either or even both. A backward-chain inference engine is known to be goal oriented because it tries to prove a goal by confirming the truth of its entire domain whilst the forward inference engine begins at the other end by analysing the knowledge base current state and it then find rules that can be satisfied from data that is given and known. It then adds the new derived rules into the knowledge base (Darlington, 2000).

2.4.1.5 Comparative Study 1: Key Aspects of Knowledge Based System

A comparative study review is now carried out from different literatures on the key aspects of knowledge based/expert systems as illustrated in table 2.1. The thoughts and insights of various authors' are documented as each author suggested his/her personal preferences on why knowledge based systems are valuable in real world settings.

Table 2.1 - Comparative study on key aspects of KBS

Authors	Key Aspects	Justification
(Kingston, 2004; Metaxiotis, 2004; Horn et al., 2002; Wei et al., 2001; Stein et al., 2001; Reimer et al., 2000; Gill, 1995).	Time Saving	The amount of time spent on working manually is significantly reduced
(Kingston, 2004; Metaxiotis, 2004; Stein et al., 2003; Horn et al., 2002; Stein et al., 2001; Bryant, 2001; Reimer et al., 2000; Gill, 1995).	Quality Improvement	The quality of decisions made increases because it provides fewer errors than if the decision was made manually
(Kingston, 2004; Metaxiotis, 2004; Nedovic and Devedzic 2003; Horn et al., 2002; Venkatraman 2000)	Applicability of practical knowledge	Expert systems can assist experts in decision making in order to aid the accuracy and timeliness of the decision
(Metaxiotis, 2004; Stein et al., 2003; Reimer et al., 2000)	Infallible and Complete	Expert/knowledge based systems will always produce a viable result unless implementation errors occurs
(Kingston, 2004; Metaxiotis, 2004; Nedovic and Devedzic, 2003; Spronck and Schilstra, 2001)	Replication	Expert systems can be replicated and be transferred to other locations. However, human experts are scarce.
(Nedovic and Devedzic, 2003, Spronck and Schilstra, 2001; Bryant, 2001; Gill, 1995)	Consistency	The produced results from an expert system throughout its lifespan are always consistent. Human experts do not always acquire this level of consistency
(Horn et al., 2002; Spronck and Schilstra, 2001).	Knowledge Update	Knowledge update can occur more easily within the knowledge base. However, human experts take time to train and digest knowledge
(Nedovic and Devedzic, 2003; Venkatraman and Venkatraman, 2000).	Productivity	By automating the manual processes within a domain, the outcome of decision making becomes error free which will in return increase the organisation's productivity

2.5 Computer Based Knowledge Representation

There has been large amount of research within the area of computer based knowledge representation. It has been established that computers are a great way of storing and retrieving information. However, many have wondered about the current advancements with the science behind computer information. Researchers have argued about the current way information is used by computers and if major technological advancements are bound to appear in the near future.

Barski (2003) illustrated the big picture of how knowledge representation has evolved. He stated that all computer users are associated to one of three main archetypes. The first is **“the guy in the garage”** (who began to develop computer based tools such as compilers, file systems and the most important computer invention known as the relational database management system which sparked the first greatest invention in storing and representation of knowledge that required little knowledge of advanced science), **“the writer”** (who articulated his/her knowledge in raw texts or diagrams through the second computer revolution known as the Internet era). The writer didn’t need to have an understanding of how computers operated. However, they could explicitly document their knowledge into computerised web pages which was made accessible to the world), and finally **“the scientist”** (who has had very little to play in the field of computer based knowledge representation). He also suggested that the scientist has not contributed enough in the world of knowledge representation and software. Barski (2003) suggested that these 3 main archetypes have been and will potentially be the triggers for the evolution of how computer represents and interprets knowledge. He stated that the third revolution of computer’s will be the era of the scientist which will allow computers to represent knowledge using integral calculus, theorem proving, linguistics (semantics), and other form of scientific distinct feature. The key theme of this paper successfully describes the evolution of knowledge representation but failed to address software platforms that support these technologies.

Figure 2.7 illustrates Conrad’s model of an accurate knowledge representation triangle. The oldest ideas for each archetype are illustrated at each corner of the triangle. The more recent ideas of knowledge representation are displayed along the sides.

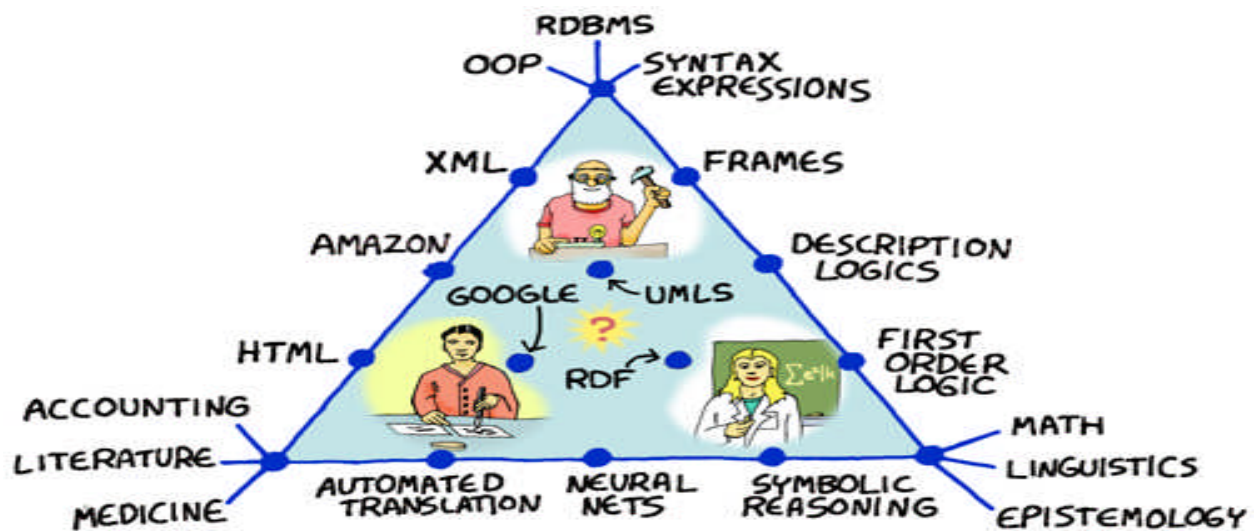


Figure 2.7 - Conrad's Somewhat Accurate Triangle of Knowledge Representation

2.5.1 Semantic Based Knowledge Representation

In today's world, most of today's web content is suitable for human consumption, however, automatically generated web content from databases is usually presented without the original information structure which can be found in the databases. Most Researchers (Uschold et al 2002) believe that the web would not have been the huge success it was, if not for search engines and even search engines have their limitations (CISnet, 2001). The results of search engines are highly sensitive to vocabulary and human involvement is of necessity in order to interpret the result into knowledge. The meaning of web content is not machine accessible which means there is lack of semantics (Uschold et al 2002). Semantics is defined as the study of meaning in communication. There is need for knowledge representation in semantics. Knowledge representation in semantics allows for the description of the problem domain, with concepts and the relations between those concepts. It allows for a shared agreement of meanings.

All Semantic based knowledge representation techniques must utilise "subject based classification". This is any form of content classification that groups objects by their subjects. It is important to understand the difference in defining the classified objects and subjects used to classify these objects (Corno and Farinetti, 2001). Subject based classification techniques are forms of knowledge representation for semantics. These are explained below:

Controlled vocabularies: this is used as a closed list of named objects for classification. It is composed of terminologies which mean a particular name is given for a particular concept. The goal of the controlled vocabulary knowledge representation is to prevent people from defining terms that are too narrow or too broad. The ambiguity of language is reduced because each concept is only described using one authorised term (Corno and Farinetti, 2001).

Taxonomies: the taxonomy knowledge representation for semantics arranges the terms in the controlled vocabulary into a hierarchical structure. This then allows items that are related to be classified together. There are only two types of relationships between the concepts. These are parent and child concepts (sub-type to super-type relationships). The parent concept represents a broader term whilst the child concept represent a narrow term. Figure 2.8 illustrates an example of a hierarchical taxonomy.

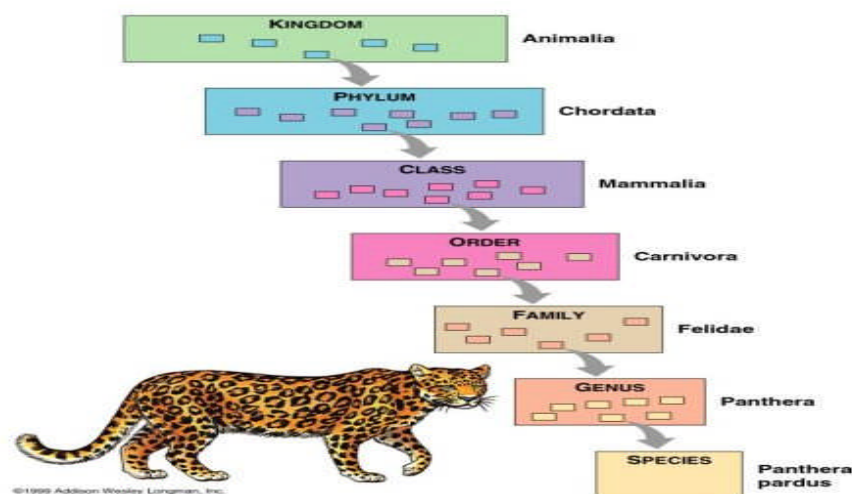


Figure 2.8 - Hierarchical taxonomy (Mierloo, 2008)

Thesauri: this sort of knowledge representation technique is an extension of taxonomy. The subjects are not only arranged in hierarchy but other statements can be made about the subjects. Taxonomy only uses broader (terms with wider or less specific meaning) and narrow terms (distinctive terms with more specific meaning). However, thesauri defines more relationships such as USE (another preferred term that could be used instead of the original term), TT (top term which is the topmost ancestor of the term), RT (a term that is related to the term without being a broader/narrow term).

Faceted Classification: knowledge representation using faceted classification allows the classification of objects using different axes. Each facet contains a number of terms and this type of classification technique is used within a thesaurus organisation. Usually a term belongs to one facet only. The advantage of using a facet classification is because of its flexibility, multi-dimensionality and scalability (Corno and Farinetti, 2001).

2.5.1.1 Ontology for Knowledge Representation

This is a model that represents a set of concepts and the relationships between these concepts. This extends the subject based classification approaches due to its open vocabularies and open relationship types. The definition of ontology was originally stated in 1993 by Gruber and was defined as a way to support the sharing and reuse of represented knowledge within artificial intelligence system. The precise short answer for defining an ontology is the specification of a conceptualisation. The use of ontologies to represent complex information has become common in government bodies such as NASA and UN (Horrocks, 2006). There are 5 distinct features of ontologies (Uschold, 2006). These are listed below:

- **Concepts:** defines the concept within the problem domain e.g. Pump, Engine, etc
- **Concepts hierarchy:** defines specialisation/generalisation hierarchy, e.g. Man is a type of human being.
- **Relations between classes:** fuel pump is part of a fuel system
- **Constraints on relations** (type-cardinality) e.g. any Jet-Engine has one fuel pump
- **Instances:** defines the main objects within the domain, e.g. pump210.

Folksonomies: this is an internet-mediated social environment knowledge representation technique. It uses tag to annotate digital resources in an online social environment. Tags are created and shared by individuals within the social environment (Corno and Farinetti, 2001).

Other subject based representation techniques (synonym rings): this knowledge representation technique connects together terms that are equivalent for search purposes. It is similar to the USE relationship of thesauri but does not incorporate the preferred term option (Corno and Farinetti, 2001)

2.5.2 Semantic Web (Industrial Advancements)

In order to understand the “Semantic Web”, it is imperative to understand the current limitations of the current web. Horrocks (2006) described the current web as “syntactic web”. He described that the information on the current web is designed only to be consumed by human beings and is not bound to automated processes. Horrocks (2006) stated that “it is hard work using this “syntactic web” and a search for his colleague “Alan Rector” on Google returned images of someone called “Reverend Alan”. He emphasised on the fact that the current web is all about presenting information and not about the semantic content. However, Horrocks (2006) paper failed to address the potential constraints of the semantic web.

The development of the “Semantic Web” has become a hot topic within the field of technological advancements. Tim Berners-Lee, also known as the (Godfather of semantics) which many credit for coining the term “semantic web” stated in 1999 that the semantic web will not replace the current World Wide Web; however, it will only be an evolution of the WWW. He also stated that his dream for the web is for computers to become capable of analysing and processing data (contents, links etc) on the web. Berners-Lee et al (1999) stated that when this technology emerges, the day-to-day mechanisms of trade, policies, etc will be handled by computers communicating to computers. The semantic web will help in creating an environment where the Internet will interpret the searches made by people online and also allows for accessibility of data held by third parties about a particular individual.

Crystal (2006) agrees with Berners-Lee view on how Semantic Web will only be considered as an evolution of the current WWW and also stated that the key difference is that the Internet is human-readable, however, Semantic Web will be machine-readable.

Berners-Lee stated that the w3c standard (international standard for the web) will ensure that the Semantic Web will maintain the integrity and privacy of online communications.

Davies (2003) leads the Web research group at BT and he strongly believes in the implementation of Semantic Web applications. Davies stated that Microsoft acquisition of Powerset and Yahoo’s search engine allows for semantic search initiative. Search-Monkey, which is currently working on improving click through rates on the Web and Google’s development, is evidence of the growth currently taken place in the field of semantics. Also,

in sectors such as sciences and healthcare, complicated ontologies already exists as these sectors realise the need to classify and conceptualise intrinsic concepts within their domain.

More current advancements on semantic technology have occurred within the enterprise space. Semantic technology is used in order to integrate information and improve efficiency. Davies stated that BT's own fusion of billing and sales in one department has allowed for £2million annual savings and ongoing semantic innovation is being considered within this sector.

Davies et al (2003) suggested that companies such as Hakia, Siderean and Ontotext are carrying out underlying research within the area of semantic search. Also, within the area of information and process integration, there are companies such as Metatomix and Ontoprise and Radar Networks who just recently announced its "Twine semantic social networks offering"

Google also announced that it was changing the way in which search engines interpret words entered by users which highlights the importance of semantics (NMK, 2009).

Figure 2.9 illustrates the famous semantic layer cake diagram that describes technologies that will make semantics possible. This diagram demonstrates the W3C standards that is utilised by the web and this diagram has often been reproduced to different versions. Burleson, (2007) argues that some version of the cake diagram integrate layers into broader concepts.

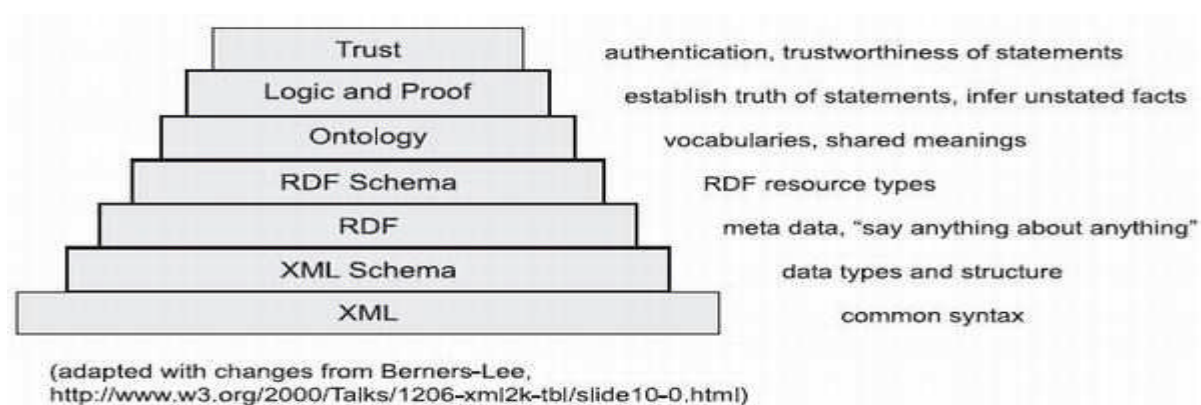


Figure 2.9 - Semantic architecture diagram (Passin, 2004), (adapted with changes from Berners-Lee)

Passin, (2004) stated that each layer builds on and requires the layer below it. A lower layer is independent in that it does not depend on the layer above it. The layers above are much more complex than the layers below. The trust layer is still under development whilst some layers have been released as W3C recommendations. According to Tim-Berners Lee who is also the founder of the W3C standards, the digital signatures and encryption keys management will play an important role in the Trust W3C standard layer.

- **XML:** Extensive Markup Language. This is only a surface syntax and requires no semantics. It defines languages used to interchange data over the web.
- **XML Schema:** Describes the structure of XML documents
- **RDF:** Resource Description Framework Model for defining the relations between things. It is flexible in that it can describe all sorts of Meta data and information.
- **RDF Schema:** Vocabulary definition language. It describes a means to articulate basic vocabularies for RDF application languages. RDF schema was agreed as ontological language; however it was weak because it didn't allow the explanation of many things (NMK, 2009).
- **OWL:** More expressive vocabulary definition language. In order to address the problem of the RDF Schema language, 2 languages were developed. OIL (developed by Europeans) and DAML (developed by US based researchers) were merged and the W3C standard OWL language came into existence.
- **Logic and Proof:** establish truth of statements, infer unstated facts
- **Trust:** providing authentication of the trustworthiness of data and services.

2.5.3 Comparative Study 2: Views on Semantic Technology/Semantic Web

This comparative study describes the various perspectives within industry (Internet Experts) in order to see how realistic the Semantic Web is and if this technology will come into fruition

Table 2.2 - Comparative study on Semantic Web

Internet Expert	Key Aspects	Justification
(Mike Wheatley, CEO of Ensembl, a recently-launched personalised news aggregator)	Promising technology but challenging	He stated that the Semantic Web is very promising just as much as the Internet was when it started gaining popularity. The Internet provided free and accessible information to all. The Semantic Web will provide much more. He stated that the benefits are enormous but still large challenges are inevitable such as the challenge of the ambiguity of language.
(Chris Gledhill, the managing director of software and services firm PDMS Limited)	Promising technology and possess strong capability	He describes the current Internet as “Technicolor chaos” and argues that the Semantic Web offers the chance of pre-defined ontologies which is beyond the powers of technical gurus.
Professor David Crystal (experts in linguistics)	Evolution of current web but fails to address the ever evolving language	He stated that the Semantic Web will be machine-readable, however, languages always evolve and there are different meanings of words across various cultures.
Professor Ian Horrocks (member of the W3C working group that developed the OWL language)	Use of semantic technology will allow computers to understand language	He stated that although a web page is accessible to humans, it is jargon to a machine. The use of adding semantic annotation to web resources will give context to computers (Deirdre Molloy, 2006)
Tim Berners-Lee (founder of W3C standards utilised by the Web)	Due to the fact that the current web as reached its peak development, the next evolution of the web could only be Semantic Web.	He stated that the current web as reached its peak development and the Semantic Web is the new evolution of the WWW and will allow machines to relate to machines by use of linguistics
(Alex Iskold, Founder/CEO of Adaptive Blue, a smart browsing company)	Too complex and unrealistic to maintain	He stated that the complexity of the original vision of the Semantic Web is unrealistic and lacks clear consumer benefits (Alex Iskold, 2007).

2.5.4 Practicality of Semantic Technology

In today's world, systems are highly complex and difficult to troubleshoot. There is a demand for technological enhanced tool for troubleshooting, especially when relating with computer systems (Litt, 1999). The use of semantic nets to model and represent the troubleshooting knowledge has proven to be useful in this particular field. Semantic nets are also often referred to as mind maps and they illustrate within a specific domain, concepts and their relations. To further more understand how semantic nets has been utilised within this field, a typical web application is accessed from a web browser on a client computer and uses HTML and HTTP in order to communicate with the server. This process contains many components from different vendors and a broad knowledge is required to troubleshoot this type of architecture. Figure 2.10 illustrates the semantic net that represents the modelled knowledge needed in order to troubleshoot the web application (Litt, 1999).

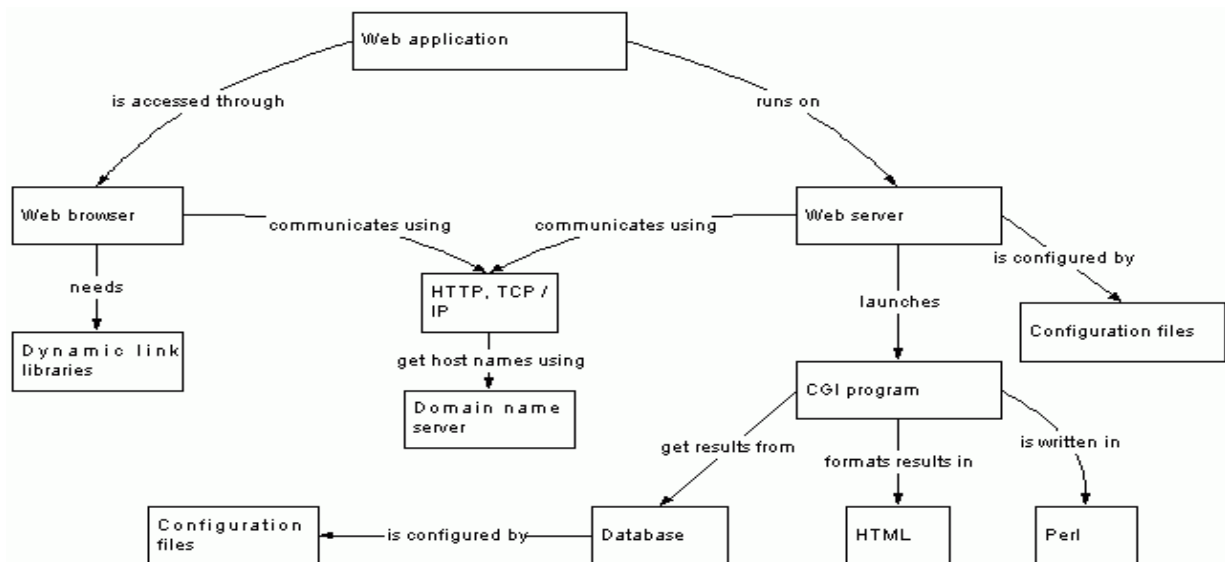


Figure 2.10 - Semantic net for troubleshooting the web application (Litt, 1999)

The Semantic net helps in identifying how things that are related may fail and Litt (1999) therefore argues that this is a good tool to support the 6th step of the universal troubleshooting process because they can describe much more than just the architectural view of the system. However, this article failed to address the critical use of ontologies and concepts within semantics. A troubleshooting problem could possibly be that the user cannot access the web application from the browser, an experienced trouble-shooter will realise the problem lies within the CGI program and start from this idea within the semantic net. An inexperienced

trouble-shooter will navigate to another idea. The semantic net offers flexibility seeing as the navigation choice is made by the trouble-shooter. Several paths can also be explored in parallel; therefore the efficiency of the trouble-shooter highly depends on the capabilities of the semantic navigation (Litt, 1999).

Hawker (2009) spoke about the development of the Immunisation Explorer which is a newly developed business application utilised to exploit semantic services through the Semantic Metatomix Platform. This Semantic application allows scientists to answer critical questions by bringing together data from a variety of systems into a amalgamate view as modern antibodies are registered. By deploying this application, UCB has been able to consolidate data from various sources ranging from Excel spreadsheets to Oracle databases in order to aid their business user's address their objectives.

UCB is a global bio-pharmaceutical company which functions in more than 40 countries and are based in Belgium. The company is recognised as a leader worldwide in treatments for epilepsy and other types of allergies. They generated revenues of £3.6 billion in 2007 (Hawker, 2009). This project started as a discussion to examine the capabilities of semantic technology; however, it has now become a giant leap seeing as it helps users make informed decisions. The problem within UCB wasn't a lack of data; however, it was too much data which was spread across different IT systems geographically.

By deploying the Semantic Platform through Metatomix, UCB was able to combine data from a rich process through the integration of semantic modelling, creating the ontological model to support the data integration requirements and data gathering from the existing data sources. The Metatomix platform possess a central capability which allows it to respond to what is known and trigger the appropriate query which then transforms the data into the resource description framework (RDF) and makes it accessible for the case at hand (Hawker, 2009). This article demonstrates the potential of semantic technology but fails to address how knowledge was captured for the integration of semantic modelling. Figure 2.11 illustrates the architecture.

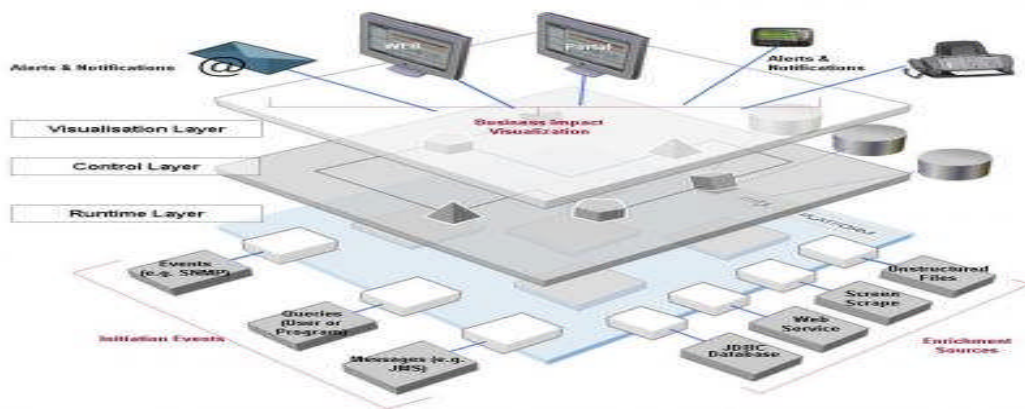


Figure 2.11 - Architecture for Metatomix Semantic Application Platform for UCB (Hawker, 2009)

An extension has been made to Media Wiki (wiki system used for Wikipedia) which is called Semantic Media Wiki. Articles in media wiki are just plain texts, however, Semantic media wiki allows for structured and organised data. SMW is based upon the fact that data exists in many articles and users only need to mark appropriate places in order for the system to access relevant data without understanding the remaining text. SMW possess the capability to solve search problems, browse, organise, evaluate and incorporate user-friendliness within the wiki's content (Ontoprise, 2009). However, this article fails to comment on language evolution and the use of synonyms.

Vulcan Inc has selected Ontoprise as a prime contractor in order to implement an extension for the Semantic Media Wiki for a project named "project halo". The integration of the Semantic Media Wiki and the "halo extension" will function as a user-friendly web based collaboration tool that will allow for the acquisition of scientific knowledge (Ontoprise, 2009). The halo extension used with the SMW will improve navigation within the ontology by incorporating a GUI-based ontology browser, incorporate filtering techniques that will allow users to detect inconsistencies and also enhance the quality of the authored knowledge, provide new types of relations between concepts such as inverse, transitive and symmetric and improved accessibility of knowledge within the Semantic Media Wiki (Ontoprise, 2009). However, this article fails to address how the API will provide web services.

At the 7th International Semantic Web conference in 2008, a Semantic Wiki Media on a USB stick was introduced. It is a USB memory stick that is integrated with a SMW. When plugged in, a customised version of the SMW is launched with the conference events and information

relating to the conferences. Figure 2.12 depicts the conference ontology for the Semantic Wiki.

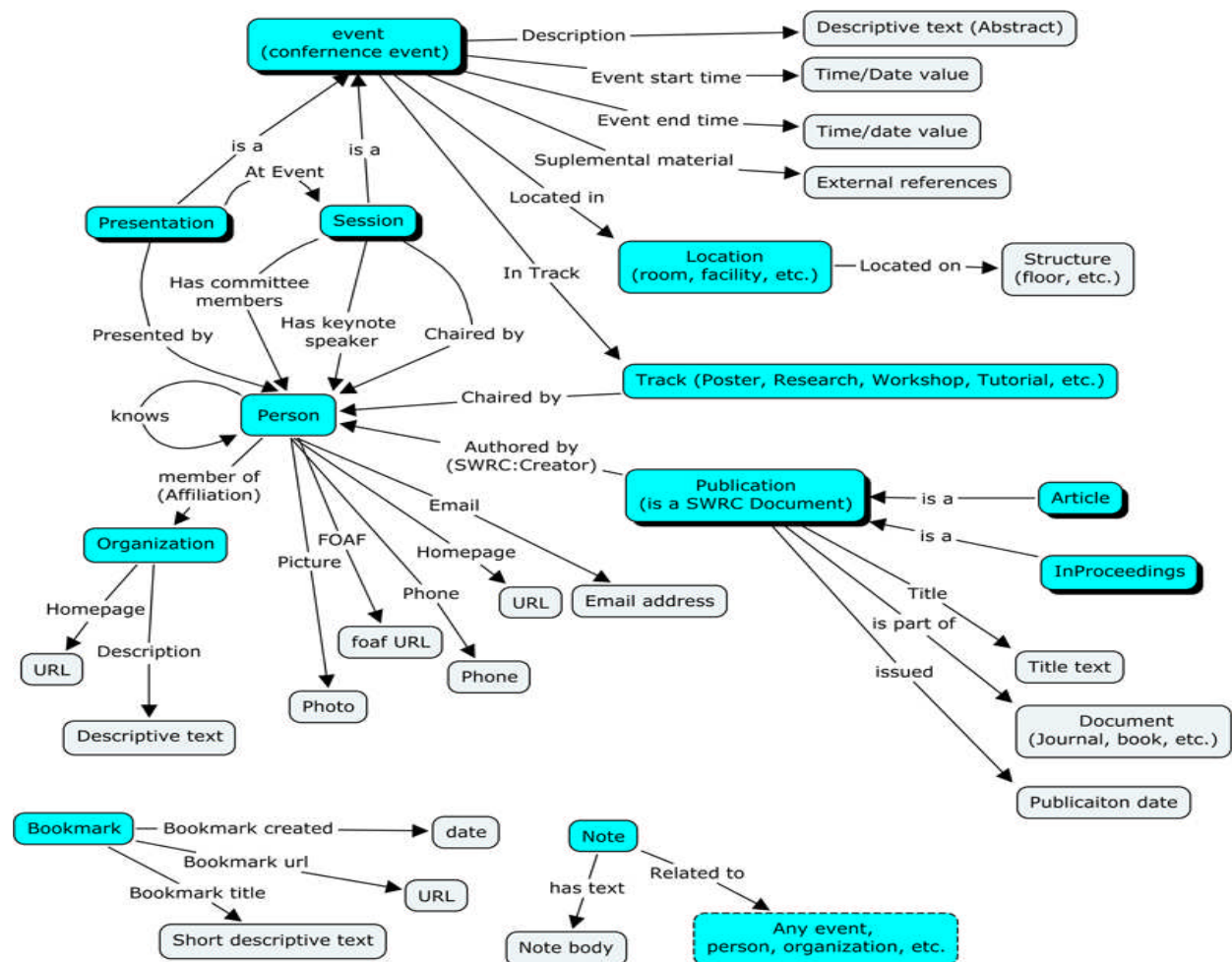


Figure 3.12 - Conference ontology for Semantic Wiki (Axelrod, 2008)

2.6 Maintenance Support

Many Researchers (Yam et al, 2001) argue that today's equipments incur high cost for maintenance due to its complexity. Therefore, it is necessary to enhance modern maintenance management systems. The conventional condition-based maintenance (CBM) is usually used to reduce maintenance activities and operates according to the indication of an equipment condition. Yam et al, (2001) illustrates that a recent study of maintenance management practices demonstrates that the three major problems facing modern engineering plants are the reduction of high inventory cost for spare parts, pre-planning maintenance work for complex equipment under a complex environment and avoiding the risk of major failure and eliminating unforeseen circumstances of equipment or systems. This paper suggests that the quality of maintenance could be improved through the integration of the intelligent predictive decision support system (IPDSS) for CBM which will incorporate the concepts of equipment condition monitoring, fault diagnosis and prediction of equipment depreciation and deterioration. The key theme of this paper illustrates a practical example of this concept. This concept has been introduced in a power station and the prediction of the IPDSS has proven useful and has enhanced the maintainability functionality for a complex automated engineering plant. The IPDSS helped in detecting minor equipment problem failures long before they become critical.

Patel and Kamrani (1996) illustrate the new diagnosis and maintenance off-line decision support system (ROBODOC) that will aid in diagnosing and fixing robotic failures. This technology utilises a group technology approach (GT) in order to segment symptoms and a decision tree approach in implementing the system. The strength of this system is that it has the capability to produce both detailed and overall reports for problems and solutions. The system is also modular which means it is easier to adjust the knowledge base and transfer diagnostic knowledge from an automated system to the other without completely developing the knowledge base from scratch. The key theme illustrated in this research suggests that the result of the system will give design recommendations based on past experiences and heuristics which will produce an easier means of maintaining equipment designs. This system also incorporates a friendly user-interface that allows for a consultation phase so that the user can arrive at a diagnosis.

Feng et al (2008) suggests that maintenance has become an imperative factor that strongly effects the survival of businesses. The key theme of this paper suggests that maintenance management requires additional support for decision support systems. This paper argues that there are vast amounts of equipment parts in a power plant and the maintenance requirements for these equipment parts are different. The idea of condition based maintenance in a power plant is a systemic maintenance management operation which strongly requires a special maintenance decision support system. This view is also supported by Yam et al (2001). This paper highlights the importance of defining system goal, system functionalities, framework and platform before developing any intelligent maintenance decision support system.

Cao and Jiang (2008) supports the view of other researchers about the significance of system maintenance and support due to highly complex equipments. In this paper, an Integrated Intelligent Equipment Maintenance Decision (IIEMD) platform is developed based on Service Oriented Architecture (SOA) environment. The key theme of this paper suggests that integrating these concepts allows for a collaborative maintenance decision and remote equipment diagnosis. The key strength of this paper lies in the fact that it uses an ontological model to support the hybrid conceptual architecture of the IIEMD. It then illustrates the framework of the SOA architecture and uses an ontology to model the knowledge base development. It also uses a mixture of rule based and case based reasoning which resulted into the prototype development of this ontology based maintenance decision support system.

In this paper, Fuchs et al (2006) supports the view of most researchers about the complexity of industrial systems and the need for highly capable maintenance systems for monitoring data. The key issue highlighted by this paper suggests that there is lack of linguistics in representing and querying data from multiple sources. The solution is then to apply Semantic Web technologies to large scale systems. However, this paper fails to address in detail, the new challenges faced by incorporating this new technology. It does mention the challenge of incorporating real world data but does not state possible solutions for rectifying this problem.

2.7 Cost Modelling

2.7.1 The need for Cost Modelling

According to Rush and Roy (2000), cost reduction is imperative for survival and cost is now perhaps the most deterministic factor that decides the end result of a product or service. In order for companies to remain competitive, they need to improve the quality and flexibility of their cost reduction process. Curran et al (2004) argues that production is the result of engineering labour and this process is driven by technical constraints. This paper suggests that although cost is known as an important criterion for design, it is not recognised in advance of production which means that cost estimation is required. This then brings forth the idea of concurrent engineering and integrated product process development (IPPD). The aim of these concepts is to rectify the simultaneous sharing of tasks that occurs within independent engineering operations which will aid in controlling combined decision making. Curran et al (2004) suggest that this is best achieved with modular elements that also incorporate generic elements in order to enhance the integration of multi-functional diverse models. Concurrent engineering allows the integration of data systems which will aid in estimating isolated costs in diverse models and various levels. This approach is more effective than the traditional fragmented approach.

Rush and Roy (2000) suggests that cost estimating aids a company decision-making process. It is also known to be the beginning of the cost management process and estimating costs during the initial stages of a development life cycle is essential. High cost estimation means that the business could lose out to a competitor and a low cost estimation means that the company might not make a reasonable profit from the project. Rush and Roy (2000) suggests that most authors agree that 70-80% of a production cost is liable during the conceptual phase and decision making is crucial at this stage because modifying products/processes are more expensive further down the development cycle as illustrated in Figure 2.9.4.

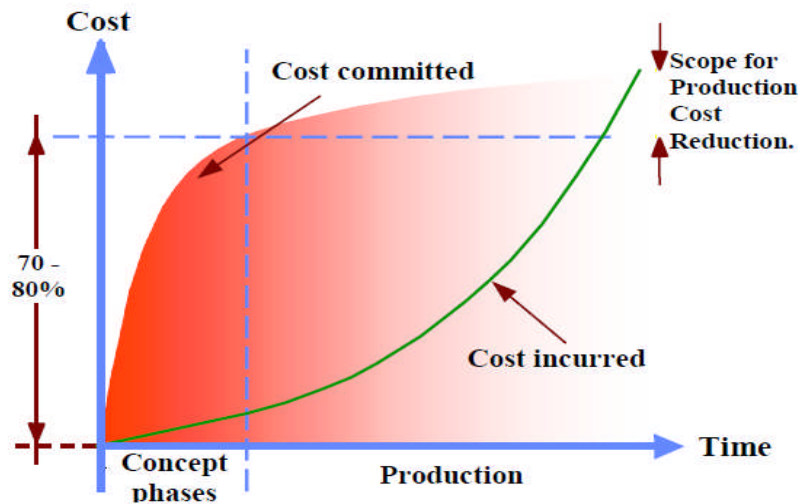


Figure 2.13 - Cost commitment curve (Rush and Roy, 2000)

Therefore, cost modelling tools need to be reasonable and true in product development and should be based on heuristic data (experience) which will in turn satisfy both parties (customer and company). The key strength of this particular paper by Rush and Roy (2000) highlights an overall review of cost modelling techniques. It also highlights the need for changing and using the appropriate cost modelling tools for a new environment due to technological advancements which causes previous cost modelling tools to become obsolete (Rush and Roy, 2000). The next section discusses cost categories.

2.7.2 Categories of Cost

Costs are categorised in different ways. The typical cost for a product can be arranged into a cost breakdown structure as suggested by Liebers (1998). The cost of a product is usually classified by 3 main types, which are: (1) non-recurring or recurring costs, (2) direct or indirect costs (3) variable/fixed costs. Another cost type is known as relevant and irrelevant costs. Relevant costs are usually defined as costs that exist in several product design alternatives but absent in other product design alternatives which can therefore be associated with differential costs which plays a vital role in the decision making processes and means all other costs are defined as irrelevant.

Curran et al (2004) suggests the importance of understanding the various types of costs. Non-recurring costs usually refers to costs that occur once in the life cycle of a project or activity. Recurring costs usually refers to costs that are incurred on an ongoing basis starting from the

first unit of output and still required to maintain the set-up and life duration of the product as a whole. Current et al (2004) suggests that there is usually confusion between recurring and non-recurring costs compared to fixed and variable costs. The difference is that the term fixed and variable costs are usually associated with break-even analysis. Fixed costs are usually assessed in order to determine if the company's financial status is stable and if profits are high or low. Recurring overheads could be fixed whilst non-recurring costs could be specific to the contract. Variable costs are then costs of production that change when the output rate is altered (Curran et al, 2004). Direct costs can usually be broken and associated with specific items. They are easily identified and usually produce an end result such as a service or product. However, indirect costs cannot be identified so easily because the allocation base for indirect costs needs to be defined, whereas the allocation base for direct costs are already known. Indirect costs are usually referred to as overheads and burden. The next section discusses cost estimating techniques.

2.7.3 Cost estimating techniques

According to Rush and Roy (2000) and Curran et al (2004), there are two main types of traditional cost estimating techniques. These are known as “**first sight**” and “**detailed cost estimating**”. Curran et al (2004) states that “cost estimating is the process of predicting or forecasting the cost of a work activity or output by interpreting historical data”. First sight estimating is usually carried out in the early design stages and is based on the experience of the cost engineer whilst detailed cost estimating is carried out to produce accurate cost estimation. Rush and Roy (2000) argues that detailed cost estimating can only be achieved when a product is well known and understood.

Detailed cost estimating is based upon time/costs for various rates of work such as operations, operation rates, material costs, labour, etc for a manufacturing product/process. Curran et al (2004) refers to detailed cost estimating as a **bottom up approach** because the cost engineer will need access to a detailed design documentation for the system components and information on material, labour, equipment, etc. Activity based costing (**ABC**) is also another traditional cost estimation technique and it is used to measure the cost of activities incurred by an organisation. Activities that exist in an organisation are identified and then an average cost is assigned to an activity. This method is similar to detailed costing, however

both methods are not useful for modelling cost in the conceptual phase of the development life cycle (Rush and Roy (2000), Curran et al (2004)).

A more recent method for cost estimating in the initial stages of the development is known as parametric estimating (**PE**) which is a form of cost estimating that uses mathematical equations to draw its conclusion for cost estimation. Rush and Roy (2000) argues that both industry and government has embraced this technique and research has proven that many authors agree with the capability of this cost estimating technique.

Curran et al (2004) suggests that the analogy based reasoning cost estimation technique is one of the best-established and applied ways of modelling cost. Rush and Roy (2000) states that this technique is best applied by understanding the differences and similarities of items through the use of historical data and experience. Case based reasoning is known as the modern approach for the analogy cost estimating technique. Rush and Roy (2000) argues that the CBR can be classified as a form of artificial intelligence because of its capability to capture knowledge for service resolution. A CBR stores and organises past knowledge (cases, solutions, etc) and then re-uses and adapts the stored knowledge for a new case. Curran et al (2004) implies that a CBR also utilises analogy rules and is also known as a knowledge based tool. A more detailed view on cost modelling techniques/technologies is carried out in the next section

2.7.4 Advance cost modelling techniques/technologies

Feature based costing has become popular due to the development of CAD/CAM and other 3d technologies. By using a feature based cost model approach, products can be defined with a number of features such as holes, edges, etc which suggests that each feature has a cost implication. The more features integrated with a product, the more manufacturing is required for the product (Rush and Roy, 2000).

Another advanced cost modelling technique is the use of neural networks (NNs) and fuzzy logic. Rush and Roy (2000) suggests that these techniques present the next technological advancements for computerising the thought process taken by humans. Research has proven that (Rush and Roy, (2000), Curran et al (2004)) that many developers are implementing artificial intelligent systems (AI) and applying them to cost estimation cases. Curran et al

(2004) argue that fuzzy logic is of special interest to cost modelling because in theory, fuzzy sets form the basis of logic. According to Rush and Roy (2000), a great advantage that neural network has over parametric costing is its ability to detect hidden relationships among data. This means that the cost engineer does not need to define the conditions of a product to its cost relationship which then simplifies the overall process of the development of the final equation. The idea of neural network suggests that a computer can learn for itself. In the case of cost modelling, data can be provided to a computer so that it can learn which product attributes possess more of an influence in the final cost output (Rush and Roy, 2000).

According to Rush and Roy (2000) knowledge based systems helps in modelling specialised knowledge so that it can be re-used which overcomes many human errors that could produce a negative impact. Errors such as poor memory, incorrect data input which affects data quality, illness, job change, etc suggests the importance of KBS in cost modelling (Curran et al, 2004).

Rush and Roy (2000) suggested that the development of artificial intelligence will play a significant role in the improvement of cost modelling seeing as cost has become an essential factor in the success of an organisation and cost engineers should utilise these modern technologies in order to improve their cost management process and cost estimating tools. Research has proven that several companies lacked the discipline in their cost estimating approach and those that are successful will have the right tools and process in place to confidently predict costs before undergoing a project.

Table 2.3 illustrates a summary of the tools and processes for cost estimating and when to use them in a product development life cycle.

Table 2.3 - Estimating process matrix, (Rush and Roy, 2000)

TOOLS AND PROCESSES	PE	NN	CBR	ABC	Detailed Cost Estimation	Cost Management			
						VA	VE	DTC	TC
USED WHEN:									
Concept design phase (innovation)	✓	✗	✓	✗	✗	✗	✓	✗	✗
Concept design (similar products)	✓	✓	✓	✗	✗	✗	✓	✗	✓
Feasibility Studies	✓	✓	✓	✗	✗	✗	✓	✗	✓
Project definition	✓	✓	✓	✗	✗	✗	✓	✓	✓
Full Scale development	✗	✗	✗	✓	✓	✓	✗	✓	✓
Production	✗	✗	✗	✓	✓	✓	✗	✓	✓

2.8 Research Gap Analysis

Research has proved recently that semantic technology has been used within medical centres (Theodor's Agorastos et al, 2009) and also within the financial Industry (AXONomics, 2008). This type of technology is highly required within the defence equipment support market for the capture & maintenance of complex knowledge; however, semantic technology is not being utilised. This is where the weak links exists and the outcome of the proposed project will evaluate & validate the use of this technology within the defence equipment support market by developing an equipment diagnosis prototype as a demonstrator to quantify the use of semantic technology.

Fuchs et al (2006) also highlighted a key issue by suggesting that there is lack of linguistics in representing and querying data from multiple sources. Also, research has shown that the development of artificial intelligent will play a significant role in the improvement of cost modelling (Rush and Roy, 2000). Research has proven that several companies lack the discipline in their cost estimating approaches seeing as it is difficult to integrate data from multiple sources due to lack of linguistics (semantic), therefore the outcome of this project will quantify the use of semantic technology by transforming an existing excel based cost model into a fully operational semantic based cost model application.

The research gaps identified in the literature review suggests lack of study on:

- Use of semantic technology for the development of cost models
- Use of semantic technology for maintenance support and the diagnosis of equipments

In order to achieve the goal of the project, it is imperative to define the boundaries of the project:

In scope

- The tools developed are prototypes which will be based on small areas of the problem domain in order to quantify the benefits of semantic technology.
- The developed prototype(s) will be deployed as a desktop application.
- The tool developed will connect to a database so that it can act as a demonstrator to potential clients.
- Accessibility for knowledge capture will be made available.

Out of Scope

- A real life data set will be used to validate the tool

2.9 Summary of the Previous Research Work

It is evident that Semantic Technology is needed within Industry and the potential capability of this technology goes far beyond one's imagination. Machine understanding linguistics will bridge the gap and help bring forth true artificial intelligence. Previous research work has suggested that the new evolution of computers will be the era of the scientist and this will allow computers to understand and represent complicated knowledge via using integral calculus, theorem proving, linguistics (semantics) Barski (2003). Previous research work has also shown that various technological advancements are taken place and the minority of industry are actually developing practical semantic applications such as the Metatomix Semantic Application Platform for UCB and the extension to media wiki known as the semantic media wiki (SMW) (Hawker, 2009) (Ontoprise, 2009). In the area of maintenance support, research has shown that the use of intelligent predictive decision support system (IPDSS) for case based maintenance will help in fault diagnosis and equipment monitoring. Various applications have been built (ROBODOC) that has utilised the IPDSS. Also, research has demonstrated the use of ontologies for maintenance support and the use of rule based and case based reasoning for the prototype development of a maintenance system (Cao and Jiang, 2008).

Previous research work has also demonstrated various techniques that assist in estimating costs. There have also been advancements in cost modelling techniques/technologies (Rush and Roy, 2000) such as the use of neural network and fuzzy logic, knowledge based systems which are all applications of artificial intelligence.

The next chapter identifies existing methodology and adopted methodology in order to achieve the aim of this research project.

CHAPTER 3:

RESEARCH METHODOLOGY

3.1 Introduction

Adopting an appropriate research methodology is an imperative factor when undertaking any type of project. The adopted research methodology depends on the aim and context of the research project. The correct methodology for a project must be adopted in order to successfully meet the goal and objectives and arrive at accurate results.

Section (3.2) illustrates the existing research approaches which consist of the quantitative and qualitative approach. The adopted methodology is then explained in detail. A summary of the chapter is then presented.

3.2 Research Approaches

The research approaches that were necessary to consider are as follows: the quantitative and qualitative approaches.

3.2.1 Quantitative Approach

The term ‘quantitative’ signifies quantity of some sort. The aim of the quantitative approach is to construct statistical models in order to describe what is being observed in a domain and to prove that the results predicted are true. With quantitative approach, the results are always statistically reliable. This approach is based on the fact that the researcher realises exactly what he/she needs. This approach is also known as “theory-driven” since it is based on previous experience and knowledge.

The three main types of quantitative approaches are the experiments, quasi-experiments and use of surveys. The experiments are based on assignments that are random with the capability to control these assignments experimentally. The quasi-experiment is based on non-random assignments whilst the survey uses interviews and questionnaires to collect data which includes semi structured interviews, close/open ended questionnaires, etc.

3.2.2 Qualitative Approach

The term qualitative signifies quality and the aim of a qualitative approach is to gain an in-depth understanding into the know-how knowledge of experts within a domain and the rules that govern such knowledge. The qualitative approach establishes the decision making thought process of an expert and it tends to focus on human behaviour. The ability to **observe** is a crucial aspect for a successful qualitative approach.

The researcher needs certain qualities in their character in order to be able to capture knowledge effectively from the expert. Qualities such as the ability to be open-minded and listen effectively are valuable characteristics to have when using this approach. Qualitative approach is based on complex data, the ability to understand, interpret and elicit is crucial. This approach is not based on any initial assumptions or preconceptions, however it is based on the ability to learn and investigate an idea of a problem.

There are 3 different types of qualitative approaches which are as follows: the case studies, the ethnographic studies and the phenomenological studies. The case study approach is based on researching information from a variety of cases and carrying out a comparative study on them. The ethnographic study approach is based on a study of a cultural group within a period of time, whilst the phenomenological study is based on human experiences in terms of nature and description.

The qualitative phenomenological study is an interesting study for this research project due to the fact that ontologies are used to model the semantic based prototypes for the domain areas and an ontology is described as the study of being and existence.

3.2.3 Knowledge Capture

In the knowledge capture phase, the qualitative approach was used. The quantitative approach was not adopted because the knowledge required has already been captured and validated within the Excel based cost model and bicycle manual repairs. The qualitative approach was adopted via:

- Observing and listening to the expert whilst experimenting with the validated model

3.2.4 Quantitative vs. Qualitative

Table 3.1 illustrates the features of qualitative and quantitative approaches as suggested by Neil, (2007).

Table 3.1 – Features of Qualitative and Quantitative Research (Neil, 2007)

Qualitative	Quantitative
"All research ultimately has a qualitative grounding" - Donald Campbell	"There's no such thing as qualitative data. Everything is either 1 or 0" - Fred Kerlinger
The aim is a complete, detailed description.	The aim is to classify features, count them, and construct statistical models in an attempt to explain what is observed.
Researcher may only know roughly in advance what he/she is looking for.	Researcher knows clearly in advance what he/she is looking for.
Recommended during earlier phases of research projects.	Recommended during latter phases of research projects.
The design emerges as the study unfolds.	All aspects of the study are carefully designed before data is collected.
Researcher is the data gathering instrument.	Researcher uses tools, such as questionnaires or equipment to collect numerical data.
Data is in the form of words, pictures or objects.	Data is in the form of numbers and statistics.
Subjective - individuals' interpretation of events is important ,e.g., uses participant observation, in-depth interviews etc.	Objective - seeks precise measurement & analysis of target concepts, e.g., uses surveys, questionnaires etc.
Qualitative data is more 'rich', time consuming, and less able to be generalized.	Quantitative data is more efficient, able to test hypotheses, but may miss contextual detail.
Researcher tends to become subjectively immersed in the subject matter.	Researcher tends to remain objectively separated from the subject matter.

3.3 Research Methodology Adopted

The research methodology for a “*Semantic Based Approach for Knowledge Management*” is illustrated in five phases as described in Figure 3.1. The research methodology is adopted in order to achieve the project aim and objectives

PHASE I – DEFINE PROJECT AIM AND OBJECTIVES: The first phase defines the project aim and objectives. This is achieved by understanding the problem domain. A literature review is also carried out in order to identify research gaps and understand the

review of literature cases on use of semantics. The output of this phase should identify the current use of semantics to manage and maintain knowledge in Industry. The deliverables for this phase are illustrated in Figure 3.1.

PHASE II – SOFTWARE TRAINING: The second phase is to undertake training on the software, (proposed by TechModal) which will be used to develop the semantic prototypes. Understanding how to use the software to declare ontologies, semantics, concepts, rules for modelling different types of problem domain, and queries is essential in achieving the aim.

PHASE III – KNOWLEDGE CAPTURE AND REPRESENTATION: The purpose of the third phase is to capture and represent knowledge effectively using knowledge representation techniques such as UML (Unified Modelling Language) and ontological knowledge representation techniques (Taxonomy). This phase also involves collecting and understanding the validated ‘Excel’ based cost model and validated manual repair for a bicycle in order to transform these knowledge models into semantic based platforms.

PHASE IV – PROTOTYPE DEVELOPMENT: The semantic based prototypes are developed using semantic applications from a company known as Ontoprise who are one of the leaders of semantics in industry. OntoStudio semantic based platform is used for developing the cost model for a composite part whilst SemanticGuide is used for developing the maintenance support and diagnosis for bicycle parts. From the prototype development, discussions and conclusions which involve key aspects, contribution to knowledge, application of results and a comparative study on both semantic applications can be established.

PHASE V – VALIDATION OF PROTOTYPE: Phase five validates the developed prototype and ensures the appropriate dissemination of the project results.

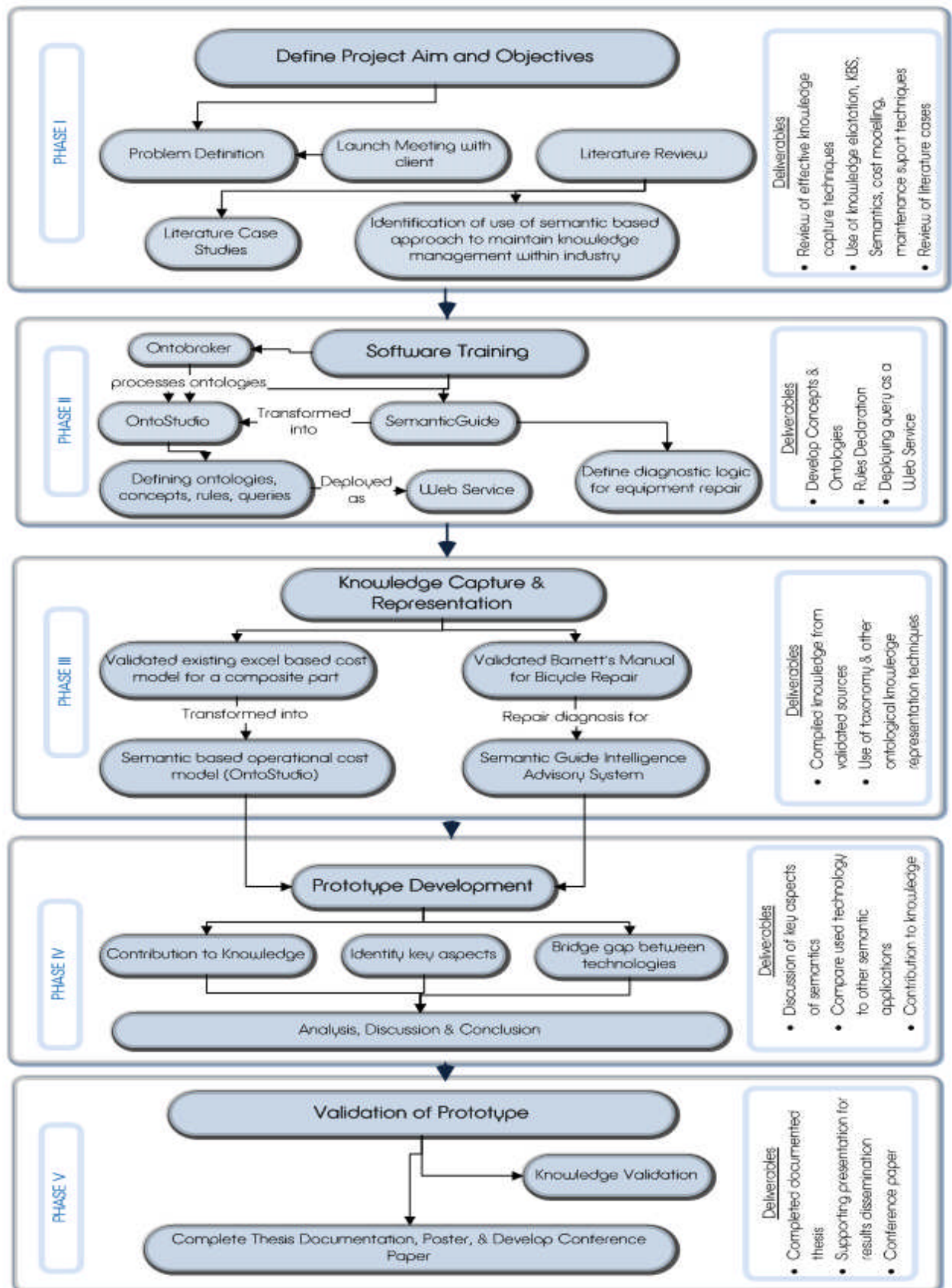


Figure 3.1 - Research Programme Methodology

3.4 Chapter Summary

This chapter has described the quantitative and qualitative methodologies and has successfully identified the advantages and disadvantages of using these methodologies. The adopted methodology is also described which aims to achieve the project in 5 phases. The main deliverables of each phase are identified in Figure 3.1. The research programme methodology is a critical aspect of this research project because it contains imperative tasks that need to be implemented efficiently and effectively in order to achieve the objectives of this research project.

The next chapter introduces the current AS-IS model in order to describe the current Excel based cost model and bicycle manual repair and identify the limitations with the AS-IS models.

CHAPTER 4:

CURRENT AS-IS PROCESS AND TOOLS

4.1 Introduction

In order to achieve the purpose of this project which was to demonstrate a semantic based approach for knowledge management, several actions were carried out. A crucial step was to identify and understand the current AS-IS model in order to understand the tools and limitations of the current Excel based cost model and bicycle repair manual. This chapter aims to also explain some of the core concepts within the Excel based cost model that were essential to adopt for the semantic based model. Snap shots of the current Excel based cost model and bicycle repair manual are illustrated in order to capture the visibility of the current AS-IS models.

A study on the current AS-IS cost model and was undertaken in order to identify the available functionalities and understand the current limitations. The AS-IS models were experimented on practically in order to investigate potential areas of improvement by optimising the processes and functionalities of the Excel based cost model and bicycle repair manual.

4.2 AS-IS Excel Based Cost Model

4.2.1 Introduction

The Excel based cost model calculates the cost for a composite part. The term ‘composite’ refers to a mixture of different components/materials. A composite material is defined as a material that gains its strength from a mixture of other supplemented materials. Composite materials are known to be lightweight and strong enough to withstand harsh conditions which make them high performance materials for aerospace parts, **bicycle** frames, car bodies, etc.

This section describes the process of the manufacturing of a composite part and how it is currently represented in the AS-IS Excel based cost model. The stages describes the representation of components dimensions, component materials, components manufacturing process, top level parameters which includes general and administration costs, profit costs, levy costs, burden costs, and the final cost estimation for the composite part.

Figure 4.1 illustrates a basic introduction to manufacturing.

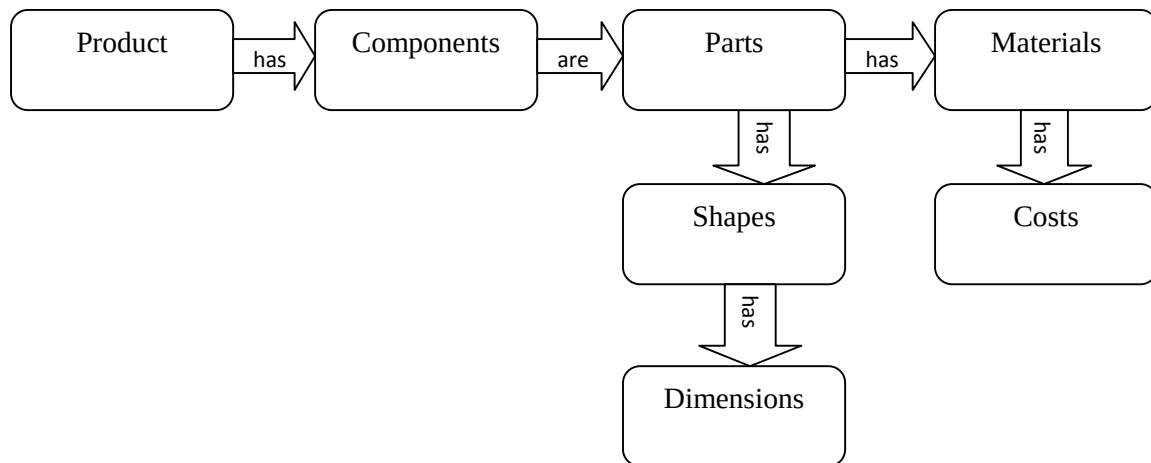


Figure 4.1 – Basic introduction to manufacturing

4.2.2 Shape Dimensions

Figure 4.3 illustrate the current AS-IS Excel based model for component dimensions. As illustrated in the Excel based cost model, the yellow fields represent the inputs for the component dimensions whilst the green fields represent the outputs. There are 4 types of shape. These are ‘Panel’, ‘Sleeve’, ‘L-Channel’, and ‘T-Channel’. The shape inherits inputs depending on its type. For example, the sleeve shape is the only shape to have a diameter. However, all shapes have the same outputs as illustrated in Figure 4.3. Figure 4.2 illustrates the shape types with their various input dimensions. The screen shots are extracted from the Excel based cost model.

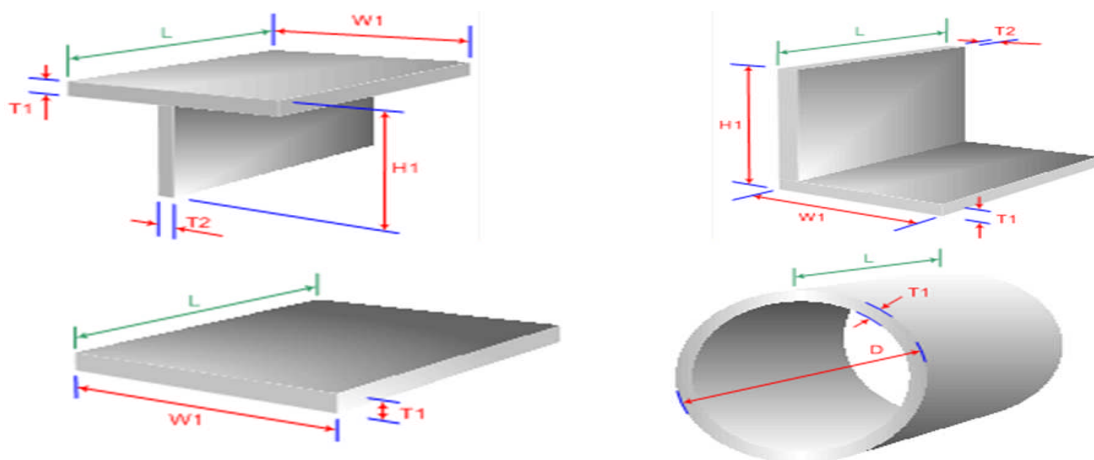


Figure 4.2 – Shape types input dimensions

	Dimensions (m)																	Ply Orientation %		
	Shape	Length	Width	Thickness 1	Thickness 2	Height	Diameter	Complexity	Cross Section Area m2	Finished Volume m3	Periphery m	Developed Area m2	Raw Volume m3	Part Height m	Part Width m	Part Thickness m	Autoclave Area m	0	45	90
Component 1	Panel	1.000	1.000	0.010					0.010	0.010	4.000	1.000	0.010	0.010	1.000	0.010	1.000			
Component 2	Sleeve	1.000		0.010			0.100		0.003	0.003	0.628	0.314	0.003	0.100	0.100	0.010	0.100			
Component 3	L-Channel	1.000	1.000	0.010	0.010	1.000			0.020	0.020	5.980	1.990	0.020	1.000	1.990	0.010	1.000			
Component 4	T-Channel	1.000	1.000	0.010	0.010	1.000			0.020	0.020	5.980	2.980	0.020	1.000	2.980	0.010	1.000			

Figure 4.3 – Excel based cost model representation for shape dimensions

Figure 4.4 furthermore illustrates a spreadsheet within the Excel based cost model that identifies which attributes belong to which type of shape.

Shape ID	Shape Name	Length	Width	Thickness 1	Thickness 2	Height	Diameter
1	Panel	Yes	Yes	Yes	No	No	No
2	Sleeve	Yes	No	Yes	No	No	Yes
3	L-Channel	Yes	Yes	Yes	Yes	Yes	No
4	T-Channel	Yes	Yes	Yes	Yes	Yes	No

Figure 4.4 – Shape Attributes

Figure 4.5 illustrates the rules that govern the outputs of the shape dimensions. This is also extracted from the Excel based cost model. For example, in order to calculate the periphery of sleeve shape, the formulae ($2 * \pi * \text{Diameter}$) as illustrated in Figure 4.5 will produce the correct output.

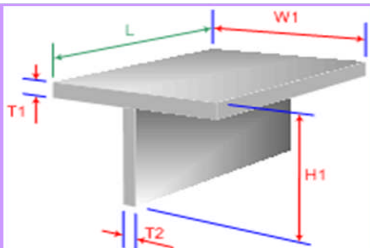
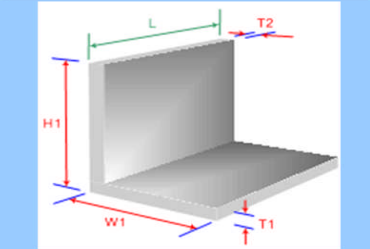
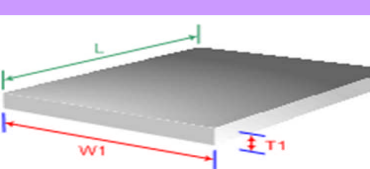
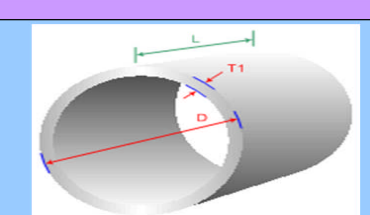
T Channel		Width 1 (W1)	ELSE IF T_CHANNEL THEN $\text{Periphery} = 2 * (\text{OverallLength} + W1 + (H1 - T1))$ $\text{TotCrossSecArea} = ((W1 * T1) + ((H1 - T1) * T2))$ $\text{FinishedVolume} = \text{TotCrossSecArea} * \text{OverallLength}$ $\text{RawVolume} = \text{FinishedVolume}$ $\text{PartHeight} = H1$ $\text{PartWidth} = W1 + (2 * (H1 - T1))$ $\text{DevelopedArea} = \text{PartWidth} * \text{OverallLength}$ $\text{PartThickness} = ((W1 * T1) + ((H1 - T1) * T2)) / (W1 + (H1 - T1))$
		Thickness 1 (T1)	
		Height 1 (H1)	
		Thickness 2 (T2)	
L Channel		Width 1 (W1)	ELSE IF L_CHANNEL THEN $\text{Periphery} = 2 * (\text{OverallLength} + W1 + (H1 - T1))$ $\text{TotCrossSecArea} = ((W1 * T1) + ((H1 - T1) * T2))$ $\text{FinishedVolume} = \text{TotCrossSecArea} * \text{OverallLength}$ $\text{RawVolume} = \text{FinishedVolume}$ $\text{PartHeight} = H1$ $\text{PartWidth} = W1 + (H1 - T1)$ $\text{DevelopedArea} = \text{PartWidth} * \text{OverallLength}$ $\text{PartThickness} = ((W1 * T1) + ((H1 - T1) * T2)) / (W1 + (H1 - T1))$
		Thickness 1 (T1)	
		Height 1 (H1)	
		Thickness 2 (T2)	
Panel		Width 1 (W1)	ELSE IF PANEL THEN $\text{Periphery} = 2 * (\text{OverallLength} + W1)$ $\text{TotCrossSecArea} = W1 * T1$ $\text{RawVolume} = \text{FinishedVolume}$ $\text{DevelopedArea} = \text{OverallLength} * W1$ $\text{FinishedVolume} = \text{TotCrossSecArea} * \text{OverallLength}$ $\text{PartHeight} = T1$ $\text{PartWidth} = W1$ $\text{PartThickness} = T1$
		Thickness 1 (T1)	
Sleeve		Diameter (D)	ELSE IF SLEEVE THEN $\text{Periphery} = 2 * \pi * D$ $\text{TotCrossSecArea} = \pi * ((D * T1) - T1^2)$ $\text{RawVolume} = \text{FinishedVolume}$ $\text{DevelopedArea} = \text{OverallLength} * (D * \pi)$ $\text{FinishedVolume} = \text{TotCrossSecArea} * \text{OverallLength}$ $\text{PartHeight} = D$ $\text{PartWidth} = D$ $\text{PartThickness} = T1$
		Thickness 1 (T1)	

Figure 4.5 – Rules/calculations for shape output dimensions

4.2.3 Materials

Figure 4.6 illustrates the materials spreadsheet extracted from the current Excel based cost model. Again, the yellow fields represent the inputs and the green represents the outputs. The properties of materials are material name, material type, thickness, density, area cost, volume cost and weight cost. This spreadsheet illustrates that cost types may be missing in a material which means the available cost must be used to get the value of the missing cost(s). For example, the foam core material is missing an area cost and weight cost but has a volume cost. The volume cost is then used to calculate the area and weight costs for the foam core material.

Material Name	Material Type	thickness mm	density kg/m3	cost £/m2	Cost £/m3	Cost £/kg
Pre-preg F263 0.25x75mm	HLU-Pre-Preg	0.250	1,600	£ 60	£ 240,000.00	£ 150.00
Pre-preg F263 0.25x150mm	HLU-Pre-Preg	0.250	1,600	£ 60	£ 240,000.00	£ 150.00
Pre-preg F263 0.25x1200mm	HLU-Pre-Preg	0.250	1,600	£ 60	£ 240,000.00	£ 150.00
Pre-preg 8552 0.125x75mm	HLU-Pre-Preg	0.125	1,600	£ 50	£ 400,000.00	£ 250.00
Pre-preg 8552 0.125x150mm	HLU-Pre-Preg	0.125	1,600	£ 50	£ 400,000.00	£ 250.00
Pre-preg 8552 0.125x1200mm	HLU-Pre-Preg	0.125	1,600	£ 50	£ 400,000.00	£ 250.00
Pre-preg 8552 0.25x75mm	HLU-Pre-Preg	0.250	1,600	£ 50	£ 200,000.00	£ 125.00
Pre-preg 8552 0.25x150mm	HLU-Pre-Preg	0.250	1,600	£ 50	£ 200,000.00	£ 125.00
Pre-preg 8552 0.25x1200mm	HLU-Pre-Preg	0.250	1,600	£ 50	£ 200,000.00	£ 125.00
Foam	Core Material	5.000	0	£ 2.50	£ 500	£ 3,968.25
Honeycombs Al-48-3	Core Material	2.000	29	£ 5.60	£ 2,800	£ 96.55
Honeycombs Al-64-3	Core Material	2.000	29	£ 6.40	£ 3,200	£ 110.34
Honeycombs Al-96-3	Core Material	2.000	29	£ 8.80	£ 4,400	£ 151.72
Copper Foil (0.1x300mm)	Lightning Strike Mesh	0.100	4,425	£ 7.30	£ 73,012.50	£ 17
Copper Foil (0.1x800mm)	Lightning Strike Mesh	0.100	4,425	£ 7.30	£ 73,012.50	£ 17
Copper Mesh 110 (0.1x300mm)	Lightning Strike Mesh	0.100	1,200	£ 4.80	£ 48,000.00	£ 40
Copper Mesh 110 (0.1x800mm)	Lightning Strike Mesh	0.100	1,200	£ 4.80	£ 48,000.00	£ 40
Copper Mesh 110 (0.3x300mm)	Lightning Strike Mesh	0.300	1,200	£ 14.40	£ 48,000.00	£ 40
Copper Mesh 110 (0.3x800mm)	Lightning Strike Mesh	0.300	1,200	£ 14.40	£ 48,000.00	£ 40
Aluminium 1145 (0.1x300mm)	Lightning Strike Mesh	0.100	600	£ 1.08	£ 10,800.00	£ 18
Aluminium 1145 (0.1x800mm)	Lightning Strike Mesh	0.100	600	£ 1.08	£ 10,800.00	£ 18
Aluminium 1145 (0.3x300mm)	Lightning Strike Mesh	0.300	600	£ 3.24	£ 10,800.00	£ 18
Aluminium 1145 (0.3x800mm)	Lightning Strike Mesh	0.300	600	£ 3.24	£ 10,800.00	£ 18

Figure 4.6 – Material costs

4.2.4 Operations

Figure 4.7 highlights the operations for the composites part. The operations describe the various processes involved in manufacturing a part that is composed of composite materials. An operation rate belongs to an operation type. For example, the 'Mesh Layup' operation has four types of operation rates which are 'Lightning Mesh Layup', 'Lightning Mesh Layup Rate Setup', 'Lightning Mesh Cutting' and 'Lightning Mesh Cutting Setup'. The spreadsheet captured from the Excel based cost model illustrates the rate value and rate unit.

Operation Name	Operation Type	Rate	Unit
Release Agent Application	Cleaning	30.00	m ² /hr
Cleaning	Cleaning	6.25	m ² /hr
Ply Layup	Ply and core Layup	30.00	m ² /hr
Ply Layup Setup	Ply and core Layup	5.00	min
Ply Cutting	Ply and core Layup	20.00	m/min
Prepreg Cut Setup	Ply and core Layup	5.00	min
Core Layup	Ply and core Layup	20.00	m ² /hr
Core LayUp Setup	Ply and core Layup	0.03	hr
Core Cutting	Ply and core Layup	1.00	m/min
Core Cut Setup	Ply and core Layup	5.00	min
Core Preparation	Ply and core Layup	0.50	m/min
Lightning Mesh Layup	Mesh Layup	60.00	m ² /hr
LightningMeshLayupRateSetup	Mesh Layup	5.00	min
Lightning Mesh Cutting	Mesh Layup	0.50	m/min
LightningMeshCuttingSetup	Mesh Layup	5.00	min
Seal Deposit	Tool Closing	30.00	m/hr
Debulk Interval	Tool Closing	10.00	plies
Bagging	Tool Closing	10.00	m ² /hr
AeroVac Placement	Tool Closing	5.00	min
AeroVac Sealing	Tool Closing	1.00	min
AeroVac Vacuum Attachment	Tool Closing	1.00	min
FormInterval	Hot Ply	5.00	
Hot Ply Forming Time	Hot Ply	20.00	min
HotPlyFormingSetup	Hot Ply	5.00	min
AreaMovingRate	Remove	7.00	m ² /hr
WeightMovingRate	Remove	550.00	kg/hr
RemoveFactor	Remove	0.25	
PartFinishMachineSpeed	Finish	10.00	m/min
PartFinishResinSealSpeed	Finish	10.00	m/min
PartFinishSetup	Finish	20.00	min
Autoclave Loading Time	Autoclave	60.00	min
Autoclave Area	Autoclave	20.00	m ²

Figure 4.7 – Operations and operation rates of composite materials

4.2.5 Manufacturing Process

The manufacturing process describes the necessary part operations sequentially in order to complete the manufacture of a part/composite part. The operation rates are applied to the manufacturing processes for a composite part. Figure 4.8 illustrates the manufacturing processes required and the output states the manufacturing times for the process. As illustrated in the Excel spread sheet, manufacturing rules are used to govern the manufacturing process. The Excel based rule that governs the process 'ply cutting' is illustrated in Figure 4.8. This rule requires data from other spreadsheets and this illustrates one of the weaknesses of Excel based cost models which is its inability to present complex data in an unambiguous manner.

The output of this process results into the overall labour hours for the manufacturing times as illustrated in Figure 4.8. This is then multiplied by the standard labour rate per hour which is illustrated in Figure 4.9

=IF('Component Dimensions'!D6="",0,('ComponentDimensions'!O6*I6)/(VLOOKUP('Component Process'!\$Q\$5,Operations!\$D\$5:\$G\$34,3,FALSE)*"Top Level Parameters"!\$E\$5))

Component	Material Thickness of Part m			Number of Layers		Cleaning (Hrs)		
	Pre-Preg	Core	Mesh	Prepreg	Core	Release Agent Application	Cleaning	Total Tool Cleaning Direct
Component 1	0.005	0.005	0.000	20		0.02	0.08	0.10
Pre Preg Part Layup (Hrs)				Core Part Layup (Hrs)				
Prepreg Cut Setup	Ply Cutting	Ply Layup Setup	Ply Layup	Core Cut Setup	Core Cutting	Core LayUp Setup	Core Preparation	Core Layup
0.08	0.05	0.08	0.33	0.08	0.05	0.03	0.10	0.03
Autoclave Loading Time	Tool Remove	Part Remove	Tool Opening	Total Remove	Part Finish Machine	Part Finish Resin Seal	Total Finish	Labour Hours
0.03	0.12	0.00	0.11	0.23	0.30	0.30	0.60	2.24
								£ 100.94

Figure 4.8 - Manufacture process times for composite part

4.2.6 Costs

In order to achieve the final price for the composite part, various factors are considered. Figure 4.9 illustrates external factors that affect the price of a composite part after manufacturing. The G&A, Levy, Burden and Profit are all costs that a company will need to consider in the making of a composite part. The percentage at which each cost is attributed is defined in Figure 4.9. This is extracted from the Excel based cost model.

G&A: General and administration costs

Levy: Tax costs

Burden: Overhead costs

Profit: Net income

Figure 4.10 illustrates the final price to sell the composite part once the G&A, Levy, Burden and Profit costs are added.

Seconds in a minute	60.0
Minutes in an hour	60.0
Hours in a day	24.0
mm in a metre	1000.0
Excess for bagging	0.20 m
Labour Rate	£ 45
G&A %	8%
Levy %	9%
Burden %	8%
Profit %	10%

Figure 4.9 – Top level parameters

Component	Shape	Component Labour	Feature Labour	Component Material	Feature Material	Labour G&A	Labour Total	Material Levy	Material Burden	Total Material	Profit	Total
Component 1	Panel	£ 164.81	£ 40.26	£ 2,400.00	£ 0.79	£ 16.41	£ 221.47	£ 216.07	£ 192.06	£ 2,808.93	£ 303.04	£ 3,333.44
Component 2	Sleeve	£ 68.06	£ -	£ 678.58	£ -	£ 5.44	£ 73.50	£ 61.07	£ 54.29	£ 793.94	£ 86.74	£ 954.19
Component 3	L-Channel	£ 270.90	£ 26.74	£ 4,776.00	£ 0.40	£ 23.81	£ 321.46	£ 429.88	£ 382.11	£ 5,588.39	£ 590.98	£ 6,500.83
Component 4	T-Channel	£ 787.45	£ -	£ 7,960.00	£ -	£ 63.00	£ 850.45	£ 716.40	£ 636.80	£ 9,313.20	£ 1,016.37	£ 11,180.02

Figure 4.10-Costs for composite part

4.2.7 Excel Limitation

From the current AS-IS Excel based cost model, the current limitations are documented as follows:

- Inability to split data and rules
- Complicated
- Lacks user-friendliness
- Difficult to query data
- Lack of visual reporting tools
- Excel macros are prone to get easily corrupted

4.3 AS-IS Maintenance Support for Bicycles

4.3.1 Introduction

This section describes the current AS-IS model for the bicycle diagnosis. An introduction to bicycles in general is illustrated followed by few facts and challenges about bicycle repairs. The manual chosen for bicycle repairs is the ‘Barnett’s Manual’ which is an in-depth four volume sets that describes bicycle parts from different manufacturers. This validated knowledge documented illustrates various symptoms and solutions for bicycle parts. It is known as the absolute guidebook for bicycle maintenance and is composed of multiple experts’ opinion which allows for alternative ways to represent knowledge and thoughtful contributions from multiple experts

4.3.2 Bicycle Facts and Challenges

Below illustrates few facts and challenges about bicycles.

- There are more than a billion bicycles in this world which is twice as much as cars. 50 million bicycles are produced every year which is also twice as much as cars.
- A typical bicycle has over 80 mechanical parts as illustrated in Figure 4.11 which could at any time become defective due to unforeseen symptoms.

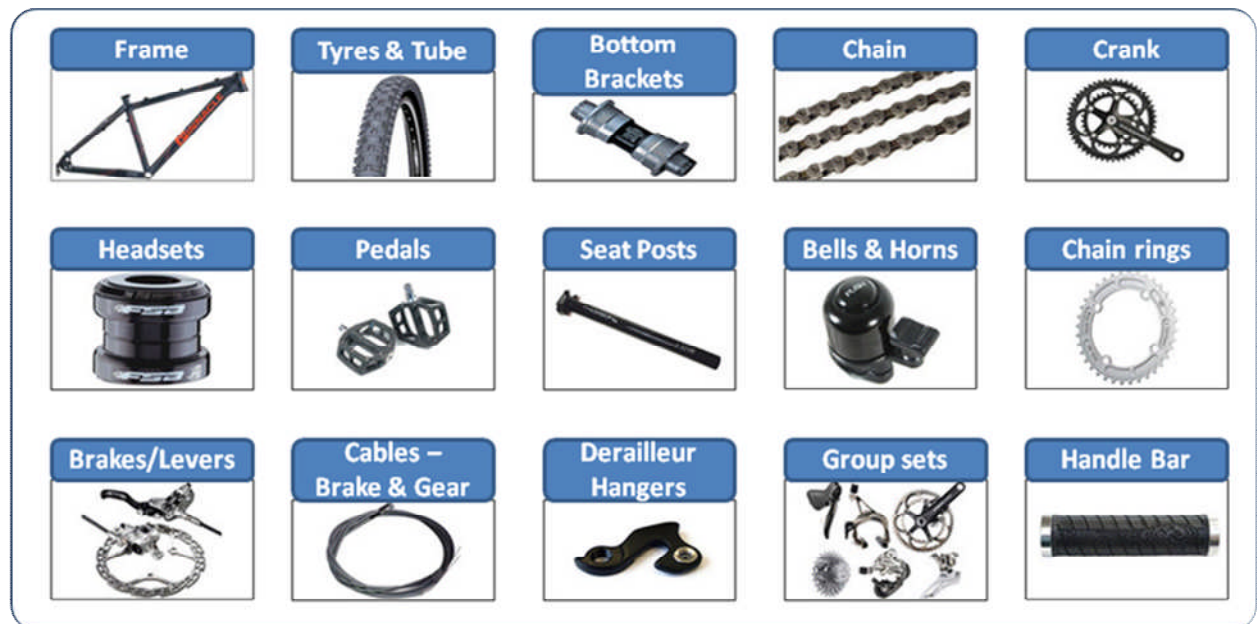


Figure 4.11 - Bicycle Repair: Some of the many parts

- One of the biggest challenges faced in bicycle repairs is diagnosing noise
- The most common road/mountain bicycle failure problem that occurs is a flat tire
- Headset failure is the most common problem people have from a mechanical stand point for a BMX bicycle

4.3.3 AS-IS Barnett's Manual of Bicycle Repair

The AS-IS bicycle manual repair contains different symptoms and solutions for various problems that could potentially occur in bicycles. However, there is no diagnosis logic which means the user will have to manually identify which cause is affecting the bicycle in order to carry out an appropriate solution. The lack of questions and answers diagnosis means there will be no rapid discovery of appropriate solutions.

The manual is also complex and some of the solutions are significantly vague and abstract. However, the use of attachments to further more describe the actions will enhance service resolution.

Appendix A illustrates the extracted symptoms and solutions from the 'Barnett's' Manual of Bicycle Repair'. The validated knowledge within this manual built the foundation for the semantic based prototype for bicycle repairs.

4.4 Chapter Summary

The aim of this chapter was to present an overview of the current AS-IS model for the Excel based cost model which consists of the core concepts that was used to develop the cost model. Screen shots were also used to illustrate how the cost model for the composite part is represented using an Excel based platform. An overview of the bicycle repair manual is also illustrated in order to identify the core concepts the document is based on which consists of symptoms, causes and solutions for solving problems for various bicycle parts. The capture of both AS-IS models defines the limitations of both platforms.

The next chapter introduces various computer based knowledge representation techniques in order to elicit knowledge effectively for the two semantic based prototypes that are to be developed.

CHAPTER 5:

KNOWLEDGE CAPTURE AND REPRESENTATION

5.1 Introduction

In this chapter, various knowledge representation techniques are used in order to capture and represent knowledge effectively. It is imperative to understand that the chosen knowledge representation techniques are based upon the effectiveness of these techniques to accurately capture the knowledge required before developing the prototypes. As illustrated in phase 3 of the research programme methodology in Figure 3.1, the first part of this project models the cost for a composite part whilst the second part of this project carries out maintenance support (failure analysis diagnosis) for that part using semantic technology. In this case, the part is a bicycle frame, bicycle wheel, bicycle pedal-mounting, etc.

5.2 Taxonomy for Composite Cost Model

Figure 4.1 illustrates a taxonomy that represents the classification/hierarchy for the semantic based composite cost model. Concepts are used to define independent entities that exist within this domain. The use of this knowledge representation technique demonstrates the concept generalisation/specialisation hierarchy in order to visualise how knowledge is structured for this semantic based cost model application.

As illustrated in Figure 5.1, there are 7 main concepts which are then classified into sub-concepts. For example, there is a generalised 'concept named 'part' and then a specialised concept named 'composite part'. There is also a 'Shape' concept which consists of 3 sub-concepts of 'Shape' known as 'Panel', 'Sleeve', and 'Channel'. 'Channel' also has sub-concepts such as 'L-channel' and 'T-channel'. By arranging and grouping these concepts, a systemic and systematic view of the system can be captured. It is also imperative to understand the difference between taxonomy and ontologies. Taxonomy is simply the classification of concepts whilst an ontology is specifying relationships between one or more concepts which will later on be illustrated in this chapter.

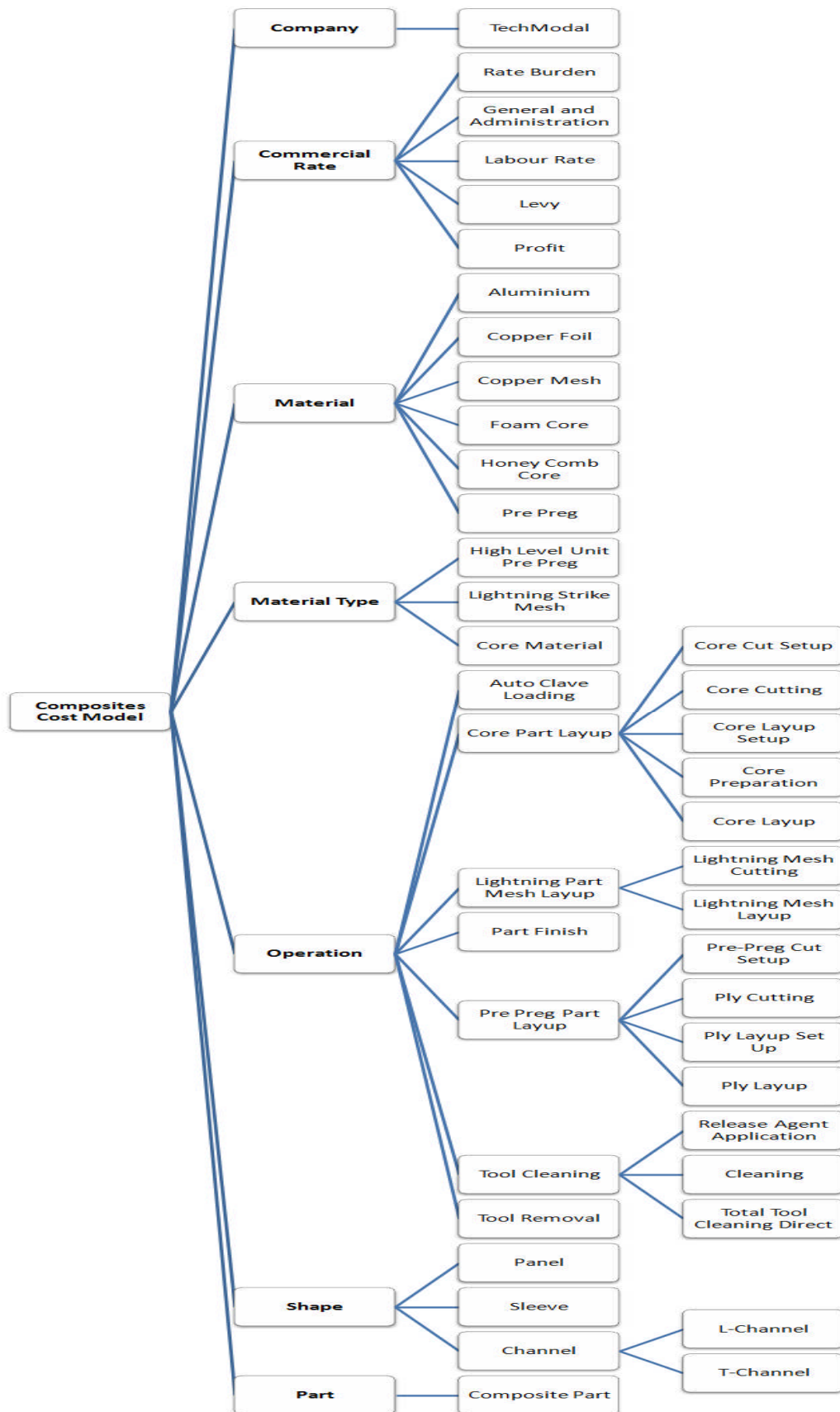


Figure 5.1 - Taxonomy for Composite Cost Model

5.3 UML Class Diagram for Composite Cost Model

In manufacturing, a product is composed of many components which are also known as parts. A typical part has many shapes and a shape has various calculated dimensions as illustrated in the class shape of Figure 4.2. A part also has material and materials are composed of material types. UML stands for unified modelling language and it is an industrial standardised graphical notation tool that is used to model and construct software systems. There are various diagrams that are supported by the UML. The purpose of the UML Class diagram is to define objects with their respective relationships. UML Class diagrams helps in defining the attributes of each class and understanding relationship types between classes.

As illustrated in Figure 5.2, a company has an ‘association’ relationship with class commercial rate which simply means that a company ‘has’ commercial rates. The association relationship between 2 classes consists of composition and aggregation. In the composition relationship, once the parent class is destroyed, so is all the child classes connected to it. However, in the aggregation relationship the class child is independent and can exist without the parent class. Figure 5.2 illustrates that the relationship between class company and class part is a ‘composition association’ relationship because although a company makes parts, the company and part are 2 separate entities and can exist without each other. The UML class diagram also illustrates that a part ‘is A’ composite part which suggests a ‘generalisation’ relationship type. This means that a part is a parent class and the composite part child class will inherit all of parent class part attributes.

A part also has a ‘composition association’ relationship with material, however a material has a ‘aggregation association’ relationship with material type seeing as a material type cannot exist independently on its own without being associated to a material. A part is also composed of many shapes, however a shape can exist independently on its own without being associated with a part which therefore means that there is an ‘aggregation association’ relationship between part and shape. Panel, sleeve and channel are also types of shape. A part also has an operation which can also exist independently on its own. An operation has operation rates and operation rates are bound to an operation which means that a ‘composition association’ relationship exists between operation and operation rate.

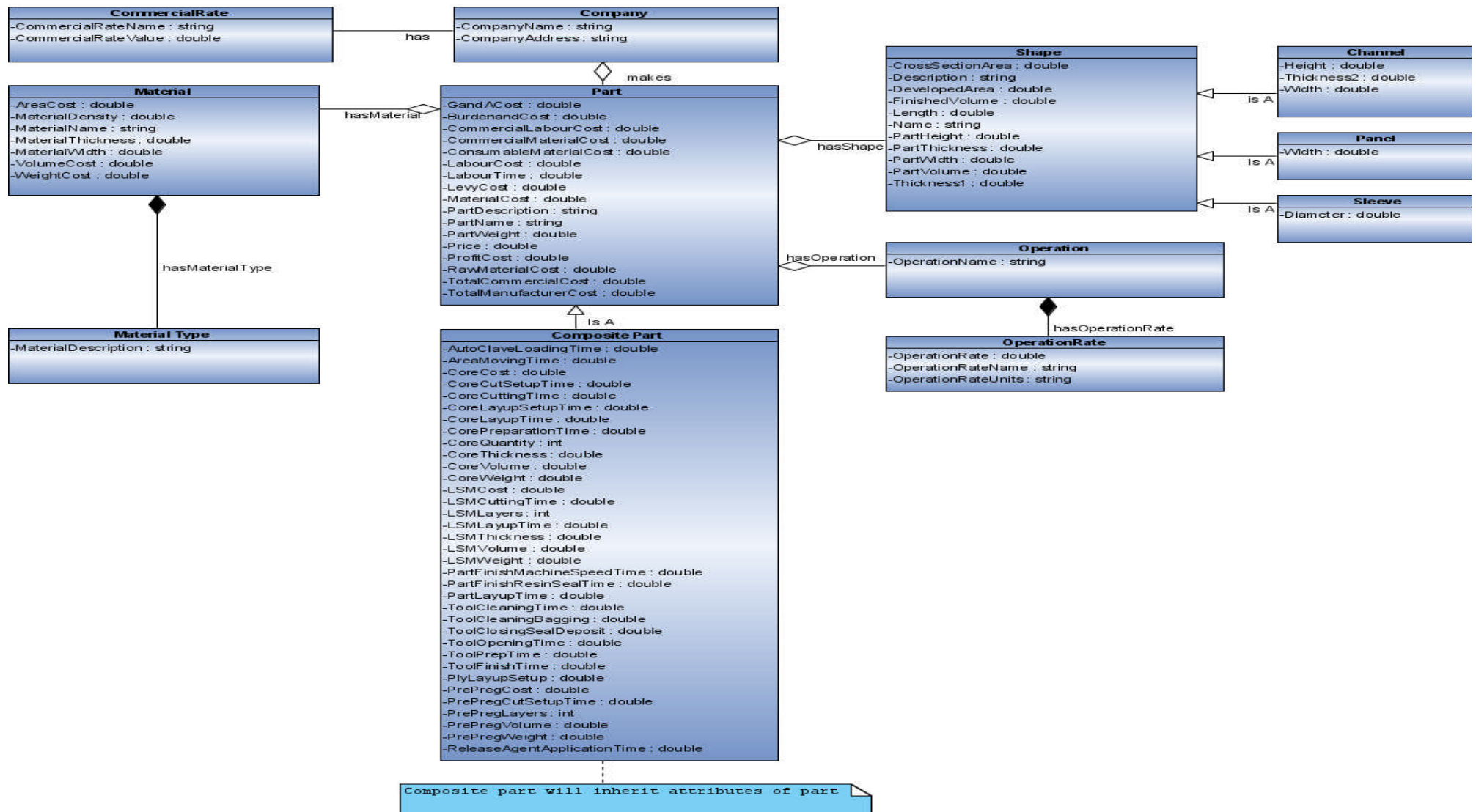


Figure 5.2 - UML Class Diagram for Composite Cost Model

5.4 Entity Relationship Diagram for Composite Cost Model

Figure 5.3 illustrates the entity relationship diagram that represents the modelling of the database. This type of ERD diagram is known as the crow's foot notation diagram. This diagram represents the entities within the domain, relationships between them and attributes associated to each of them. It is essential to define and understand the relationship types between entities as this helps in declaring business rules for the database. As illustrated in Figure 5.3, there are 7 entities within the domain which means there are 7 different tables. Entities in database are the same as concepts in semantics.

The ERD depicted in Figure 5.3 demonstrates that a user can create one or many parts which signify a one-to-many relationship between the entity user and entity part. This type of relationship is known as an optional relationship because the user is responsible for choosing to create one or more parts. However, in ERD modelling, the relationship exists both ways so a part could only be created by one user seeing as 2 users cannot create a part. The primary key of entity user which identifies the unique attribute of the table user becomes a foreign key in table part as illustrated in Figure 5.3. This established link means that the details of the user responsible for creating a particular part can be viewed.

Figure 5.3 illustrates that a part also has many operations. A mandatory relationship exists seeing as a part must have more than one operation and each operation is used by only one part. An operation also has many operation rates and each operation rate belongs to only one operation. A part is also known to be a parent entity and the child entity composite part inherits the attribute of part. The composite part name attribute in entity composite part is known as the subtype discriminator which is used to distinguish a specific subtype from its generic super type.

A part could also be made up of one or more different composite materials and different shapes. The primary key in the part entity becomes foreign key in other entities in order to establish a relationship between all tables in the database. The highlighted attributes are attributes that are of necessity for the entity/table to operate. In entity operation rate, the attributes 'operation ID', 'operation name', 'operation rate name' and 'rate' are necessary for this particular entity.

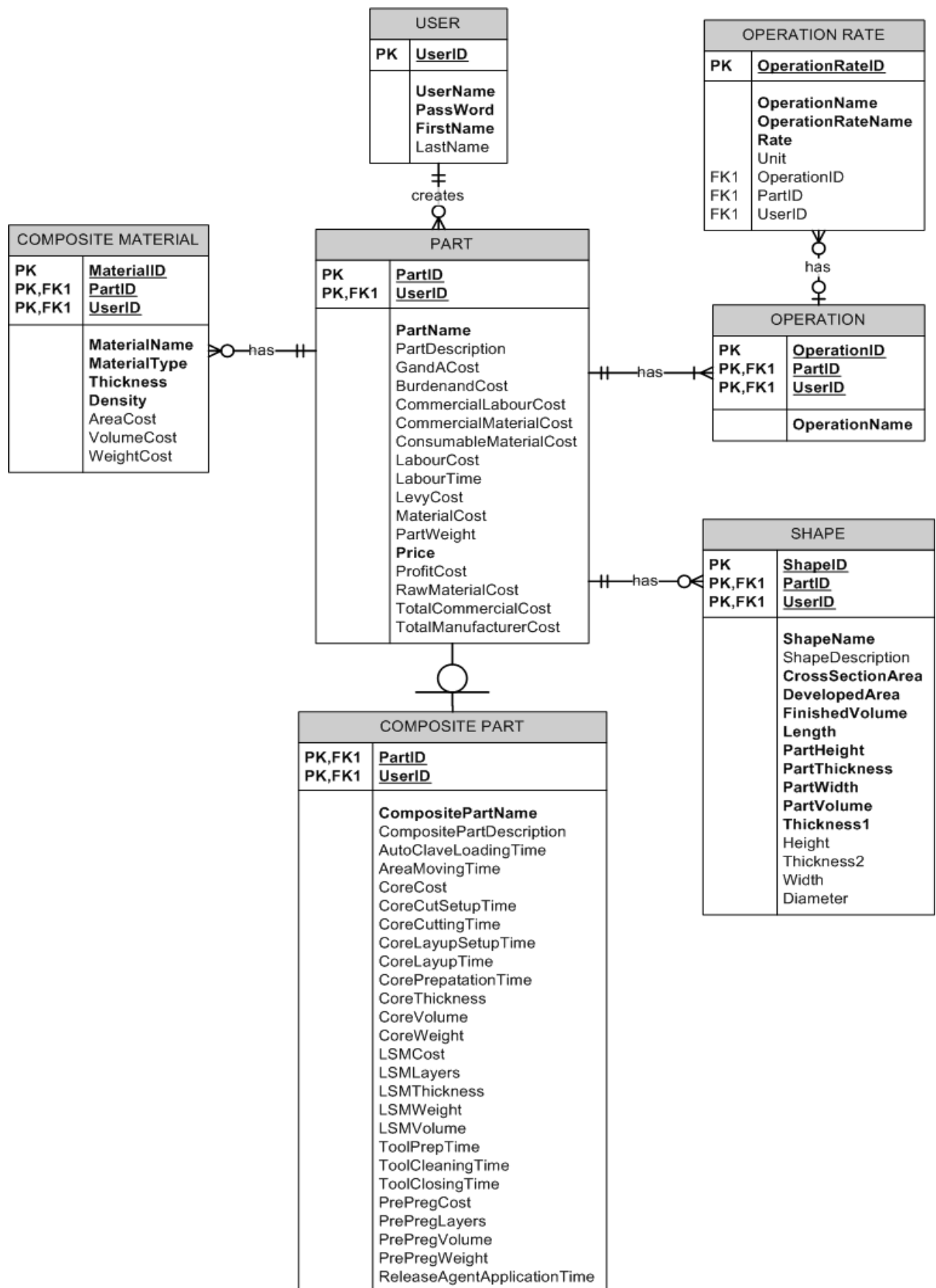


Figure 5.3 - Entity Relationship Diagram for Cost Model Database

5.5 Taxonomy for Bicycle Diagnosis Maintenance Support

After capturing and representing the knowledge required for the cost of a composite part, the next step is to carry out maintenance for that part. The product is the bicycle whilst the part could possibly be in form of a frame, headset, pedal-mounting, wheel, etc. The product bicycle is chosen because there are various challenges faced when it comes to bicycle repairs.

A different semantic technology is used to carry out failure analysis diagnosis for the bicycle parts. Figure 5.4 illustrates a taxonomy that demonstrates the domain classification of bicycle parts. Figure 5.4 demonstrates that the product bicycle has sub-products and the problem noise has sub categories of problems. The taxonomy represented in Figure 5.4 captures the maintenance focus that the implemented prototype will model.

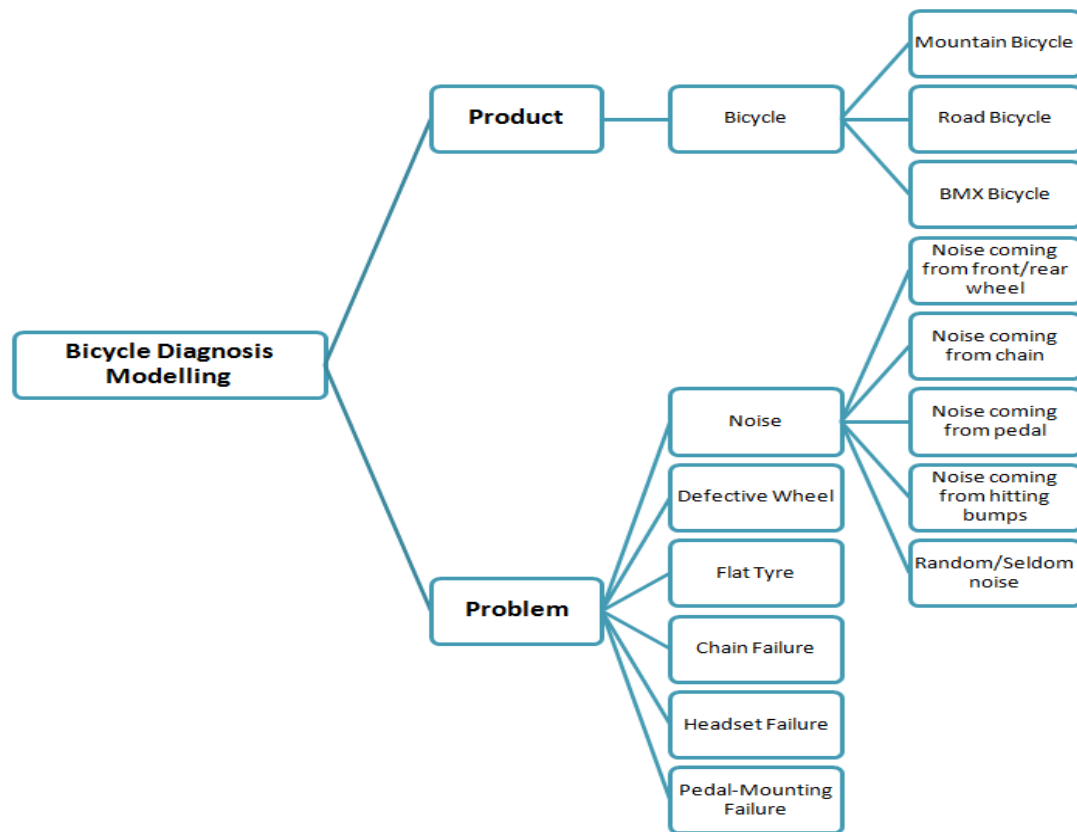


Figure 5.4 - Taxonomy of Bicycle Failure Analysis

5.6 UML Use Case Diagram

Use case diagrams are defined by the Unified Modelling Language (UML) and its main purpose is to depict the overall functionality supplied by the system in terms of “*actors*” which are considered as external entities and also their “*use cases*” which can be considered as the functionality of the semantic based intelligent advisory system.

Figure 5.5 illustrates the UML use case diagram for the bicycle maintenance support using SemanticGuide. The system has 2 types of actors which represents generalised concepts. The system engineers which consists of the knowledge manager and knowledge editor and the users of the system which consists of service technicians and call centre representatives. Figure 5.5 defines the interaction of each actor with the system. For example, the knowledge manager is solely responsible for creating a knowledge area which consists of a product and problem definition. The role of each actor is described in Figure 5.5. Although they are 2 types of actor ‘user’, they both have access to the same functionalities provided by SemanticGuide. The only difference is in the way in which the system is deployed which is further more illustrated in the system architecture of SemanticGuide (chapter 6).

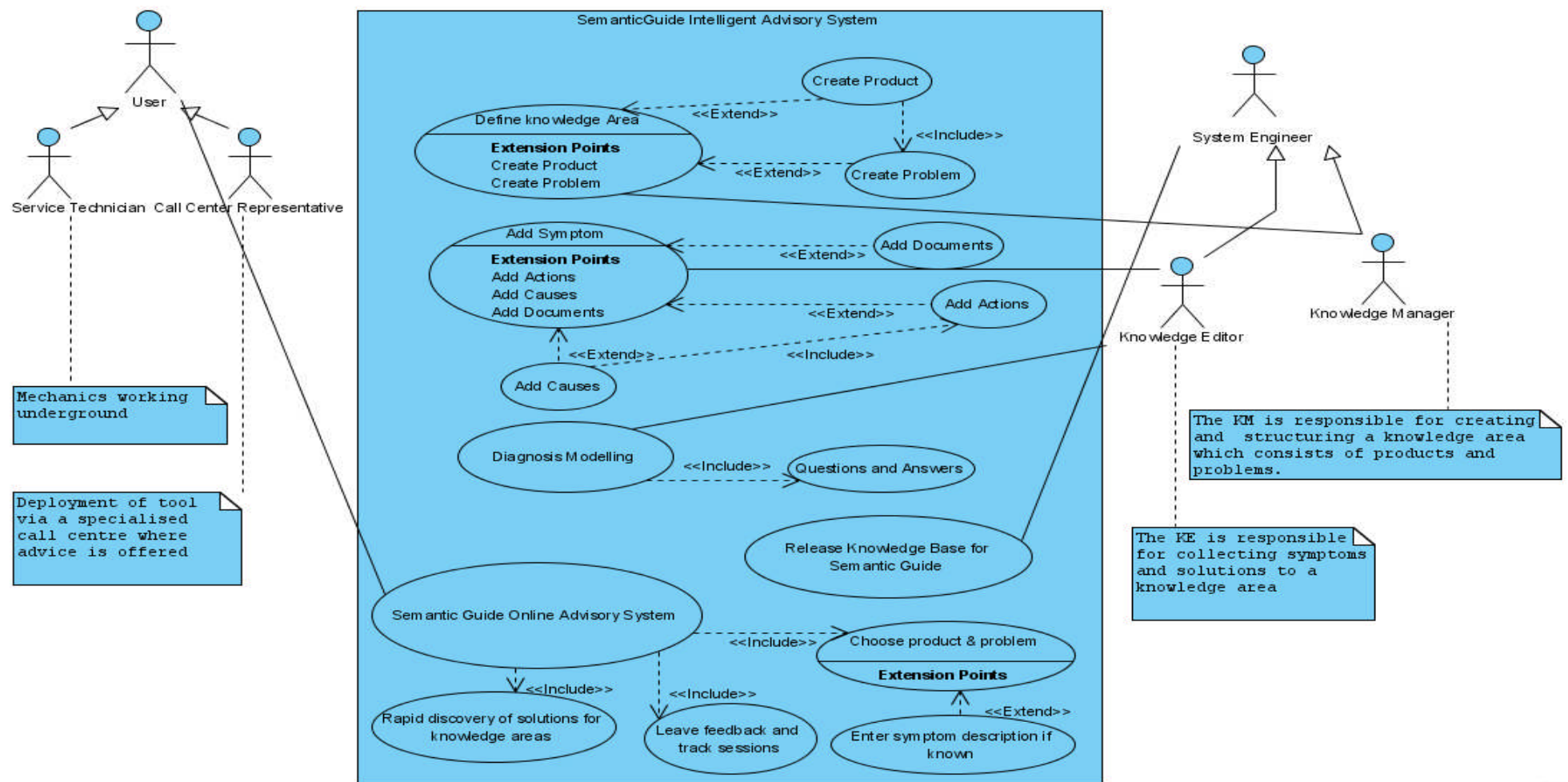


Figure 5.5 - UML Use Case Diagram for SemanticGuide

5.7 Diagnostic Logic Modelling for Bicycle Repair

Once the identification of users and system functionalities has been acquired through the UML use case diagram, the next step is then to extract knowledge from the validated “Barnett’s Manual” repair for bicycles and model that knowledge. Figure 5.6 illustrates symptoms for a knowledge area in the “Barnett’s Manual” that has been modelled using semantic technology. As illustrated in Figure 5.6, a symptom for a product has solutions which consist of causes and actions. Each symptom has a diagnostic modelling logic which includes questions and possible answers and this modelling logic will guide the user to the appropriate solution. The diagnostic modelling represents the rules for the knowledge base and it is always recommendable to construct a small outline of the answering process that will be modelled within the graphical diagnosis editor in SemanticGuide. 40 symptoms (see Appendix A) for different knowledge areas are to be developed for the prototype; however, one example is demonstrated in order to view how the diagnostic modelling process for a knowledge area is constructed and represented which is illustrated in Figure 5.6.

<i>Cause</i>	<i>Solution</i>
SYMPTOM: <i>When riding, one ankle feels as though the end of the pedal is rocking up and down, and/or it feels as though the surface of the pedal is rotating back and forth.</i>	
Pedal shaft is bent from a crash.	Remove pedal and inspect end of pedal shaft for oscillation when rotating. Replace if bad. If symptom persists when pedal shaft is good, crank arm is bent and should be replaced.
If pedal shaft is not bent, crank arm is bent.	Replace crank arm.
SYMPTOM: <i>A popping sound or sensation is experienced once per crank-revolution, often on the down-stroke of the right pedal.</i>	
Loose pedal-cage piece(s).	Check and secure pedal-cage piece(s).
Loose pedal mounting.	Check and secure pedal mounting.
Shoe cleat is moving on cage or in retention mechanism.	Check cleat wear and security.
Cleat-retention mechanism is loose.	Check and secure cleat-retention mechanism.
Loose crank arm.	Check and secure crank arm.
Loose chainring bolt(s).	Check and secure chainring-mounting bolt(s).
Loose bottom-bracket cups, lockrings, or retaining rings.	Check and secure bottom-bracket cups, lockrings, or retaining rings.
Bent chainring tooth.	Inspect and bend back.
SYMPTOM: <i>The pedal loosens up while riding</i>	
Pedal was improperly torqued.	Secure pedal to 300–360in-lbs.
SYMPTOM: <i>Looseness is felt in the pedal</i>	
Loose pedal mounting.	Check and secure pedal.
Loose cage-retention bolts or cleat-retention-mechanism bolts.	Check and secure cage-retention bolts or cleat-retention-mechanism bolts.
Loose bearing adjustment or loose bearing-unit retention.	See chapters 14 and 15.

Figure 5.6 - Symptoms and validated solutions for pedal-mounting knowledge area

As illustrated in Figure 5.7, the diagnostic logic for a symptom within product “bicycle” and problem “pedal-mounting failure” knowledge area is constructed. The questions and answers leads the user to an appropriate solution which then displays causes, actions, remarks and external documents to assist in the problem resolution. From question 1.2 in Figure 5.7, a different diagnostic logic branch is created which starts with asking the user if he/she is wearing a shoe cleat, followed by question 1.2.1 which asks the user if the shoe cleat is secured. The symptom for this knowledge area is “A popping sound or sensation is experienced once per crank-revolution, often on the down-stroke of the right pedal” which is extracted from the validated Barnett’s bicycle repair manual in Figure 5.6

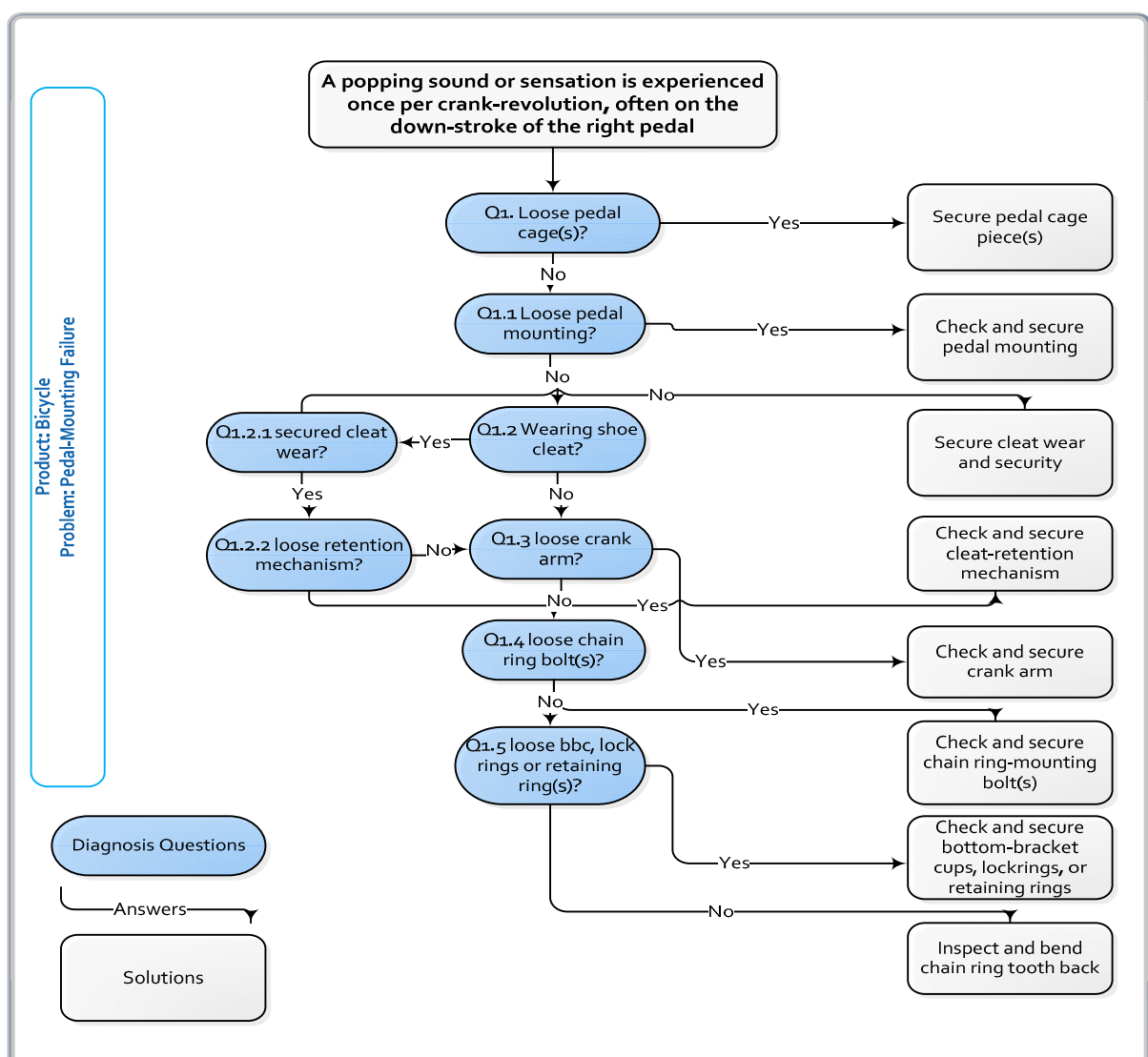


Figure 5.7 - Diagnostic modelling for the bicycle/pedal-mounting knowledge area

5.8 Chapter Summary

This chapter has highlighted various techniques used to capture and represent knowledge before developing both semantic based prototypes. The use of taxonomy to represent and classify various concepts within the cost model domain and bicycle maintenance support domain has proven to be an effective means of identifying, understanding and classifying concepts according to common characteristics. The UML class diagram has proven to be an effective knowledge representation technique seeing as this technique has defined attributes in each class and relationships between classes. Strong and weak relationships are also defined which highlights classes that depends on other classes for its survival. Classes such as “Operation Rate” cannot exist without class “Operation”. Also, classes such as “Part” and “Shape” are independent and can exist on their own. ERD are also essential diagrams and they have proven to be useful in defining tables and relationships amongst them for database modelling. This has strongly helped in structuring and defining the integrity of the database system.

UML use case diagram has also been effective in defining external entities and internal functionalities of the prototype for the intelligent advisory system. It is imperative to understand that the diagnostic modelling for the bicycle semantic based system is firstly constructed before being modelled within the knowledge base designer of Semantic Guide.

The knowledge representation techniques chosen were based upon their effectiveness and appropriateness of capturing the knowledge required. The next chapter introduces the development of the semantic based prototypes.

CHAPTER 6:

PROTOTYPE DEVELOPMENT AND VALIDATION

6.1 Introduction

In this chapter, step by step processes are documented in order to demonstrate how the semantic based prototypes have been developed. Prior to developing the prototypes, it is essential to design the system architecture in order to illustrate the principle and structure that governs the operations of the system. The steps taken to develop both the semantic based cost model and SemanticGuide advisory system for bicycle repairs are illustrated. A comparative study is carried out between the two developed systems in order to identify the similarities, differences and uniqueness of both semantic based prototypes.

6.2 Module 1: Cost Modelling

Figure 6.1 illustrates the system architecture for the semantic based cost model. As depicted in Figure 6.1, the existing excel cost model for a composite part is transformed into a semantic based platform known as OntoStudio which is developed by Ontoprise. OntoStudio is an engineering environment which uses ontologies and semantics to develop applications with particular emphasis on rule based modelling. OntoStudio uses the idea of **concepts** (domain model ontology), **rules** (operational model ontology) and **queries** to model a problem domain. Figure 6.1 also illustrates a connection between the SQL server (database storage) and the composite cost model developed in OntoStudio.

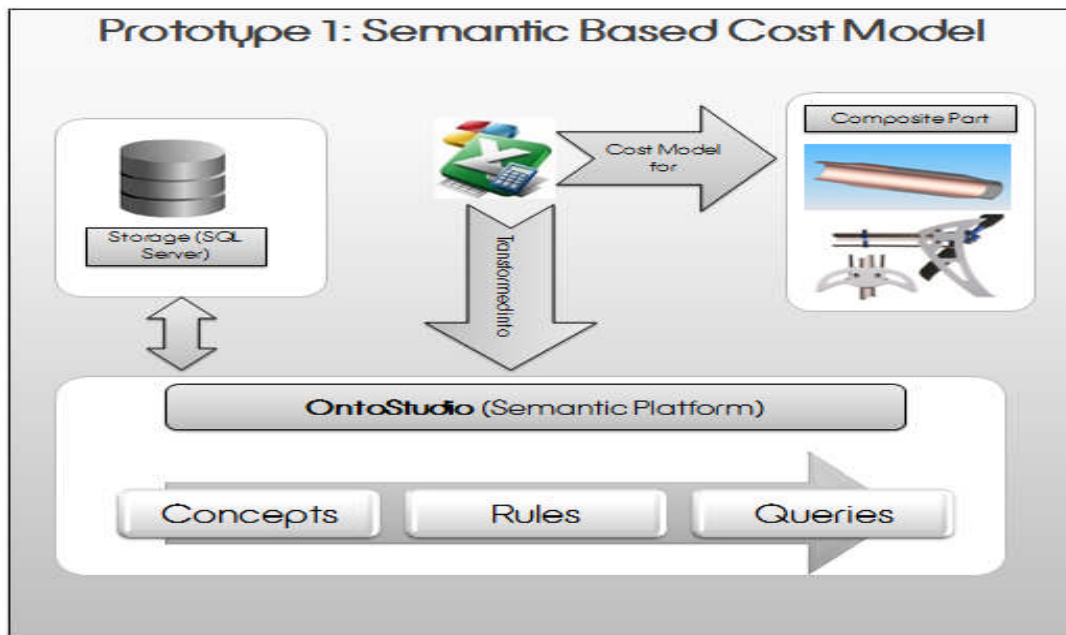


Figure 6.1 - Semantic based cost model system architecture

6.2.1 Concept Development

Figure 6.2 illustrates the OntoStudio engineering environment. This shows that multiple projects can be shared in one workspace. An office ontology was developed in order to become acquainted with use of this semantic technology. A bicycle ontology has been developed by TechModal. Figure 6.2 shows all these projects in one workspace and illustrates the development of concepts for the composite cost model. The concepts developed are based on the UML and taxonomical diagrams that were designed in **chapter 5: knowledge capture and representation** which are also based on the validated existing excel cost model developed by experts in TechModal.

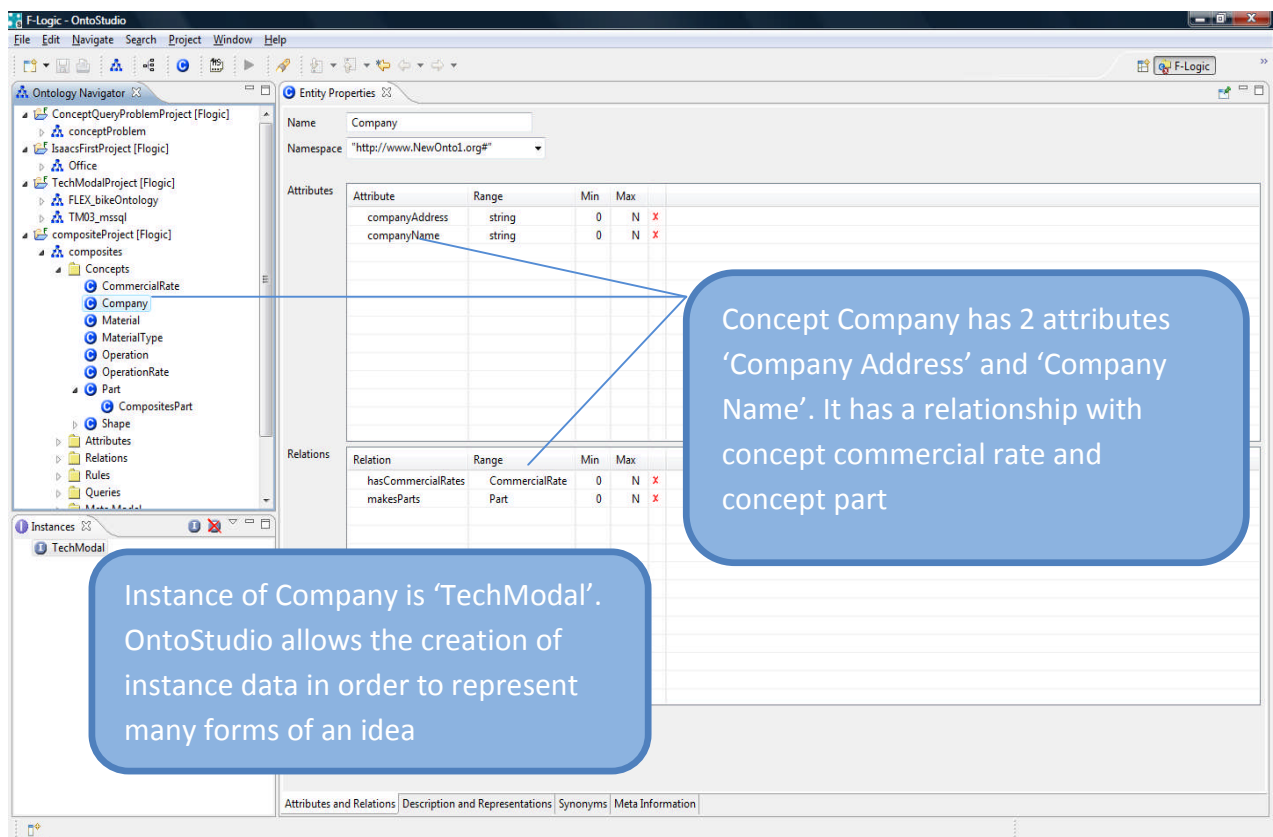


Figure 6.2 - Development of Concept Company

As illustrated in Figure 6.2, the first step is to create a concept, once a concept is created, attributes for the concept is added which consists of the attribute name and the attribute data type. Once that is created, the relationship between that concept with other concepts in the domain is defined. As illustrated in Figure 6.2, “hasCommercialRates” is the relationship name used to define a relationship between the concepts “Company” and “Commercial rate”. A minimum and maximum value can also be defined so it is possible to say that a company

has at least 2 minimum commercial rates and 5 maximum commercial rates. Figure 6.3 illustrates that data has been provided for the instance of concept “Company”. As illustrated, a name has been given to this instance and the relationship value has been defined.

Property	Value
companyName	TechModal Ltd
companyAddress	Null

Property	Value
hasCommercialRates	commercialRateLabourRate;commercialRateLevy;commercialRateG&A;commercialRateBurden;commercialRateProfit;
makesParts	TestPart;

Figure 6.3 - Data provided for instance of concept Company

Figure 6.4 – 6.12a illustrates the rest of the concepts within the domain which consists of attributes of the concepts, concepts relationship, and instance data. **Data has been provided to all instances of all concepts.** For the purpose of demonstration, only few will be illustrated. The important aspect of each concept definition has been annotated.

Attribute	Range	Min	Max
commercialRateName	string	0	N
commercialRateValue	number	0	N

Relation	Range	Min	Max
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Figure 6.4 - Development of concept “Commercial Rate”

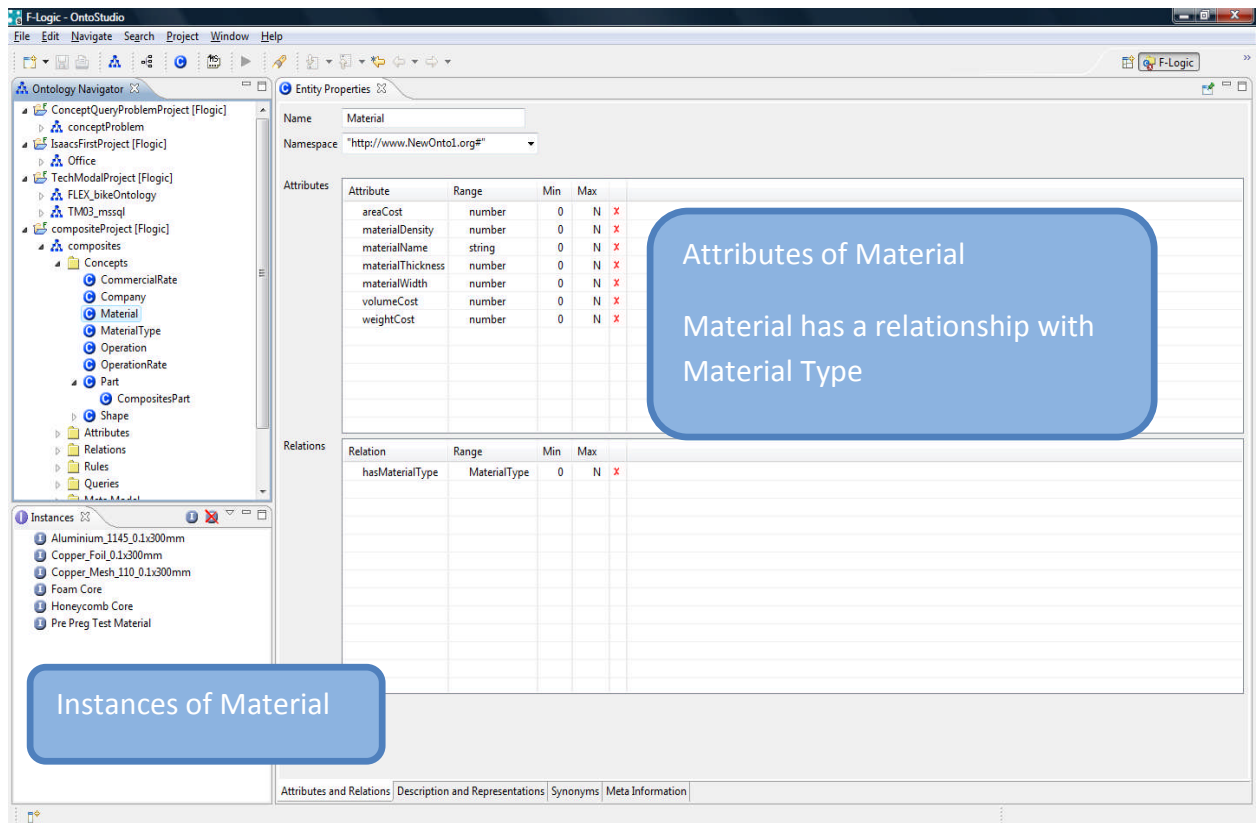


Figure 6.5 - Development of concept “Material”

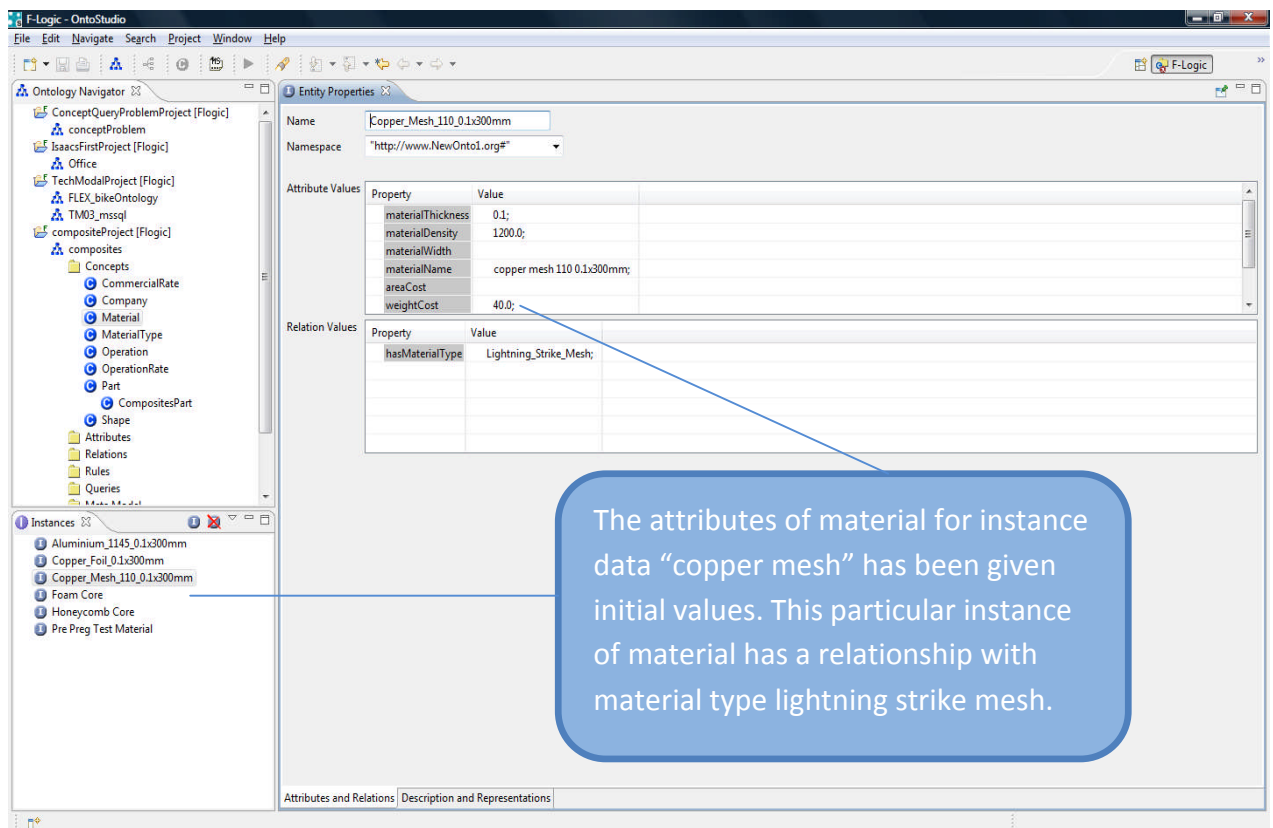


Figure 6.6 - Data provided for instance of concept “Material”

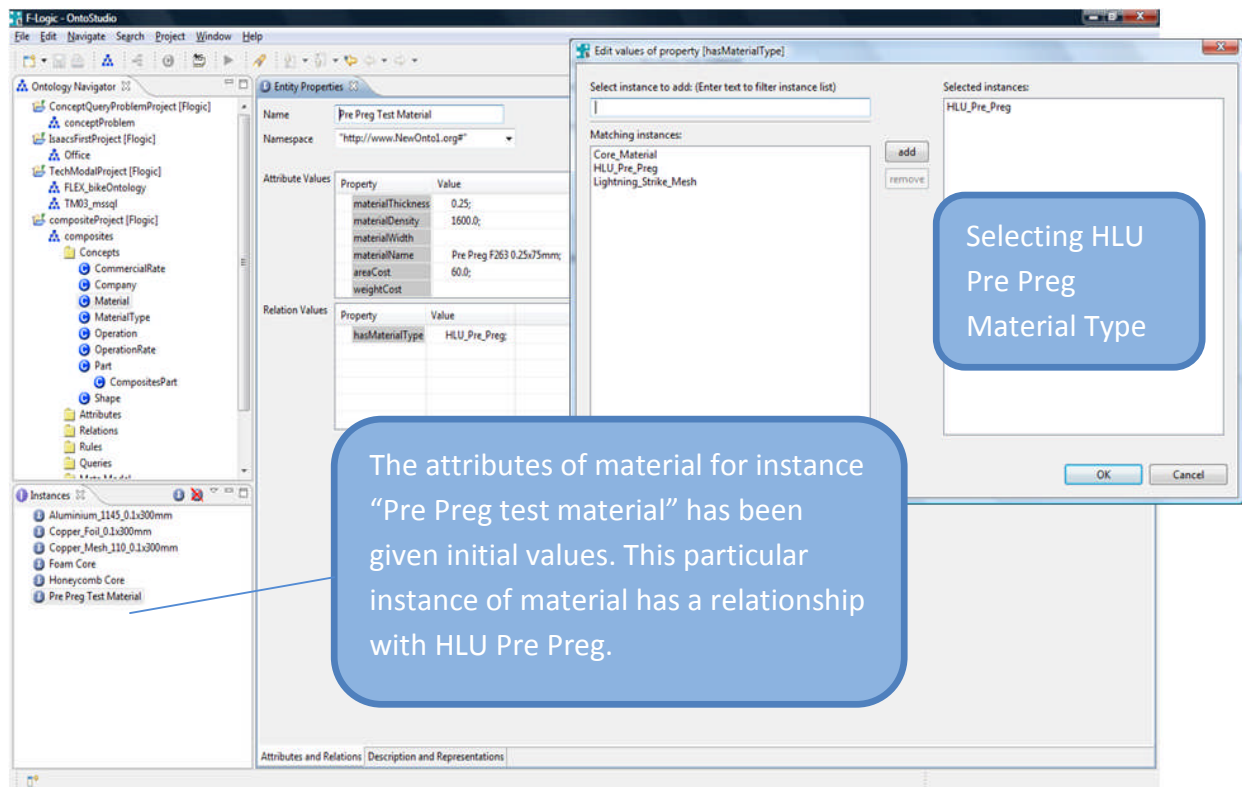


Figure 6.7 - Development of Pre Preg test material

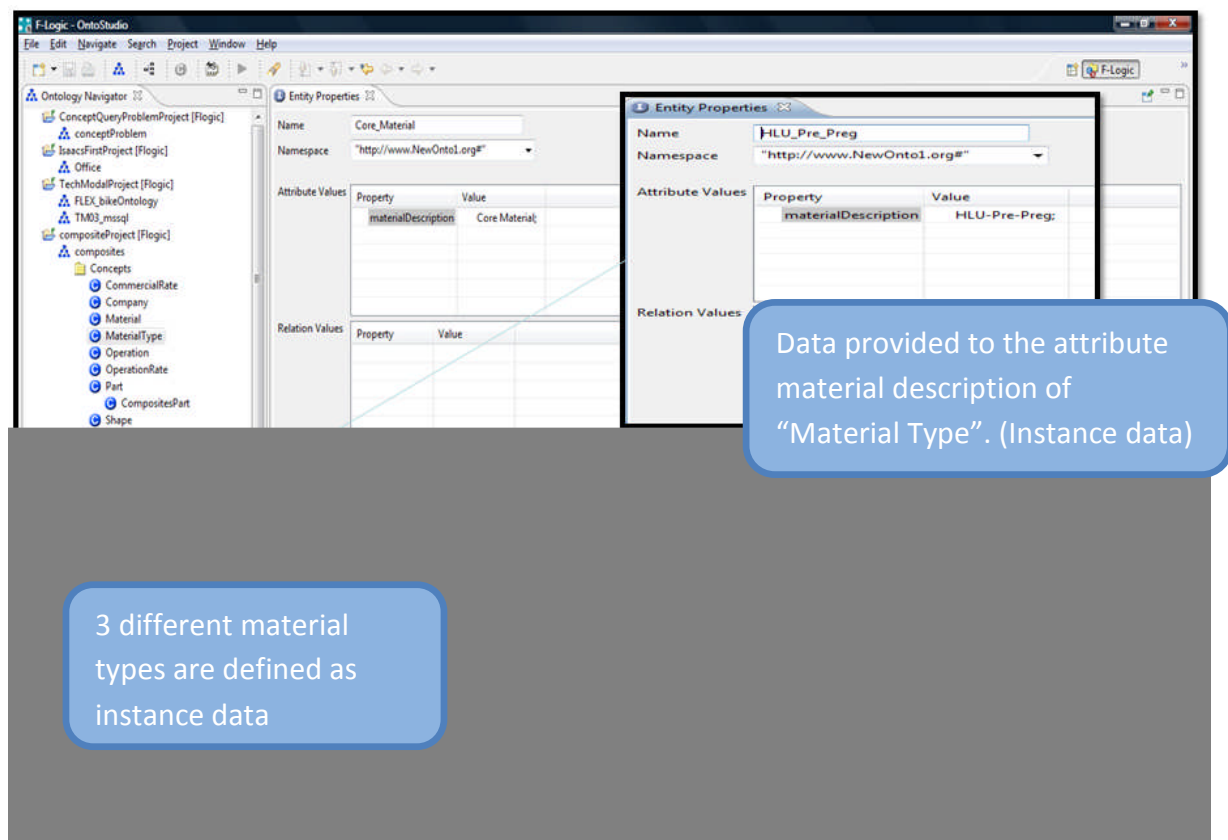


Figure 6.8 - Development of concept "Material Type"

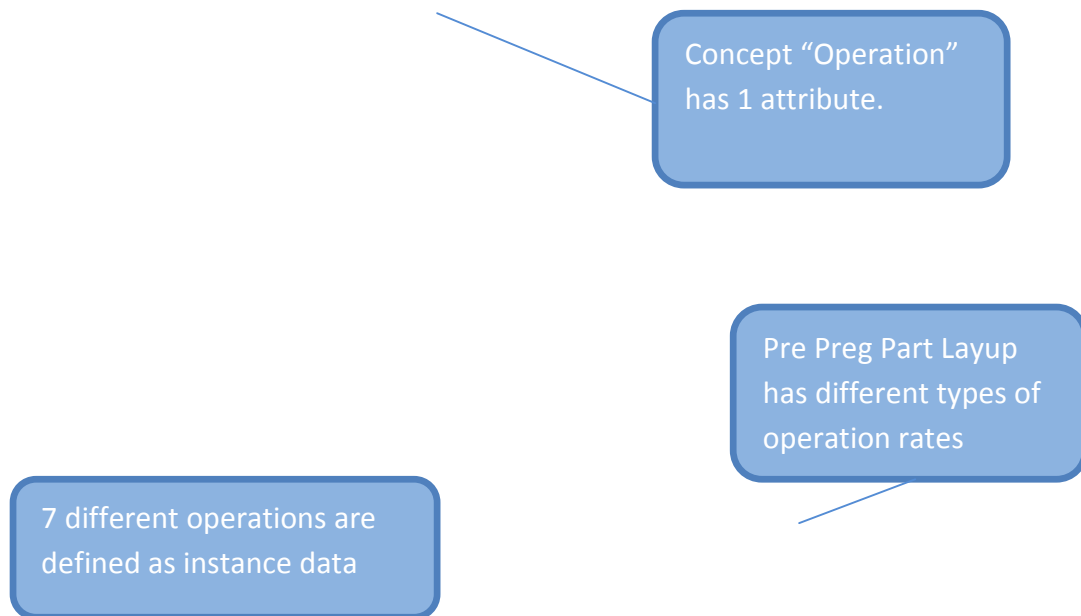


Figure 6.9 - Development of concept "Operation"

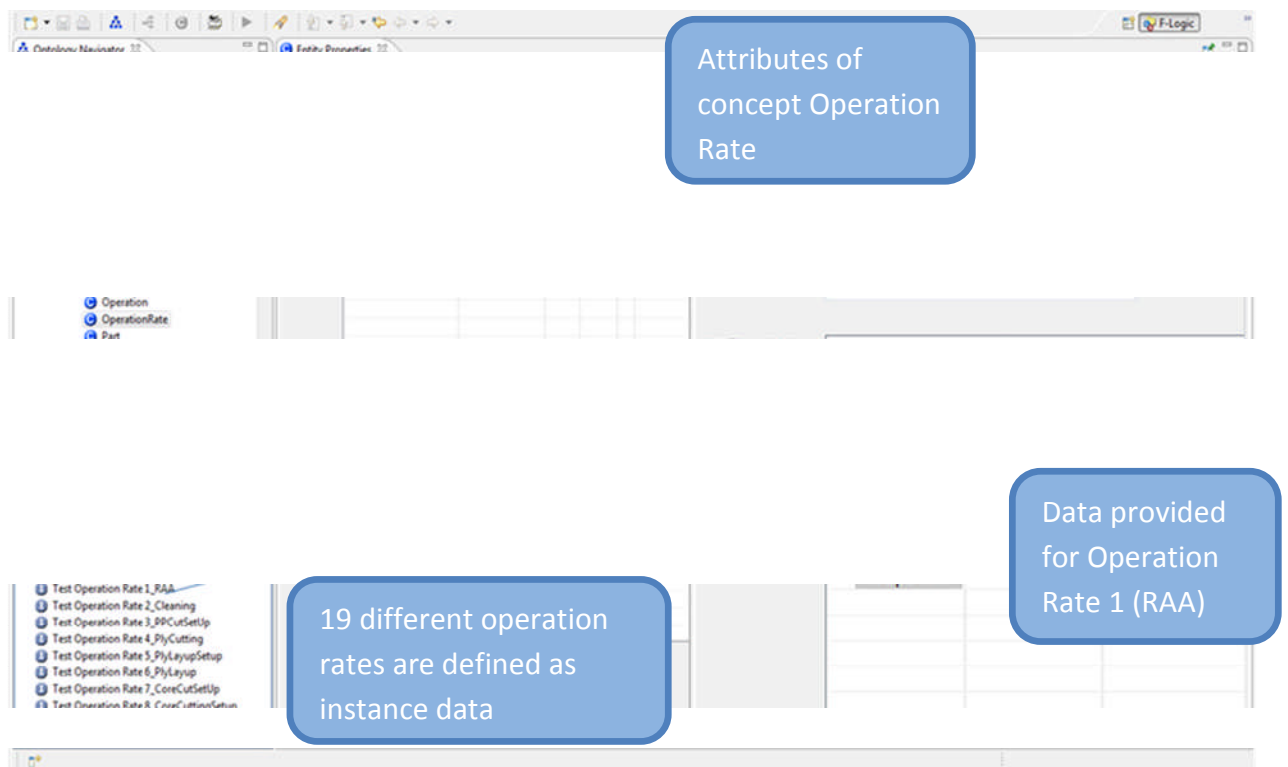


Figure 6.10 - Development of concept "Operation rate"

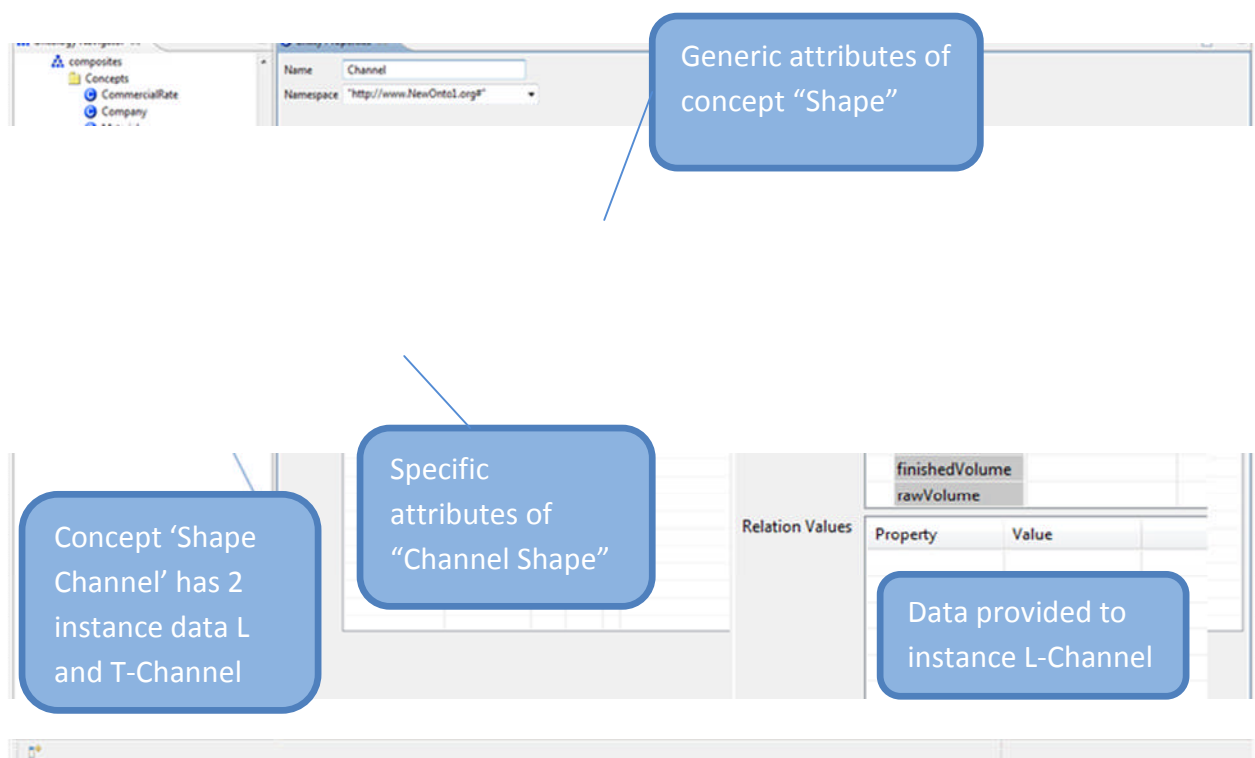


Figure 6.11 - Development of concept "Shape"

The concept "Part" is defined as a generic concept. It has attributes that has been captured from the excel cost model. A Part has a relationship with material, operation and shape as defined in this screen shot

Figure 6.12a - Development of concept "Part"

Figure 6.12b illustrates the ontology visualiser for concept part. The attributes and relationships of concept part are depicted graphically. This illustrates one of the features of OntoStudio.

Figure 6.12b – Ontology visualiser for concept part

Figure 6.13 illustrates the specialised concept of part named composite part. The attributes of composite part are also defined and composite part inherits the attributes and relations of its parent class part. Composite part has over 30 attributes because a composite part has a huge amount of manufacturing times associated with it due to its composite materials.

Figure 6.13 - Development of concept “Composite Part”

6.2.2 Rule Based Modelling for Cost Model

After developing the concepts within the domain, the next step is to model the knowledge base by declaring rules. The rule is a condition that governs a behaviour and it represents the internal functionality of the system. In OntoStudio, rules are graphically defined and mapped out which then produces the corresponding “F-Logic” syntax. F-Logic is a knowledge representation ontological language and has been chosen for its speed and accuracy. Predicates are used in OntoStudio to define a rule. Predicates have pre-defined functionalities. Functionalities such as dividing, multiplying, adding, average, etc are all embedded within predicates. The developer can also choose to develop his/her own predicates if knowledge on the “F-Logic” syntax is acquired. **90 – 100 rules** (see Appendix B) have been declared to represent commercial rates, costs, manufacturing times, material properties, part properties and shape dimensions for the composite cost model. Few of these rules are illustrated in order to demonstrate how these rules are implemented. Figure 6.14 illustrates the rule declaration to calculate the developed area for shape sleeve. The English representation for this rule is also defined.

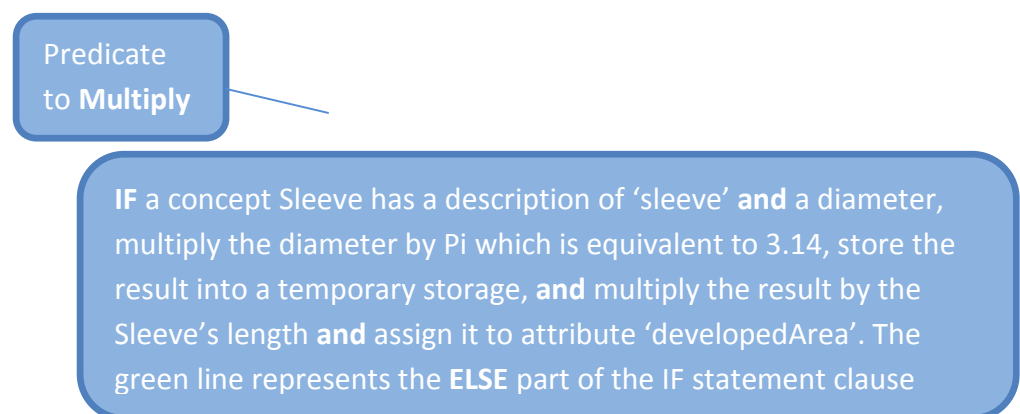


Figure 6.14 – Rule based modelling for shape sleeve 'developed area'

Figure 6.15a represents another rule declaration that calculates the part thickness of shape channel t-channel. As illustrated in Figure 6.15a, the **rule is triggered** if the shape channel

has a **description** of **t-channel**. Figure 6.15a illustrates the complexity of some rules. All rules are extracted from the validated excel cost model which is in appendix A. The excel equivalent of the rule part thickness for shape t-channel is also illustrated in Figure 6.15a.

Figure 6.15b illustrates the F-logic syntax for the rule defined. OntoStudio transforms the graphical modelled rule into F-logic which can then be edited. As illustrated in Figure 6.15b, functionalities such as “FORALL” and “AND” are used to represent the graphical modelled rule.

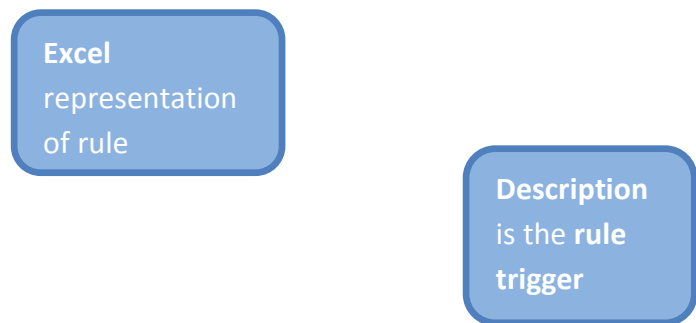


Figure 6.15a – Rule based modelling for shape channel ‘part thickness’

Figure 6.15b – F-Logic syntax for shape channel part thickness

Figure 6.16 illustrates another rule that calculates the Pre Preg layers of part properties. This particular rule demonstrates the idea of semantics in rule modelling. The English representation of this rule states that ***IF** a composite part has a **material** and the material has a **material type** and the material type has a **material description** of “**HLU Pre-Preg**” divide the **material thickness** by a **thousand**, store the result into a temporary location, divide the stored result by the “**Pre-Preg thickness**, store the result into another temporary location, add **0.49** to the result (in order to change it to a whole number) and then use a “**dround**” predicate to round the value to **0** decimal places, and finally assign the result to attribute **Pre Preg Layers** for concept composite part.*

Figure 6.16 – Rule based modelling for composite part Pre-Preg layers

Figure 6.17 illustrates a rule that models the release agent application manufacturing time for a composite part. The English representation states that ***IF** a composite part has an **operation** and an operation has an **operation rate** and an operation rate has an operation rate name of “**Release Agent Application**” and a composite part has a **shape** which has an attribute **developed area**, divide the developed area from the operation rate in order to get the result for “**Release Agent Application Time**”.* Figure 6.18 illustrates the rule based modelling for part profit cost in OntoStudio.

Figure 6.17 – Rule based modelling for composite part RAA manufacturing times

IF a company makes a part and has commercial rates and a commercial rate has a description of **profit**, divide the commercial rate value by 100 and multiply it by the total commercial cost and assign the result to attribute **profit cost** for concept **part**

Figure 6.18 – Rule based modelling for part profit cost

6.2.3 Query Development

90 – 100 rules for the composite cost model have been defined within the knowledge base; the next step is then to create a query in order to test the defined rules. A query is also a way of restricting a search by setting a search criterion for the results that are to be displayed. A query also tests the logic of the defined rules. Figure 6.19 illustrates the query created for the composite cost model. This shows that all of the attributes of the concepts within the domain can be accessed by concept part because concept part has a relationship with the main concepts within the domain.

Figure 6.19 – Creation of Query final for composite cost model

Figure 6.20 illustrates what happens when the query is executed. The query returns values for all the attributes checked in the query search restriction. The rules defined are fired once the query is executed. Figure 6.20 illustrates that the price for this particular composite part is **£867.55** which is based on the inputs entered in the instance data. The query returns the results in XML format which means a front end application (Flex) can then embed these results within a user interface. The scope of this particular project was to develop only the back end application with the use of semantics and ontologies. However, a small

demonstrator that illustrates how the system will work if it were connected to a front end application is demonstrated in Figure 6.22.



Selling Price for
Composite Cost
Model: £867.55

Figure 6.20 – Query final execution

One of the key features of OntoStudio is the capability to publish and deploy a generated query as a web service which allows the deployment of the functionality developed in OntoStudio onto the web. The tomcat web service is used to achieve this and OntoBroker acts as the **semantic middleware inference engine** which processes the ontologies. OntoBroker should be running in the back in order to access the generated query. Figure 6.21 demonstrates the publishing of a generated query. The WSDL file is created and is used by the front end developer to access data provided by OntoStudio.

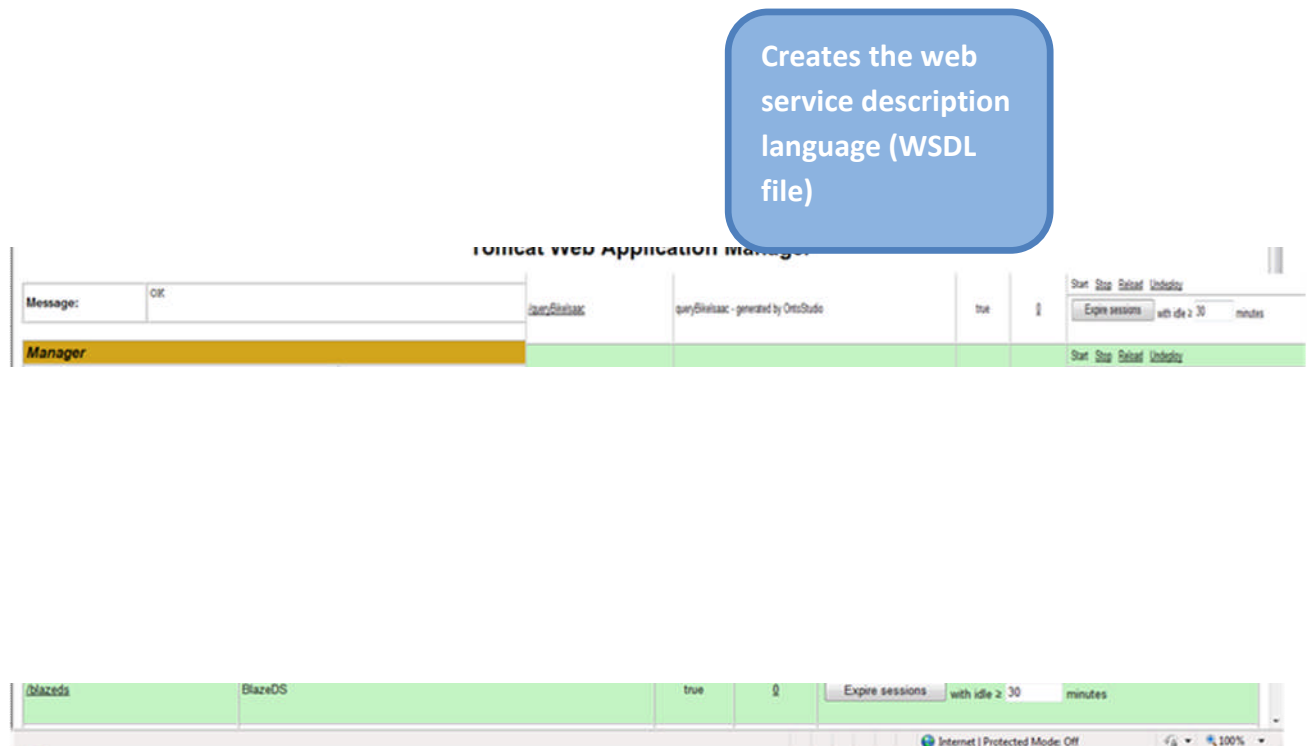


Figure 6.21 – Tomcat web application manager query publishing

Figure 6.22 illustrates a flex front end application that has been developed in order to capture user inputs for concept shape and produce the calculated dimensions for these inputs based on the rules declared in OntoStudio for shape dimensions.

Figure 6.22 – Front end flex application demonstrator for concept Shape

6.2.4 Database Development

In real world settings, a database will be connected to the OntoStudio environment in order to access and retrieve data. MS SQL Server 2005 is used as the platform for developing the database. The developed database is based on the ERD diagram designed in the knowledge capture and representation chapter. An integrated platform known as business intelligence (supported by Microsoft visual studio.net) has been used to automatically transform some of the spreadsheets within the existing excel cost model to tables within the database. Figure 6.23 illustrates the table for operation rates in MS SQL Server. The equivalent excel spread sheet has been illustrated in Figure 4.7 in the AS-IS Excel based model (chapter 4).

Figure 6.23 – Database table for operation rates

6.2.5 Semantic Integration

Once the database has been developed, the next step is to integrate the developed database with the OntoStudio platform. The database is imported into the OntoStudio environment and OntoStudio automatically creates an ontological representation of the database schema which is then mapped with the domain model ontology. The idea of semantic integration is to use

metadata to describe the meaning of data which is very similar to data mapping. However, semantic integration allows concepts in one system to be mapped to concepts in other systems. Integrating concepts means their attributes and relationships are also automatically integrated which emphasis the key aspect of inheritance. Figure 6.24 illustrates the importing of the database within the OntoStudio platform whilst Figure 6.25 illustrates semantic integration between the domain ontology (*ontology created in OntoStudio*) and the database schema ontology.

Figure 6.24 – Importing database schema to the OntoStudio environment

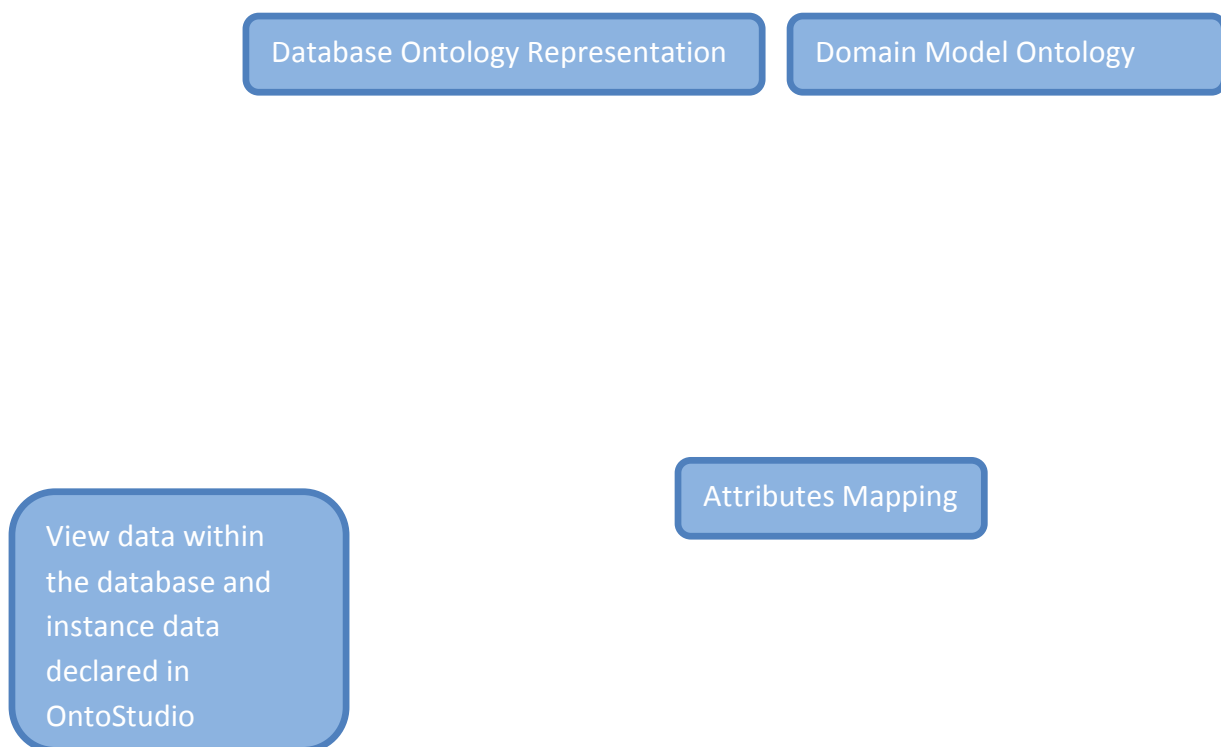


Figure 6.25 – Semantic integration of concepts

Figure 6.26 summarises the whole process. A query **invokes** the rule which means the query causes the defined rules to fire. The fired rule then **references** the domain model ontology developed in OntoStudio. The domain model ontology then **pulls out** the instances of the database schema from the ontology representation of database schema which is automatically defined in OntoStudio when the database is imported into the environment. Although the defined rules in OntoStudio are solely based on the concepts that exists within the domain model, the rules are also fired across the mapped database meaning when the query is executed, the results for instances within the database is also given as well as instances that has been defined in the OntoStudio platform. This process illustrates the advantage of semantics which will later be discussed in the last chapter of this thesis.

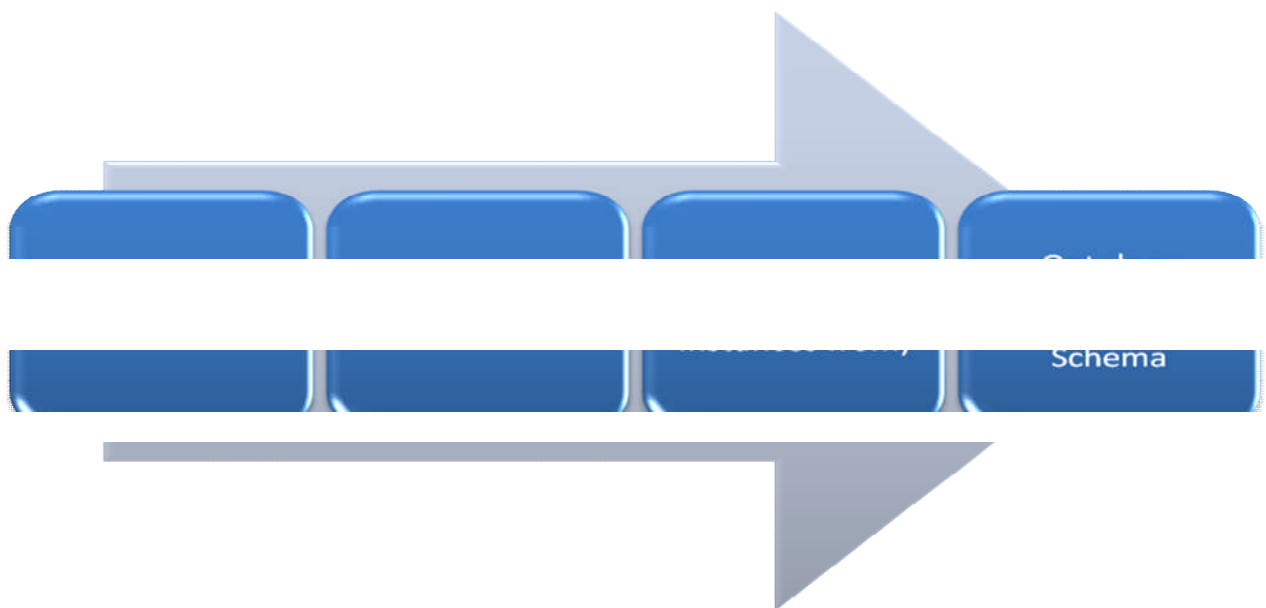


Figure 6.26 – OntoStudio Semantic Process

6.3 Module 2: Maintenance Support

After the successful development of the semantic based cost model for a composite part, the second semantic prototype is now implemented. This development is based on maintenance support for different bicycle parts. SemanticGuide is developed by Ontoprise and is known as an **ontology based intelligent advisory system** which allows for knowledge automation. Figure 6.27 illustrates the SemanticGuide system architecture. The system architecture illustrates that SemanticGuide has 2 types of system engineers which are known as the knowledge engineer and knowledge editor. The knowledge engineer is responsible for structuring and developing the architecture of the knowledge base whilst the knowledge editor is responsible for adding and editing knowledge within the knowledge base.

SemanticGuide can be deployed via a call centre version or a mobile version which is utilised by service technicians working underground in form of a PDA. One of the core features of SemanticGuide is **automated diagnosis** which allows sensors to be attached to the system in order to detect problems occurring. The automated diagnosis saves time and man power. SemanticGuide is also connected to various data sources such as oracle database for the knowledge base designer, Internet for web accessibility, etc. SemanticGuide is composed of 3 core features which are the **knowledge base** which consists of rules declaration, the **knowledge model** which consists of ontology for knowledge representation and **OntoBroker** which acts as the middleware inference engine.

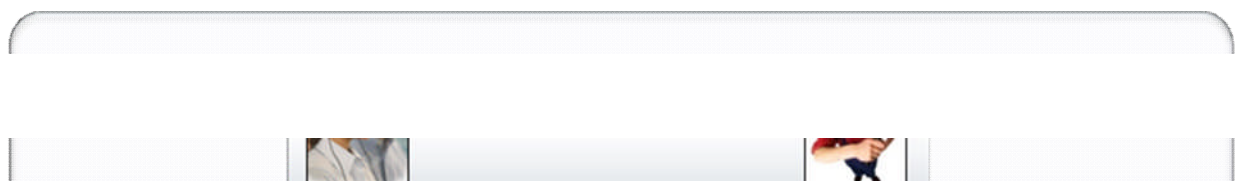


Figure 6.27 – Semantic Guide System Architecture

6.3.1 Semantic Guide Methodology

Figure 6.28 illustrates a methodology that captures the process of SemanticGuide. The 5 phases with key aspects for each phase required from the initial knowledge base design to the final SemanticGuide intelligent advisory online system is represented.

Figure 6.28 – Semantic Guide Methodology

6.3.2 Define Knowledge Area

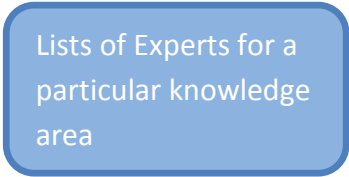
Figure 6.29 illustrates the menu of SemanticGuide. As illustrated, a secured login is required in order to have accessibility to the knowledge base designer. The knowledge base designer allows a system engineer to model the knowledge base by maintenance of diagnosis questions and answers. The diagnosis process for SemanticGuide can also be tested within the knowledge base.

Figure 6.29 – SemanticGuide Menu

Defining a knowledge area is the responsibility of the knowledge manager. As illustrated in Figure 6.30, a knowledge area consists of concept product and problem. The concept hierarchy is also defined seeing as there are different types of bicycle (road, mountain and BMX bicycles) and sub categories of problems can also be defined as illustrated in the bicycle taxonomy for SemanticGuide in chapter 5.

Figure 6.30 – Knowledge map overview for bicycle knowledge areas

Figure 6.31 illustrates a product bicycle and problem defective wheel specific knowledge area. Experts can also be included in a knowledge area as depicted in Figure 6.31.



Lists of Experts for a
particular knowledge
area

Figure 6.31 – Specific knowledge area for product bicycle and problem defective wheel

Figure 6.32 illustrates a different knowledge area that consists of a specific product BMX bicycle and problem headset failure. As shown in Figure 6.32, another expert has been included in the knowledge area and symptoms for this particular knowledge area can also be added.

Figure 6.32 – Specific knowledge area for BMX/headset failure

6.3.3 Add Symptoms and Solutions

Once the knowledge area has been defined, the next step is to add symptoms and solutions for the defined knowledge area. A symptom is a characteristic or indication of a problem. A symptom has solutions which consist of causes and actions. The status quo of the knowledge base states that **40 symptoms** have been included for the bicycle knowledge areas. Figure 6.33 illustrates that 23 symptoms has been included within the knowledge area **Bicycle/Defective Wheel**. The status of each symptom is also defined in Figure 6.33.

Figure 6.33 – key symptoms for bicycle/defective wheel

Figure 6.34 illustrates how the symptom status is defined within the knowledge base. Released symptom status means that the symptom has been released as on ontology within SemanticGuide and can be accessed by users.

Figure 6.34a – Define symptom status

Once a symptom has been defined for a knowledge area, the next step is to add solutions for that symptom which consists of causes, actions remarks and attachments as illustrated in Figure 6.34b.

Figure 6.34b – dimples/bulges solution for knowledge area Bicycle/Defective wheel

Figure 6.35 illustrates the adding of solutions to the knowledge area Bicycle/Noise for symptom noise coming from the front/rear wheel.

Figure 6.35 – Resolutions for knowledge area Bicycle/Defective wheel

Figure 6.36 illustrates the adding of solutions within the knowledge area Bicycle/Pedal-Mounting.



Figure 6.36 – Resolutions for knowledge area Bicycle/Pedal Mounting

6.3.4 Graphical Diagnosis Modelling

The GDE allows for the graphical representation of the diagnostic process modelling which adds clarity to an explanation and makes understanding easier. The GDE allows for the declaration of If/Else rule statements which represents the diagnostic logic for each symptom within a knowledge area. **40 symptoms** have been added within the knowledge base which means there are **40 diagnostic modelled processes**. Figure 6.37 illustrates the GDE for the knowledge area Bicycle/Noise. The solutions for this particular knowledge area are listed in Figure 6.35. It is essential to note that the solutions are recorded in **order of frequency**. This means the most common solution for a symptom occurrence within a knowledge area should firstly be recorded within the knowledge base.

Figure 6.37 – GDE for symptom within knowledge area Bicycle/Noise

Figure 6.38 illustrates the GDE for a symptom within the knowledge area Bicycle/Pedal-Mounting. The solutions for this knowledge area are listed in Figure 6.36.

Figure 6.38 – GDE for symptom within knowledge area Bicycle/Pedal-Mounting

Once the GDE for a symptom has been modelled, the logic can then be tested in order to validate if the system suggests the right solution based on the answers selected by the users. Figure 6.39 illustrates a key feature of the GDE.

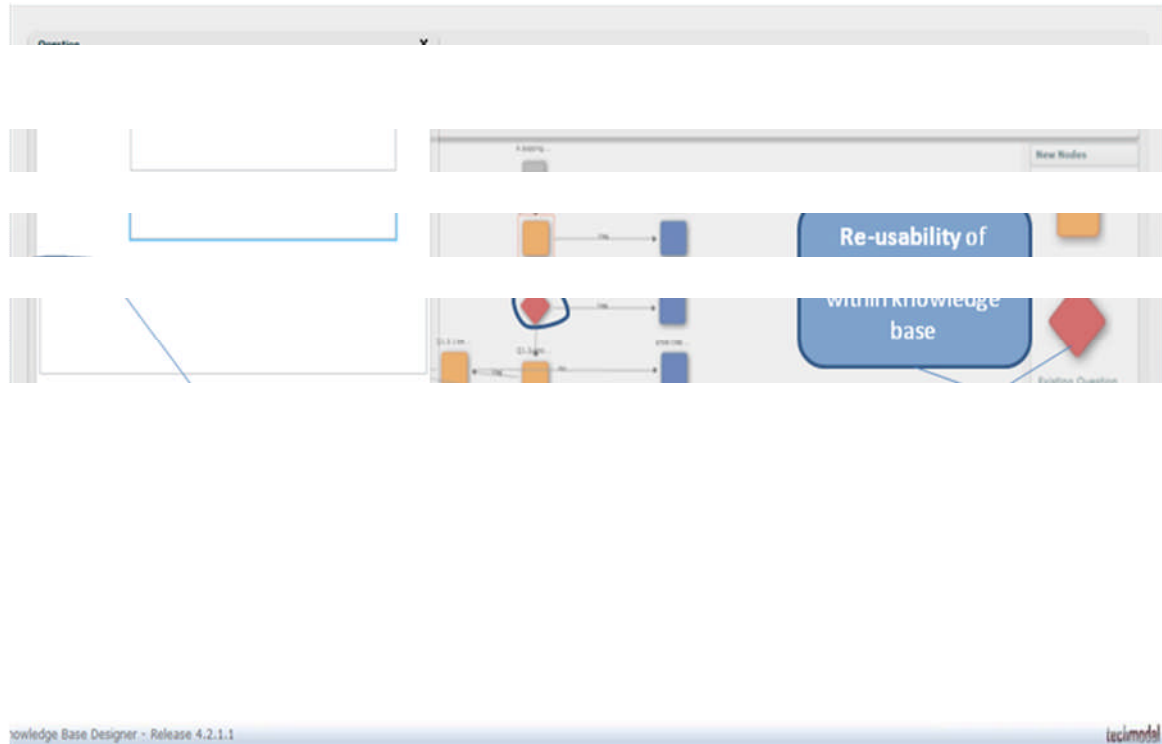


Figure 6.39 – Re-usability of questions

Figure 6.40 illustrates that the modelled diagnostic logic is automatically transformed into a tabular format once the developer returns to the knowledge base designer.

Figure 6.40 – Tabular format of diagnosis questions modelled in the GDE

Figure 6.41 illustrates a global solution pool whilst Figure 6.42 illustrates a global question pool which allows for re-usability of stored knowledge within the knowledge base

Figure 6.41 – Global solution pool

Figure 6.42 – Global question pool

Figure 6.43 illustrates an extra feature of SemanticGuide which allows the recording of synonyms within the knowledge base designer

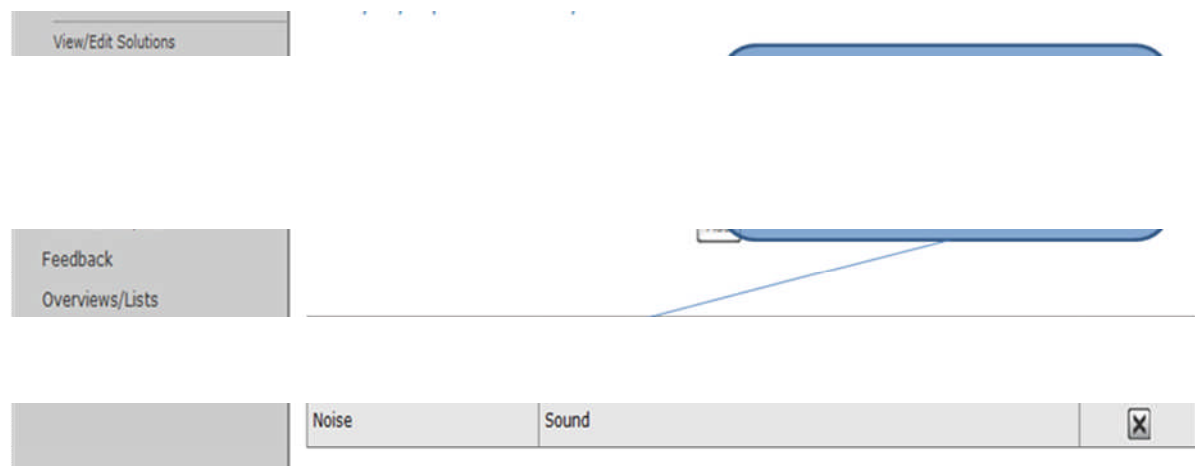


Figure 6.43 – Synonyms definition within the knowledge base designer

6.3.4.1 Key Aspects

Below is a list of key aspects for the SemanticGuide knowledge base designer:

- Define generic and specific knowledge areas which means problems can be resolved at lower levels of abstraction
- GDE allows for the graphical representation of the diagnostic process modelling which adds clarity to an explanation and makes understanding easier
- Attach documents to symptoms of a knowledge area which furthermore enhances problem resolution
- The use of a global solution and question pool allows for re-usability of diagnosis questions and answers which saves time and effort
- Defining synonyms makes it easier for users to get along within the knowledge base

6.3.5 Knowledge Base Export

Once the knowledge base has been developed and the diagnostic process has been modelled, the next step is then to release the knowledge base for SemanticGuide which is similar to publishing a query in OntoStudio as a web service. Figure 6.44a illustrates the SemanticGuide Administration menu.

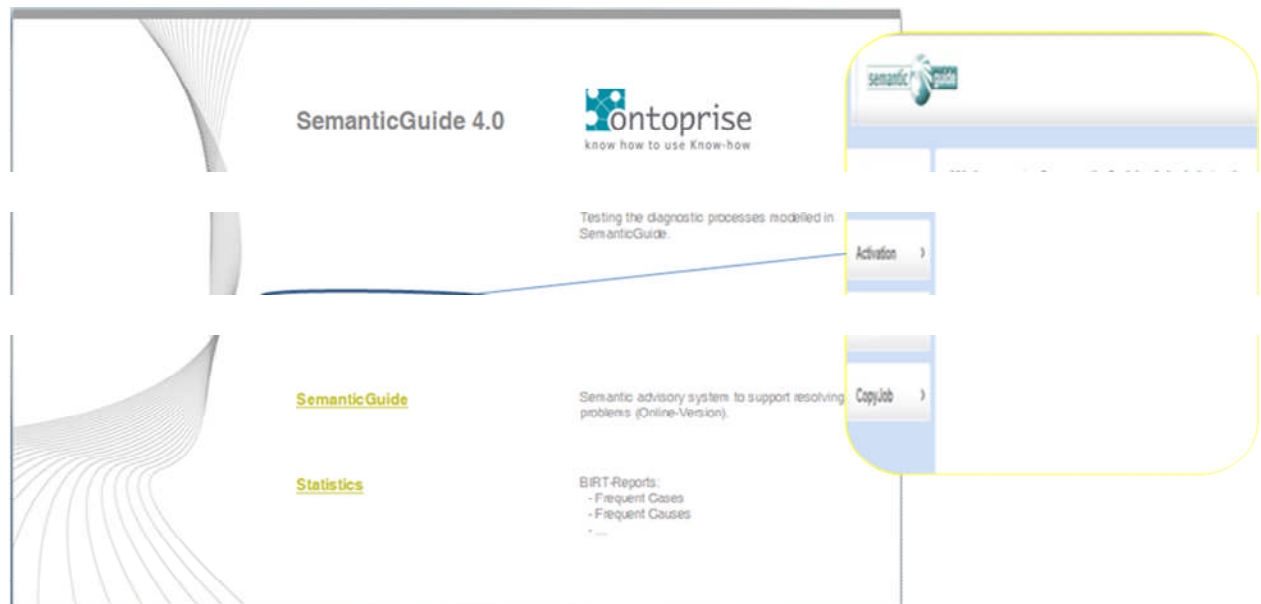


Figure 6.44a – SemanticGuide Administration

Figure 6.44b illustrates the 3 simple steps that is undertaken in order to release the knowledge base as an ontology for SemanticGuide.

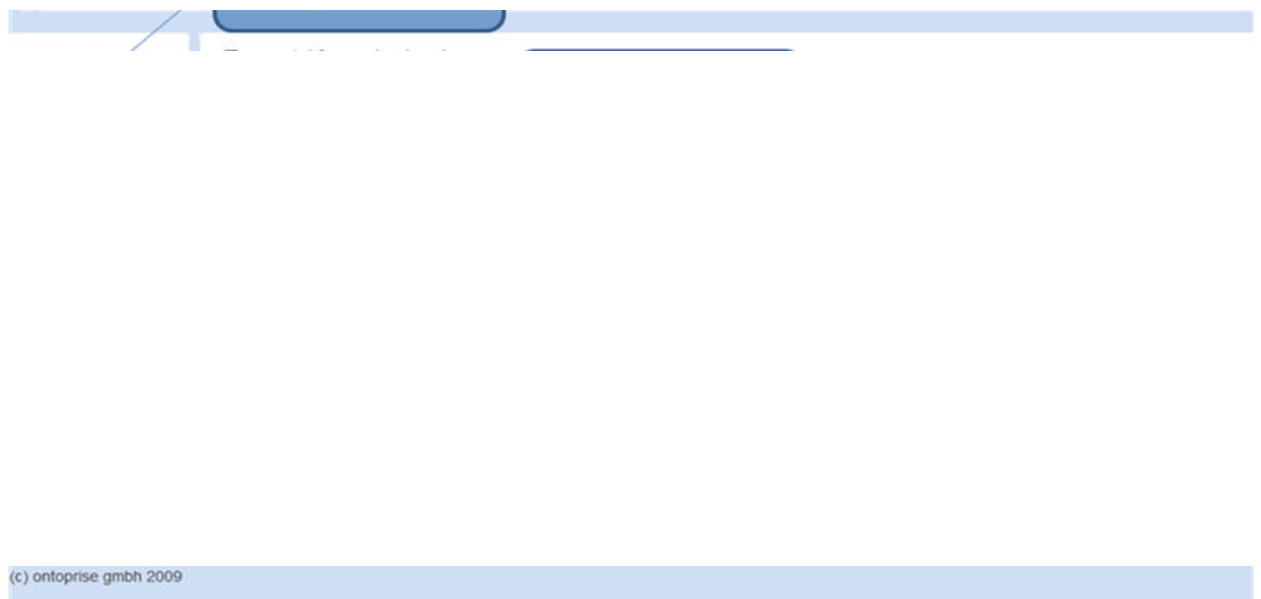


Figure 6.44b – SemanticGuide release mechanism

Below is a list of key aspects for SemanticGuide knowledge base export:

6.3.5.1 Key Aspects

- A simple 3 step process to deploy the knowledge base designer and release the problem resolution functionality to the rest of the world
- The knowledge base export process suggests that SemanticGuide can be deployed gradually which means it can mature with the platform
- The knowledge base export process automatically creates and sorts ontologies within the knowledge base for SemanticGuide to utilise
- The knowledge base export can be configured to also index files which are not in the KBD database which means users can search for external files in SemanticGuide which will furthermore enhance problem resolution

6.3.6 SemanticGuide Online Advisory System

Once the knowledge base has been exported as an ontology for SemanticGuide, the user can now interact and access the diagnosis process developed within the knowledge base designer. The modelled knowledge base is embedded within a user friendly interface offered by SemanticGuide. Figure 6.45 illustrates the SemanticGuide application.

Figure 6.45 – SemanticGuide Online Advisory System

SemanticGuide allows the user to select a product/problem and view the symptoms with solutions for the selected knowledge area. The user can also enter a symptom description if known in order to carry out a diagnosis to reach an appropriate solution. Figure 6.46a illustrates the symptoms for product bicycle and problem defective wheel.

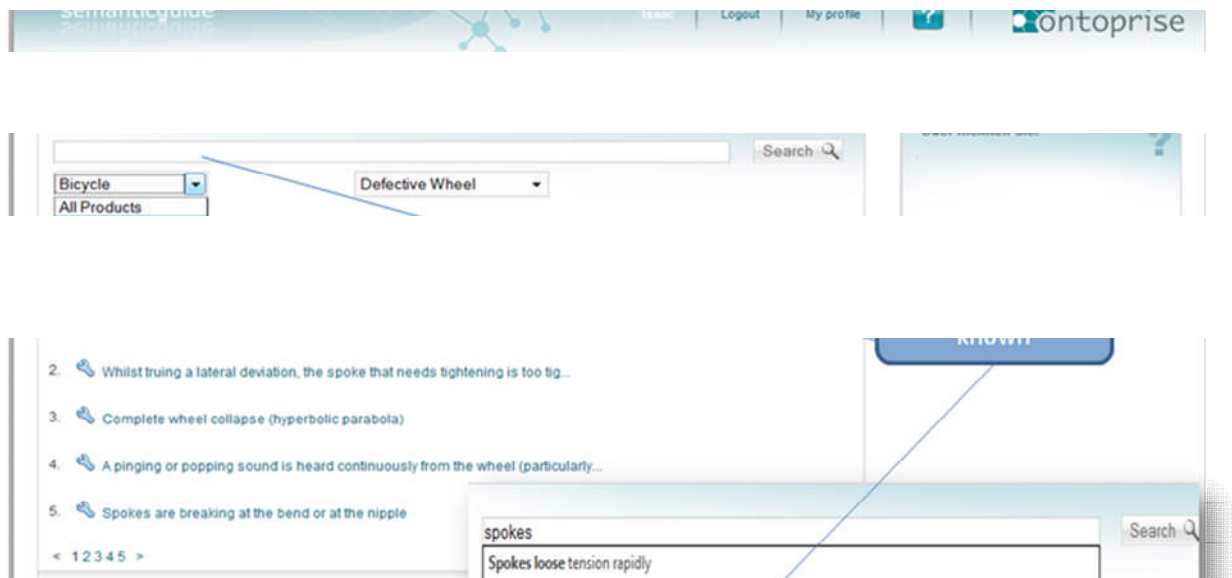


Figure 6.46a – SemanticGuide User Interface

Figure 6.46b illustrates an example of documents and solutions within SemanticGuide

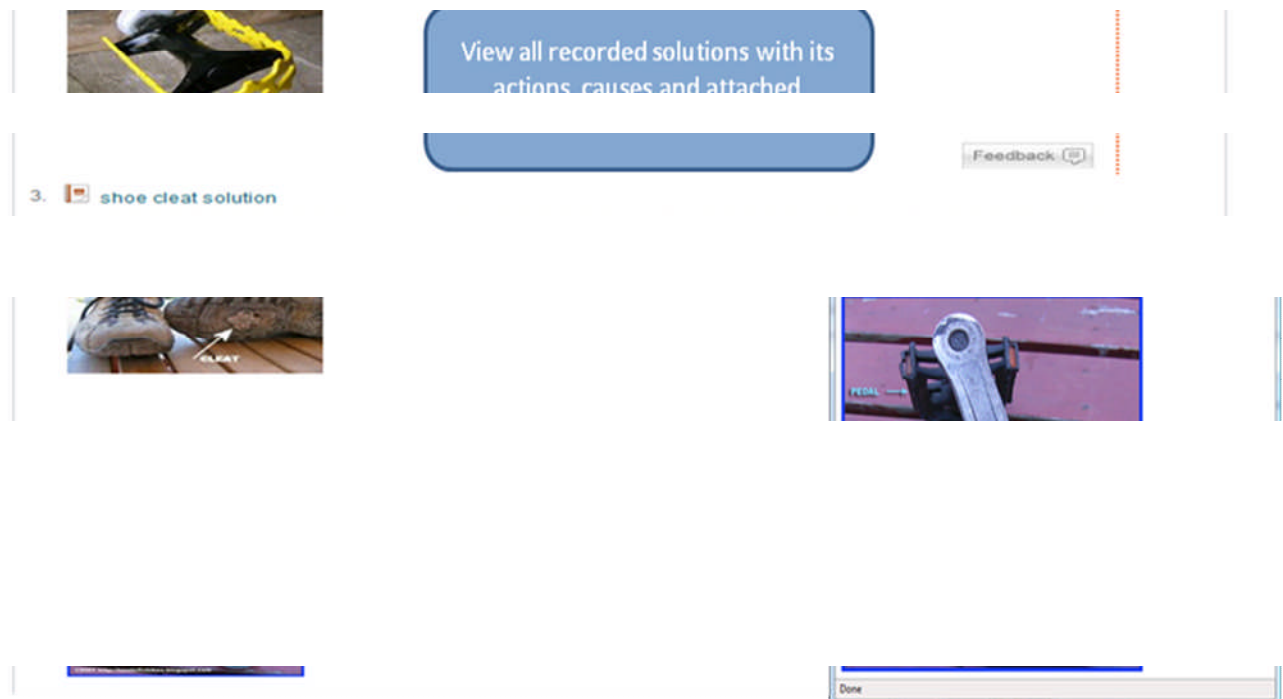


Figure 6.46b – Documents and solutions in SemanticGuide

Figure 6.47 illustrates an example of a diagnosis process in SemanticGuide.

Figure 6.47 – SemanticGuide Diagnosis Process

As illustrated in Figure 6.47, the user has selected the answer ‘No’ to the diagnosis question. Figure 6.48 illustrates what happens next.

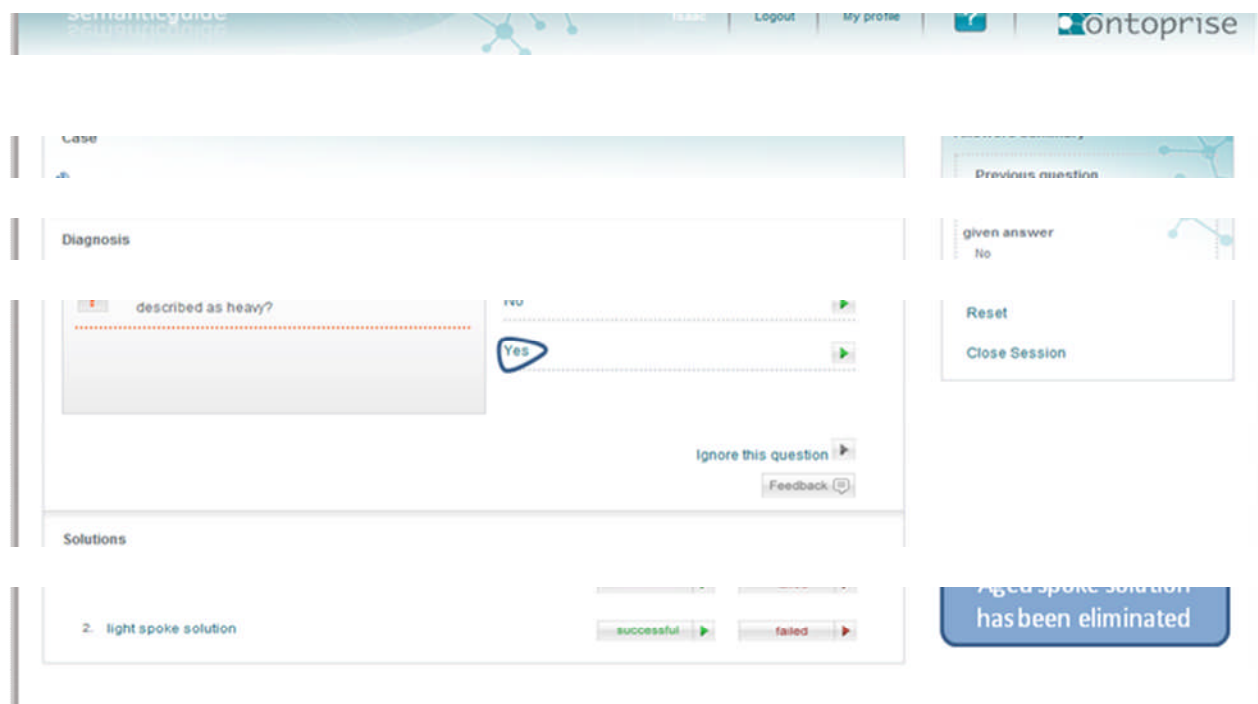


Figure 6.48 – Elimination of aged spoke solution

Figure 6.48 illustrates that the user has selected yes to this particular diagnosis question. Figure 6.49 then illustrates the appropriate solution.

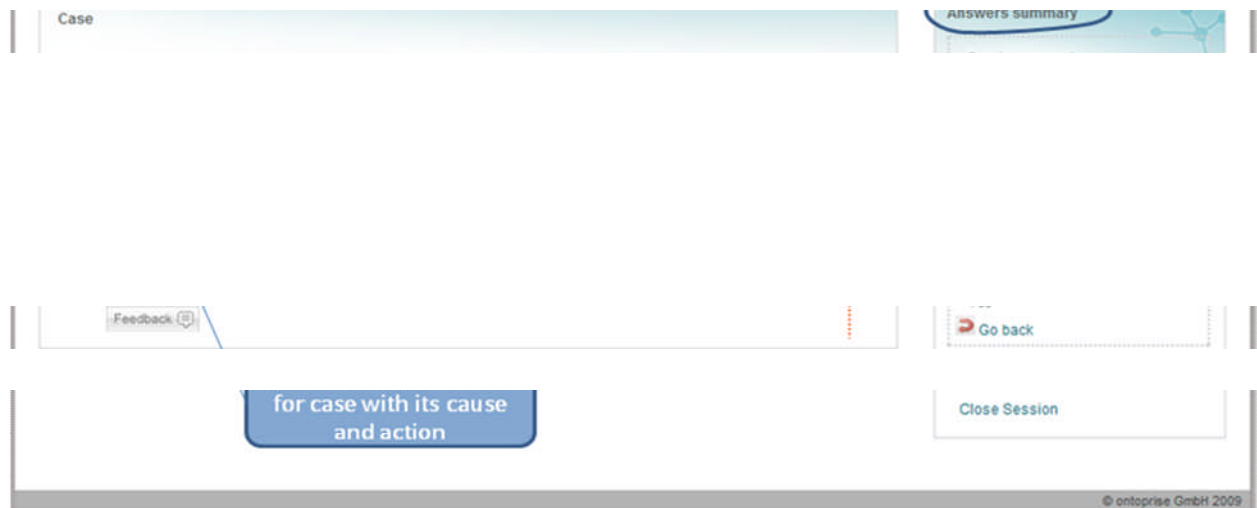


Figure 6.49 – SemanticGuide resolution for symptom

Once a solution has been offered by SemanticGuide, the user can select if the solution was successful or unsuccessful and leave feedback that will be transmitted to the knowledge base designer as illustrated in Figure 6.50 and Figure 6.51.

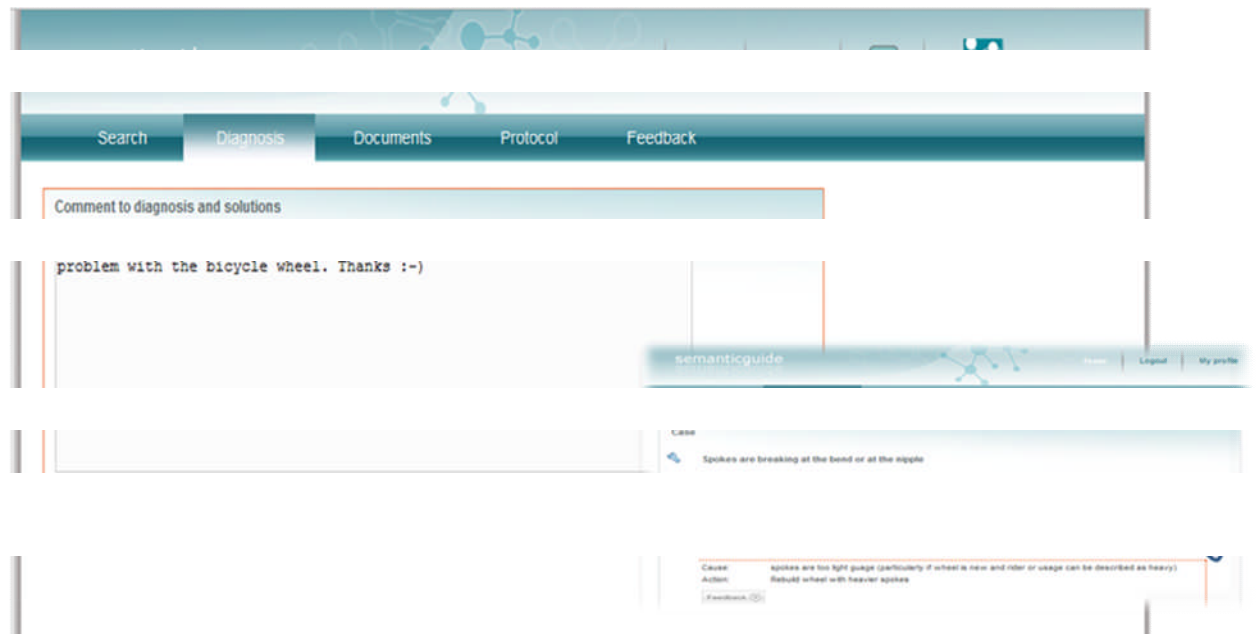


Figure 6.50 – SemanticGuide feedback to diagnosis and solutions

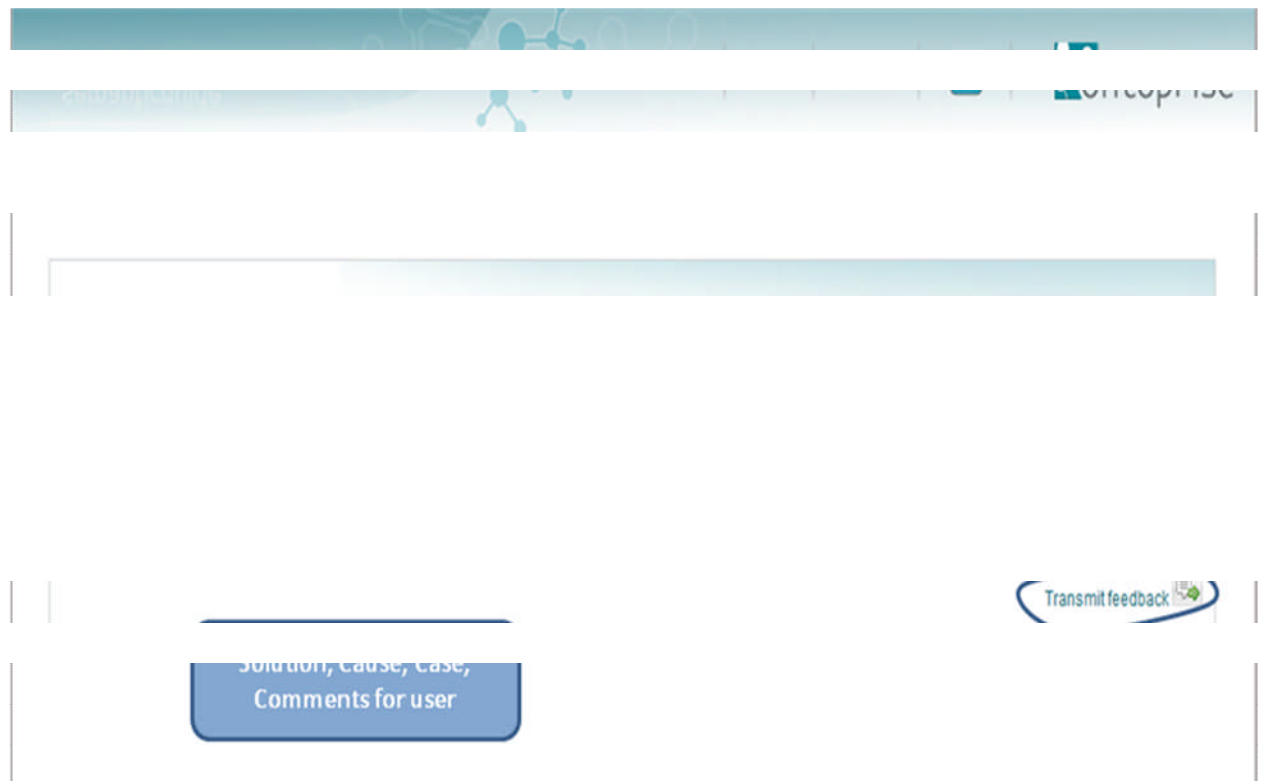


Figure 6.51 – SemanticGuide feedback transmission to knowledge base

Figure 6.52 demonstrates that users can track their previous sessions in SemanticGuide. This particular functionality is essential for the BIRT (Business Intelligence and Reporting Tools Analysis) although this thesis does not cover the implementation of this last stage of SemanticGuide due to time constraint and project scope.

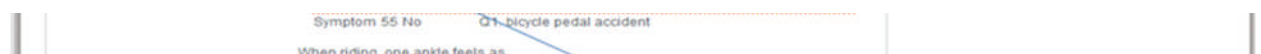


Figure 6.52 - Session tracking with SemanticGuide

6.3.6.1 Key Aspects

Below is a list of key aspects for SemanticGuide online advisory system:

- The diagnostic process logic guides the user to arrive at an appropriate solution
- The system incorporates a high level of user-friendliness
- The user can select solution failure/success rates which acts as input to the BIRT analysis
- The feedback mechanism allows users to transmit feedbacks into the knowledge base which strongly enhances the performance and improvement of the system and ensures that users views are recognised
- The protocol functionality allows users to view and track various cases SemanticGuide has resolved through service resolution

6.4 Comparative Study on Semantic Based Prototypes

Table 6.1 illustrates a comparative study which consists of the similarities, differences and uniqueness between OntoStudio and SemanticGuide platforms.

Table 6.1 – Similarities, Differences, Uniqueness: OntoStudio and SemanticGuide

Similarities	Differences	Uniqueness
Both of them possess a knowledge model which consists of concepts definition	OntoStudio is a back end application whilst SemanticGuide is considered as a front end application (user-interface)	OntoStudio has the capability to import data structures such as UML 2.0, OWL, etc
Both of them possess a knowledge base which consists of rules definition	SemanticGuide knowledge base is defined within the oracle database whilst OntoStudio defines its knowledge base within the OntoStudio environment	SemanticGuide can depict the systemic view of the overall system
Both of them has the capability to define relationships between concepts (ontology) in the knowledge model, However, it is done differently	SemanticGuide defines relationships in a tabular format, whilst OntoStudio defines relationship within the properties of the concept	SemanticGuide is far more user-friendly for the knowledge base developer and user
Both of them has a release mechanism for exporting the knowledge base	OntoStudio publishes the query as a web service, Semantic guide uses the admin interface	OntoStudio is more suitable for modelling that requires mathematical calculations
Both of them is connected to a database	OntoStudio uses MSSQL Server 2005, SemanticGuide uses	SemanticGuide is more suitable for maintenance support

	Oracle	repairs
Rules definition for both platforms are graphically defined and mapped out		OntoStudio concept and ontology definition could be viewed graphically
Both of them has the capability to define declarative rules		
Both technologies could utilise synonyms which is an imperative aspect for representing knowledge semantically		
Both of them could collaborate with the semantic middleware inference engine (OntoBroker)		
The defined rules for both technologies could be tested prior to releasing it.	OntoStudio uses a 'query' whilst SemanticGuide uses the 'decision tableau'	
Global pool to store knowledge	OntoStudio has a global pool for attributes, SemanticGuide has a global pool for questions and answers	In SemanticGuide the global pool of knowledge can be defined first
Both knowledge base can gradually mature with the platform		

6.5 Chapter Summary

This chapter has demonstrated the use of semantic based platforms to develop an Excel based cost model and implement maintenance support for equipment diagnosis. The core foundations of the developed semantic based prototypes are concepts definition, ontologies and rule declaration. The development of both prototypes has quantified and demonstrated the benefits of semantic technology. The ability to graphically define rules and define relationships between concepts is imperative in the maintenance and management of knowledge. The developed prototypes have demonstrated that using a semantic based approach for knowledge management enhances the re-usability and flexibility of knowledge. The last chapter identifies key discussion and conclusion points. Various arguments are identified in order to demonstrate the extent of the work carried out.

CHAPTER 7:

DISCUSSIONS AND CONCLUSIONS

7.1 Introduction

The need for developing a more efficient and effective means of managing knowledge was established in the literature review. There is lack of ‘linguistics’ within the way computer systems communicate and companies are beginning to realise the importance of ‘semantics’ within IT systems. For this purpose, the research project focused on identifying and developing prototypes that adopts the use of semantic technology for knowledge management purposes. The semantic based prototypes involved the transformation of an existing excel based cost model into a semantic based application and a manual repair for bicycle diagnosis into a semantic based maintenance support application.

This last chapter gives an in-depth discussion and conclusion on the outcomes of this research project. Firstly, a summary of the key aspects of semantic technology is listed in order to identify the benefits of semantic technology. Thereafter, a critique of the adopted methodology is described in order to identify its strengths and weaknesses. The research results are also discussed which is followed by the application of the use of semantics within other context. The research limitation which is mainly due to time constraints are discussed, followed by the contribution to knowledge which is an important aspect of this thesis. Subsequently, the research conclusions are established which reminds and justifies the key objectives of this research project. Finally, future proposals that highlight further research opportunities within the field of semantics are proposed.

7.2 Summary of the key findings (Benefits of Semantic Technology)

The result of this research project has discovered important aspects on the use of semantic technology for the management and maintenance of knowledge. The key findings that the outcome of this research project as identified are as follows:

Re-usability, Maintainability – These are some of the core benefits of using semantic technology. The re-usability of concepts, ontologies and rules are an imperative factor in use of semantic technology. In order to illustrate this point further, the semantic based cost model was developed for a composite part. Concepts have been defined in a generalisation/specialisation hierarchy. This means if a semantic based cost model for a metallic part was to be developed, Instead of re-creating the shape, material, material type ontologies for the metallic project, one could re-invent the wheel and import the pre-defined ontologies within the composites model into the metallic project which means it is easy to re-use concepts, ontologies and rules for other projects. In comparison to the excel cost model, re-usability of knowledge is difficult to adopt. The use of ontologies enhances knowledge maintainability because ontologies model a specific domain in a generic manner. Therefore, semantic technology definitely reinforces the re-usability and maintainability of knowledge.

Flexibility – Semantic technology is also easily adaptable. The ability to adapt rules and ontologies using OntoStudio and SemanticGuide offers high flexibility. This flexibility offers the capability to **split rules and data**. Using the excel application to develop a model, the rules and data are combined which makes it a monotonous and difficult process in differentiating between rules and data. However, using semantic technology (OntoStudio and SemanticGuide), one can have the rules separate and create instance data to test those rules. The data can always be brought in at a later stage during the implementation phase. However, with an Excel based tool, data and rules needs to be implemented in parallel.

Dynamic – The developed semantic based prototypes also proved that semantic technology is dynamic in nature. It adapts and changes over time. The functionalities within OntoStudio and SemanticGuide can be deployed gradually which means that it can **mature with the platform**. Whereas, the excel cost model is static in nature. Static in terms of it is inactive once developed.

Ownership - There is also this idea about ownership. Ownership is essential because it gives the owner control and access over the developed properties. OntoStudio allows for ownership of the system because although the front end is published over the web and made accessible to the world, the integrity of the system is maintained within the backend application which is not accessible by others. The system can also incorporate password accessibility. The benefit of this functionality is the idea to lock rules and maintain the consistency of the declared rule in order to establish an assurance that the rules will not be accidentally or maliciously altered or destroyed except by the knowledge engineer. SemanticGuide for maintenance support also establishes a sense of ownership because in order to access the knowledge base which consists of the diagnosis process and logic, a password authentication is required.

Instantiation – Semantic technology also allows for instance data which is one of the core features of object oriented programming. Instance data is described as an object of a particular class. The instance data created within OntoStudio is used to represent the implementation of the object being executed. Instance data allows for the representation of the several parts of the entity which reinforces data accuracy and maintains the independence of each dimensions of a concept.

Declarative rules – Semantic technology allows for declarative rules which are rules that can adapt to change of data rather than the traditional procedural rules. This means that rules can be defined without data availability and once the data is available, the rule automatically fires which is not the case for the Excel based cost model.

User-Friendly – The usability and friendliness of semantic technology is one of its core benefits. The ability to define functionalities/rules graphically makes function understanding and editing easier than in conventional programming where syntax is composed in order to implement a function. One of the biggest disadvantages of Excel based cost models is its complexity. However, the use of semantic technology rectifies this problem and offers a better approach for modelling costs and for carrying out maintenance support for equipments.

Easy Integration – The use of Semantic technology allows for easy integration with other platforms. An example is the ease of importing a database into the OntoStudio platform and the use of ‘semantic integration’ to map out concepts and attributes of the domain model ontology and the database schema ontology representation.

7.3 Discussion

7.3.1 Discussion of Adopted Methodology

The adopted research methodology for the project can be considered as appropriate because it aided in accomplishing the overall aim and objectives of the research project. The success of this project was based on various factors. This includes:

- An extensive in-depth review on literature cases in order to acquire and understand the knowledge surrounding the problem domain.
- The capture and representation of knowledge using UML and other computer based knowledge representation techniques in order to represent the existing excel based cost model and bicycle maintenance diagnosis repair manual.
- Appropriate training on the semantic based platforms which was essential for the development of the prototypes.
- The prototype development which was time consuming due to the magnitude of the work carried out. Testing and constant knowledge validation by the expert and researcher had to be implemented for the verification and validation of knowledge. The cost model contained between 90 – 100 rules whilst the bicycle maintenance support contained about 40 diagnosis logic for bicycle repairs.

Although the adopted methodology accomplished the goal of the project, some strengths and weaknesses were identified. Below are a list of the strengths and weaknesses for the adopted methodology

Strengths:

- For the bicycle maintenance support, a standard bicycle manual repair document was used to model the problem domain. This explicit documented knowledge aided in validating the prototype. One can assume that the standards that created the model have already verified and validated the knowledge included within the standard.
- The bicycle manual was developed by a team of bicycle experts which enforces the validation of this particular semantic based prototype development.

- One of the key strengths about the adopted methodology was that an expert was present during the development of the semantic based cost model. This helped in correcting and editing errors within the Excel based cost model.
- Qualitative approach was adopted in terms of observing how the expert rectified few errors that occurred within the Excel based cost model

Weakness

- The process of capturing knowledge for the Excel based cost model and bicycle maintenance repair could have been improved via use of a workshop consisting of cost model and bicycle experts. This will ensure the verification and validation of the semantic based prototypes.
- The knowledge model that the semantic based cost model application was based on was developed by a single expert. Once the prototype had been developed, it could have been validated with experts that are not concerned with the development of the knowledge model itself. This will help in ensuring the accuracy of the prototype.
- The prototype development was time-consuming due to the fact that this phase was a major part of the research project. The use of SemanticGuide was more time-consuming because the system had to be installed and errors occurred with the system due to configuration issues. OntoStudio for the Excel based cost model had already been installed which speeded the development time for the semantic based cost model
- The diagnosis questions and answers for SemanticGuide bicycle repairs could possibly have been jointly developed with experts in form of a workshop in order to reinforce the accuracy of the diagnosis process.
- The quantitative research approach was not adopted because the knowledge required for the semantic based prototypes had already been captured within the validated Excel based cost model and bicycle repair manual. The use of semi-structured interviews, card-sorting, etc would have been adopted if this was not the case.

The main difficulty of the research was in the complexity of the project itself. The project was large and abstract at the beginning. The project outcome was supposed to be the development of one prototype but ended up resulting into the development of two semantic based prototypes. Another challenging aspect of the project was bridging the gap between the two sub-projects carried out. After discussion with an expert from the industrial sponsoring company, it was suggested that the first part of the project should calculate the cost for a composite part and the second part should implement maintenance support for the calculated part which could be in form of bicycle parts.

7.3.2 Discussion of Research Results

This research project relied heavily on the existing validated excel based cost model, an expert and the ‘Barnett’s’ manual repair for bicycle maintenance. For this purpose, it is imperative to identify the difficulty of transforming these knowledge sources into semantic based platforms. This is due to the complexity of capturing and understanding tacit knowledge from the expert and excel based cost model. The bicycle manual was explicitly documented and less challenging to transform into a semantic based application. However, the excel cost model was complex due to the fact that it contained tacit knowledge and few corrections that the expert had to validate. It was vital for the researcher to adopt a qualitative approach in observing and understanding the know-how of the expert’s knowledge which enabled the accurate capture and implementation of the semantic based cost model application.

Moreover, deriving important conclusions from the Excel based cost model was complex due to the fact that some of its logic was inaccurate which meant the expert had to re-verify and re-validate the excel based cost model whilst the semantic based cost model was in the process of implementation. For example, certain manufacturing processes for a composite part such as “Manual and Aerovac Debulking” could not be modelled in the semantic platform due to its in-accuracy in the excel based cost model. However, this is a minor issue that once rectified could be easily adapted within the semantic based platform due to the **flexibility** of semantic technology as illustrated in section 7.3.

The lack of semantics to maintain and manage knowledge was the main issue of this research project. Although the prototypes developed only focused on a small area of the problem domain, it still demonstrates and quantifies the potential of semantic technology and how

efficient and effective it is for the management and maintenance of knowledge within the defence equipment support market and other sectors through the semantic based cost model for a composite part and semantic based bicycle maintenance support for equipments diagnosis.

7.4 Application of the Results

The developed semantic based prototypes can be extended and applied in other sectors. Semantic technology can be used in any sector that understands the importance of the maintenance and management of knowledge which means all sectors of industry. This includes sectors such as finance, accounting, manufacturing, health, administration, etc. the use of semantic technology within the defence equipment support market is crucial.

In spite of the fact that the research project is based on a cost model for a composite part and maintenance for bicycle diagnosis, it would be interesting to see how one would use OntoStudio to model the cost for a more complex product, i.e. a tank within the defence equipment support market. The complexity of such a domain will contain thousands of rules definition within OntoStudio. It will also be interesting to see how SemanticGuide would be used to model aircrafts such as typhoon, etc within the defence market for maintenance purposes.

7.5 Research Limitations

The work presented in this thesis concentrated on the use of a semantic based approach to manage knowledge. One of the major limitations of this study due to time constraints was the BIRT (Business Intelligence and Reporting Tools) functionality offered by SemanticGuide could not be illustrated. Although, SemanticGuide is used for the maintenance and management of knowledge which helps in recommending solutions for problems, it also helps in enhancing business performance. The BIRT functionality would have illustrated the most common cases and causes within the knowledge base so that businesses could identify which areas they need improved performance. This functionality could aid in highlighting the weaknesses and strengths of solutions as chosen by the users of SemanticGuide

Several other limitations of the project are listed below:

- The choice of the semantic based application was chosen through the industrial sponsor. However, their choice has been based on validated research within the area of semantic applications
- A theory exists that SemanticGuide consists of files named 'Flo files' that can be transformed within the OntoStudio platform in order to view how OntoStudio defines concepts and ontologies that exist within SemanticGuide. It would have been interesting to see how this works but due to time constraint, it was not possible.
- The developed SemanticGuide prototype is based on bicycle repairs. A more complicated model such as the diagnosis for defence equipments will furthermore test the robustness and integrity of the semantic based application. The research project was supposed to be for the capture and diagnosis of defence equipments, but due to in-accessibility for knowledge capture, a bicycle prototype was developed in order to quantify the use of this technology.

7.6 Research Contribution to knowledge

The research contribution to knowledge is as follows:

- The use of semantic application is very similar to that of object oriented programming. The main three of OOP are inheritance, encapsulation and polymorphism. Semantics has the capability to portray these three key features. However, semantic technology is different because of the **use of synonyms** which allows one or more words to be interchanged within a context. This gives semantic technology an advantage over the OOP paradigm.
- Semantic integration is similar to data mapping. However, semantic integration uses **metadata with the use of synonyms** in order to describe the linguistics in data whilst data mapping is simply concerned about the data source and destination. Semantic integration also allows the development of ontologies so that various concepts can be mapped out. The use of semantic integration (synonyms) offers higher advantages than the traditional data mapping approach.

- In the .NET platform and other Object Oriented Programming platforms such as Eclipse, JBuilder, etc the user interface can be modelled graphically. However, the functionality requires syntactical implementation (classes, objects, etc) and understanding of the OOP code written. Whereas, with semantic technology, it is possible to graphically model our functionality (rules) and the code behind it is then automatically generated as illustrated in the semantic based cost model application.

7.7 Conclusions

The research project has demonstrated the benefits of a semantic approach to maintain and manage knowledge. The objectives defined before the initiation of the project have been listed below followed by their method of completion

- Transform an existing Excel based cost model into a semantic based application.
 - o The existing Excel based cost model for a composite part had already been validated and minor errors were rectified by the expert. UML class diagrams were used for the representation of concepts, concepts attributes and concept relations in form of ontologies. The database was modelled using an ERD diagram that identified the relationships between the tables in the domain. OntoStudio was used to define concepts, rules and queries which are the basis of this semantic based application. This objective was successfully achieved and a fully operational cost model for a composite part was developed.
- Capture complex knowledge about maintenance and diagnosis of equipments in one central knowledge base.
 - o The validated 'Barnett's' manual for bicycle repairs contained complex knowledge about maintenance and diagnosis. The next step was then to capture and record symptoms and solutions for a knowledge area which was accomplished using the knowledge base designer provided by SemanticGuide. The global pool allowed the capture of solutions and questions which could be assigned to symptoms of a knowledge area. 40 symptoms and over 100 solutions for bicycle repairs were recorded in the knowledge base.
- Incorporate within the prototype a two way dialogue to help in diagnosing a problem and allow for rapid discovery of appropriate solutions.

- It was necessary to construct a small answering outline process that illustrates the logic of the diagnosis questions and answers in SemanticGuide. The graphical diagnosis editor was used to model the diagnosis logic.
- Evaluate and validate use of semantic based approach to manage knowledge within the defence equipment support market.
 - The development of both semantic based prototypes has accomplished this objective. By modelling the cost for a composite part and carrying out a maintenance support for bicycle diagnosis, this has demonstrated that semantic technology can also be used within the defence equipment support market although it will mean developing a larger knowledge base.
- Use of multiple cases to demonstrate the benefits of semantic technology.
 - The semantic based prototype developments have demonstrated the benefits of semantic technology as illustrated in section 7.2.

7.8 Further Work

This research study has provided the use of a semantic based approach to manage knowledge. From the basis of this research project, future work could commence. These are listed below:

- The use of a semantic based approach to model a complex domain such as an aircraft within the defence equipment market. The prototype developed for this project in SemanticGuide was based on bicycle repairs, modelling an aircraft will be complex although it has been proved in this research project that if one can model a bicycle knowledge base with the use of semantic technology then one can do the same for an aircraft.
- The first prototype calculated the cost for a composite part whilst the second prototype implemented maintenance support for the composite part which could possibly belong to a bicycle. These two modelled domain are closely associated with each other and it is therefore necessary to investigate the **cost of maintenance** using semantic technology which could extend this research project.

- Also, the use of semantic based approach to improve business performance could be an extension of this research project. Companies need to realise how the use of semantics could be used to improve business performance and identify critical factors. For example, the BIRT functionality offered by SemanticGuide identifies common cases/causes so that businesses can understand which area of their services needs more focus in order to improve business performance and improve customer satisfaction.

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APPENDICES

Appendix A:

Symptoms and Solutions from Barnett's Manual Repair

WHEEL DEFECT

FLAT TURE AND TUBE SOLUTION

CHAIN FAILURE

Appendix B

Rules Declaration in OntoStudio

RULE **AUTOCLAVE AREA** FOR SHAPE T-CHANNEL

RULE **CROSS SECTIONAL AREA** FOR SHAPE T-CHANNEL

RULE **FINISHED VOLUME** FOR SHAPE T-CHANNEL

RULE **PART HEIGHT** FOR SHAPE T-CHANNEL

RULE **PERIPHERY** FOR SHAPE L-CHANNEL

RULE **PRE PREG PLIES PER LAYER** FOR COMPOSITE PART

RULE **LSM COST** FOR COMPOSITE PART

RULE **RAW MATERIAL COST** FOR COMPOSITE PART

RULE CORE THICKNESS FOR COMPOSITE PART

RULE CORE WEIGHT FOR COMPOSITE PART

RULE **CORE SETUP TIME** FOR COMPOSITE PART

RULE **LSM LAYUP TIME** FOR COMPOSITE PART

RULE **PLY CUTTING TIME** FOR COMPOSITE PART

RULE **PRICE** FOR PART