KNOWLEDGE REUSE IN QUALITY SYSTEMS: AN EXPLORATIVE STUDY

CALVIN NG ENG PENG

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PREFACE

Except for commonly understood and accepted ideas, or where specific reference is made, the work reported here in this thesis is my own and includes nothing that is the outcome of the work done in collaboration. No part of the dissertation has been previously submitted to any university for any degree, diploma or other qualification.

Calvin Ng Eng Peng

National University of Singapore

May 2008

SUMMARY

This research aims to offer new insights into knowledge reuse in quality management systems. From the literature, common terms of knowledge management were found to be knowledge transfer, knowledge sharing and, more recently, knowledge reuse. The focus of knowledge reuse research was found to range from product innovation to replication. However, none of the knowledge reuse studies were done from a manufacturing quality systems perspective. In fact, today's managers and executives face a struggle to find concrete realistic studies as they try to help their organisations build a more efficient process of managing knowledge.

In a manufacturing organisation, quality management systems are considered default when it comes to good management practises. These quality management systems can even act as a competitive advantage for future potential businesses to the manufacturing organisation. Using the current quality management systems (for example ISO9000:2000) and the knowledge reuse theories, it is possible to study the linkages of quality management and the knowledge reuse and establish the relationship occurring between them. Considering this background, the direction of this research to answer the questions of "what" and "how", thereby makes the research explorative in nature.

Focus was placed on creating new lines of thinking using an explorative research methodology based on 4 cases. The data was collected from interviews, personal observations and triangulation methods. The purpose was to keep data as rich as possible in

order to achieve more insightful findings. When the data was analysed, frequent references were made back to existing theories in order to keep the findings academic and relevant to practitioners. The findings of the research questions were then used to create frameworks and the matrix. These outcomes were then used to understand the relationship between quality management systems and knowledge reuse.

Some implications and limitations were observed based on the findings, but these can be expected due to the scope, experience and effort of the researcher.

The key contributions of this research are:

- The development of a toolkit consisting of a framework of the knowledge reuse initiative and a knowledge reuse strategy adoption matrix (from a quality system perspective).

- The establishment of a knowledge reuse mechanism framework (from a knowledge management strategy perspective).

ACKNOWLEDGEMENTS

Writing this thesis has been similar to putting the last piece of a jigsaw into the puzzle. The completion of this research would not have been possible without the strongest support and encouragement of my family, friends and people whom I have worked with on and off the project.

I would like to express my gratitude and appreciation to my Project Supervisor, Dr. Chai Kah Hin, for his patience and guidance during the years of this research. Similar gratitude extends to ISE, ETM and all NUS staff for making this learning opportunity a wonderful experience. I also would like to express special gratitude to Eileen New and He Qi of ISE, NUS for providing the extra hands.

As well, I would like to express my deepest gratitude to Mr. George Poh, who has given me the opportunity to walk down this extraordinary path of self-discovery. In addition, I would like to thank all the managers, engineers, technicians and colleagues who have provided me with their valuable experiences and feedback during the interview sessions for this research.

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1. Introduction

1.1 Background

In these times of increasing competition, companies fight for a bigger share of the pie in the open market. Market leaders compete for more business by offering better technology, services (customer orientated) and pricing, but face competition from emerging new technologies. Sometimes, this competition can be radical and disruptive, as described by Bower and Christensen (1995). The market becomes increasingly dynamic, up to the point that knowledge is seen as the only true resource (Drucker, 1993). It is no longer enough to offer a technologically great product, but businesses must also have the expertise to provide it to the right customers in the right market at the right price and with the right service. This trend seems to prove itself with all successful knowledge based companies (i.e. Toyota, Hewlett Packard, Ernest & Young, McKinsey & Company).

Similarly, in a manufacturing industry the expertise to provide products and services requires knowledge embedded in the organisation. The industry's basic survival instinct is to increase market share, reduce operational costs and provide the right service, all toward the goal of achieving customer satisfaction. As well, customers are frequently on the lookout for better, cheaper and more reliable manufacturers. Hence, manufacturing companies often face demanding needs from their customers and, at the same time, must fight for the market share from the competition. Clearly, success stories occurring in past research have shown that knowledge management can help a business retain its competitive edge. Four main areas of operation that are necessary to sustain and create a business have been identified by Okes (2005). As shown in Figure 1.1, they are order fulfilment, product/process technology,

customer relationship management and strategy development/deployment. A layer of knowledge management exists to interface the common management systems. One of the key systems is the quality management system, which is commonly used in manufacturing industries.

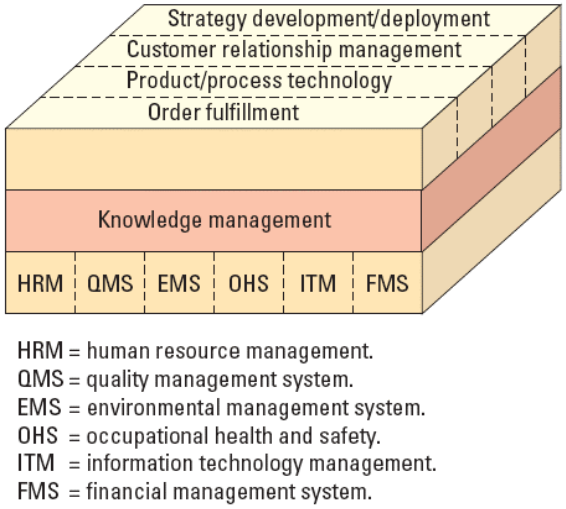

Figure 1.1, A sandwich of knowledge management in between management systems

(Source: Okes, 2005)

In knowledge management theories, many discussions can be found in the research literatures that focus on how knowledge is transferred, shared and used. Markus (2001) looked into 4 types of knowledge reuse, specifically the documentation process, of which the work was focused on the documentation of knowledge for later knowledge reuse for the purpose of replication. On the other hand, Majchrzak, Cooper and Neece (2004) pointed out that knowledge reuse can also be successful for radical product innovation, not only for the replication of products and services. Similar findings were also observed by Winter and

Szulanski (2001). While most of the knowledge reuse research has been diversified in terms of the research scenarios, there has been little reference linking knowledge reuse to management systems, especially in quality systems (although knowledge reuse for replication is arguably close). Another hot topic in the 19th century was Total Quality Management (TQM). It embodies concepts of continuous improvement, as well as other management concepts (i.e. human resources), to quality management systems as a holistic approach to fulfil customer satisfaction, and even partially incorporates knowledge management elements. As Mukherjee, Lapre and Wassenhove (1998) have discussed Total Quality Management borders along the lines of learning organisations.

As such, in order to extend knowledge reuse theories into meaningful research, a quality management approach was selected for this. This research is expected to assist the practitioner in the understanding of knowledge reuse in quality management systems, as well as to create useful insights for future academic research.

1.2 Research Objectives

This research explores the use of quality systems to manage knowledge (specifically in reuse aspects) and its effectiveness in doing so. The primary objective is to gain a better understanding of knowledge reuse theories in terms of quality problem recurrences, which is termed as quality issues. The secondary objective is to study the mechanisms involved in the process of knowledge reuse based on the quality management system so that a meaningful relationship can be established. The emphasis of this research is placed on developing

insightful knowledge reuse theories, as well as to understand what can affect and influence the success of knowledge reuse.

1.3 Research Approach

As it will be shown in Chapter 2, an extensive review of the literature in the field of knowledge management (and, more specifically, in knowledge reuse) brought forth two observations:

- There is a lack of exploration in knowledge reuse in quality management systems.
- Knowledge reuse mechanisms and the relationship to the knowledge management strategies are not defined.

The lack of a robust knowledge reuse theory, as explained in Chapter 2, calls for a theory building approach. The basis of this research is to identify if quality management systems are able to address knowledge reuse issues and if knowledge reuse itself has elements and mechanisms. 4 automotive component quality issues within an organisation were selected for the case studies, as they were found to be appropriate in addressing the research objectives. The study relied predominantly on a collection of in-depth interviews with managers and engineers as well as the technicians and operators. Access to the company's internal documents and direct observations were added to provide richness and validity throughout the data collections.

1.4 Structure of the Thesis

The thesis is divided into 5 chapters. The remainder of the dissertation is structured as follows.

1.4.1 Chapter 2 Literature Review

This chapter presents a review of the relevant literature pertaining to knowledge management. It begins with an introduction on the definitions of knowledge and knowledge management. Other relevant areas include research in typologies of knowledge, knowledge sharing processes, perspectives of knowledge management and knowledge reuse implications. The process of the literature review was conducted to achieve two effects: (1) to let the research build on the existing theories and (2) so that the research done is novel. Several knowledge management concepts and theories are presented, including types of knowledge, communication processes in knowledge management, knowledge sharing and transfer theories, as well as the technologies used to support knowledge management. While eventually focusing on knowledge reuse theories, it is noted that knowledge reuse literature is generally more focused on the capturing, packaging, distributing and eventual reuse of knowledge for replication. Other knowledge reuse studies including radical innovation and non-documentation methods for knowledge reuse were described. With these large diverse variations in the research, none has touched on the quality management system (non-radical innovative) scenarios. Also in this chapter, quality management systems are introduced to allow for a brief description of the current quality management systems used in industries, so that academics may understand the implication of the research to practitioners. The research questions are also defined in this chapter.

1.4.2 Chapter 3 Research Methodology

This chapter defines the research methodology used and explains why a qualitative method using case studies is best. The implementation of this methodology is further described. The research design and data collection methods are also defined. Respective analysis methods, including the variables used for this research will also be presented and discussed.

1.4.3 Chapter 4 Main Case Study and Findings

This chapter explains the 4 cases of quality issues selected for the investigation of knowledge reuse within the selected organisation. Each case description is provided for the reference of the research, and is then further linked to the research questions in order to provide a clear direction to the research findings. Observations will also be presented in this chapter for discussion. As well, the organisation is introduced in this section. The main purpose of this introduction is to provide an understanding of its business structure and a simple overview of its operations. An analysis based on the cases was carried out in order to identify what processes exist in the organisation to support knowledge reuse, and then later to determine if these processes are sufficient for effective knowledge reuse. Additionally, these findings are eventually used to derive a knowledge reuse theory with respect to the quality management system.

1.4.4 Chapter 5 Discussions and Conclusions

This chapter summarises the key findings of the research. A proposal based on the findings is presented for the current research, specifically in the scope of knowledge reuse. In addition,

practical and academic implications and limitations of the research are provided. Potential future research work is proposed and discussed.

1.5 Conclusion

This chapter introduces the research undertaken and lays the foundation for the thesis. Its aim is to understand if such quality systems can be used for the purpose of knowledge management, especially in reuse. The lack of extant literature and a practical understanding of knowledge reuse in quality management systems justify the need for this study. The flow of the research and the basic structure of the thesis are illustrated in Figure 1.2.

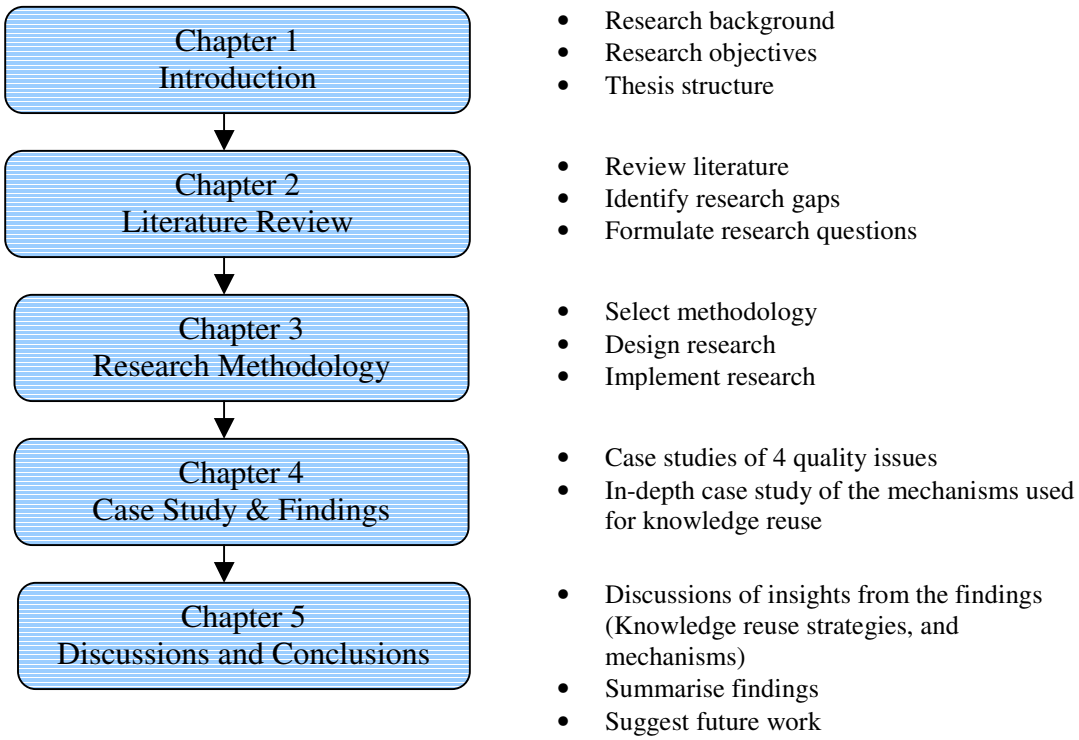

Figure 1.2, Flow of the research through the thesis

2. Literature Review

2.1 Introduction

This chapter starts with a review of quality systems and follows with the relevant research into the areas of knowledge management, with specific focus on knowledge reuse. It provides a theoretical foundation for the proposed study and identifies any research limitations and inadequacies. It can be realised from the literature review that knowledge management is a multi-faceted topic with concepts, theories and frameworks found in a variety of disciplines that span across information communication technology, human resource management, organisational learning, etc. The focus of this chapter is to identify the research gaps based on literature trends in relation to existing quality management systems and knowledge reuse theory.

2.2 Quality Management Systems

Quality management systems can be defined as a set of policies, processes and procedures required for planning and execution (production/development/service) in the core business area of an organisation. Quality management systems integrate the various internal manufacturing processes within the organisation and provide a process-based approach to the execution of quality activities. It also enables organisations to identify, measure, control and improve the various core business processes that will ultimately lead to an improved business performance.

The International Organisation for Standardization's ISO9000:2000 series describes standards for a quality management system addressing the principles and processes surrounding the design, development and delivery of a general product or service.

The concept of quality first emerged out of the industrial revolution (in the late 18th and early 19th century). Back then; goods were manufactured from start to finish by the same person or team of people. Handcrafting and tweaking of the product was provided to meet 'quality criteria'. Mass production brought huge teams of people together to work on specific stages of production where one person would not necessarily complete a product from start to finish. In the late 1800s, pioneers such as Frederick Winslow Taylor and Henry Ford recognized the limitations of the methods being used at the time in mass production and the subsequent varying quality of output. Frederick Winslow Taylor established quality departments to oversee the quality of production and rectify errors, and Ford emphasized the standardisation of design and components to ensure that a standard product was produced. Management of quality was the responsibility of the quality department and was implemented by the inspection of product output in order to 'catch' defects.

Later into the 19th century, Total Quality Management received attention in not only in the industry, but also in academic. In more recent literature, Dubois (2002) argued that the use of the term Total Quality Management in management discourse created a positive utility regardless of what managers meant by it (which showed a large variation in its understanding and applications). While Total Quality Management eventually received less attention when Abrahamson (1996) argued that fashionable management discourse, such as Quality Circles,

tends to follow a life cycle in the form of a bell curve. Following which, during the late 1990s, the use of the term Total Quality Management lost its positive utility and practitioners became negative toward its real benefits and impact on quality management (McCabe and Wilkinson, 1998). Nevertheless, Total Quality Management leaves its trace, as the core ideas are still very valuable (Hill and Wilkinson, 1995). From this, it is possible to realise that quality perspectives in Total Quality Management, although useful, have become somewhat out-dated and there exists a need to explore other meaningful concepts, such as knowledge reuse with relation to quality management systems.

Looking further, some research was done based on the context of quality management systems and knowledge management. However, the boundaries are more of the information technology type. The perspective used stemmed from the extraction and documentation of the knowledge that is then stored for retrieval. Most of the research was later used for the development of computer-based systems for quality management (expert systems). These computer systems form a library of knowledge, which is used to provide decision-making guides rather than to make decisions (Dooley, Anderson & Liu, 1999). Studies have pointed out the fact that it is difficult to capture tacit knowledge; the captured explicit knowledge in computer systems can only be used as a guideline, not as a type of decision-maker for quality issues. This means that some kind of a relationship between quality management systems and knowledge management does exist. Mukherjee, Lapre and Wassenhove (1998) further mention that Total Quality Management and knowledge have a close relationship, and suggest possible links between these two concepts to improve an organisation's effectiveness

in quality management. However, these studies were found to be rather narrow in breadth and depth.

Another aspect to quality management systems is the continuous monitoring of the quality system implementation in the organisation. Frequent audits from customers and third parties are required in order to maintain full compliance with the applicable standard. In any case, upon detection of violations with the standards, an organisation not only risks losing its certification, but also a loss of business from customers. Audits occur in two forms, namely internal and external audits. In order to maintain uniform auditing, external audit parties provide the necessary independent audits in order to validate the quality certification. Frequent audits were found to be considerably tedious and inefficient, often requiring many hours of meetings, interviews and document inspection for the validation of the quality management system. Outcomes of audits have been attributed mainly to the experience and the focus of the auditor. The existence of auditing largely remains on the requirement of the quality management systems standards, as well as the customers.

Overall, specific quality systems like ISO9000:2000 present a formal system used in today's manufacturing industry in order to maintain quality systems. The application now becomes an industrial normality, indicating its wide acceptance. Specific industry-related standards (i.e. ISO/TS16949:2002 for automotive industry) were also derived specifically for realising even greater customer expectations. More details on quality management system such as ISO9001:2000 and ISO/TS16949:2002 can be found in Appendix C of this thesis.

2.3 Management of Knowledge

After the brief overview of quality management systems, it is now time to look at the literature on knowledge management. Managing knowledge is not a new concept. For the past few decades, knowledge management has received considerable attention from academics and industry. The rush to manage knowledge is further driven by the general acknowledgement that knowledge is an important resource, which organisations cannot continue to ignore. The key challenge for leaders is the selection of knowledge management initiatives that fits the organisation and, at the same time, to leverage the available resources. This section will attempt to describe knowledge management initiatives and its processes.

2.3.1 Knowledge: a Necessity

From the time of Nonaka and Takeuchi's (1995) publication on knowledge management (The Knowledge-Creating Company), there has been a significant increase in the number of related publications. This is evident in Figure 2.1 as presented by Scarbrough and Swan (2001). The subsequent demise of learning organisations was observed as the academic world started to focus more on knowledge management terms research, producing an increasing number of articles and academic publications. Knowledge management theories later branched into further theories that are greater in their specificity, describing the way organisations learn and utilise knowledge. The term knowledge management eventually gained acceptance as a default (Kakabadse, Kakabadse and Kouzmin, 2003).

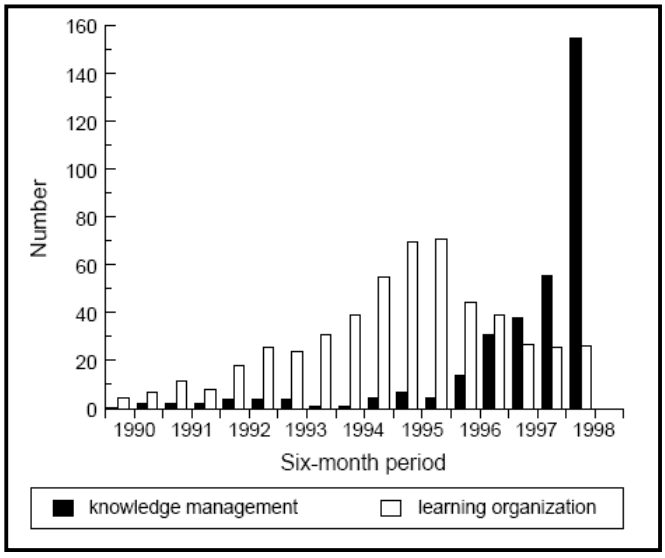

Figure 2.1, The significant increase in knowledge management publications since 1995

(Source: Scarbrough and Swan, 2001)

By reviewing this increasing trend, it is possible to identify the form of research and activities being carried out after 1995. Daniel Bell's (1973) visionary work of a "post-industrial society" during the 1970s arguably provided the necessary theoretical foundation for today's contemporary knowledge management activities. Webster (1996) also indicated that Bell's analysis was based on a typology of societies characterized by their predominant mode of employment, thus industrial societies are characterized by manufacturing activities. However, in a post-industrial society, the service sector is the greatest source of employment and is expected to be larger than the manufacturing sector. One crucial characteristic of Bell's post-industrial society is that knowledge and information play a much more significant role in economic and social life in the service sector. Hence, in all the publications and literature such as Burton-Jone's (1999), the assumption of knowledge being the new resource is expressed as an unquestionable truth, where the use of empirical evidence is not necessary.

Therefore, it is now accepted that knowledge lies in the heart of organisational performance and this directly relates to an important part of the organisation's economic resources, as indicated by Alavi and Leidner (2005).

Along these lines, organisations have since been implementing knowledge management projects. While many organisations experience partial success, some experience outright failure. Nonaka and Takeuchi's (1995) approach in this has been ground-breaking by comparing European and Japanese cultures in their epistemologies of knowledge, focusing on the human aspects of knowledge management. However, their discussion was relatively based on the "hows" and "whys" of knowledge transfer. In addition, Scarbrough and Swan (1999) presented a survey of the past knowledge management literature up to 1998, and it showed that about 5% of this literature had human-related thematic emphasis. Most research on knowledge management during this period operated on the assumption that people are willing to share knowledge, knowledge can be easily codified and that knowledge can be shared via information technology systems. While noting this deficiency, some researchers have triggered further research focusing on the human aspects to the problem of knowledge management in an organisation. Some good examples can be seen in the surveys shown in Table 2.1, and these show that most issues are rooted in social and cultural issues. An interview published in a management review study of 1600 respondents in the United States found that the most common obstacles are getting people to seek and share knowledge, as well as the measurement of success in knowledge management practices.

Author	Survey Details	Survey Results
Ruggles	431 respondents in USA and Europe. Conducted in 1997	• Biggest problem in managing knowledge 'changing people's behaviour' (56% of respondents • Biggest impediment to knowledge transferral 'culture' (54% of respondents)
Management Review	1600 respondents in the USA. Conducted 1998/99	• Three most common problems: 1. getting people to seek best practice 2. measuring results 3. getting people to share knowledge
KPMG	423 large organisations from USA, UK, France, Germany	• Two most important reasons for the failure of knowledge management initiatives to meet expectations: a) lack of user uptake due to insufficient communication (20% of respondents) b) everyday use did not integrate into normal working day (19% of respondents)
Pauline and Mason	46 respondents in New Zealand from organisations (public and private)	• The single largest barrier (45% of respondents) to knowledge management was culture
Edwards, Handzic, Carlsson, Nissen	25 academics and practitioners involved in knowledge management field	• People and Culture are the most important issues organisations should emphasize in their knowledge management initiatives

Table 2.1, Surveys conducted on knowledge management initiative barriers

(Source: Hislop, 2005)

Storey and Quintas (2001) further suggested that, for successful knowledge management initiatives, all participants within the organisation must be willing share their knowledge and expertise. To achieve this, the effect of human touch is important. The first generation of knowledge management literature lacked social-cultural considerations. Expanding further, most knowledge within an organisation is personal and embodied, and therefore requires the willingness of its possessor to codify the knowledge and share it. The interests of the knowledge possessor and their employer may not always be compatible, making the knowledge sharing process more difficult to control. Organisational control over knowledge

and knowledge management initiatives are always in contest, making it difficult for knowledge management processes to progress efficiently. Furthermore, the success of knowledge management initiatives depends on the tactfulness and sensitivity of the management toward the social-cultural context of the organisation. Comparing the first generation to current knowledge management studies, human social-cultural issues are considered as an industrial normality for effective knowledge management initiatives to take place.

2.3.2 Typologies of Knowledge

The study of knowledge management requires one to pay attention to the various types of knowledge as defined by the literature. Although the definition of knowledge has been at the centre of debates for centuries, the debate has yielded several types of propositions. It is therefore essential to look at the various knowledge types being presented, as this allows for a fundamental understanding before further research can take place.

2.3.2.1 Private Knowledge versus Public Knowledge

Matusik and Hill (1998) classified organisational knowledge by dichotomizing it into private and public knowledge. Private knowledge refers to the knowledge uniquely possessed by the organisation and as Barney (1991) puts it, private knowledge represents a resource that is valuable, rare and imperfectly irritable. It can include unique practices, documentation, business strategies and patents. In contrast, public knowledge consists of knowledge not proprietary to any particular organisation and it resides in the public domain where anyone

can have access. It includes industrial and occupational best practices, commonly known best practices include Total Quality Management, design-for-manufacturing, just-in-time inventory and lean manufacturing, all of which can be found in the public domain. As of recent, scholars have been increasingly staring to examine the characteristic and relationship between public and private knowledge. Firms and organization tend to benefit from public knowledge by appropriating them to generate private knowledge (Cockburn and Henderson, 1998; Cohen and Levinthal, 1990; Fleming and Sorenson, 2004). Conversely private knowledge or (firm) patenting strategies may impact public knowledge production (Huang and Murray, 2008). While, these theories do not influence the impact on knowledge reuse, it is nonetheless worthy to note the variations of the domain which knowledge exists. It can be seen from this, that the research intent to be carried out largely exists within the public domain.

2.3.2.2 Component Knowledge versus Architectural Knowledge

Component knowledge relates to a subroutine or discrete aspect of an organisation's operation. Literature by Amit and Schoemaker (1993), Henderson and Cockburn (1994) mentions that components found in organisations are resources, knowledge, skills and technical systems, which is similar to component knowledge theory. Component knowledge, however, may contain both private and public domain elements. Private elements are those developed internally that have yet to be made known to the public domain. On the other hand, architectural knowledge (as defined by Henderson and Clark, 1990) relates to organisation-wide routines and schemes for coordinating the various components of the organisation. Private knowledge can be further classified as architecture dimension (Matusik

and Hill, 1998). They also identified that there is no single individual who is in a position to see, comprehend and articulate all of architectural knowledge. Hence, due to the unique nature and development of architectural knowledge, no two organisations are the same. In the context of knowledge reuse, this theory might suggest that it is implicative because, in knowledge reuse, the ability to replicate is the key focus. However, due to the component and architectural knowledge influence, the reuse of knowledge based on documentation methods alone can be difficult to ensure consistency in the results from the reuse.

2.3.2.3 Individual Knowledge versus Collective Knowledge

Component knowledge, as mentioned previously, can be classified into individual knowledge or collective knowledge, as discussed by Matusik and Hill (1998). Here, individual knowledge refers to the knowledge within an individual in an organisation; this knowledge results from the organisational endeavours attempted by the individual. Davenport and Prusak (1998) state that this knowledge, if not shared with other members of the organisation, is not effectively leveraged for good use and is permanently lost when the individual leaves the organization. If the individual knowledge is shared, it then becomes collective knowledge. Collective knowledge is therefore the knowledge held commonly by a group of organisation members. Zander and Kogut (1995) explain that principles, routines, practices and the relative organisational consensus on experiences are derived from collective knowledge. Hence, architectural knowledge is one form of collective knowledge, as the knowledge process derivation is similar. As Spender (1996) explains, collective knowledge is more secure and has more strategic significance than individual knowledge; it is less volatile and less easily affected by staff turnover because the knowledge (i.e. best practice) resides

within the individuals of the organisation. Fahey and Prusak (1998) explored the transformation of individual knowledge into collective knowledge, which is a form of knowledge sharing. Sharing a similar view, Brown and Duguid (1991) maintained that shared knowledge is located in complex, collaborative social practices. Weick and Roberts (1993) demonstrated that collective knowledge resides at the organisational level. Therefore, collective knowledge is conceived to be socially and contextually embedded in an organisation and not an accumulation of knowledge held by a set of individuals.

2.3.2.4 Explicit Knowledge versus Tacit Knowledge

The most fundamental and common classification of organisational knowledge is along the explicit-tacit dimension, as argued by Nonaka and Takeuchi (1995). Explicit knowledge is considered objective and can be expressed unambiguously in words, numbers and specifications; it is structured and independent of the knower. Thereby, it can be easily transferred. In contrast, tacit knowledge is subjective, situational and intimately tied to the knower's experiences, which cannot be easily formalized, documented or communicated. Leonard-Barton and Sensiper (1998) mentioned that tacit knowledge is usually acquired unconsciously or semi-consciously. Polanyi (1966) stated that tacit knowledge is that of effortlessness. This means that the knower faces inherent difficulty when sharing tacit knowledge with others. The distinguished differences between tacit and explicit knowledge can be observed in Table 2.2.

Tacit knowledge	Explicit knowledge
• Inexpressible in codified form • Subjective • Personal • Context specific • Difficult to share • Examples include driving, swimming	• Expressible in codified form • Objective • Impersonal • Context independent • Easy to share • Examples include product manuals, tour guide books

Table 2.2, The characteristics of tacit and explicit knowledge

(Source: Hislop, 2005)

Nonaka and Konno (1998) further explained that there are two components to tacit knowledge: the technical component and the mental component. Ryle (1949) mentioned that 'know-what' and 'know-why' are similar to 'know-that', where the person with the knowledge does not capacitate the ability to act out the knowledge. 'Know-how' in contrast to 'know-that', is the knowledge, which enables action. The technical component, which encompasses informal knowledge and possesses the capacity to carry out action, is therefore known as 'know-how' (i.e. skills). Focusing on individual knowledge, Grant (1997) discussed how person-embodied knowledge can be combined with know-that and know-how concepts. He described that explicit knowledge can be articulated whereas tacit knowledge cannot. The differences can be seen in Table 2.3.

	Explicit (Articulated)	Tacit Specifiable (Articulable)	Tacit (Non-articulable)
Know-that	Theories/ Information	Rules of Thumb	Intuition
Know-how	Procedures	Shop Practices	Skills

Table 2.3, Person-embodied knowledge type

(Source: Grant, 1997)

Kogut and Zander (1993) argued that knowledge is not strictly polarized between the explicit-tacit dichotomies, but exists along a continuum of tacitness and explicitness. This is in line with the findings of Grant (1997). Building on the work of Winter (1987) and Kogut and Zander (1993), it is proposed that organisational knowledge is measured in terms of its degree of explicitness. The degree of explicitness can be measured by three sub-constructs: codifiability, teachability and complexity.

2.3.2.5 Individual-collective versus Explicit-tacit

Further building on sections 2.3.2.3 and 2.3.2.4, some research has explored taking explicit-tacit knowledge and individual-collective knowledge and combining them. The purpose of this combination, as Spender (1996) suggests, is that a relationship could be established between the individual-collective dimension of knowledge and its explicit-tacit dimension. From this, a matrix comprising four types of organisational knowledge can be created. The first type is individual explicit knowledge. This represents the expertise and knowledge available to an individual in a codifiable form. The second type is individual tacit knowledge. This is the knowledge held by an individual in the form of individual abstract knowledge. As described by Lyles and Schwenk (1992), it cannot be easily articulated. The third type is collective explicit knowledge. This is knowledge that is embedded in an organisation in forms that can be codified. It manifests itself as standard operating procedures, documentation, information systems and rules (Brown and Duguid, 1991). The fourth type is collective tacit knowledge. As defined by Lyles and Schwenk (1992), Nelson and Winter (1982) and Nonaka and Takeuchi (1995), this is knowledge residing in organisational routines, culture and the corporate mindset. Such knowledge, as argued by Spender (1994),

usually remains relatively obscure from individual members, but is accessible and sustained through organisation interaction. Hedlund (1994) explored the two knowledge levels from an individual to an inter-organisation domain and found that articulated (explicit) and tacit knowledge exists at each level. This can be seen in Table 2.4.

	Individual	Group	Organisation	Inter-organisation domain
Articulated Knowledge	Knowing calculus	Quality circle's documented analysis of its performance	Organisation chart	Supplier's patents and documented practices
Tacit Knowledge	Cross-cultural negotiation skills	Team co-ordination in complex work	Corporate Culture	Customer's attitudes to products and expectations

Table 2.4, Types and level of knowledge

(Source: Hedlund, 1994)

Several researchers such as Nahapiet and Ghoshal (1998) and Weick, and Roberts (1993) discovered that high-performing organisations are better at creating and managing collective tacit knowledge than mediocre ones. They attributed the strategic importance of collective tacit knowledge to the fact that it represents the extent of knowledge being distributed and leveraged among organisation members and that it cannot be easily replicated by rival organisations.

2.3.2.6 Embeddedness versus Tacitness

Doz and Santos (1997) has shown that several forms of knowledge exist under the additional constraints of the embeddedness and the tacitness of knowledge. This is illustrated in Figure 2.2.

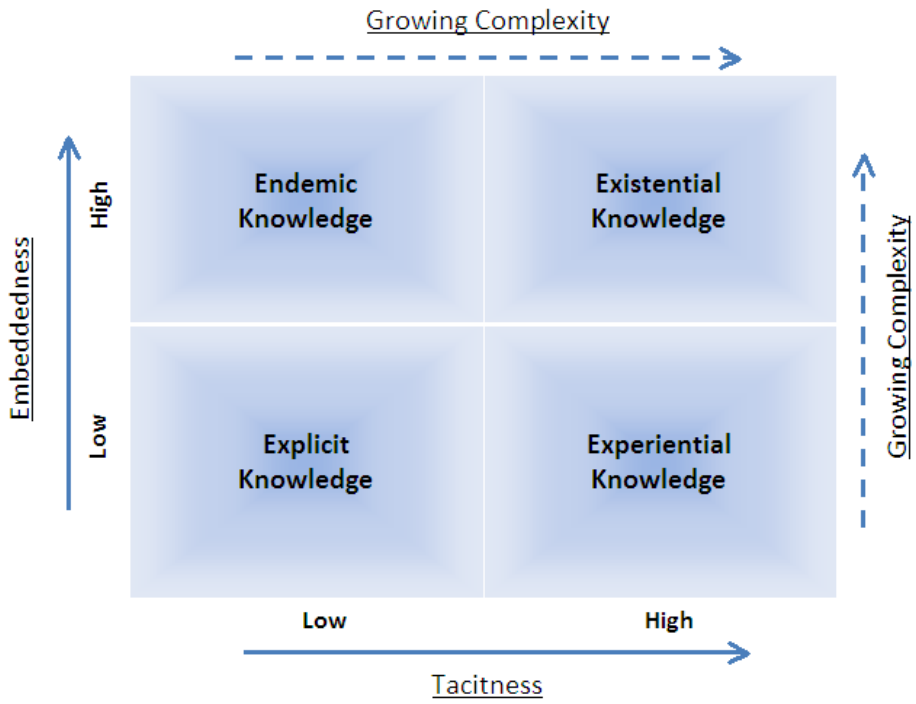

Figure 2.2, Types of knowledge based on embeddedness and tacitness

(Source: Doz and Santos, 1997)

It is mentioned that there are 4 types of knowledge required for the understanding of knowledge management. The knowledge explanations are as follows:

- Explicit knowledge is knowledge that is articulable (and often in an articulated form) and less-context specific. For example: equipment operating procedures, technical drawings and troubleshooting guides.

- Experiential knowledge is knowledge that is high in tacitness but low in embeddedness. This is knowledge that is acquired through experience and practice. For example: the ability to swim and cycle, as suggested by Polanyi (1966).

- Endemic knowledge is articulated knowledge, the usefulness of which can be apprehended only when the context to which the knowledge pertains is well understood. For example: Standard Operating Procedure (SOP), the knowledge is easily transferable in spite of its highly embedded context.

- Existential knowledge is knowledge that is not only tacit but also deeply embedded in its context. This knowledge is learned by 'feeling and living' over an extended period. For example: familiarization with another country's culture.

2.3.3 Communication Processes in Knowledge Management

In order to understand how knowledge can be shared, discussed, articulated and transferred between people in an organisation, an understanding of knowledge-sharing mechanisms is required. In a particular communication model by Shannon and Weaver (1949), they presented a transmitter-receiver model as in Figure 2.3 on the process of communication taking place. The concept behind this model is that the sender of the information and receiver at the destination are separated, and the message is delivered in a pre-determined media format. This message is encoded before sending and decoded after it is received in the form of a signal. Noise or interference can be introduced to this signal. The success of the message transfer depended on the amount of noise between the transmitter and receiver. Research in diffusions of innovations by Rogers (1995), as seen in Table 2.5, and technology transfer by Grant (1997) uses terms such as sender/receiver and home/host to denote the process. Both diffusion of innovation and technology transfer are considered parts of a series of communication process involving two or more parties.

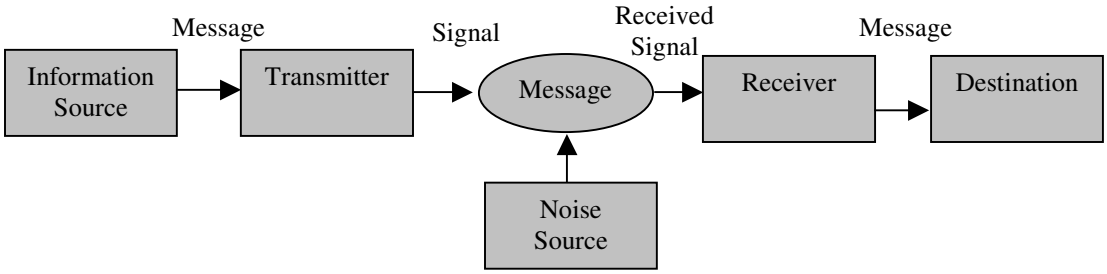

Figure 2.3, A model to describe the human communication process

(Source: Shannon and Weaver, 1949 and Rogers and Kincaid, 1981)

Strategy Making	Exploring	Evaluating	Packaging and Adapting	Transferring	Embedding	Feeding Back

Table 2.5, Technology transfer processes

(Source: Grant et al., 1997)

Table 2.6 shows the comparisons between components of communication, diffusion of innovation and technology transfer to show its similarity.

	Content	**Channel**	**User**
Communication	Signal/message	Media Channel	Transmitter/receiver
Diffusion of Innovation	Innovation	Mechanisms/Protocols	Originator/receiver
Technology Transfer	Technology	Transfer channel	Host/home

Table 2.6, Similarities between the concepts of knowledge transfer by communication model

(Source: Hislop, 2005)

However, the process of communication between parties has always been under the assumption of having an autonomous relationship. Roger (1995) explored and suggested that the communication process is in fact dependant on the type of knowledge to be transferred. The top-down approach yields knowledge leading to technology transfer (knowledge reuse), whereas the bottom-up approach yields technology innovations (knowledge creation). This is shown in Table 2.7.

Characteristics of Transfer	'Top-down' Knowledge Transfer	'Bottom-up' Knowledge Transfer
Direction of transfer	Top-down diffusion from experts to local users of knowledge	Peer diffusion of knowledge through horizontal networks
Sources of transfer	Knowledge come from lead plants (Ferdows 1997) or R&D centres	Knowledge come from local experimentation by non-experts who often are users
Decision of which knowledge to transfer	Decision is generally made by top management for strategic reasons such as cost and market entry	Local units decide which knowledge should be transferred on their evaluations of the knowledge
Importance of user's needs in driving the transfer	A knowledge-centred approach; emphasising needs (as dictated by top management) created the knowledge itself	A problem-centred approach; created by locally perceived needs and problems
Examples	New product introduction, Technology transfer, Best-practice benchmarking	Diffusion of innovation

Table 2.7, Types of knowledge transfer

(Source: Rogers, 1995)

2.3.3.1 Communication Channel

While an understanding of the communication process in organisations has been established, the medium used in the mechanisms was studied in order to investigate its influence on knowledge management. As seen in Table 2.8, the use of a rich media method (High) was

found to be the most effective for tacit knowledge, whereas the use of lean media method (Low) was found to be good for distributing data.

Media Richness	Medium	Knowledge Type
High ↕ Low	Face-to-Face	Tacit knowledge
	Telephone	Explicit knowledge
	Written, Addressed documents (note, memo, letter, email)	Information
	Unaddressed documents (flier, bulletin, standard report)	Data

Table 2.8, Media richness hierarchy coupled with knowledge types

(Source: Lengel and Daft, 1988)

Knowledge transfer requires the use of mechanisms, and these are often a composition of many different communication channels. For instance, a best practice team might meet face-to-face, exchange emails and engage in teleconferencing when carrying out benchmarking (considered as a type of mechanism). Teece (1981) suggests that one of the reasons why transfer of tacit knowledge is slow and costly is because it needs rich transfer mechanisms. This is because of the need to overcome any ambiguities, a common characteristic of tacit knowledge. Teece (1981) also observed that the transfer of tacit knowledge requires rich media, which is in line with the media richness theory explained by Draft and Lengel (1986). According to the media richness theory, rich mediums are more effective than lean mediums for effective communication. Media richness is defined as the "medium's capacity to change mental representations within a specific time interval" (Daft and Huber 1987, pg 14). Communication through a rich medium such as face-to-face meetings results in a major change in mental representation when compared to a less rich medium. Face-to-face

meetings are considered the richest medium because of their multiple cues as well as immediate feedback. Table 2.9 shows the various mediums in the hierarchy of richness. This hierarchy is arranged according to three principles: the media's ability to handle multiple information cues simultaneously, the ability to facilitate rapid feedback and the ability to establish a personal focus. These principles are most important when communicating tacit knowledge.

Media Richness Capacity	**Medium**	**Media Characteristics**			
		Feedback	**Cues/Channels**	**Intimacy**	**Language**
High ↑	Face-to-face	Immediate	Multiple	Personnel (visual, audio)	Natural
	Telephone	Fast	Audio	Personal	Natural
	Written, addressed (letter, memo)	Slow	Limited visual	Personal	Natural/ Numeric
Low	Written, unaddressed	Very Slow	Limited visual	Impersonal	Natural/ Numeric

Table 2.9, Communication medium and their characteristics of richness

(Source: Daft and Huber, 1987, pg 14)

Also mentioned by Lengel and Daft (1988), the media richness theory has explained that it was the 'how' and 'what type' of media that was being used to reduce equivocality (a result of noise) between the transmitter and receiver. This highlights the fact that when managers choose the wrong media to use for the communication process they risk having a communication failure occur. This can be further explained as seen in Figure 2.4.

Media Richness	Management Problem: Routine (Low Equivocality)	Management Problem: Non-Routine (High Equivocality)
Rich	**Communication Failure** Data glut. Rich media used for routine messages. Excess cues causes confusion and surplus meaning	**Effective Communication** Communication success because rich media match non-routine messages
Lean	**Effective Communication** Communication success because media low in richness match routine messages	**Communication Failure** Data starvation. Lean media used for non-routine messages Too few cues to capture message complexity

Figure 2.4, Selection of communication channel based on media richness theory

Source: Lengel and Daft, 1988)

From the literature review, it is now clear that the impact of the mediums that are chosen can affect the success of the knowledge transfer. When the mechanisms are not implemented correctly, they will result in highly ineffective communication of the knowledge. Hence, the success of the knowledge management process highly depends on the mediums existing in the mechanisms.

2.3.4 Knowledge Sharing and Transfer

Arguably, the most popular concept in this case is by Nonaka & Takeuchi (1995). They argue that the knowledge sharing process is a dynamic and never-ending process between tacit and explicit knowledge conversion with the underlying 4 types of knowledge sharing

architectures, as shown in Figure 2.5. Argote and Ingram (2000), pg 151, defined knowledge transfer in organisations as "the process through which one unit (e.g., group, department, or division) is affected by the experience of another". They further suggested that knowledge transfer is generally subdivided into two groups: (1) knowledge sharing, the process by which an organisation's knowledge is captured (Appleyard, 1996), and (2) knowledge reuse, the process by which an entity is able to locate and use shared knowledge (Alavi and Leidner, 2001). Using these implications from the literature review, it is evident that knowledge sharing, transfer and reuse can now be differentiated from each other.

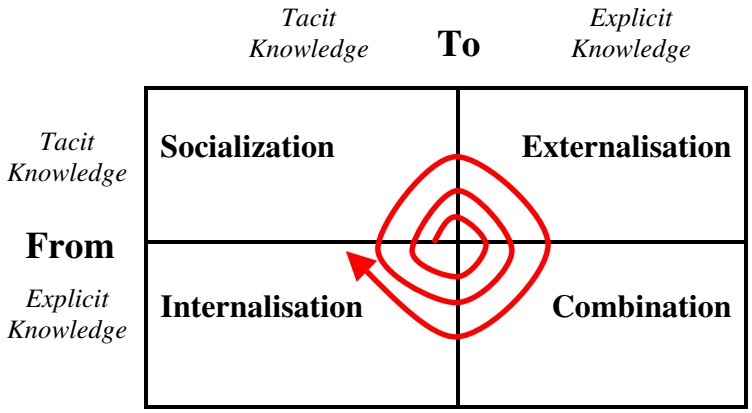

Figure 2.5, Dynamic knowledge conversion process

(Source: Nonaka and Takeuchi 1995)

Focusing on knowledge sharing, the dynamic knowledge conversion process occurs at the socialisation quadrant where tacit knowledge is "transferred" to tacit knowledge by face-to-face conversations or even hands-on training. The next stage is to convert tacit knowledge to explicit knowledge by externalisation, where the information is codified by writing work instructions or articles. In the combination quadrant, the knowledge is synthesised with other knowledge documents to create new knowledge, also known as knowledge creation. The

internalisation quadrant is to convert explicit knowledge to tacit knowledge, where the codified knowledge is learnt by executing the explicit instructions. This cycle starts again to help improve and gain more knowledge. The whole process of this dynamic conversion process is supported by the concept of 'ba' (Nonaka, 1998), where 'ba' is a context that harbours meaning and is considered as a shared space (environment) for emerging relationships during the knowledge transfer, sharing and reuse.

Following the knowledge reuse and sharing relationship further, the impact of knowledge reuse on knowledge sharing has been studied by several researchers and is often reflected in the literature taking a knowledge codification form. Liebowitz (1997) mentioned that, upon sharing (usually in the form of expert systems), knowledge is further reused. This approach is largely focused on the use of software and platforms to carry out the knowledge sharing activities, as all the knowledge is stored in a database and for future retrieval. This displays similarities stemming from knowledge reuse theories. It will be later described in section 2.4.

2.3.4.1 Knowledge Sharing and Transfer Mechanisms

With reference to knowledge sharing and transfer, it would be interesting to review the mechanisms used, in order to further understand the influence the impact on knowledge sharing and transfer. A good example of a mechanism, as defined by O'Dell and Grayson (1998), is benchmarking. Benchmarking is a process of defining, understanding and adapting outstanding practices either internally or externally. Unlike other types of benchmarking, best practice benchmarking goes beyond functional benchmarking by focusing on the search for superior management practices (Miller et al, 1992). It is harder than product and functional

benchmarking because management practices always contain elements of culture that are not easily transferable. There are three common mechanisms of best practice benchmarking: best practice, knowledge and practice networks and internal assessments and audits. Based on this list, it is noted that the cases of knowledge sharing in the extant literature have all focused on inter-organisational levels.

Mechanisms	Description
Benchmarking teams	Designated teams with a specific area to improve. The team would dissolve once the exercise is over
Best practice teams	Best-practice teams that is ongoing, continuously looking for best practice for benchmarking. Members usually have similar responsibilities in different divisions or plants in the company. Both benchmarking teams and best practice teams are often ordained from the top of the organisation.
Knowledge and practice networks	Communities of practice that emerge as result of shared interests in a specific area which receive management support
Internal assessment and audits	The effort to assess organisation performance with the objective of locating best performance for cross learning purpose

Table 2.10, Knowledge sharing mechanisms in best-practice benchmarking

(Source: O'Dell and Grayson, 1998)

Although from the literature reviewed, it has not referred these as mechanisms for knowledge reuse (there is a lack of insight to mechanisms at an organisational level for knowledge reuse) one can refer to it as lead for this research. In addition, Murray and Peyrefitte (2007) have defined that knowledge transfer mechanisms exist in 3 forms. The first is in the form of training (i.e. mentors, simulations, job rotation, lectures), the second is in the form of technology-assisted communication (databanks, teleconferencing) and the third is in the form of meetings (face-to-face, teleconferencing), of which a high and low media richness (Lengel

and Daft, 1988) relationship can be identified. While using this as an indicator of the type of mechanisms existing in knowledge transfer, it can be further concluded that both knowledge sharing and transfer share many similarities. Hence, mechanisms used in organisations are not only important to the success of knowledge management; they can also provide a competitive advantage to the organisation (Murray and Peyrefitte, 2007). This literature brings forth the message that mechanisms can make or break knowledge transfer and sharing, hence it could also impact knowledge reuse success. While having examined the extent of the current literature, it is found that there is a lack of literature in support of knowledge reuse mechanisms, indicating an important point for the research scope to take into consideration.

2.3.5 Knowledge Management Strategies

Literature on knowledge management has frequently mentioned the importance of human resource management (HRM). To clarify, Hansen, Nohria and Tierney (1999) presented, as seen in Table 2.11, the strategies used in consulting firms thereby linking the various aspects of knowledge management. Furthermore, Table 2.12 shows the various relationships between the business-knowledge link (type of knowledge management context), relevant knowledge process (type of knowledge sharing and transfer) and HRM implications (how to enhance the knowledge implementation). Based on these three contexts, there are two types of strategies, namely the codification strategy and the personalisation strategy. Although it has been realised that these two strategies exist, they shall not be utilised exclusively.

How Consulting Firms Manage Their Knowledge		
Codification		**Personalisation**
Provide high-quality, reliable, and fast information-systems Implementation by reusing codified knowledge	**Competitive Strategy**	Provide creative, analytically rigorous advice on high-level strategic problems by channelling individual expertise
Reuse Economics: Invest once in knowledge asset; reuse it many times. Use large teams with a high ratio of associates to partners. Focus on generating large overall revenues	**Economic Model**	**Expert Economics:** Charge high fees for highly customised solutions to unique problems. Use small teams with a low ratio of associates to partners. Focus on maintaining high profit margins.
People-to-Documents: Develop an electronic document system that codifies, stores, disseminates, and allows reuse of knowledge	**Knowledge Management Strategy**	**Person-to-Person:** Develop networks for linking people so that tacit knowledge can be shared
Invest heavily in IT; goal is to connect people with reusable codified knowledge	**Information Technology**	Invest moderately in IT; goal is to facilitate conversations and the exchange of tacit knowledge
Hire new college graduates who are well suited to the reuse of knowledge and the implementation of solutions. Train people in groups and through computer-based distance learning. Reward people for using and contributing to document databases	**Human Resources**	Hire MBAs who like problem-solving and can tolerate ambiguity. Train people through one-on-one mentoring. Reward people for directly sharing knowledge with others.
Anderson Consulting, Ernest & Young	**Examples**	McKinsey & Company, Bain & Company

Table 2.11, Differences in the codification and personalisation approaches

(Source: Hansen, Nohria and Tierney, 1999)

Knowledge Strategy	Codification	Personalisation
Business-Knowledge Link	Competitive advantage through knowledge re-use	Competitive advantage through knowledge creation
Relevant Knowledge Process	Transferring knowledge from people to documents	Improving social processes to facilitate sharing of tacit knowledge between people
HRM Implications	• Motivate people to codify their knowledge • Training should emphasize the development of IT skills • Reward people for codifying their knowledge	• Motivate people to share their knowledge with others • Training should emphasize the development of inter-personal skills • Reward people for sharing knowledge with others

Table 2.12, Knowledge strategies and its links

(Source: Hansen, Nohria and Tierney, 1999)

In fact, Hansen, Nohria and Tierney (1999) mentioned that organisations do not rely on codification or personalisation strategies alone. Rather, a primary strategy is first used and then supported by a secondary strategy. Usually, a mixed focus of 80% on codification strategy and the remaining 20% on personalisation strategy, or vice versa, is preferred. Organisations have gotten into serious trouble by either trying to excel by applying two strategies simultaneously or only focusing solely on one. Hansen (1999) further supplements that the knowledge strategy applied (codification or personalisation) depend on the business nature of the organisation to create and reuse knowledge.

2.3.6 Information Communication Technologies

A link worth mentioning in the study of knowledge management is to information systems. As mentioned by Nissen (2006), the information technology tools that enable knowledge flow and communication often embody explicit knowledge and, at best, only point to sources of tacit knowledge. Information Communication Technologies (ICTs) are such technologies that allow and facilitate the management of knowledge and information sharing. The term covers an enormous diversity of technologies including computers, telephones, e-mails, databases, data-mining systems, search engines, the Internet and video conferencing equipment. The use of the term ICTs is also similar to that of Information Systems (IS) which is used for knowledge management initiatives with similar effects as referred to in other literature, especially from Information Technology (IT) perspectives. A significant number of researchers suggest that ICTs can play an important role in knowledge management processes. However, there is a significant debate in the knowledge management literature, as ICTs in knowledge management processes have shown limited successes. It is noted that the approach on the use of ICTs is purely to capture explicit knowledge in organisations for storage and sharing. In board terms, there has been a retreat from the optimistic approach in the early knowledge management literature that knowledge processes can be easily mediated and facilitated with advanced ICTs.

As defined by Swan and Scarbrough (2001) who had referred to ICT as a “knowledge management as technology” perspective, ICT simply represents one channel through which explicit knowledge can be shared. As well, Hislop (2005) outlined the various roles that ICTs can play in knowledge management processes and the interrelationships between them. This

is presented in Figure 2.6. However, the argument is that there exists a certain difficulty involved with the codification of knowledge as well as in the sharing of the codified knowledge electronically. These can be difficult to determine and control but, if overcome, can lead toward a reliable foundation of knowledge databases. Its cost of implementation can sometimes be high, depending on the extent of penetration.

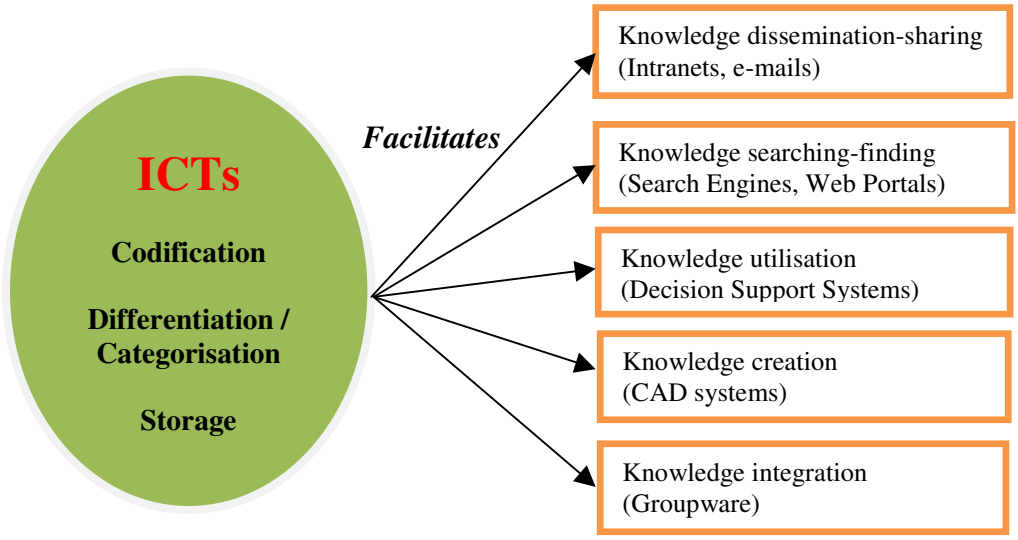

Figure 2.6, ICT roles in knowledge processes

(Source: Hislop, 2005)

Additionally, Ngwenyama and Lee (1997) defined that the use of a specific information system (IS) is essential for effective communication and knowledge activities. As in ICTs, the use of email is defined as the mechanism lowest in richness of media suitable for explicit knowledge transfer. Following this, they further argued that the richness of any communication process will not be determined by the technical characteristics of the communication medium, but will instead be shaped by a range of social and technical factors. Relevant social factors include the degree of mutual understanding, which exists between

people effectively using a communication medium. Therefore, the use of low media rich ICTs can be encouraged, but only if the organization operates using a highly personalised strategy.

Hendriks (2001) further supplemented that ICTs and knowledge management have advantages as well as drawbacks, but that there might be too many differences. He indicated that ICTs does not ensure the success of a knowledge management initiative, but only complements it. The differences between knowledge management and ICT are significant and should be seen as complementary to knowledge management, not as a main source to drive knowledge management.

2.4 Knowledge Reuse

In common literature, knowledge reuse theory has existed under the same roof as knowledge sharing (Liebowitz, 1997). Both these forms of knowledge fall under a larger umbrella known as knowledge management. According to Markus (2001), the definition of knowledge reuse is to selectively capture knowledge, effectively treat it, store it and then reuse it. Emphasis is placed on the capture, codification, storage, retrieval process and, eventually, the application (reuse) of the knowledge of knowledge. A generic process of knowledge reuse can be as seen in Figure 2.7.

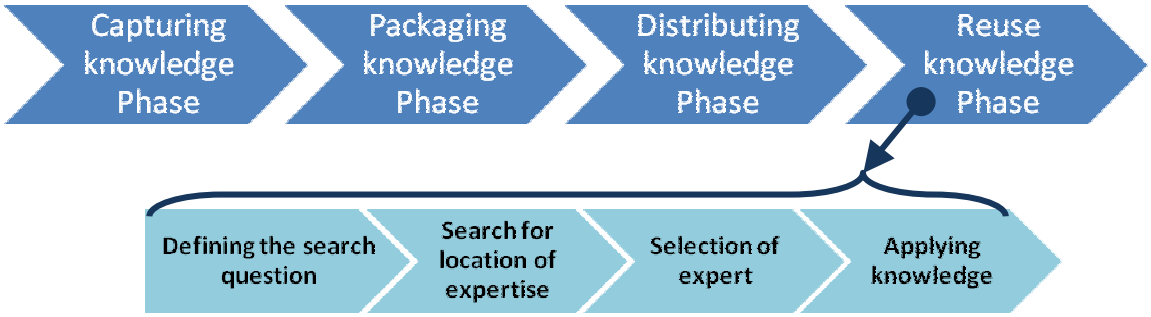

Figure 2.7, An elaboration of the process towards knowledge reuse

(Source: Markus, 2001)

Szulanski (2000) provides an example of a study with this knowledge reuse as a replication focus. The past approaches taken by researchers in knowledge reuse usually lacked in human-to-human interaction processes. Most of the research as stated by Hendriks, (2001) indicates that knowledge sharing usually ends up with complex ICTs. However, Majchrzak, Cooper and Neece (2004) mentioned that knowledge reuse requires the process of knowledge sharing. This is in line with the work of Alavi and Leidner (2001), where an entity able to locate and use shared knowledge is known to be conducting to knowledge reuse. As so, the mentioned literature has indicated that knowledge reuse is more of a codification process where the knowledge (explicit or tacit) is processed for storage into repositories (in this case mostly ICT based) and its retrieval indicates the reuse of the knowledge extracted from the repository. Markus (2001) has recently shown that knowledge reuse strategies have started to divert their main attention away from a pure ICT system and now tend to focus on human related issues in using ICTs. Therefore, in order to indicate a research gap, it is desirable to explore what is actually knowledge reuse.

2.4.1 Types of Knowledge Reuse

In this section, the typologies of knowledge reuse will be discussed. According to Markus (2001), the process of knowledge reuse consists of capturing, packaging, distributing and reuse. The reuse phase can be further broken down to more detailed processes such as defining the search question, the search for a location of expertise, selection of an expert and applying the knowledge. There are 4 types of knowledge reuse situations: Shared Work Producers, Shared Work Practitioners, Expertise-Seeking Novices and Secondary Knowledge Miners. These are shown in Table 2.13. For example, the inclusion of "Expertise-Seeking Novices" proposes a condition of having face-to-face interactions, which enable knowledge reuse. This indicates that knowledge reuse theory defines both the reuse of tacit and explicit knowledge, not just a pure reliance on ICTs.

	Shared Work Producers	Shared Work Practitioners	Expertise-Seeking Novices	Secondary Knowledge Miners
Description	People working together on a team, either homogenous or cross functional; producers of knowledge for their own later reuse	People doing similar work in different settings: producers of knowledge for each other's use	People with an occasional need for expert knowledge that they do not possess and do not need to acquire themselves because they need it rarely	People who seek to answer new questions or develop new knowledge through analysis of records produced by other people for different purposes
Purpose of Knowledge Reuse	• Keep track of current status and things needing attention • Recall reasons for decisions when decisions need to be revisited or when there is turnover among team members • Learn how the team can perform better on the next project	• Acquire new knowledge that others have generated (e.g. how to handle a particular type of problem) • Get advice about how to handle a particularly challenging or unusual situation that is new to the team • Gain access to observations that spur innovations	• Answer an arcane question or solve an ad hoc question • Approximate the performance or experts • Minimize the need for experts	• Seek answers to new questions or create new knowledge
What Reusers Need to Know, Know, and Don't Know	• Users need to know what was done (declarative, factual knowledge), how it	• Users need to know how to do something and why a particular procedure knows	• Users need access to other's expertise (e.g. an answer to a question) without	• Users need solutions for novel problems • Users have general

	is/was done (procedural knowledge), why it was done (rational), what could be done better (analytical knowledge) • Users share general knowledge and specific contextual knowledge related to project and their area of expertise/ involvement • Users may not know about the work of the other team members, particularly those in cross-functional teams	• Users share general knowledge and share knowledge of what contextual knowledge is useful • Users may not have specific contextual knowledge of the producers' settings	actually needing to acquire the expertise itself (e.g. the ability to answer related questions) • Users have knowledge of the local context • Users do not have relevant general knowledge • Users do not know what aspects of local context are important • Users may not know how to analyse general knowledge against specific context knowledge	analytic expertise • Users often lack the general and specific knowledge of the people creating the records
Challenges Reusers Experience (and Strategies They Use)				
Defining the search question	• Minimal problem in homogeneous shared work teams since members share general and specific knowledge • More challenging in cross-functional teams	• Minimal problem because of shared general knowledge and knowledge of important dimensions of context	• May not know they need expert advice • May lack knowledge of expert jargon • May not be able to recognise technical 'symptoms' in local context • May be unable to articulate the question or problem well	• Defining the question will be especially challenging in the case of knowledge discovery
Selecting Experts or Expertise	• Not usually a problem	• Use knowledge of reputations to assess quality of experts/expertises	• Lack suitable criteria for judging quality of experts/expertise	• 'Spurious results' are a common problem • Results should be triangulated and pilot tested
Applying the Knowledge	• If they can find what they are looking for, this is not usually a problem	• Usually have little difficulty applying the expertise, once it has been selected	• May lack ability to apply good answers/advice successfully	• Not usually a problem

Table 2.13, Types of knowledge reuse situations

(Source: Markus, 2001)

Based on the literature presented by Markus (2001), she pulled information from a wide variety of sources to describe the theory behind successful knowledge reuse. She also derived the 4 distinct types of situations where knowledge reuse has existed. Even Alavi and Leidner

(1999) suggested that the approach is to build a theory of knowledge reusability, with particular emphasis on the role of knowledge management systems and the repositories. Not only did Markus identify that knowledge reuse involves having access to experts (i.e. face-to-face interactions) and codified expertise (i.e. information), she also added that there is an increasing trend for knowledge reuse systems to provide expert identifications and selection mediations for their knowledge reuse. Anand, Manz and Glick (1998) were also observed to have support these processes for knowledge reuse.

2.4.2 Factors in Knowledge Reuse Success

While looking at 4 types of knowledge reuse situations identified by Markus (2001), the factors for ensuring successful implementations were also looked at and some problems were identified. Based on this, she offered several pointers in specific areas to improve the success rate of knowledge reuse initiatives. These are shown in Table 2.14.

	Shared Work Producers	Shared Work Practitioners	Expertise-Seeking Novices	Secondary Knowledge Miners
Recommendations for Promoting Successful Knowledge Reuse	• Maintain context in the record • Provide support for indexing and searching (e.g., periodically summarize transcripts threads and purge old records) • Require documentation of rationale knowledge • Do not provide public access to these repositories	• Repackage knowledge providing quality assurances (e.g., authorship), freshness dating, and appropriate indexing and searching capabilities • Decontextualise knowledge, but publish context information along with the content • Provide access to experts as well as to packaged expertise • Push packaged	• Repackage knowledge, decontextualising it, but provide support for recontextualisation in the local context • Make heroic efforts to translate knowledge into terminology that novices can understand and search • Provide awareness training and consultation	• Store context information (i.e. metadata) with all repositories to facilitate secondary reuse • Provide through training in knowledge base structures • Provide through training in analysis, synthesis and drawing valid conclusions • Verify all results (e.g., conduct pilot tests)

		knowledge to appropriate recipients • Provide appropriate incentives for contributions and reuse		

Table 2.14, Recommendations to improve success rate in knowledge reuse initiatives

(Source: Markus, 2001)

Based on the needs and types of knowledge reuse involved in each situation, the three additional factors in the successful knowledge reuse determined by Markus (2001) are:

- The costs involved in creating and using the entries
- The incentives for people to create and use entries (incentives can be monetary, rewards and/or promotion)
- The roles of intermediaries in the creation and maintenance of repositories and the facilitation of their use

Therefore, this suggests that organisations must provide support to sustain the process for knowledge reuse. Incentives for the users and the maintenance of the repositories must be provided prior to achieving knowledge reuse success.

Hansen, Nohria and Tierney (1999) mentioned that incentives have been built into the performance reviews along the lines of contribution to and utilisation of the knowledge assets of the organisation. Markus (2001) also made a conclusive remark that the future challenges are to find ways for IT to take on an increasingly intermediary role in knowledge reuse

initiatives. This suggests that knowledge reuse must depend on codification strategies using ICTs to support the process while also using some personalisation strategies as a supplement to support knowledge reuse.

2.4.3 Innovation and Replication from Knowledge Reuse

As identified in section 2.3.4, knowledge transfer can be for reuse and sharing. In past research studies, Szulanski (2000) presented a case of knowledge reuse as replication. Furthermore, Majchrzak, Cooper and Neece (2004) mentioned that knowledge reuse could be identified as for one of two conditions, replication or innovation. This further suggests that knowledge reuse is not only applicable to knowledge replication, but also for innovation. While focusing on knowledge reuse for replication, it was mentioned that Grant (1996) categorizes these frameworks into knowledge acquisition and knowledge integration. Knowledge reuse for replication can therefore be summarized as knowledge capturing (acquisition) for future shared usage (replication), whereas knowledge reuse for innovation is different. Grant (1996) argues that knowledge acquisition (or replication) is not necessarily an efficient approach, especially when innovation is required in terms of the content of the knowledge being transferred as well as the evaluation criteria used during the knowledge search process. Majchrzak, Cooper and Neece (2004) later proposed a model of the process for knowledge reuse to achieve innovation, as seen in Figure 2.8.

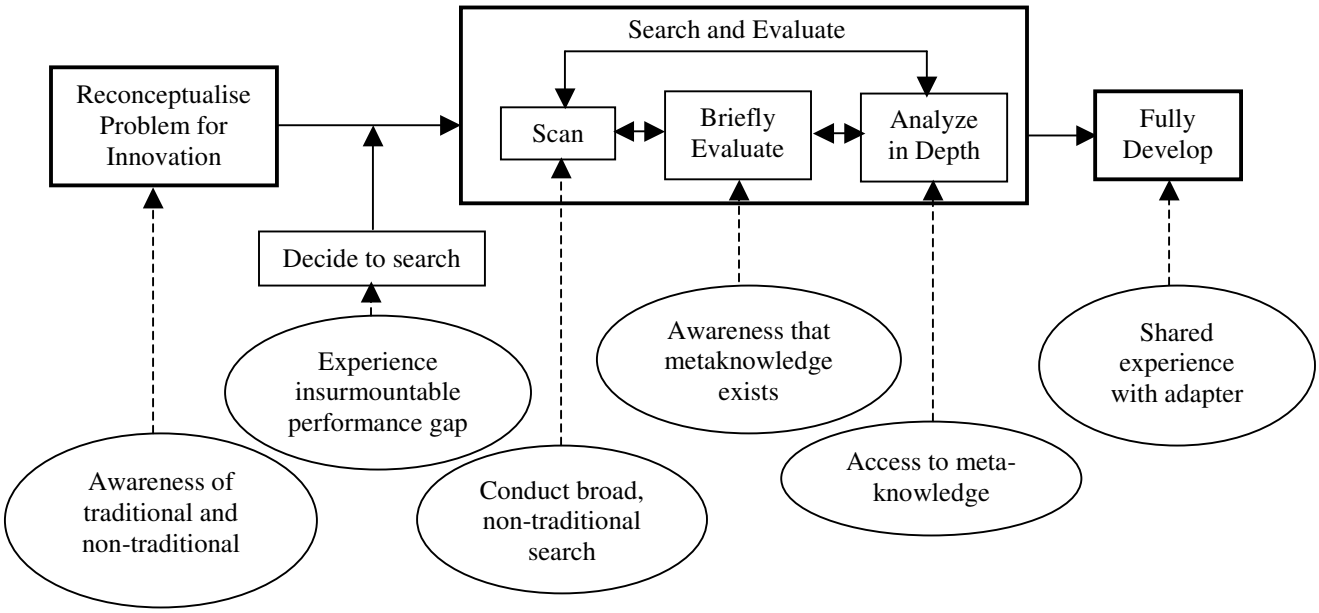

Figure 2.8, Model process of knowledge reuse for innovation

(Source: Majchrzak, Cooper and Neece, 2004)

When presented with this knowledge reuse model for innovation, it can be observed that there are 3 critical areas: (1) reconceptualise the problems for innovation (awareness), (2) search and evaluate the solution and then (3) fully develop the solution to fit the problem. This has provided useful insights on the reuse process when it comes to knowledge reuse in innovation. However, based on the model by Majchrzak, Cooper and Neece, 2004, there are significant differences in the emphasis of innovation. As compared to the knowledge reuse model (reuse phase) as seen in Figure 2.7, the methodologies are largely similar in function and sequence. Knowledge reuse still depends on the capturing, packaging, distributing and eventual reuse of the knowledge. In this case, the main influence of knowledge replication or innovation only occurs at the reuse phase.

2.5 Summary of Literature Contributions and Limitations

This chapter reviews the work in relation to knowledge management and quality management systems. Starting with the quality management systems, the basis of quality was discussed and introduced. Quality management systems are a set of processes within an organisation used to improve business performance that started during the industrial revolution (late 18th century to early 19th century) and later emerged as the well-known Total Quality Management concept. A paper by Dubois (2002) called to attention that Total Quality Management was not as clear as it should be, as most managers interpret its meaning with large variances. Although it was derived in the 19th century, many Total Quality Management concepts are still used today and this can be considered as good values passed down (Hill and Wilkinson, 1995).

As it is expected to shed new insights on to quality management, the rationale for the interest in knowledge management becomes clear. When quality management is considered out-dated, the knowledge management research by both academics and industries (Hislop 2005, Scarbrough and Swan 2001) increases and shows its popularity. This review started with the definition and identification of the various types of knowledge. There were several important insights into the theoretical foundations of knowledge; arguably, the most substantial research literature focused on tacit and explicit knowledge was by Nonaka and Takeuchi (1995). However, the literature only discussed the theory of the knowledge creation process, and this is a result of human interactions between tacit and explicit knowledge based on a collection of case studies of learning organisations.

Having reviewed the literature pertaining to knowledge typologies, the next step was to look at the interaction process where humans engage in communication. As mentioned by Hislop (2005), the communication process is critical for the 3 types of knowledge transfer concepts:diffusion of innovation, technology transfer and communication. The success of these knowledge transfers is highly dependent on the mediums used. Lengal and Daft (1988) proposed that the media richness theory is important and will influence the success rate of knowledge transfer, and this also enforces how the media richness hierarchy coupled with knowledge types and mediums (i.e. telephone, meetings, emails) are used. Depending on whether tacit or explicit knowledge is being transferred, the medium can be changed to suit the needs; otherwise, the risk of failure is high. This literature has contributed to the research that knowledge (explicit/tacit) is very much dependent on the transfer mediums used.

Next, it is time to look at communication from a knowledge sharing and transfer process perspective. The key is to find out the links between research disciplines and understand the implications they have to each other. From the work of Nonaka & Takeuchi (1995), it can be identified that knowledge sharing is dynamic and occurs in several stages and, during the knowledge sharing process, moves between tacit and explicit knowledge frequently. With regard to knowledge transfer, Appleyard (1996) found that knowledge transfer itself contains both knowledge sharing and reuse, which is similar to the definition by Alavi and Leidner (2001). The links between knowledge sharing, reuse and transfer have hence been identified. Liebowitz (1997) later on observed that there was a heavy reliance on ICTs for the knowledge sharing process. The mechanisms used for both knowledge transfer and sharing, as defined by the literature, were found to be similar in trends. Both showed similarities in

terms of the type of knowledge to share/transfer, which will affect the type of medium selected to use for each knowledge transfer or sharing process. Hence, this literature provides a clear indication of the similarities between knowledge transfer, sharing and reuse, and the communication links that form the basic connections between them.

Further building on the importance of knowledge transfer, sharing and reuse, some research conducted on knowledge management strategies in order to understand practices adopted by organisations has yielded some important insights. Hansen, Nohria and Tierney (1999) pointed out that organisations adopt two forms of strategy for knowledge management: codification and personalisation. Codification exists in most knowledge sharing organisations, as explained by literature from Liebowitz (1997). This research pointed out the trend that codification is the preferred method used for knowledge sharing and transfer scenarios. Again, as pointed out by Hansen, Nohria and Tierney (1999), it is not advisable to adopt only a single strategy to manage the knowledge within an organisation. Based on their analysis, most organisations with only one strategy failed; it is best to adopt an 80/20 approach. This section therefore has provided insights into the knowledge management strategies used in knowledge transfer, sharing and reuse.

This thesis will now focus on the topic of knowledge reuse after the identification of the relationship between knowledge transfer and knowledge sharing, as defined by the researchers Majchrzak, Cooper and Neece (2004), Alavi and Leidner (2001), and Szulanski (2000). As presented by Markus (2001), the literature on knowledge reuse for replication theory described that there are 4 unique types of knowledge reuse situations (including both

tacit and explicit knowledge transfer). Markus's approach was more inclined toward the use of ICT and codification (documentation) strategies of knowledge management. Based on the past literature review, knowledge reuse is often expected to be for duplication (replication) purposes simply by the use of codification strategies. Interestingly, a study by Majchrzak, Cooper and Neece (2004) has revealed that knowledge reuse is in fact applicable to innovation as well. The study was conducted on several highly innovative products and the results were surprising. It was found that a lack of knowledge and a high level of uncertainty help to create innovative ideas and solutions, thereby increasing the knowledge reuse for innovation rate. However, this study was applicable to knowledge reuse for innovations, and no further implications to knowledge reuse for replication were assessed or compared. However, both models show suspiciously similar functions in the reuse phase process for knowledge reuse.

The review of the existing literature has synthetically examined the numerous contributions that stem from the extensive research conducted in knowledge management and quality management. It has been noticed that there have been a largely ignored aspect of knowledge reuse in quality systems (the point that knowledge reuse is indeed an extension of knowledge management). This is then put into a matrix as where the research interest of knowledge reuse and quality implications are interrelated to find out any intersecting similarities, hence resulting in Table 2.15. Thus far, it can be observed that the literature review has provided significant insights into knowledge management theories. The contributions and limitations are as shown in Table 2.15.

Areas of Literature review	Research Foci	Main Contributions	Limitations	Concerns of this research			
				Knowledge characteristics	Knowledge Reuse mechanisms	Processes for Knowledge Reuse	Quality implications
Total Quality Management	What is Quality Management? How successful is Total Quality Management?	Quality management from a holistic perspective	- Limited to customer orientated, process orientated and continuous improvement - Partial implication to knowledge reuse - Mostly in relation to codification of knowledge			●	●
Typologies of knowledge	What is knowledge? Who has the knowledge?	Meanings and characteristic of knowledge	- Mainly theoretical - Cannot be readily applied to practice - Lack of insight from a knowledge reuse perspective	●			
Communication Research	How communicators choose their medium?	Medium selection theories	- Not enough consideration into other factors affecting knowledge reuse		●		
Knowledge sharing and transfer	How knowledge was share and transferred between entities? What are the mechanisms used for knowledge sharing?	Provided links between knowledge sharing, transfer and reuse	- No detailed insights to knowledge reuse in relation to transfer and reuse			●	
Mechanisms used for knowledge management	How can it affect the success of knowledge transfer, sharing and reuse?	Richness in media selection theory Mediums used Mechanisms used by organisations	- Not enough consideration into other factors which affect their success to knowledge reuse		●		
Knowledge management strategies	What management strategies are best suited to which type of organisation? What are the knowledge strategies?	Provide the acknowledgement of ICTs and the concept of codification in knowledge management strategies	- Limited insight to knowledge reuse management strategies	●		●	
Knowledge reuse	How was knowledge reused? What are the types of knowledge reusers?	Meanings and characteristics of knowledge reuse for replication	- No insight into the limitations of the suggested improvements for knowledge reuse		●	●	
Knowledge reuse for innovation	How could knowledge reuse be applied in innovation specific context?	Knowledge reuse model for innovation	- Only innovation on new product was discussed - Lacking in knowledge reuse for replication	●	●	●	

Table 2.15, Contributions and limitations of various relevant research disciplines

2.6 Linking Literature Review and Research Interest

Now that insights to the literature review have been presented, it is important to link it to the purpose of the research. Using Table 2.15, the areas of literature review being presented has revealed that there have been discussions and studies into knowledge management related agendas (i.e. Total Quality Management, typologies of knowledge, communication research, knowledge sharing and transfer, mechanisms for knowledge management, knowledge management strategies, knowledge reuse and knowledge reuse for innovation). It can be later generalised that the literature review of the various subjects falls into 4 categories of interest, being knowledge characteristics, knowledge reuse mechanisms, processes for knowledge reuse and quality implications. These four points summarises the approach taken for the formulation of the research questions.

While drawing the matrix into Table 2.15, it can be noticed that typically lack of study into quality systems for knowledge reuse. Interestingly, the lack of a management system to manage knowledge reuse is also one of the weak points during the literature review. While much discussion has taken place in terms of knowledge management as a concept, a lack of common platform to identify the proper way of doing it effectively still awaits formation.

Simply, the research shall focus on two points. The first point is towards knowledge management aspects (consisting of knowledge characteristics, knowledge reuse mechanisms and processes for knowledge reuse) and the second point is towards quality management aspects within a given system (i.e. quality system). Thereby identifying on these two points' weak academic link, using current existing systems (i.e. quality systems) to leverage and

manage knowledge would be one of the interesting ways one can take. Imagine, without having to reinvent the wheel (by recreating new management system as compiled in Table 7.1), it is possible to scale up the operations into a large databases of knowledge, waiting for immediate reuse.

2.7 Formulating the Research Questions

Knowledge management aspects consist of 2 areas of interest in this research: process of knowledge reuse and knowledge reuse mechanisms. For the exploration into quality aspects, there exists only 1 area of interest in this research: the quality implications onto knowledge reuse. Since literature review on knowledge characteristics and quality management systems have shown that they are mature and well established, they will remain as the foundation of this research. Hence, the focus will be on the processes of knowledge reuse and mechanisms while using knowledge management and quality management systems as a basis for this research. Based on the above discussion, the research questions are:

1. How has knowledge reuse influenced quality issues?
2. What mechanisms in quality management systems influence knowledge reuse?

2.8 Conclusion

Through the process of writing this thesis, as well as observed in the literature review, the terms used for the description of knowledge have been largely vague in meaning. In order to minimise the confusion, it is best to define the terminology used hereafter. Knowledge as

used by academics has been the main ingredient, often derived alone or between intelligent beings (i.e. human beings), knowledge management in general, encompasses all aspects of manipulating, utilising and storing of the main ingredient, knowledge. Now in the deeper context, the term knowledge reuse looks in greater detail on the process whereby knowledge is being captured, filter (cleaned), stored and then later taken out again for reuse. Quality issues exist as very rich data, of which case studies were presented from these issues, which is a result of the manufacturing process involved.

Now, discussions in this thesis have extensively covered all aspects pertaining to managing knowledge within the organisation, particularly in the areas of knowledge reuse. A quality management system operating in most manufacturing companies seems to provide a platform for good knowledge reuse opportunities, based on the observation that knowledge reuse does reside in an organisation which has implemented quality management systems. This suggests the possibility that links between knowledge and quality can be established. This chapter explored the research availability, of which the gaps and contributions were revealed and discussed. For meaningful research, it is best to attempt to look into less explored areas of knowledge reuse and quality implications, as well as areas that can provide significant novel results. Based on this review of the literature, the research questions were eventually formulated and proposed.

3. Research Methodology

3.1 Introduction

This chapter describes the research methods used. The inclusion of the data collection methods, with reference to the available resources and the selected cases, is further explained. Implementation and data analysis are justified and the benefits of a triangulation approach are discussed.

3.2 Positivist and Interpretivist Paradigm

Research is intended to contribute new knowledge and perspectives to the current body of knowledge. The method is to propose new theories derived by combining, confirming or refuting existing theories. Philosophers have been investigating the approach on research approach for decades, and numerous approaches have emerged. However, if one has a realistic focus on research methodology, then only two research paradigms have emerged. Each one is derived from ontological and epistemological roots. Ontology is the most fundamental branch of metaphysics and its concern is with the study of existence. Its implications are on the way we view the world and our understanding of reality. The other view is epistemology, which is the branch of philosophy concerned with the definition of knowledge, or what we perceived as truth. However, it has been noted that there are many types of thought on these two terms, each taking a different perspective. However, in this research it is important to define the purpose of ontological and epistemological positions. Due to the nature of the research topic and the lack of common literature supporting the presence of knowledge reuse theory, this research will take an ontological position. When

taking an ontological stance there are two main research paradigms: positivism and interpretivism. These are shown in Table 3.1.

Tradition	Positivism and Post-positivism	Interpretive Research
Assumptions about reality	Realism: Objective reality that can be understood by mirror of science: Definitive/probabilistic	Relativism: Local intersubjective realities composed from subjective and objective meanings: represented with concepts of actors
Goal	Discover truth	Describe meanings, understanding
Tasks	Undertake explanation and control of variables: discern verified hypotheses or nonfalsified hypotheses	Produce descriptions of member's meaning and definitions of situations: understand reality construction
Unit of Analysis	Variable	Verbal or nonverbal action
Method focus	Uncover facts, compare these to hypotheses or propositions	Recover and understand situated meanings, systematic divergences in meaning

Table 3.1, Research traditions

(Source: Gephart, 2004)

Some management researchers have adopted a middle ground by combining methods from each of the two paradigms (Easterby-Smith and Mark, 2002). However, for this research the interpretivist perspective will be used. This is because this research is concerned with developing understanding, defining concepts though the collection of data, giving importance to the context, trying to find different views of a same phenomenon, carefully choosing a specific sample and then investigating it in depth. The view on knowledge management research has also majored toward descriptive methods due to the large variance expected in the data. Hence, interpretive research will be used for the research of this similar nature.

3.3 Research Strategies

This research aims to develop an understanding of the effects of knowledge reuse in quality systems (based on quality issues), as well as to identify whether the knowledge reuse has been effectively undertaken. If it is ineffective, 'what' is required to improve the situation and 'how' it can be achieved? From this observation, it will be possible to observe the mechanisms in use and interpret their influence on the success of knowledge reuse on the quality issues. Based on the research questions, it is possible to see that the question of 'how' often appears. Yin (2003) suggested that the choice of research methodology should be made based on the nature of the research questions (see Table 3.2).

Method	Form of research question	Requires control over behavioural events	Focuses on contemporary events
Experiment	How, Why	Yes	Yes
Survey	Who, What, Where, How many, How much	No	Yes
Archival Analysis	Who, What, Where, How many, How much	No	Yes/No
History	How, Why	No	No
Case Studies	How, Why	No	Yes

Table 3.2, Research strategies

(Source: Yin, 2003)

Therefore, the nature of the research question suggests three approaches for the research: Survey, Archival Analysis and Case Studies. In this research, it is clear that there is a lack of a combination of both knowledge reuse and quality systems. Hence, the three methods suggested are all suitable for use in researching such conditions. None of the methods mentioned require control of the behavioural events, as this would make the data obvious.

The focus on contemporary events is also critical to the research presented, which makes the data realistic and palatable for the real world.

Another view on the choice of methodology is the study of the research type. As defined by Eisenhart (1989), the lack of extensive fundamental theories (in this case, knowledge reuse and quality systems are argued to be new due to the lack of literature to support them) suggests that this research will aim to contribute to the development of new theories, constructs and frameworks. In this context, an optimal strategy would be more inductive and qualitative, rather than deductive and formal (Adler, 1989). The need to integrate a fragmented and disciplinary confined field of research calls for the flexible use of a set of data for a holistic approach. Therefore, the nature of the research question, coupled with the objectives of the research and the lack of supportive literature, all call for the use of a case study methodology.

3.4 Research Design and Implementation

Viewing case studies as a research strategy (Yin, 2003), this research follows the case study research roadmap proposed by Eisenhart (1989). This method integrates and synthesizes the previous and abundant work on qualitative methods, as seen in Table 3.3. This research follows the steps presented as closely as possible (see the Research Activity Conducted column of Table 3.3). However, it is to note that the sometimes due to the ambiguous nature of the research during the early phases, the early steps requires somewhat of an iterative approach in its form.

Step	Activity	Reasons	Research Activity Conducted by Researcher
Getting Started	Definition of research questions Possibly a priori constructs Neither theory nor hypotheses	Focuses efforts Provide better grounding of construct measure Retains theoretical flexibility	▪ Literature review ▪ Research question formulation ▪ Formed Table 2.15
Selecting Cases	Specified population Theoretical, not random sampling	Constrains extraneous variation and sharpens external validity Focuses efforts on theoretical useful cases	▪ Selected the organisation which fulfils the requirement of having implemented a recognised quality management system ▪ The people to interview within the organisation was also identify, in order to give a wide perspective from all stakeholders ▪ Specific selection of several quality problems within the organisation after the understanding of the operational protocols within the organisation ▪ Formed Table 4.1
Crafting instruments and protocols	Multiple data collection methods Qualitative data and quantitative data combined Multiple investigators	Strengthens grounding of theory by triangulation of evidence Synergistic view of evidence Foster divergent perspectives and strengthens grounding	
Entering the field	Overlap data collection and analysis including field notes Flexible and opportunistic data collection methods	Speeds analyses and reveals helpful adjustments to data collection Allows investigators to take advantage of emergent themes and unique case features	▪ Data collecting via interviews, documentation analysis, observations ▪ Third party observers were used to supplement and enhance the validity of the evidence in the data ▪ Triangulation was used in order to ensure consistency in the data
Analyzing Data	Within-case analysis Cross-case pattern search using divergent techniques	Gains familiarity with data and preliminary theory generation Forces investigators to look beyond impressions and see evidence through multiple lenses	▪ The data from the case studies were compared for similarities ▪ Any odd-one outs were further listed down for further verification, which was later triangulated with the appropriate person in charge ▪ Formed Table 4.2 and 4.3
Shaping hypothesis	Interactive tabulation of evidence for each construct Replication, not sampling, logic across cases Search evidence for "why" behind relationships	Sharpens construct definition, validity and measurability Confirms, extends and sharpen theory Builds internal validity	▪ Data and trends after analysis was later presented in Figure 4.3, 4.4 and 4.5 ▪ These forms the fundamental work of the research of which the theory was build to encompass breadth and depth, to suit both academic and practitioners ▪ Answering the research questions and further revealed possible future work to be carried out to ensure research vigour ▪ Thesis writing to document and provide accountability of the research conducted
Enfolding literature	Comparison with conflicting literature Comparison with similar literature	Builds internal validity, raises theoretical level and sharpens construct definitions Sharpens generalizability, improves construct definition, and raises theoretical level	
Reaching closure	Theoretical saturation when possible	Ends process when marginal improvement becomes small	

Table 3.3, Process of building theory from case study research

(Source: Eisenhart, 1989)

3.4.1 Unit of Analysis

Based on the research questions and the previous descriptions, it is determined that a case study type research model shall be utilised. Miles et al. (1994), define a case as a phenomenon of some sort occurring in a bounded context, and claim that the case, heart and focus of the study are also the unit of analysis for case study research. While reflecting on selected cases and considering the various sampling techniques, it is recommended to focus and bind the collection of data during the early stages of the research. This helps provide some early insights to trends and patterns in the data, thus allowing some degree of flexibility in the later data collections and research in somewhat of an iterative pattern.

Yin (1994) stresses that the unit of analysis definition should be closely based on the research questions. The 2x2 matrix of Yin (2003), as seen in Figure 3.1, indicates that there are four basic types of case study design.

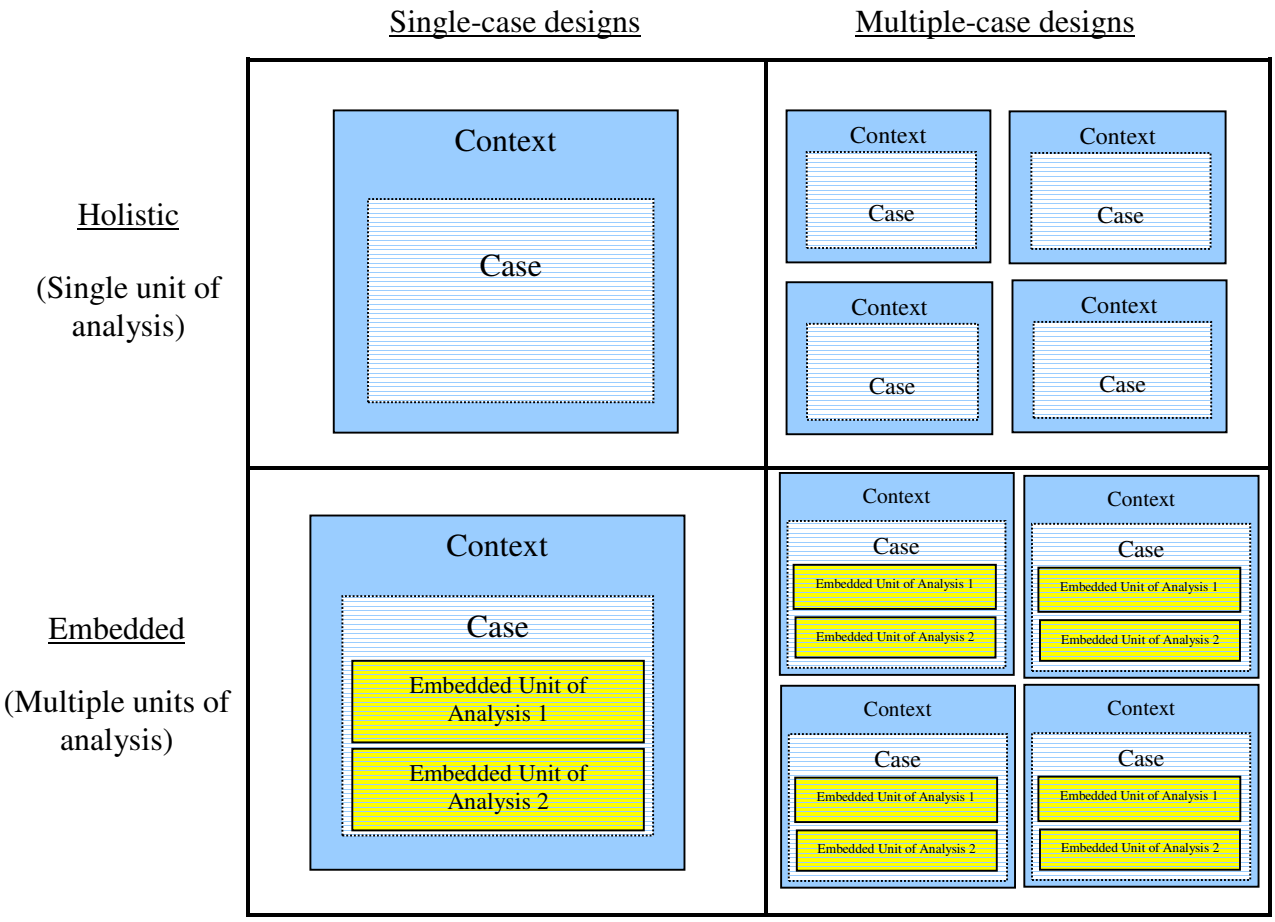

Figure 3.1, Basic types of design for case studies

(Source: Yin, 2003)

In this research, the research questions call for an embedded design. In this case, the resources available to the researcher suggest that the research should be carried out as multiple case studies. For each single case, two units of analysis are considered. The first question is to identify how knowledge reuse has been implemented and maintained in a quality system. Since knowledge reuse success is fuzzy and difficult to measure, it is necessary to anchor the observations to be quality issue occurrences. If there is a chronic occurrence of the same issue, then the knowledge reuse can be considered ineffective.

Quality and knowledge reuse success and failures shall be the unit of analysis for research question 1 where the main agenda is to look at "How has knowledge reuse influenced quality issues?"

With regard to the second research question, "What mechanisms in quality management systems influence knowledge reuse?" There exists a need to look at the mechanisms used in the knowledge reuse during the resolution of the quality issues. This can help to identify the possible causes of failed knowledge reuse and identify why it has occurred. The unit of analysis for this shall be different compared to research question 1, and the knowledge reuse mechanism now becomes the unit of analysis.

From this, the suggested units of analysis can be seen as follows in Figure 3.2. The same units of analysis will be used for each of the multiple cases in this research.

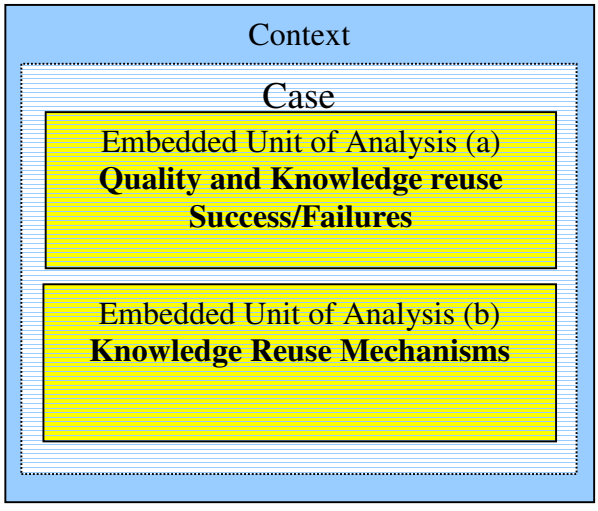

Figure 3.2, Embedded single case design of research

3.4.2 Sampling Strategy

The sampling strategy affects the research findings to an important degree. This is because the more data that is included the more the phenomenon becomes significant. In quantitative research, the amount of data present is critical in the modelling of the population, whereas for qualitative research there is a lack of the luxury to acquire such numbers for the data set. The truth is that case studies do not seek and can rarely obtain large sample sizes, as mentioned by Miles and Huberman (1994). Instead, the quantitative approach commonly uses selective sampling that can be assimilated to purposeful sampling (Coyne, 1997, Voss, Tsikriktis and Frohlich, 2002). Overall, this sampling strategy serves the purpose of leading the researcher by guiding the case selection progressively, together with some specific criteria. As Schatzman and Strauss (1973) have mentioned, selective sampling is a practical necessity that is "shaped by the time the researcher has available to him, by his framework, by his starting and developing interests, and by any restrictions placed upon his observations by his hosts". King (1994) added that selective sampling significantly improves the efficiency and accuracy of qualitative research. Selective sampling is a generic term, and as seen in Table 3.4, some specific methodologies can be chosen that have similar traits to selective sampling. Additionally, it can be realised that, these are the strategies used by many researchers in management theories alike.

Patton (1990) All sampling is purposeful – 15 strategies	• Extreme or deviant case sampling • Intensity sampling • Maximum variation sampling • Homogenous sample • Typical case sampling • Stratified purposeful sampling • Critical case sampling • Snowball or chain sampling • Criterion sampling

	• Theory-based or operational construct sampling • Confirming and disconfirming cases • Opportunistic sampling • Purposeful random sampling • Sampling politically important cases • Convenience sampling
Strauss and Corbin (1990) Theoretical sampling - 3 stages	• Open Sampling • Relational and variational sampling • Discriminate sampling
Morse (1991) Four Types	• Purposeful sample • Nominated sample • Volunteer sample • Total population sample
Sandelowski et al. (1992) Two types	• Selective Sampling • Theoretical sampling
Sandelowski (1995) All sampling is purposeful – three kinds of variation	• Maximum variation • Phenomenal variation • Theoretical variation

Table 3.4, Various examples of qualitative sampling strategies

(Source: Coyne, 1997)

3.4.3 Selection of Cases

Pertaining to the selection of the cases for this research much thought and planning was involved. It was decided to limit the cases to one unique representative in which all the units of analysis could be acquired in a strategic and scientific manner. The context of the case can be again referenced to Figure 3.2, where there is now one context, but with many cases within it, as seen in Figure 3.3. There are two main reasons for this rationale.

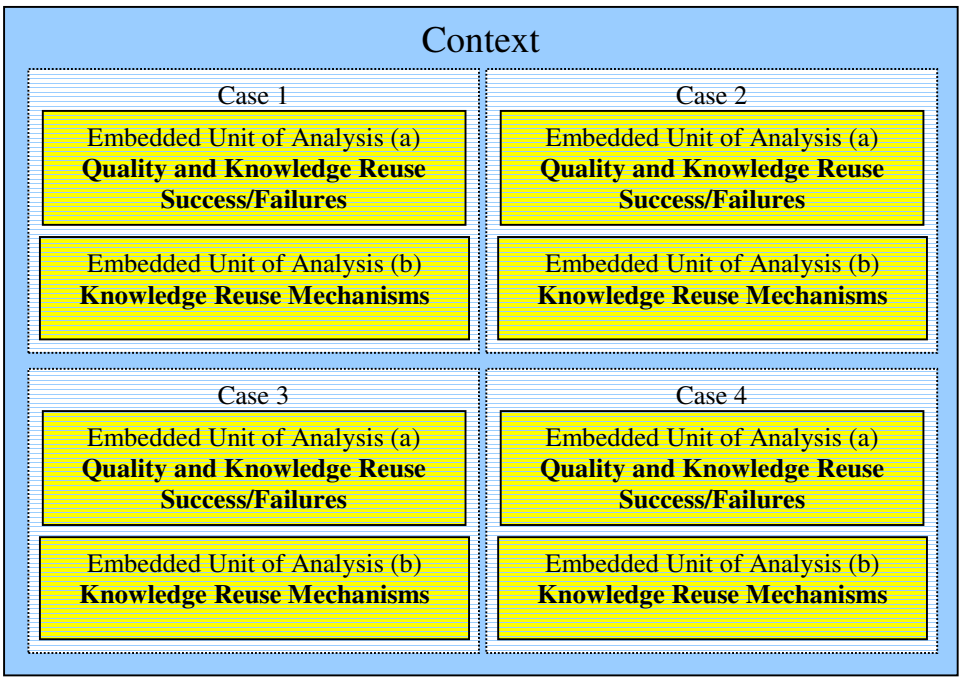

Figure 3.3, Case selection schematic

Firstly, the focus is placed on the knowledge context within an organisation; this research does not encompass inter-organisations. The following Voss et al. (2002) statement, "for a given set of available resources, the fewer the case studies, the greater the opportunity for depth observation", means that research data restricted to a few meaningful sets will offer more insightful details that a larger data sets might camouflage.

Secondly, as stated by Yin (2003), the representative case study selected for this research will be consistent for most general conditions in similar organisations. The events, individuals and mechanisms should not differ in large amounts, and hence this will remain the basis for the assumption. In addition, as Gummeson (1993) has emphasised, access to the data must first be available before any good research can be conducted. Therefore, the core research

shall focus on knowledge reuse, mechanisms and quality systems. The other considerations before the selection of the cases within the organisation include:

- Knowledge is an important resource to the organisation due to the business nature, based on the evidence of proprietary knowledge within the organisation (i.e. patents, licenses, etc).
- The organisation has implemented a third party certified quality management system to define the effects of quality systems in the research question.
- The organisation allows access to all levels of staff (i.e. managers, engineers, technicians and operators) and documents are provided accordingly, so it is possible to paint a clear picture from the data collected.
- The organisation has chronic and spike-case quality issues existing in current production in order to identify the trend exhibited in the product quality.

The four points listed above are can be used to describe many organisations. With this strategy, it is possible to produce useful insights, which will make this research meaningful to more practitioners. The next step of the research is to look at the unique specimen and its selected cases. Following from the above justifications, the important point is that it must fulfil the research questions stated previously. Since the research is focused on knowledge reuse with respect to the quality management system, this can be selected from a whole selection of companies. Now the researcher at the point in time was being employed in a Singaporean small to medium enterprise (more information pertaining to the organisation will be later presented in Chapter 4.1), naturally it was obvious to select it as a source of data.

As well, the researcher has been working in the organisation for a fair bit of time, which has gained experienced and understanding of the organisation, this makes the interviewees (within the organisation) more willing to cooperate and provide data. It is commonly expected that for most full-time researchers, there is a significant difficulty in gaining access to available data, as it all depends on the willingness in cooperation of the data source. Since the organisation fits the selection criteria and is available for study, it makes perfect sense to utilise the situation. This study context will be given the name Alpha. Within Alpha, 4 cases of quality issues were further selected for in-depth analysis.

Based on this, the research shall identify 4 cases within the organisation of the case study. Selection requirements that the cases must posses are as follows: -

- In the process of quality issues detection, the problem can be internally or externally detected.
- The problems selected must happen recently (at least one year from time of data collection)
- The problem must happen at least one (spike case) or two (chronic/repeated case) times.
- The problem resolution must utilise instruments (i.e. documents, protocols, meetings, briefings, evidences, photos, samples, etc)
- The cases selected must be of automotive origin (in order to fulfil the ISO/TS16949 quality management system)

When the selection criteria above have been identified, the next stage is to go through the quality records of the past year and select the cases, which closest fit the requirements. Thereby, making the data more diversified and interesting.

As seen in Figure 3.4, the flow of the research implementation shall be based on the initial literature review. Based on the literature, it is possible to understand the gaps and the possible links between the theories. As well, in doing so it is possible to build the next level of theory upon the pre-existing ones and create novel views. From this, after the selection of the cases, it can be defined that the scenarios and the purpose of the research can be further broken down to extract the units of analysis pertaining to individuals and the mechanisms.

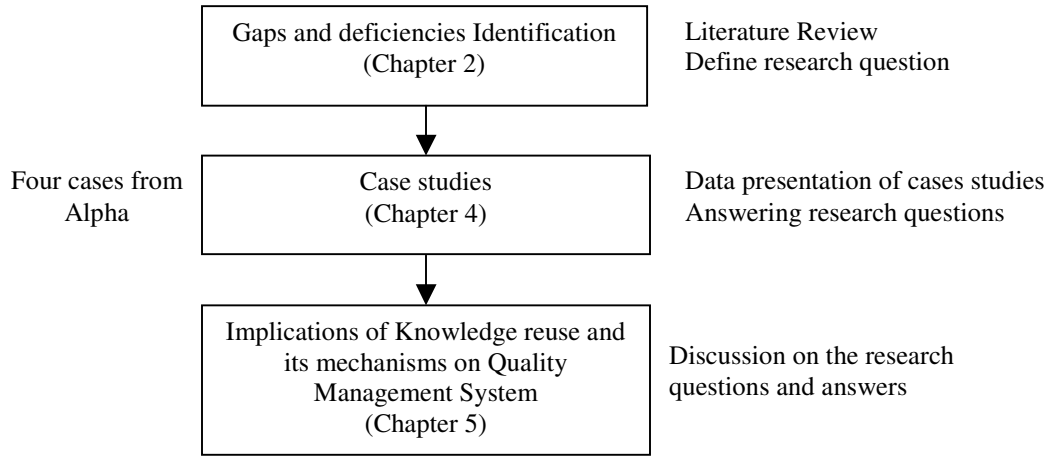

Figure 3.4, Research design and implementation

3.5 Data Collection Method

One of the strengths of qualitative case studies research over other methods is that this approach allows for data collection from various sources, which improves validity and

reliability (Yin, 2003, McCutcheon and Meredith, 1993). Collecting data from multiple sources also provides a richer picture compared to questionnaire surveys for a subject like knowledge reuse. Adler (1989) even suggests that knowledge management researchers should learn from the discipline of history, where research is done through scrupulous attention to all data of any type that may improve understanding of the phenomenon being researched. Therefore, three methods being used in the data collection for this research are interviews, observations and documents.

3.5.1 Interviews

An interview is a means of capturing historical and real time qualitative data from original sources. As Brenner, Brown and Canter (1985) have stated, "There is an explicit sharing and negotiation of understanding in the interview situation which is not so central, and often not present, in other research procedures". As a data collection method, it has the advantages of allowing clarifying means that a mail survey or secondary data may lack. This is particularly important in this research because the meaning of words such as knowledge, knowing and learning are often ambiguous. Through interviews, richness and subtlety of understanding can be achieved since the interview allows for instant clarification and flexibility (Parkhe, 1993). All interviews carried out for this research were conducted in Mandarin (Alpha is situated in China). In certain cases (i.e. expatriate managers from Singapore), English was used. This was dependant on the interviewees' mother tongue. Language is an especially important variable for creating better rapport, as mentioned by Tsang (1999).

Because the researcher is employed within Alpha, third parties (two Mandarin speaking interns from the National University of Singapore) were used to support the interviewees. In interviews, the impact of the interviewer on the candidates can be quite significant, as it is possible that information might be withheld or wrongly put forth. For this purpose, it was important to utilise a neutral person (not from within Alpha) to generate as little influence and bias as possible. The researcher listed a set of interview questions and then planned for the neutral third person (interns) to question the interviewees. The researcher however was present at all times of the interview, supporting and joining in the discussions as and when necessary. Questions were asked by the interns and recorded down by the interns as well. A friendly and diplomatic tone was maintained throughout. Through this, the non-intimidating ambience of the interview revealed interesting and highly tacit accounts.

Subsequently, the collected data was subjected to post interview meetings between the interns and researcher. Final facts and documents were consolidated to ensure triangulation and data accuracy. Filtering of the data was performed in order to keep relevancy to the subject matter. For more information on the interview questions, refer to Appendix 7.1.

3.5.2 Observations, Document Analysis and Triangulation

Qualitative observation is a method of collecting data by witnessing the events relevant to the research topic in a natural manner. In this research, qualitative observation was used to collect and validate data obtained from other sources, as defined by Miles and Huberman (1994).

Document analysis was used to supplement and validate data obtained through interviews and observations. It provided secondary data about the context of the macro environment in which the cases were subjected. Documents are a good source for triangulation purposes. The verbal statements (tacit in form) given by interviewees are verified by documents (i.e. work instructions, emails, informal written notes, etc). Such documents hold the explicit knowledge of the organisation and are useful for qualitative research.

Triangulation methods, as mentioned, were also used for this research case, and both method and data types were leveraged. As pointed out by Miles and Huberman (1994), triangulation is more a way of research life then a strategy. When a researcher constantly doubles checks their findings using multiple sources and modes of evidence, the verification processes is built into the data collection. Throughout this research, wherever possible, attempts were made to obtain data from more than one source (asking different people the same questions), through different methods (formal interviews, observations and informal conversations) and from different data type (records, emails, documents, etc). As shown in Table 3.5, the activities taken during the interview process and post interview are as described.

Data Source during data collection phase	Triangulation method used for each situation
Statements collected during interviews, through story telling (What people say)	• Documents (Procedure documents, Work Instructions, Emails) • Records (Daily production records, daily check sheets, ec) • Reports (Non-conformance Reports, Reports from customers) • Samples (defective samples) • Cross checking with another witness • Verification of keywords used by all interviewees • Verification of certain situations with respective interviewees
Observations collected during plant tours and informal	• Confirmation with another third party (of different authority level)

discussions with other non-interviewees (What researcher personally observed)	• Asking of each individual (after their comment) for the documented proof (exists as email, reports, hand written notes) • Personally participating in the mentioned activity (from the discussions) • Cross checking with several other witnesses • Daily personnel observation

Table 3.5, Data validation and triangulation perform

The process of triangulation and the interviews have revealed valuable data for this research, the rich information presented embodies information of both tacit and explicit nature. The next phase is to utilise the data collected for the answering of the research questions posed.

3.6 Data Analysis

Eisenhardt (1989) states that, "analysing data is the heart of building theory from case studies, but is both the most difficult and least codified part of the process". Data analysis consists primarily of three concurrent flows of activities: data reduction, display and conclusion drawing/verification (Miles and Huberman, 1994). Similarly, data reduction is the process of selecting, focusing, simplifying, abstracting and transforming the data that appears in written-up field notes or transcriptions. Data display is "an organised, compressed assembly of information that permits conclusion drawing and action" and conclusion drawing is recognising and verifying "regularities, patterns, explanations, possible configurations, causal flows and propositions" (Miles and Huberman, 1994). In practice, these three activities (data reduction, data display and conclusion drawing) are interwoven with each other. They form a cyclical process during the data collection and analysis period.

In this research, data reduction was achieved by note taking during the interviews as well as after the interviews. Data display was facilitated through a combination of case summaries and matrices with key constructs that emerged from the data. Conclusion derivation was facilitated by employing within case analysis and cross-case analysis. To achieve within case analysis, categories, themes or patterns were generated by going through each of the case studies independently. This approach maintained the sensitivity to data collected in each case study before comparing and contrasting them in the cross-case analysis. The similarities and differences between the cases were noted, reducing the information processing biases of the researcher mentioned by Eisenhart (1989) as well as improving the external validity of the research.

3.7 Research Validity and Relevance

In recent times, many critics rose and denounced the limitations of solely considering tests of validity. Their main reason was that although establishing validity is unquestionably a requirement for any research topic, it is not sufficient in itself to remain as validated. There is a need to relate to practitioners and issues that are important to the real world. Bennis and O'Toole (2005) wrote that business schools have adopted an inappropriate model of academic excellence based exclusively on scientific rigour. Hence, indicating a lack of relevancy in research by business schools today.

Most research is evaluated by two sets of criteria. The first is concerns about the validity of any theories that are developed and the second is to take sides with the practitioners and question the relevance of the proposed findings. However, it is noted that most researchers

maintain the positivist paradigm; they view validity as the most substantive dimension to consider when appraising the quality of an empirical work. Hence, as suggested by Leonard-Barton (1990), Easterby-Smith et al. (1991) and Yin (2003), there are four important types of validity and several tactics are recommended to avoid a variety of validity pitfalls. The tactics used to overcome such pitfalls are presented in Table 3.6.

Criteria	Interpretivist viewpoint	Case-Study Tactic	Phase of research
Construct Validity	Has the researcher gained full access to the knowledge and meanings of informants?	Triangulation by data source and method to establish chain of evidence; reinforce with literature	Data collection
Internal Validity / Reliability	Will similar observations be made by different researchers on different occasions?	Did pattern matching Did explanation building	Data analysis
External Validity / Generalisability	How likely is that ideas and theories generated in one setting will also apply in other settings	Theoretical sampling, i.e. companies chosen from two difference industries In each industry, replication logic was used, i.e. chosen companies with similar background	Research design

Table 3.6, Research validities and tactics used to improve them

(Source: Leonard-Barton 1990, p.253, Easterby-Smith et al 991, p.41, Yin 2003)

As Dubin (1976) and Mitroff et al. (1974) have added, the practical usefulness of research must be assessed by using the practitioner as a frame of reference. In order to prevent these pitfalls from occurring, this research follows the criteria used by Thomson and Tymon (1982) as well as Chai (2000). These five criteria are shown in Table 3.7. The 'as achieved by' column reflects the research conducted on Alpha.

Criteria	Addresses (Issues pertaining to the criteria)	And achieved by (Suggested by the Researcher in this thesis)
Descriptive relevance	Refers to the accuracy of research findings in capturing phenomena encountered by the practitioner in his or her organisational setting	- Constructive discussions with positive feedback from individuals in Alpha - Alpha follows the understanding of the fact that this research will bring to them in depth understanding as well as possible solutions
Goal relevance	Refers to the correspondence of outcome (or dependant) variables in a theory to the things the practitioner wishes to influence	
Timeliness	Concerns the requirement that a theory be available to practitioners in time to use it to deal with problems	
Operational validity	Concerns the ability of the practitioner to implement action implications of a theory by manipulating its casual (or independent) variables	- The observed variables for the knowledge reuse process in the quality system can allow the practitioners to use the framework as a tool - The mechanism observed can also be used or adapted for providing guidance for future knowledge reuse initiatives
Non obviousness	Refers to the degree to which a theory meets or exceeds the complexity of common sense theory already used by a practitioner	- This research has brought forth a unique perspective to knowledge reuse and quality systems, Chapter 2 proves this lacking

Table 3.7, Practical relevance of the research

(Source: Adapted from Thomson and Tymon 1982)

In this case of exploring knowledge reuse and researching, by selecting a few samples of cases from a source can be generalised into most situations. This is based on the facts that organisations have knowledge residing in certain locations and form (documented, or captured in memory of a person) and organisations manage knowledge differently. Although the management style and processes can be significantly different, it however always follows a sequence of fixed processes (in the event of knowledge reuse by Markus, 2000). By studying the process of knowledge reuse, it can help to identify certain trends and possible

theories can be derived. In addition, knowledge can be reused, as often mentioned by many researchers, the fact also proves the most research publications to date have been based on the study of a few selected organisations, and this prove the fact that knowledge reuse is indeed being generalised to a certain extent. Using this as a platform, the research was further focused on the intricate movements of the knowledge reuse process, right down to the microscope level of its processes (from single organisation level). Hence, providing even more valuable insights from a detailed microscopic perspective.

3.8 Conclusion

This chapter aimed to describe and justify the chosen research methodology. A case study approach was selected due to the qualitative based research. From the four cases selected within Alpha, data was collected through interviews, observations and evidence finding (i.e. documentation availability) and triangulation. Data was analysed using data reduction, display, and conclusion drawing/verification methods. In all, such techniques provided an opportunity not only for fact-finding, but also for the derivation of new insights into the research scope.

4. Main Case Study and Findings

4.1 Introduction

This research focused on quality based management systems and knowledge reuse for replication relationships. In this context, 4 quality issues resulting from the mass production of parts were selected within Alpha. These cases are all automotive components and the development of these parts was from process design to mass production manufacturing, which strictly follows the requirements of the ISO/TS16949:2002 quality management system. It is to be noted that Alpha does not incorporate product design as part of its ISO/TS16949:2002 certification. However, it offers manufacturing process design based on product drawings provided by its customers.

4.1.1 Introduction to Alpha

Alpha is situated in Shanghai, China. It was awarded ISO/TS16949:2002 certification on the 26th May 2006 (with approximately a one and a half year record of certification since the approval). It holds several manufacturing license and design patent rights in the key areas of fastener technology. These licenses are grouped into two major types. For recess licenses they are TORX®, TORX PLUS® and MICROSTIX® and for the thread licenses they are TRILOBULAR® (TAPTITE), REMFORM®, PT® and DELTA-PT®. Its major industry focus is on hard-disk drives, consumer electronics and automotive cold-forged products. Alpha's headquarters is in Singapore, and there are several satellite offices in Northern (Beijing) and Southern (Shenzhen) China, Japan and the United States. From its humble beginnings as a trading house for fasteners, it has grown to be one of the leading fastener manufacturers. As

well, Alpha engineers components with a turnover of approximately S$50 million and employs an estimated 1000 staff worldwide. Alpha was recently nominated as one of FORBES 2007 “200 Best Under a Billion" leading Asian public companies with less than US$1 billion in sales.

4.1.2 Fasteners Manufacturing Process

Alpha manufactures fasteners with proprietary designs. The general process of making a typical carbon steel/stainless steel screw (as extracted from Alpha’s Process Flow Diagrams) is described as follows in Figure 4.1. Depending on the customer’s requirements and the screw’s application, the secondary processes may differ slightly.

Heading is a cold (room temperature) forging process used to produce a near net shape work billet. The material is plastically deformed using compressive forces in specialised tooling and machines. Advantages of heading include zero material lost, improved microstructure of the work billet and highly stable work billet dimensions. The next process applied to the bottom of the work billet (the side without the head) is a bulk deformation process known as “thread rolling”. This is another type of cold forging process where cylindrical parts have the thread applied by rolling the work billet through two threaded dies called rolling dies. The thread rolling process is usually chosen over machining because thread rolling provides higher production rates, zero material lost and stronger thread due to work hardening and, finally, better fatigue resistance because the work billet undergoes compressive stresses during the rolling process.

Fasteners are manufactured in batches. Typically, the rate of production output is approximately 100 pieces per minute (dependant on the upsetting ratio of the material). The fasteners are then subjected to outgoing (dimensional/visual) inspections and respective tests to ensure the quality of the screws before delivery to customers. This complete manufacturing process and its quality control are governed by ISO/TS16949:2002 requirements.

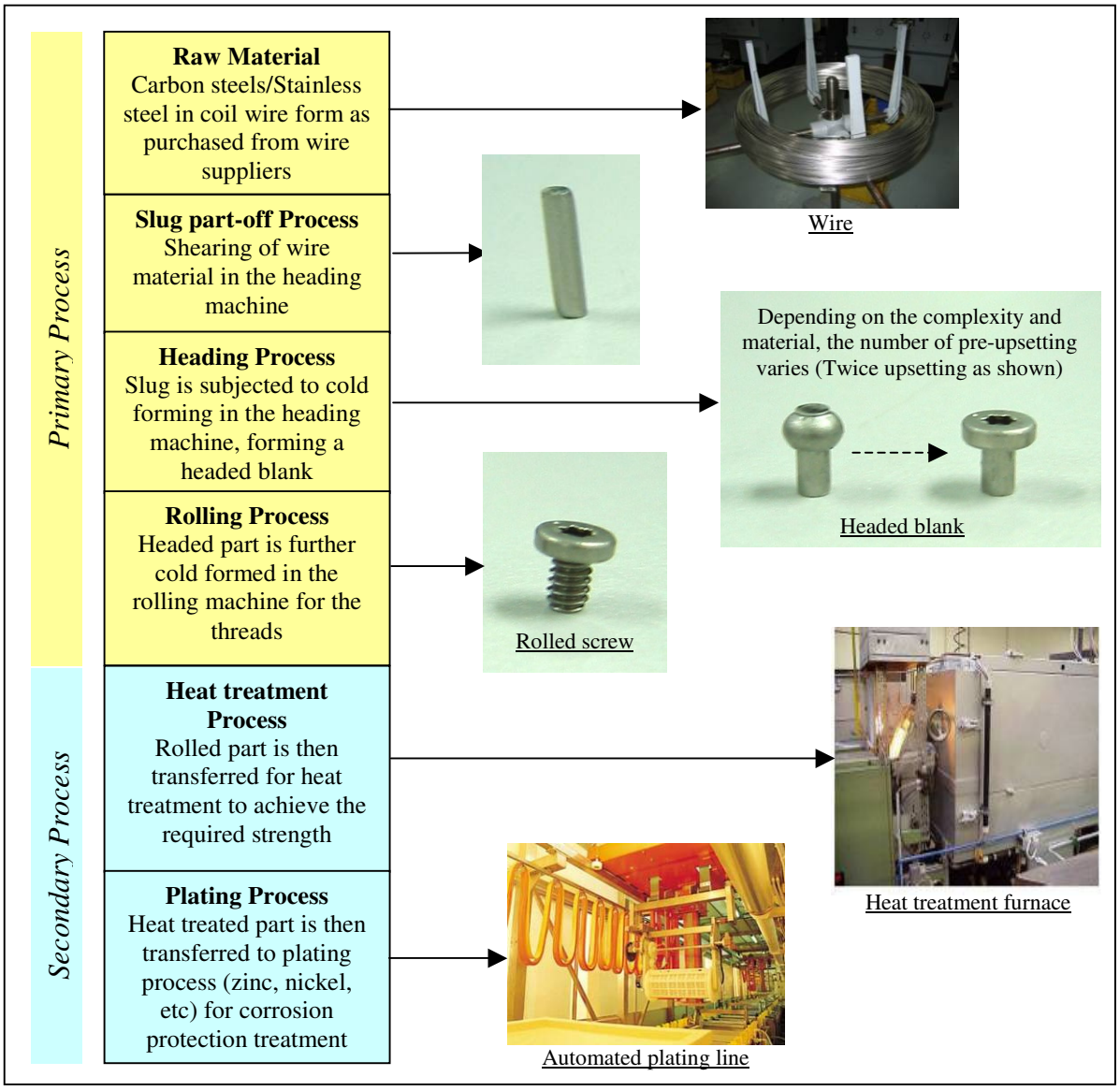

Figure 4.1, A typical carbon steel fastener manufacturing process

4.1.3 Organisation in Alpha

Alpha is organised to suit the operational needs of ISO/TS16949:2002. There are 15 departments, each with its respective area of expertise. For example, product and process development are solely carried out in the Engineering Department, the Production Department is in charge of the mass production output quantity and the Quality Department takes charge of quality control. Other departments provide the other critical supporting functions. Several key ideas of management and several guiding policies are in place in order to motivate and guide all of the staff. A breakdown of the organisational structure can be seen in Figure 4.2.

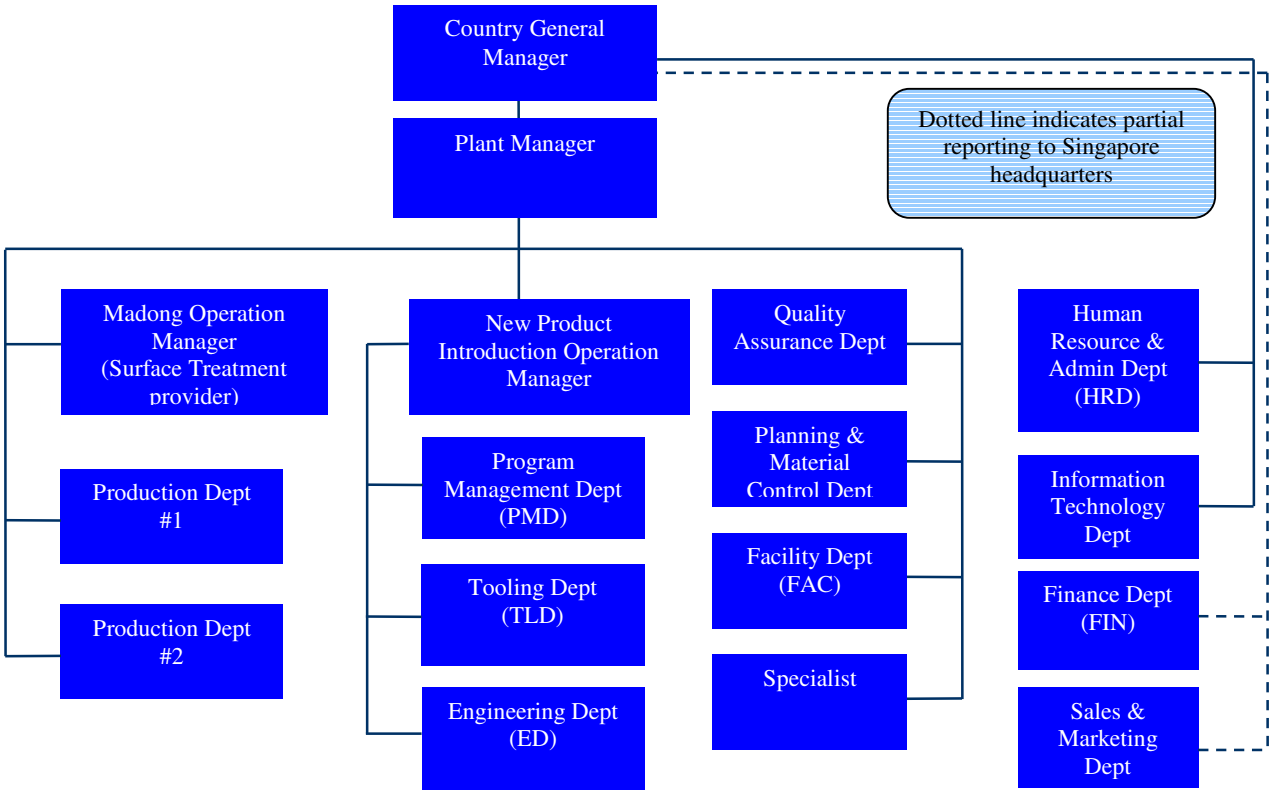

Figure 4.2, Alpha's organisational chart

4.2 Case Descriptions

In order to study knowledge reuse within Alpha, 4 cases were selected from a list of automotive quality issues that occurred from the beginning to end of 2007. For this research, the data was collected by face-to-face interviews and personal observations and was then triangulated by a document review. There are two aspects to the selection criteria, (1) the cases must be less than one year old in order to ensure that the memories are still fresh within the interviewees. (2) Due to a high staff turnover rate within Alpha, the cases must be as new as possible to ensure that witnesses are available for interviews because their participation is critical for providing relevant information and data.

This type of approach and considerations add relevance and timeliness to the research (Thomson and Tymon, 1982). The following gives an account of 4 real-world cases encountered in Alpha. The emphasis is on the knowledge reuse phases and the way Alpha has managed the quality issues. In order to know more about the way Alpha has managed knowledge within its organisation, the researcher interviewed the interviewees based on events that have actually happened. The cases will be described in the next four sections. For Cases 1 and 2 (external complaints which have been duly feedback by Alpha's cusotmers), customer complaints and a formal team were assembled to perform a 5-Whys analysis (a tool used by Alpha for root cause troubleshooting; the outcome includes short term corrective actions and long term preventive actions, as well as management systemic corrective actions). This is illustrated in Table 4.2. For Cases 3 and 4 (internal problems which have been detected by internal parties of Alpha, it is not complaints by Alpha's customers), there was no problem solving and the solution was dependent on the informal team of investigators'

experience and resourcefulness. Table 4.1 provides an overview of the 4 cases and their background.

4.2.1 Selected Cases Relevancy

In order to justify the selection of the 4 cases presented here, with reference to Table 3.6, a matrix is prepared and presented in Table 4.1 to show the links of research to case studies in order to achieve solution to the research questions. This clearly depicts the relationship of the cases selected to the initial research intent.

Criteria	Interpretivist Viewpoint	Case-Study Tactic	Phase of research
Construct Validity	1) There were a few pre-interviews conducted in order to understand the conditions to be expected in Alpha 2) A study of the organisations operations protocol and products was also needed to provide a general idea. 3) From the first understanding of Alpha, it is possible gain a set of data for later analysis	1) From the first cut of interviews conducted, it is possible to understand pre-determined data available. 2) From the second cut of interviews conducted, the questions helped to focus on the research questions and agenda	Data collected was from Alpha mangers, engineers, technicians, etc. during the initial start of the research after the literature review phase and after the formulation of the research questions
Internal Validity / Reliability	1) With the use of 2 other intern for the interviews, the general observations and points highlighted were similar in ideas, after the interview sessions. 2) A post interview session was conducted to digest the data collected and extract useful bits and pieces of information, possibility to detect a pattern or trend in the answers.	1) The post interviews were highly consistent in the data and evidence matching 2) Using the two types of case scenarios (external and internal quality issue), it is able to define the richness of the research scope and availability of the results to the research questions	The data was later processed. Trends and key influencing factors were defined and indicated for later assimilation to useful frameworks and theories
External Validity / Generalisability	This aspect is not being catered for in this research.	However, it is not difficult to extend the same model of data collection to other organisations	The research design for this thesis is restricted to within one organisation, Alpha.

Table 4.1, Research validities cross-referenced to actual research conducted

Case	Part number	Detection source	Occurred before?	Defect rate	Problem description	Root Cause	Solution	When occur?	Interviewees	Secondary Sources
1	40015250	Customer complaint	Happened before (1 time last year)	3/50k pcs (60 DPPM)	The plastic housing hole boss stripped during the screw tightening sequence, causing damage to the expensive housing	Screws being stuck within the washing barrel of the plating line (supplier), resulted in repeated acidic washing of the screw. The major diameter of the screw thread was drastically reduced.	Ensure proper clearing of the barrel at the plating process by human visual inspection before loading in new batch of screws for the next acidic washing	Jul-07	Operations manager Production manager Materials manager Production supervisors Quality engineers Sales engineers	Personnel observations Emails Reports Meetings Engineering Drawings Procedure Documents FMEA Process Flow Diagrams
2	3016421	Customer complaint	First time	3/16k pcs (187.5 DPPM)	Foreign small screws stuck within the recess of the screw (3016421), resulting in the screw being unable to be fitted into the bit of the electric driver, hence affecting assembly process	Small screws were not fully cleared before the loading of the larger screws. The smaller screw later was stuck in the recess of the larger screw.	Ensure proper clearing of the barrel at the plating process by human visual inspection before loading in new batch of screws for the next acidic washing	Apr-07	Plant manager Operations manager Material supervisor Quality engineers Sales engineers	Personnel observations Emails Reports Meetings Engineering Drawings Procedure Documents FMEA Process Flow Diagrams
3	CN05E07.01.05	Internal Quality Inspection	Happened before (4 times last year)	1/500 pcs (2000 DPPM)	Screw without proper thread (half threaded) during rolling process was found during internal outgoing inspection by Quality Dept.	Abnormal small head screws from the heading process was not detected and then input into the rolling process. This caused the rolling machine to produce a half threaded defective screw	No real action taken, sorting was triggered for the affected date code of the detected lot	Jun-07	Operations manager Quality engineers	Personnel observations Emails Reports Engineering Drawings Procedure Documents FMEA Process Flow Diagrams
4	3013457	Internal Quality Inspection	Happened before (2 times last year)	1/500 pcs (2000 DPPM)	Screw was found to be with extra material at the side of the head	Older heading machine resulted in extra material at head when not properly adjusted. Defect screw was not 100% cleared from the machine, hence resulted in a miss out and passed down to rolling process	No real action taken, sorting was triggered for the affected date code of the detected lot	Apr-07	Plant manager Operations manager Quality engineers Production manager Production supervisor	Personnel observations Emails Reports Engineering Drawings Procedure Documents FMEA Process Flow Diagrams

Table 4.2, Case description and its corrective actions taken by Alpha

4.3 Case Study 1 (External)

Case 1 is considered an external customer compliant. The customer of Alpha complaint part number 40015250 on 13/07/2007 found stripping issues while using the mentioned screws. This resulted in a high yield loss at customer production lines. The screw thread is a 6mm self-thread forming type commonly used for plastics, and the proprietary product name of the thread is called Delta PT®. When the stripping issue occurs, the screw will ream out the plastic boss and cause the usually more expensive plastic unit to be damaged (such damages cannot be repaired, hence leading to a scrapped part). At this point, the customer investigated the issue and found out that the screw's major outer diameter was grossly undersized. The customer took some photos and sent an email to Alpha's sales engineer to inform him of the issue. The customer also asked for a corrective action report, in this case an 8D[1] report, as well as an exchange for the defective goods. Alpha was fully informed of this defect within the 1st day of occurrence, after the trigger from the Sales Department to the Quality Department.

The following day an internal meeting was called immediately to discuss the plans for handling this issue. The outcome of the meeting was to confirm the internal parts; this was because the actual problem was still not clear to Alpha. Next, the quality engineer and the sales engineer requested that the existing stock in customer locations (26,000 pieces) to be returned for further investigation. They also investigated the remaining internal stock (24,000 pieces). The customer samples had not returned yet, so they proceeded to inspect the internal

[1] 8D report (where D means Discipline) is used frequently to inform customers on the status of the quality problem experienced at the customer site, the contents include root cause analysis and the corrective actions as well as preventive actions, there is a timeline requirement for the submission to the customer

samples and found that the internal stock was within the specification limits. They could not detect this problem of a small diameter. The quality engineer eventually asked for the samples that the customer had taken pictures of (the samples took about 3 days to arrive).

When the samples arrived on the 5th day, they further investigated the issue and found that the threads were grossly undersized and the edges of these samples were not sharp like the prime samples. It was evident that the defect was true but its rate of occurrence was very low. At this point, the quality engineer called for another meeting to be conducted with the operations manager (at that time, he was the acting quality manager as well, since the post of quality manager was vacant). After many discussions, verifications and tests, the problem was finally identified to be cause by the plating process. This was achieved after much role-playing[2] and "what-ifs". In addition, the 5-Whys method was applied at this meeting. Finally, the plating supplier responsible for this defect was informed of the problem by phone and the picture of the defect was sent to them via email.

The next day they replied with an investigation report, which indicated that the problem was caused by the screw becoming stuck in the barrel of the plating process. The plating suppliers responded that the screws had been caught in the edges of the barrels, left inside the barrels after the first wash, and then the barrel had been reused for subsequent plating. The plating process requires the screws to be weak-acid washed prior to the actual plating to get rid of surface contaminants. This ensures proper plating adhesion and deposition, and the acid

[2] Role-playing is used in Alpha to re-enact the chain of events that might have occurred. These events are usually not within their control (i.e. out-sourced processes), and in order not to overlook these possibilities, they assume and discuss the potential of their occurrence. Those with high occurrence potential will be focused on in the actual investigations.

washing etches the material (low carbon steel) from the screw. After this, the screw (which was stuck in the barrel) was subjected to additional acid washes. This resulted in the screw being over-washed beyond the normal one wash process, hence causing the screw threads to become grossly undersized due to the over-etching of the screw threads. The supplier also indicated a corrective action for this issue: the operator would be re-informed to inspect that the barrel was 100% empty before loading in new screws. The next batch of the screws was then used to verify the corrective action's effectiveness.

This report and information was re-generated by the Alpha quality engineer into an official 8D report for the customer. The sales engineer later submitted the report to the customer for their perusal. Later, the case was dealt with internally and the defect was added to the defect sample library (the evidence was verified). A defect sample library is maintained so that future newcomers can be informed of possible defects and are sensitive to such defects when manual sorting work is carried out. Internally, Alpha also required 3 consecutive lots to be screened without failure before the case was deemed as closed. A process engineer from the Engineering Department was tasked with the job to update this defect in the part's Failure Mode and Effects Analysis (FMEA) and control plan, but this problem was not cascaded to other parts with similar process methodology. The update was later verified by the researcher. The next day, during the morning briefing, the Material Department and Quality Department were informed of the defect occurring at a customer's site (a form of knowledge distribution). This resulted in the dissemination of knowledge to others within the department. However, there was no evidence of similar activities done for the other departments.

Most of the knowledge being passed down was observed to be on a need to know basis. The defect had occurred at the plating supplier, which resulted in the Material Department having to perform a 100% sorting of the incoming screws. The Quality Department enforced the sorting process. This means that the control of the quality issue for this defect was purely by sorting and manual inspection, as plating suppliers have consistently caused mixtures in the lots after processing.

4.4 Case Study 2 (External)

Case 2 is considered an external customer complaint issue. On 13/04/2007, the customer found that, while using the screw, they could not insert the bit into the recess of the screws. This resulted in high down time at the customer production lines. Upon further investigation, the customer found that the recess had smaller screws stuck inside, hence preventing the tightening of the screws. Immediately, the customer alerted the Alpha sales engineer of the issue by sending an email and a picture of the defect. The total affected quantity of screws at the customer location was 160,414 pieces. The screw was a M6.0 machine screw thread with patching with a T30 recess. Within the same day of being informed, the quality engineer arranged for an informal meeting with the operations manager (due a vacant quality manager post) and the declaration of the current stock on hand (including stock at suppliers' locations). At the informal meeting, the next stage of investigation was formulated and the existing parts were sorted out (since they had to provide a recovery plan to exchange the parts at customers' locations). The operations manager suspected that the problem might have been caused by the plating (note that this plating supplier is different from Case 1), as similar problems had occurred before based on his memory.

Further reference to the defective sample list found that a recess stuck with screws had not been documented before; rather, most of the defects were found to have debris stuck in the recess. The operations manager later instructed the quality engineer responsible to proceed to the plating supplier's location for a corrective action implementation and audit. The supplier acknowledged that it was highly possible the issue had been caused by them as, according to their records, a batch of small screws had been in the same barrel before the affected lot was plated. This means that the issue was likely to have been caused by the plating supplier. However, identifying whether the stuck screws were the same parts reflected in the records of the plating process could not be done immediately; the samples would take a few days to arrive at Alpha. In addition, the samples might not be Alpha's parts. This posed a limitation on the identification of the samples.

The quality engineer, after a short discussion with the supplier, formulated tighter controls and inspection plans to correct the problem at supplier side. An 8D report was then written for Alpha to review. The corrective action was to ensure barrels would be manually cleared using a magnet to pick up any remaining screws. This would be followed by flushing water through the barrel and the hitting its sides to ensure no screws are still stuck inside. Finally, a visual inspection by the operator would be done before loading the next batch of screws for plating. In addition, they derived a preventive action plan for this issue. After using the 5-Whys, they found that the issue had not been detected by the internal sorting personnel due to the inspection method used. There was no emphasis to inspect the recess area, hence the possibility of having escaped screws stuck within the recess. Alpha also identified that the inspection personnel were not fixed, and this caused non-uniform and inconsistent inspection

methods. Alpha later fixed this by specifying specific manual sorters to perform these sorting tasks for specific automotive parts only. A list of the personnel was documented for this purpose and a double inspection sampling size was implemented (however, no evidence of these lists was presented).

The enforcement of the barrel clearing methods for the plating supplier was with a work instruction, and this was documented by Alpha for the supplier to follow strictly. Later the same day, when Alpha received this 8D report from the plating supplier, Alpha extracted the information and added additional information into the 8D report (since the supplier used Alpha's format for the 8D report). The next day, the operations manager and plant manager called for another immediate meeting to settle the issues. This meeting resulted in a 5-Whys report, and these two reports were later submitted to the customer for their reference and review. In parallel, the sorting of the existing stock in Alpha had already started. However, until then, there has been no detection of any similar issues in the screws' recesses. The case was still open however, as there was no clear indication of the effectiveness of the corrective action. Therefore, Alpha implemented 3 consecutive lots monitoring procedures before deeming the case to be closed. They also indicated that the solution had to be replicated to other similar products' FMEA and Control Plan, since inspection methods and sampling sizes had changed (Further investigation of the latest FMEA and Control Plan revealed that the documents have not been updated yet. At the time of the research, the issue was still pending, as the three consecutive lots have not been reached, but the customer did not complain after the lot was exchanged.).

The knowledge was then disseminated by morning briefings on the next working day. No other knowledge dissemination methods were observed. The two departments being briefed were the Material and Quality Departments. Since the problem occurred within the plating suppliers, the other departments were uninformed. This can be confirmed to be true, as when the production manager was approached, he did not recall this information being disseminated.

4.5 Case Study 3 (Internal)

This case is considered an internal quality issue. The problem was detected on 07/06/2007 for part number CN 05E07.01.05 by the quality inspector of Alpha. During a routine inspection, the quality inspector detected the problem of half thread (the screws were not fully threaded). The reject rate for this defect at that time was 0.2%. This resulted in her issuing an internal Non-Conformance Report (NCR), a report generated within Alpha for the disposition of the affected production lot. Most of the data (i.e. quantity, quality issue, corrective action and disposal of the lot) can be found in this document. This report helps to facilitate the disposal of the defective lot. The rolling process caused the half thread issue, as this is where the forming of the threads occurs. This was not the first time such defects had occurred.

There were two common reasons for the root cause of the problem. First is that the thread had inconsistent feeding during the rolling process. This results in the screws being unstable and produces threads that have such problems. In some drastic cases, this can even result in threads being half formed. Machine adjustments are critical to prevent this issue. The second

reason is that the head of the screw was not properly formed during the heading process. This resulted in the screw being force fed into the rolling machine, hence causing the half thread defect. The latter was found to be the real cause, as the defective sample was found to have its head not properly formed.

The next working day, after the NCR was issued, an internal NCR meeting was called by the quality engineer who usually organise such meetings daily (or sometimes on alternate days, depending on the workload of the engineer in charge). This meeting included Engineering Department, Quality Department and Production Department representatives (most of them were the experienced knowledge experts within the department).

After many phone calls and reminders, the meeting was eventually held after it was delayed for a few minutes. In this meeting, the problem was discussed and eventually a root cause was identified. Questions like, "Did this problem occur before? How did this problem occur? How come production inspectors did not pick out this issue?" were asked. Most of the questions asked were pertaining to why it happened and why it was not detected by the hourly quality inspections that the production operators have to carry out. In this NCR meeting, a quick and conclusive answer was derived by the group. The corrective action decided upon was to sort out the defects in this batch of screws then to remind the production operators to pay more attention to the defects. In addition, the production technician responsible for the produced lot was reminded to be more observant of this issue. No preventive actions were planned for this NCR. The meeting did not include a formal 5-Whys analysis as compared to customer quality complaints. The NCR was disposed of with

additional sorting of the defective screws performed by the Material Department, and a final validation of the sorting outcome was done by the Quality Department. The information was not disseminated during the morning briefing meeting.

Observations and investigations show that this defect has become a chronic routine problem in the manufacturing process of fasteners in Alpha. This is due to the lack of the further drive to eliminate the problem as well as the lack of new ideas to prevent the problem from occurring. It was observed that there was no mention of updates to FMEA and Control Plans for this defect, and actual reference by triangulation to the documents reflects likewise observations.

4.6 Case Study 4 (Internal)

Case 4 is an internal issue that was detected by the quality inspector on 12/04/2007. The product with the part number 3013457 was detected to have screw head improper forming defect; the reject rate was at 0.2%. There was excessive material protruding from the side of the head of the screw; this is known to be a defect caused by the heading process. This defect occurs when the material fails to be fully fed into the main die of the heading machine. The material then flows out of the die, causing an abnormal head to be formed during the heading process.

From this, there are two main possible causes. First, the material itself, if slightly bent, can cause it not to be smoothly fed into the main die during forming. The other reason is the alignment of the heading machine during the feeding: with an improperly aligned heading

machine, material is even more difficult to feed into the main die. Upon detection, the quality inspector immediately issued an NCR for the defective lot. This NCR was then handed over to the quality engineer in charge at that time for the defect.

This NCR was discussed during the NCR meeting with representatives from the Engineering, Quality and Production Departments. The engineering manager was the only manager to attend, the rest were all technicians and engineers. After many reminders and invitations, the NCR was held later than the scheduled time. The delay caused unhappiness amongst some of the people. The engineering manager asked questions and the rest of the engineers just provided suggestions and answers. Eventually, the defect was disposed of almost instantaneously without any further probing. The corrective action was to get the Material Department to sort for the defects. There were no preventive actions to eliminate the problem for this NCR. During the NCR meeting, the 5-Whys method was not used to analyse the problem; most of the discussion was based on the experience of the attendees to re-solve the issue.

During the NCR meeting, it was derived that it was possible to eliminate the problem, but this would mean changing the heading machines to newer models. This is impossible in Alpha because the machines (there were approximately 10 units of the heading machines) were already a sunk cost for the company's assets. Modifications to the existing machines were also not possible. The corrective action was observed to be purely a guess without any verification being conducted.

The technician involved was kindly reminded not to make the same "mistake" (the technician did not agree with the reason made during the NCR meeting; however, no further reasoning was put forward). Note that the representatives understood that the problem remained unsolvable, unless the machines were changed. A higher management decision was required in order to resolve this problem. The morning meetings were later used to "make-known" the problem to all quality inspectors and production operators.

It was observed that there was no mention of updates to FMEA and Control Plans for this defect. While referring to the FMEA and Control Plans, there was no mention of the defects in the documents and no indication that initiatives was taken to update the documents accordingly. Similar to case 3, the problem was considered as a chronic issue and there was a lack of new ideas to prevent the problem.

4.7 Quality Issues Resolution in Alpha

From the previous sections, there are two types of quality issues in Alpha, namely external and internal. More information on problem solving techniques can be seen in Appendix D.

4.7.1 External Quality Issues

External issues are dependent on a team-based approach to look into the problem. Brainstorming sessions are held in formal meetings where there is a chairperson to control the problem-solving processes. Much of this information is later compiled into the 5-Whys document for recording and for compiling an 8D report for customer submission.

Occasionally, knowledge experts from outside of Alpha are used to help solve quality issues. For internal quality issues, the approach is solely dependent on the engineers in charge. Most often, personal experience and resourcefulness are required in order to get the job done effectively. The information is packaged in self-made notes and verbally acquired from the knowledge experts within Alpha. Informal meetings are common and largely based on casual discussion.

External issues are dependent on a team-based approach to look into the problem. Brainstorming sessions are held in formal meetings where there is a chairperson to control the problem-solving processes. Much of this information is later compiled into the 5-Whys document for recording and for compiling an 8D report for customer submission. Occasionally, knowledge experts from outside of Alpha are used to help solve quality issues. For internal quality issues, the approach is solely dependent on the engineer in charge of the problem-solving abilities. Experience and resourcefulness are required to in order to get the job done effectively. The information is packaged in self-made notes and verbally acquired from the knowledge experts within Alpha. Informal meetings are common and largely based on casual discussion.

From these cases, customer complaints range from 60 to 187.5 DPPM, whereas for internal quality detection they are at 2000 DPPM. There is a trend that customer complaints have defects of lower DPPM than compared to the internal complaints. Due to the significantly lower DPPM, it can be considered that internal systems have managed to detect such defects before delivery to customers. Therefore, one can conclude that the quality system

ISO/TS16949:2002, as implemented by Alpha, shows evidence of reducing mass defects from being delivered to customers, thereby achieving customer satisfaction.

Another point of observation is Alpha's effectiveness in preventing quality issues from recurring. 3 out of 4 cases selected were observed to be recurrent, indicating that the problem has not been resolved at its root (i.e. the root cause corrective action was not effective). Investigations have shown that the root causes were identified using 5-Whys and the corrective actions, as stated in the 8D, were in place. However, by further looking into the corrective actions, evidence has indicated that they were usually reactive by nature. This approach has allowed problems to continue to exist that resulted in future recurrences. The effectiveness of corrective actions is only temporal, whereas preventive actions are long term and permanent, thereby eliminating the problem for good. A lack of preventive actions has been observed in almost all the cases, meaning that the root causes were not eliminated. This leads to a recurring problem, resulting in repeated customer complaints.

4.7.2 Internal Quality Issues

Observations for the internal quality issues have led the researcher to point out that the engineers involved in the trouble-shooting process did not rely on FMEA (explicit knowledge) for assistance. They preferred to rely on hearsay from knowledge experts within Alpha (tacit knowledge) and their own experience and knowledge to solve the issues. For customer quality complaints, it is mandatory in Alpha to practise a formal team based 5-Whys analysis (a problem solving technique) and then submit an 8D report to the customer on the temporary corrective action as well as the long-term preventive actions. Such

documentation and processes suggest that knowledge had been captured in explicit and tacit forms. The purpose of these measures is to ensure (to a certain degree of confidence) that the problem is within control and will not recur. However, once the problem has been resolved, the information was not updated in the FMEA documentation. Reasons given for this by the interviewees were 'lack of time', 'forgotten', 'not sure if updating was required' and such. These are discipline and enforcement issues and will not be discussed further in this thesis. Note that ISO/TS16949:2002 advises the use of knowledge experts (e.g. experienced engineers) and puts emphasis on preventive corrective actions to improve customer satisfaction.

Data sources and interviewees have been provided for reference. It was observed that most parts within Alpha have sufficient documentation like Process Flow Diagrams, Control Plans, FMEA and other reports to ensure that the manufacturing process is within control. However, during problem-solving sessions, the documents were not used and the interviewees mentioned that most of the brainstorming was based on the experiences and knowledge of the experts and engineers. When experiences are used, the knowledge is tacit. ISO/TS16949:2002 has failed to address this gap in its requirements, as it is largely a system based on documentation efforts.

Engineering drawings in Alpha are treated as a main source of information and are frequently updated. Hence, when changes occur, the first document to be updated is in the engineering drawing. Once this is done, the Process Flow Diagram, Control Plan and FMEA have to be duly updated. However, in the context of Alpha, Control Plan was neglected and often found

to be in error. In this research, emails were used for the triangulation of statements made by the interviewees. Quality complaints from customers and engineering changes are often sent through email, making it a valuable ICT tool. It is observed that emails were used as a form of documentation and communication in Alpha as well.

4.8 Answering Research Question 1

With reference to the research aims, the first research question was "How has knowledge reuse influenced quality issues?" The answer to research question 1 is that knowledge reuse has been able to affect quality issues, through the way quality issues are being treated, the subsequent actions determines the actions taken in order to circumvent it, and the way it influences quality issues will be further answered in subsequent sections of 4.8.1 and 4.8.2.

4.8.1 Processes of Knowledge Reuse in Quality Systems

The following can be observed with reference to Table 4.3. These sections describe Cases 1 & 2, which are external quality issues. The knowledge reuse scenario observed follows the respective process of capturing, packaging, distributing and, eventually, reusing the knowledge. This is shown in Figure 2.7. In contrast to the work of Szulanski (2000), Markus (2000) and Majchrzak, Cooper and Neece (2004), this research hopes to achieve a much more detailed view of the aspects of knowledge reuse in a quality environment.

4.8.1.1 Capturing Knowledge Phase

The process of knowledge capture starts at this phase. By observing external and internal quality issues, it is possible to make an instinctive judgement on the trends observed in order to theorise.

External Quality Issue

Information from the customer was transferred in the form of phone calls and emails (as seen in Cases 1 and 2 of Table 4.3). Conversations from the phone calls were then converted to the explicit aspects in the form of emails or written personal documents by the engineers. Alpha engineers and technicians often capture their own information by self-documenting for future reference. The knowledge captured is very focused on the problem faced by the customer. This information is then used at the beginning of problem-solving meetings.

The capturing phases of knowledge reuse can be found during problem-solving sessions in Alpha. The use of 5-Whys, for example, is effective in identifying root causes. Note that a trend observed within Alpha is that knowledge usually comes from the "minds" of the problem-solving meetings. During these meetings, it was observed that explicit knowledge from documents (Process Flow Diagram, Control Plan and FMEA) was not usually used. Engineering drawings however, were frequently used to confirm the required dimensions and its secondary processes. Alpha depends largely on tacit knowledge from the problem-solving team members to solve problems.

Internal Quality Issue

Knowledge (tacit) was captured (as seen in Cases 3 & 4 of Table 4.4) by the quality inspector and then further assessed by the quality supervisor. The quality inspector later wrote this information into the NCR for the team members (managers, engineers, technicians) to discuss and decide what actions to take. During the routine inspection, there was communication to the engineers in order to decide whether these defects were acceptable. Alpha's engineers also documented information for their own purposes during the problem-solving phase. Samples were placed in a bag to be attached to the NCR for future reference.

4.8.1.2 Packaging Knowledge Phase

The process of knowledge packaging starts at this phase. In a similar fashion, comparisons of external and internal quality issues are defined below.

External Quality Issue

After the problem solving meeting (tacit knowledge), knowledge is then packaged into explicit knowledge (as seen in Cases 1 & 2 of Table 4.3). This knowledge exists in the form of 5-Whys and 8D reports after the meetings. However, the information packaged here has been observed to be audience group specific. Depending on the level of seriousness and the impact of the problem, the reflected knowledge in the actual situation and the written situation sometimes differ largely. This was observed to be for reasons of competitive advantage against market competition. In both cases 1 and 2, the 8D report from the supplier indicates the real problem, and the report was later simplified and edited by Alpha to notify the customer (there was a customer version 8D report). Another trend observed in Case 1 was

the packaging of knowledge in sample form wherein the defect sample was kept in the Defect Sample Reference Book (DSRB) to be used for future reference (for training and verification purposes). However, for Case 2, there was a lack of DSRB updating. This was observed to be lacking in consistency.

Internal Quality Issue

The NCR meeting largely depended on the input of the technicians and supervisors; the meeting was carried out without any reference to the available documents (FMEA, CP, PFD and engineering drawings). Engineering drawings were not largely used for these problems because the problems were not dimensional based. The other documents were not used because Alpha relied mostly on experience-based knowledge to tackle its problems. The NCR was later signed off and the parts were later triggered for the next phase of treatment, which is either to scrap, sort or accept the lot, depending on the risk assessment. The team members' final decision was largely influenced by the evidence and its justifications pertaining to the case on hand (as seen in Cases 3 & 4 of Table 4.4). It was also noted that, in both cases, there were no discussions on how to prevent the problem from happening; focus was on the disposal of the lots and then quickly moved on. Such conditions could mean that the problems were already being treated as chronic and viewed as human-related rather than process-related.

4.8.1.3 Distributing Knowledge Phase

The process of knowledge distribution starts at this phase. In a similar fashion, comparisons of the external and internal quality issues are defined below.

External Quality Issue

There are two types of distributions of the knowledge. First is to distribute knowledge to solve the problem. Second is to distribute the knowledge to prevent the problem (as seen in Cases 1 & 2 of Table 4.3). The morning meetings were frequently used to distribute knowledge amongst the staff of Alpha. However, it was observed that there was a lack of explicit knowledge used to enhance this knowledge distribution. After being packaged, the documents were not distributed internally and there was a lack of distribution channels. It is noted that the methods used in Alpha are to "push" the knowledge to certain groups of people who need to know this knowledge, and this occurs more frequently for tacit knowledge when problems occur. The explicit knowledge is usually distributed during the On-the-Job-Training (OJT) phases.

Internal Quality Issue

The distribution of knowledge (tacit) was by morning meetings, which disseminated the existence of the problem, and all staff was told to "watch out" for more of such defects. The purpose of this was simply to alert others of the problem, and much of the dissemination was by face-to-face discussions and instructions. Samples were also shown to the audiences (as seen in Cases 3 & 4 of Table 4.4). The NCR was later disseminated for the other managers of the departments to sign-off. It was noted that during the signing most managers would only sometimes briefly request a status update before signing off the NCR.

4.8.1.4 Reuse Knowledge Phase

The process of knowledge reuse starts at this phase. In a similar fashion, comparisons of external and internal quality issues are defined below.

External Quality Issue

The knowledge at the reuse phase is similar to the definition by Markus (2001). The last reuse phase consists of 4 activities: (1) to define the search question, (2) to search for the location of the expert/expertise, (3) to select the appropriate expert/expertise from prior activity and (4) to apply this knowledge. Likewise, in Alpha, the engineers search for knowledge (tacit) from the experts, however, this search for expert/expertise frequently ends at the managers. In most problem-solving sessions, there was a lack of search for explicit knowledge (as seen in Cases 1 & 2 of Table 4.3).

Internal Quality Issue

Knowledge was reused mostly based on input by the managers, and managers' knowledge was mostly based on experience. The engineers supported the problem solving process with their initial investigations. Since the knowledge was already stated in the FMEA, there was no need to document the problem. It was noted that during the problem-solving process no documents were used. Again, most of the knowledge was based on the experiences and tacit knowledge of the members within the NCR meeting (as seen in Cases 3 & 4 of Table 4.4).

Case	Capturing Knowledge How was the knowledge captured?	Packaging Knowledge How was the knowledge packaged?	Distributing Knowledge How was the knowledge distributed?	Reusing Knowledge How was the knowledge reused?
1	**How (Inputs)** - Problem described from customer (photos, samples) via email and telephone - Internal verification audits of samples (in-house) - Short discussions with suppliers on issue (supported with photos) **Outcome** - Screw was subjected to more than once acid washing process , hence causing the erosion of the material (Root Cause) - records for the delivered parts are used for the investigation during the troubleshooting phase - Some self-made notes for the engineers involved	**How (Inputs)** - Informal findings summary meeting with expert (Ops manager) - 8D report from Alpha's contracted supplier **Outcome** - 5-Whys report - 8D report to customer - Defect Sample Reference Book	**How (Inputs)** - Knowledge distributed during morning meeting - Documents (5-Whys, 8D & Defect Sample Reference) from the problem solving process - Knowledge from experts and during problem-solving process **Outcome** - Defect Sample Reference Book used to train OJT (OJT record sheet) - Morning meeting to briefly discuss about the issue to all (Training record)	**How (Inputs)** - Knowledge from morning meeting - Knowledge from OJT training - Knowledge from experts (managers) **Outcome** - Knowledge gained only as reference for most engineers - Reuse of knowledge is strictly based on experts within the organisation (managers, engineers) to drive
2	**How (Inputs)** - Problem described from customer (photos, samples) via email and telephone - Internal verification audits of samples (in-house) - Short discussions with suppliers on issue (supported with photos) **Outcome** - Previous batch of screws (smaller in size) was not fully cleared from the barrel during plating process, resulting in the small screws to get stuck in the larger screw's recess - Records for the delivered parts are used for the investigation during the troubleshooting phase	**How (Inputs)** - Informal findings summary meeting with expert (Ops manager) - 8D report from Alpha's contracted supplier **Outcome** - 5-Whys report - 8D report to customer	**How (Inputs)** - Knowledge distributed during morning meeting - Documents (5-Whys, 8D) from the problem solving process - Knowledge from experts and during problem-solving process **Outcome** - Morning meeting to briefly discuss about the issue to all (Training record) - Informal conversations and discussions on the issue	**How (Inputs)** - Knowledge from morning meeting - Knowledge from OJT training - Knowledge from experts (managers) **Outcome** - Knowledge gained only as reference for most engineers - Reuse of knowledge is strictly based on experts within the organisation (managers, engineers) to drive

Table 4.3, Case 1 and 2 presentation (External quality issue) of the how and outcome at each process phase of knowledge reuse

Case	Capturing Knowledge How was the knowledge captured?	Packaging Knowledge How was the knowledge packaged?	Distributing Knowledge How was the knowledge distributed?	Reusing Knowledge How was the knowledge reused?
3	**How (Inputs)** - Problem detected by out-going inspection process, in-process inspection (5pcs/0.5hr) failed to detect - No 5-Whys or analysis being done - Experts knowledge input was at Production supervisor (manager was not fully involved) **Outcome** - Routine human-error in setup of machine for mass production - Occurrence rate at 2%, no need to waste the whole lot, disposition to 100% SORT for total quantity (9.2k pieces) - No new knowledge captured - Defect is stated in FMEA	**How (Inputs)** - Informal findings summary meeting with expert (supervisor) - Non-conformance report (NCR) was issued - FMEA already stated this as a potential issue (considered as a chronic issue by the problem solving team) **Outcome** - Disposition of NCR by manager level - NCR report is being recorded for monthly and annually tracking for monitoring purpose	**How (Inputs)** - No new knowledge was distributed - Problem was made known to all respective parties based on NCR signing off - Such knowledge is expected to be known (common) **Outcome** - NCR was issued to notify all departments managers - NCR was disposed of by sorting (Corrective actions) - No further study into preventive actions was in place	**How (Inputs)** - Knowledge from expert (supervisor) **Outcome** - No new knowledge being created - Existing knowledge is being reused - No effort invested to create knowledge awareness for reuse - No impact to the problem although it's been documented and the knowledge is being reused, no solution to problem
4	**How (Inputs)** - Problem detected by out-going inspection process, in-process inspection (5pcs/0.5hr) failed to detect - No 5-Whys or analysis being done - Experts knowledge input was at Production supervisor (manager was not fully involved) **Outcome** - Routine human inspection miss out during in-process inspection - Machine capability, causing occasional defect - Occurrence rate at 2%, no need to waste the whole lot, disposition to 100% SORT for total quantity (37k pieces) - No new knowledge captured - Defect is stated in FMEA	**How (Inputs)** - Informal findings summary meeting with expert (supervisor) - Non-conformance report (NCR) was issued - FMEA already stated this as a potential issue (considered as a chronic issue by the problem solving team) **Outcome** - Disposition of NCR by manager level - NCR report is being recorded for monthly and annually tracking for monitoring purpose	**How (Inputs)** - No new knowledge was distributed - Problem was made known to all respective parties based on NCR signing off - Such knowledge is expected to be known (common) **Outcome** - NCR was issued to notify all departments managers - NCR was disposed of by sorting (Corrective actions) - No further study into preventive actions was in place	**How (Inputs)** - Knowledge from expert (supervisor) **Outcome** - No new knowledge being created - Existing knowledge is being reused - No effort invested to create knowledge awareness for reuse - No impact to the problem although it's been documented and the knowledge is being reused, no solution to problem

Table 4.4, Case 3 and 4 presentation (Internal quality issue) of the actions at each process phase of knowledge reuse

4.8.2 Influence of Knowledge Reuse on Quality System

This section aims to provide insights on the data collected. This is to allow research question 1 to be better answered. In order to understand how knowledge reuse affects quality, three observations can be made: there is a need for (1) "Emphasis", (2) "Effort" and (3) "Enforcement" in knowledge reuse.

4.8.2.1 Emphasis in Knowledge Reuse

Emphasis can be defined as a top-down initiative from upper management. With this top direction, it is the first step to achieving knowledge reuse success. It is a commitment from upper management to set up policies to support and endorse these knowledge reuse initiatives. Once the management is decided, the roadmap for success is seeded.

However, the fact is that in most organisations the implementation of knowledge reuse initiatives will require an investment of resources. From the upper management point of view, the additional resources invested to fulfil the knowledge reuse initiatives would probably yield no immediate tangible returns. This can lead to a lack of incentives and motivation for the upper management to implement knowledge reuse initiatives. Especially in smaller organisations where excess financial resources are not available, it becomes even harder to see the value.

4.8.2.2 Effort in Knowledge Reuse

Effort is a combination of execution and emphasis, and can be seen as a commitment by the whole organisation (not just upper management). Execution is by the whole organisation; the users of the knowledge reuse initiative and those who operate the system. Without these people, the system cannot be executed, and they will need to endure in order to make the knowledge reuse initiative successful and useful. However, a possible barrier is that the manpower that has been tasked to resolve the quality issue will probably need to document (package) the knowledge (for reuse when replying to customers or for internal knowledge reuse). This manpower will then need to distribute the knowledge (stored in a repository) into the knowledge reuse system for future reuse. From the manpower point of view, this is considered as an additional workload. Therefore, to ensure the success of the knowledge reuse initiative, awareness and acceptance [3] by the manpower is required; only then, execution will be in place. Emphasis is again the on blessings of resources from the upper management. The resources for the effort to execute and emphasize knowledge reuse initiatives have a direct impact on the bottom line, and this is definitely seen as an additional workload for the users of the knowledge reuse initiative.

As seen in Table 4.5, effort varies over the different phases and types of quality issues faced. The data shows that lesser effort is invested when at reuse process and when the quality issue is an internal problem. In addition, based on the cases, most of the effort was put in for documentation, customer satisfaction (the customer needs the reports for internal records) and quality system (the auditors need the reports for the audits) requirements. Most of the

[3] For acceptance of the knowledge reuse initiative, the users must be encouraged to utilise and retrieve knowledge from the repository. If no real value is generated from the initiative, the idea will soon die a natural death, resulting in knowledge reuse failure.

time, reports must be submitted to customer within a short time period. At times, the supplier is required to bear the cost of the quality issue (i.e. sorting costs, logistics costs, etc). For organisations facing these pressures, they have to balance and prioritize according to what resources are available with the existing workload. In order for knowledge reuse to succeed, tolerance from upper management and acceptance from the employees of the system are needed.

Knowledge Process	Capturing	Packaging	Distributing	Reusing
External Quality Issues (Case 1&2)	- Team spent approximately larger amounts of time to plan, troubleshoot, interview and collect data **(Effort: HIGH)**	- The knowledge was required to be packaged to a detailed 5-Whys report, 8D report, defect sample reference book **(Effort: MEDIUM)**	- The knowledge was only briefed during the morning meetings -5-Whys report was put in the repository - 8D report was submitted to customer -Defect sample reference book was put into repository **(Effort: MEDIUM)**	- Knowledge was not input to any other process for further utilisation -The defect sample reference book was used for training **(Effort: LOW)**
Internal Quality Issues (Case 3&4)	-Engineer spent lesser time to capture the knowledge - Lesser people also was required to troubleshoot **(Effort: MEDIUM)**	- Only a simple non-conformance report was documented **(Effort: LOW)**	- non-conformance report was disseminated for signing-off **(Effort: LOW)**	- No reuse of knowledge **(Effort: LOW)**

Table 4.5, Comparison of effort invested in quality issues from the case studies

4.8.2.3 Enforcement in Knowledge Reuse

Enforcement means that the certification body shall state continuously inspect and monitor the implementation of knowledge reuse. In Cases 1, 2, 3 & 4, the knowledge was not reused after the quality issue was resolved. Clause 7.3.2.1 of the ISO/TS16949:2002 clearly states, "The organisation shall have a process to deploy information gained from previous design

projects, competitor analysis, supplier feedback, internal input, field data, and other relevant sources, for current and future projects of a similar nature." This automatically implies a need for somewhat of a knowledge reuse initiative. However, in all of the cases, there was shown to be a lack of this initiative at the reusing phase (no application of knowledge was captured). The researcher further attended some third party and customer audits and noticed that the audit did not focus on clause 7.3.2.1. This further confirms that enforcement of knowledge reuse initiatives is not critical.

4.8.2.4 Knowledge Reuse Initiative Framework

By combining these three observations, a simplified framework of the knowledge reuse initiative for the 4 cases can be seen in Figure 4.3. This framework explains the current state as taken from the data collected during the research (in Alpha). Knowledge reuse is expected to have a significant influence on quality systems only when there is enforcement (from third parties) in place to drive knowledge reuse initiatives in organisations. Upon that, it is the responsibility of the organisation to execute and emphasize the implementation. Similar to suggestions by Mukherjee, Lapre and Wassenhove (1998), the relationship of knowledge management and quality management systems can prove to be beneficial. As seen in Figure 4.4, a lack of focus in this area was seen in all 4 cases, as shown by the dotted line (i.e. Missing Link). In order to achieve knowledge reuse success, increased emphasis of knowledge reuse initiatives within Alpha would be the best course of action. The focus would be in the distribution and reuse aspects of the framework. This framework can provide the practitioner with an immediate overview of the status of the knowledge reuse initiative. Once the weakness is known, appropriate actions can then be taken to overcome them.

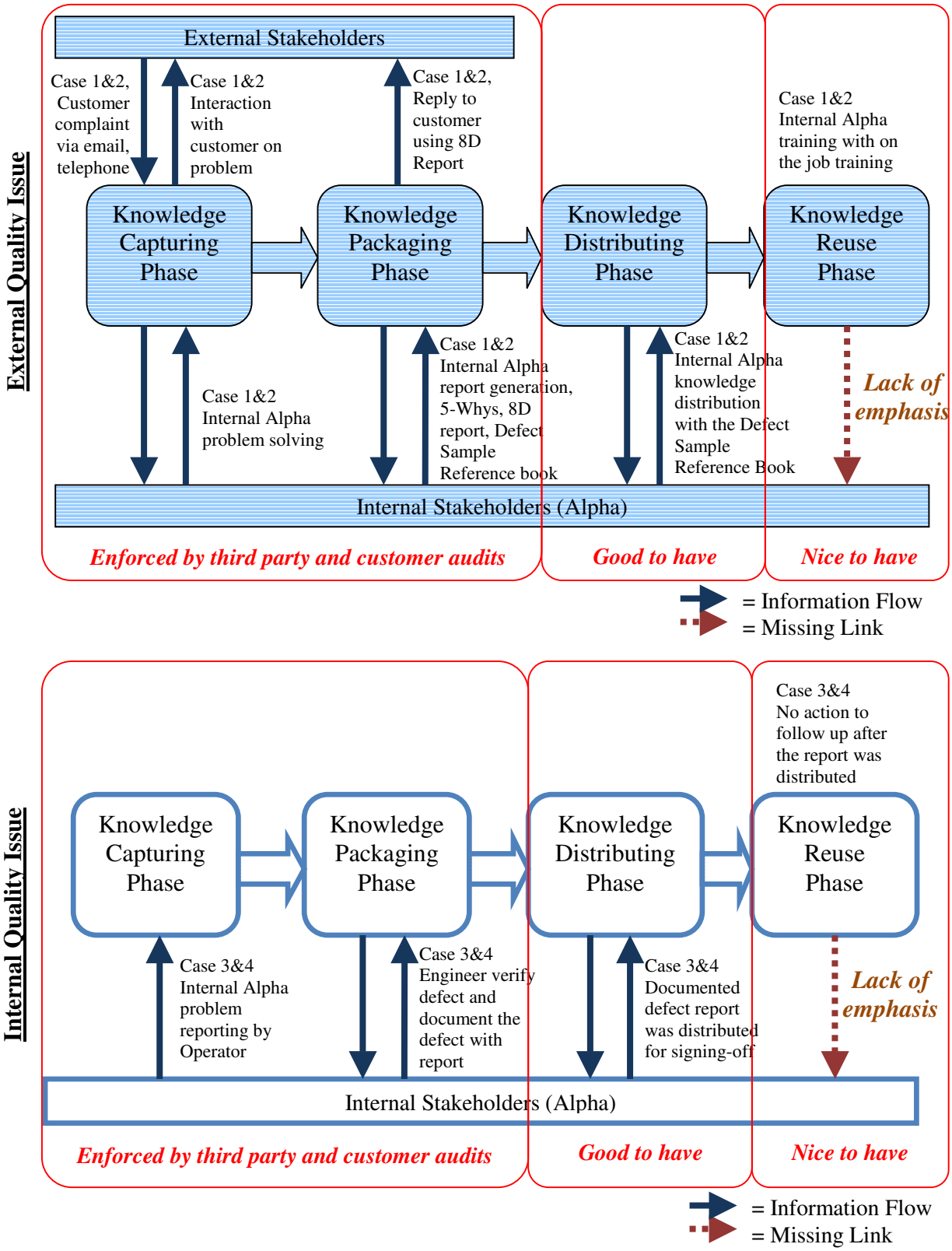

Figure 4.3, Alpha's quality issue and knowledge reuse phenomenon

4.8.2.5 Knowledge Reuse Strategy Adoption

In order for this research to be useful and insightful, a 2x2 matrix (as seen in Figure 4.4) is proposed. This matrix links the knowledge reuse theory with quality systems while embodying a third party and management for control and monitoring. By using this framework, it is possible to clarify any knowledge reuse situation faced by the organisation. This is based on the quality issues and the knowledge reuse implementations. The 4 quadrants explain the course of action to take in light of the current situation faced by the organisation, and serve to visualise the various knowledge reuse strategies available for adoption.

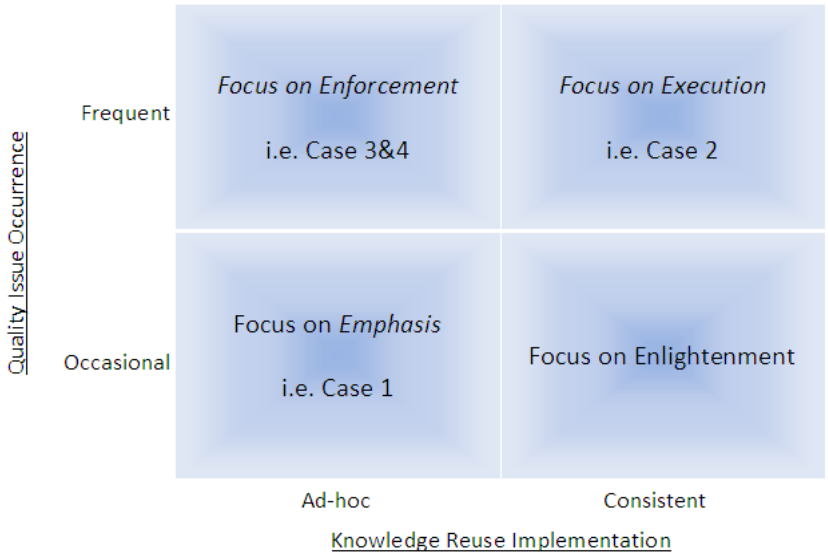

Figure 4.4, A 2x2 matrix for knowledge reuse strategy adoption

In order to clarify further, the following is provided:

- Enforcement is from a third party aspect (external stakeholders), for example, auditors or customer requirements. These are considered external factors that will

help to influence the organisation's mindset on knowledge reuse initiatives. Due to the drive from these external factors, the organisation will be more willing to invest resources to set up a viable knowledge reuse system.

- Emphasis is from the organisation's management effort (internal stakeholders), for example, the management have to commit 'blessings' to set up knowledge reuse initiatives. Using a top-down approach, it will result in focus for the whole organisation. Consequently, there will be a need to invest in resources. As well, total knowledge reuse awareness will have to be promoted in order to get the lower staff to accept and utilise the implemented knowledge reuse initiatives.

- Execution is from an organisational effort (internal stakeholders) and, in this case, it is a bottom up approach. For example, the management team has emphasized achieving knowledge reuse initiatives and puts in resources to drive and implement them. However, due to poor adoption rates within, some gaps result in an under-performing system. Systemic issues or simply an illegal operation of the implemented system can cause these gaps.

- Enlightenment is a state of "success" where the knowledge reuse is mature and consistent and the quality issues are few. However, this state is achievable by few organisations. Even if they do, they will find hard to maintain. In order to achieve such conditions, the organisation has to emphasise, execute and commit effort

(resources). This can be adopted by coupling with the relevant enforcement parties (customers and third party auditors).

4.9 Answering Research Question 2

The second research question is defined as "What mechanisms in quality management systems influence knowledge reuse?" The purpose of this research question is to identify the knowledge reuse mechanisms and mediums that exist from the 4 cases of quality issues selected to answer research question 1, since the cases existed within a quality management system as well, it makes sense to utilise and explore the data collected from the first research question. As the use of quality issues was the basis for this research, it is reflected in the 4 case studies, of which the mechanisms observed are as follows:

1. Ad-hoc meetings
2. Teleconferences
3. Daily Morning Meetings
4. Engineering Documentation Reviews
5. On-the-Job-Training
6. Server data repositories
7. Corporate Telephone Directory Listings

Research was conducted using interview methods with the respective employees of the organisation based on the 4 cases. Data collection was conducted at the same time as for research question 1. Personal observations, including observations from interns who assisted

in the data collection phase, were used as supplementary sources. For more details on the interview questions, refer to Appendix B.

4.9.1 Quality Issue Resolution Mechanisms

Table 4.6 summarises the mechanisms used for problem solving. It also states the strengths and weaknesses, as well as the cases, involved for each mechanism.

Mechanism used for Problem Solving in the 4 case studies	Where used?	Strengths	Weaknesses
Ad-hoc meetings for critical quality complaints	Case 1, 2	- Good for immediate response to critical quality issues	- Can be hard to gather key staffs together all at once - Information might be lacking at the initial phase of the meeting
Teleconference (using telephone, mobile phones, Skype)	Case 1, 2, 3, 4	- Good for immediate response to critical quality issues - Able to clarify certain less embedded knowledge	- Can be difficult to convey message pertaining to sound, sight and smell. - Embedded knowledge is difficult to convey
Daily Morning Briefings	Case 1, 2	- Provides a immediate dissemination of knowledge to key staffs	- Not sure if all the receivers adsorbed the same key knowledge
Engineering Documentation Review	Case 3, 4	- Provides insight to the initial design phase of the product - Enable corrective action from the root	- Corrective action might not be feasible as deemed by management - To be fulfilled as a part of audit requirements
On-the-job Training	Case 1, 2	- Provides a database for the trainees to learn - Allows the older trainers to refresh knowledge at the same time	- The knowledge might be too much for trainee, affecting adsorption
Server data repositories (includes AutoCAD files, reports, engineering specifications, etc)	Case 1, 2, 3, 4	- Provides an archive location for all documented knowledge and information - Access provided to all	- Costly and difficult to maintain order
Corporate Telephone Directory Listing	Case 1, 2, 3, 4	- Provides a listings for the whole organisations	- Does not indicate the knowledge experts, but recognises the managers of each department to be the expert by default - Listings can be out-dated

Table 4.6, Knowledge mechanisms strengths and weaknesses

In order to provide a clearer description of the mechanisms used, this data will be further explained in the following sections.

4.9.1.1 Ad-hoc Meetings

The first type of the mechanism is ad-hoc meetings, which are used based on the urgency of the issue. In this case, the quality issue required immediate actions; the managers in the interview named them "Fire-fighting". The ad-hoc meetings act like nerve centres to tackle the problem at hand. The significance of ad-hoc meetings is that they can help to reveal problems within a very short time frame; however, the resources and effort put in can be tremendous. Frequent usage of such ad-hoc meetings can be overloading to the organisation. As in Cases 1 & 2, an engineer and manager gave surprisingly similar statements: "All we do is just attending these unplanned meetings, where do we have time to sit down and work!"

4.9.1.2 Teleconferencing

The second type of mechanism is teleconferencing. This is when people of several backgrounds in different geographical locations come together using telecommunication devices to exchange similar interests or ideas in a formal manner. Teleconferencing is used when access to information is limited or embedded in the other party. Usually, teleconferencing can help to reduce more than half of the queries that arose during the start of the conference. However, there are certain limitations on this mechanism. For example, it was found to be difficult to convey messages that have highly embedded knowledge; things like operating procedures are hard to describe. The reduced media richness capacity also

limits the type of knowledge that is transferable. Some examples are properties pertaining to colours or textures.

4.9.1.3 Daily Morning Briefings

The third mechanism is morning briefings. A morning briefing is a gathering of the whole department where the lower level staffs is informed by the seniors of the day's upcoming activities as well as the consolidation of the past day's work. Other information, like ad-hoc 'additional' issues, is also disseminated. The tone of the briefing is more like an instructional-based approach; however, the effectiveness of the knowledge disseminated is highly unreliable, as some of the receivers might have different understandings of the subject. The seniors were observed to remind and double-check of the work status after the briefings were done.

4.9.1.4 Engineering Documentation Review

This is the forth type of mechanism used in the 4 quality issues. This is a relevant process done in order to ensure that the documented process and the actual process do not deviate. As reported by one of the managers, "In certain cases, there were found to be different from the Control Plan, the dimensions and tolerances were different from the documentations." Such cases usually occurred because the previous changes were not being updated and reflected in the relevant documentation. From a personal observation, the amount of work invested to keep the documents up to date can be tremendous. In addition, Alpha has a full-time engineer responsible for such amendments and tracking changes. During an interview session, one

engineer cried out, “We have to update these documents, or else during customer audits; we will be given a non-conformance!” The focus of keeping the document updated is to fulfil the requirements of audits. The documents were observed to provide limited use in areas of knowledge reuse. Nonetheless, it is a key area of the mechanism.

4.9.1.5 On-the-Job Training

The fifth type of mechanism is the on-the-job training for employees in Alpha. This is a phase used to distribute knowledge once the knowledge is clear. The training is then carried out for the current employees and stored to provide training to new employees in the future. This training can include the use of a defect sample reference book. These are actual samples held in documented files, describing the root cause of the defect and containing physical samples. This provides a ‘feel’ of the defect, thus enabling employees to pick up knowledge for the job within a short period.

4.9.1.6 Server Data Repository

The sixth mechanism is the use of a server data repository. This is to provide an easy retrieval of all past quality issues, for data processing, for the storage of engineering documents and other knowledge (standards, etc). Access to the server is straightforward; anyone provided with a computer will have instant access to the server. However, one limitation is that there is no search engine provided to locate specific documents. It is still up to the creator of the knowledge to provide the location, thus limiting the user-friendliness of the

system. As well, the knowledge is very much diffused in the server, but no system is in place to enhance the ease of use.

4.9.1.7 Corporate Telephone Directory Listing

The seventh and final mechanism is provided in the server data repository. Access to this listing is granted under similar conditions to the server. Because Alpha has several locations all over the world, the listings are separated within these companies. This directory lists all employees (up to engineer level) and their desk phone number, mobile phone number, Skype address, email address and corporate office address. There are two disadvantages to this listing. First, the listings are difficult to keep up to date; there is constant turnover of employees within the organisation, especially when it concerns several different subsidiaries. Second, the listings do not indicate the knowledge experts. Rather, it provides the manager for each department, who is taken to be the most senior of the department. Hence, they are expected to provide the necessary knowledge.

4.9.2 Quality Issue Resolution Mediums

As explained, the 4 cases have indicated that there are several mechanisms involved during the problem solving process (as seen in Table 4.7). The mechanisms can be further broken down based on the medium's content. These mediums provide more colour to the research and are worthy of further investigation. Upon further analysis, the mediums used within the mechanisms can be loosely grouped into two types: people-oriented and document-oriented.

These mediums were found to exist when the problem solving was conducted based on the analysis of the 4 cases.

Types of Medium	Case 1&2		Case 3&4	
	What mediums used?	Who?	What mediums used?	Who?
People-oriented	- Face-to-face discussions - Ad-hoc meetings - Telephone calls - Information & communication technology	- Customer - Manager - Engineer - Technician	- Face-to-face discussions - Informal meetings - Formal meetings	- Manager -Engineer -Operators
Document-oriented	- 8D reports - 5-Whys report - Purge notice report - Self written notes - Emails - Defect samples photos - Fax - Telephone Directory -Defect sample reference book	- Customer - Manager - Engineer - Operators	- NCR report - Self written notes - Emails - Telephone Directory - Fax	- Manager -Engineer

Table 4.7, Mediums used for the 4 cases

There are three observations from this:

- In all cases, it is preferable to use people-oriented mediums rather than documented-oriented medium. This is in parallel with the media richness theory, as suggested by Lengel and Daft (1988), because most of the mediums used at the capturing, packaging and distribution phases of the problem solving are influenced by a highly urgent quality issue. The inclination to use a people-oriented medium could suggest more interesting facts than just a habit.

- Documented-oriented mediums were used for recording purposes. The documents are usually required (for a reply to customer, for archives, for audits, etc.) only after the root cause has been identified (less uncertainty involved). Hence, the preference was to use a documentation-oriented medium rather than a people-oriented medium.

- There are more mediums used in Cases 1 & 2 than in Cases 3 & 4. The difference between Cases 1 & 2 and 3 & 4 is that the former are external customer quality issues whereas the later are internal quality issues. The external issues were given more focus and attention, resulting in a higher utilisation of mediums. This also suggests that there is a tendency in the organisation to treat customer reactions as a top priority but to treat internal quality issues as 'not-so-urgent'.

4.9.2.1 People-oriented Mediums

People-oriented mediums are defined as when people-to-people interactions are involved. Examples include face-to-face discussions, meetings, telephone calls, etc. This type of medium is often used when there is a need to transfer knowledge in a fast and effective manner. The people-oriented mediums are similar to the experiential and existential knowledge types suggested by Doz and Santos (1997). However, it is not possible to measure the embeddedness of the knowledge for each medium, as the content of the mediums is highly diversified.

4.9.2.2 Document-oriented Mediums

Document-oriented mediums are defined as documentation based activities. The packaging phase of the knowledge is similar to the documentation required in the evidence found. The uses of 8D reports and 5-Whys reports are similar to the documentation of captured knowledge. In order to document the knowledge, there is a need to first interact with, find out and to seek the knowledge before it is possible to package and define what is required for documentation. The document-oriented mediums are in line with explicit and endemic knowledge types suggested by Doz and Santos (1997).

4.9.3 Influence of Mechanism and Medium on Quality System

Upon the establishment of the mechanisms and mediums as seen in sections 4.4.1 and 4.4.2, it is interesting to note that there is a significant trend in the use of people and document oriented mediums during the problem solving phases (i.e. capturing and packaging, as in Cases 1 & 2). From Table 4.8, the mechanisms and mediums also show a trend that people-oriented mediums were the preferred form of medium in almost all situations in the organisation (as explained in section 4.4.2). As explained by the first research question, the impact of the mechanisms used in quality issue solving pertaining to knowledge reuse is significant. On one hand, there is a need to document the knowledge (i.e. codification strategy) but, on another hand, the organisation prefers to use people-oriented mediums (i.e. personalisation strategy). Hence, as mentioned by Hansen, Nohria and Tierney (1999), a high failure rate will occur when an organisation adopts only one type of strategy. This phenomenon has been exhibited in each of the 4 cases.

Mechanism used for Problem Solving in the 4 case studies	Medium type	Medium used during Mechanism	Purpose
Ad-hoc meetings for critical quality complaints	Mix of people / document oriented	- Face-to-face discussions (Formal/Informal) - Self-made notes - Telephone - Fax - Photographs of defects - Defect samples - Email - 5-Whys reports - 8D reports - Purge notice reports	- Used as a immediate reaction to customer complaint - Assess immediate threats - Risk evaluation - Fire-fighting situation
Teleconference (using telephone, mobile phones, Skype)	Mostly people oriented	- Telephone - Mobile phones - Information & Communication Technology	- To communication with relevant people (internal and customers) in order to resolve problems
Daily Morning Briefings	Mostly people oriented	- Face-to-face discussions (Formal/Informal) - 8D reports - Personal notes	- For all staffs to update on the daily work, so that management will know what are the current status for the actual situations -To disseminate important work events for the individual departments, so as to update all relevant employees - Usually use as an aftermath of the fire-fighting
Engineering Documentation Review	Mostly document oriented	- FMEA - Control Plan - Process Flow Diagram - Face-to-face discussions	- To be carried out when the problem occurs - Conducted only as and when remembered - To be kept updated for audit purposes, not usually used for knowledge related purpose
On-the-Job Training	Mostly people oriented	- Defect sample reference book - Face-to-face discussions	- For the training of new staffs - For referencing purpose (i.e. Master sample)
Server data repository (includes AutoCAD files, reports, engineering specifications, etc)	Mostly document oriented	- Information & communication technology	- All system files and working document are store on this server - Allows easy access of system files for all employees in Alpha - Contains a large portion of the documents and reports
Corporate Telephone Directory Listing	Mostly document-oriented	- Self-searching on computer	- To ask questions to the managers - To communicate and gain understanding between departments

Table 4.8, Knowledge mechanisms breakdown chart

Therefore, the success of the knowledge reuse initiative is highly dependent on the mechanisms and mediums used. In order to achieve highly effective problem solving, knowledge transfer is to be carried out using people-oriented mechanisms. In order to fulfil

the documentation requirements of customers and third party audits, knowledge transfer is most likely to be carried out using document-oriented mediums. The challenge of achieving a knowledge reuse system that the organisation will utilise now becomes an adoption of two strategies (codification and personalisation). It is important for the managers to realise that the application of only one type of knowledge management strategy in an organisation will cripple it, not emphasise it. As seen in Figure 4.5, the framework presented shows the type of mechanisms and the strategy to be adopted. By considering the two strategies, it is possible to plan and make clear the links and prevent an oversight during the implementation of knowledge reuse initiatives.

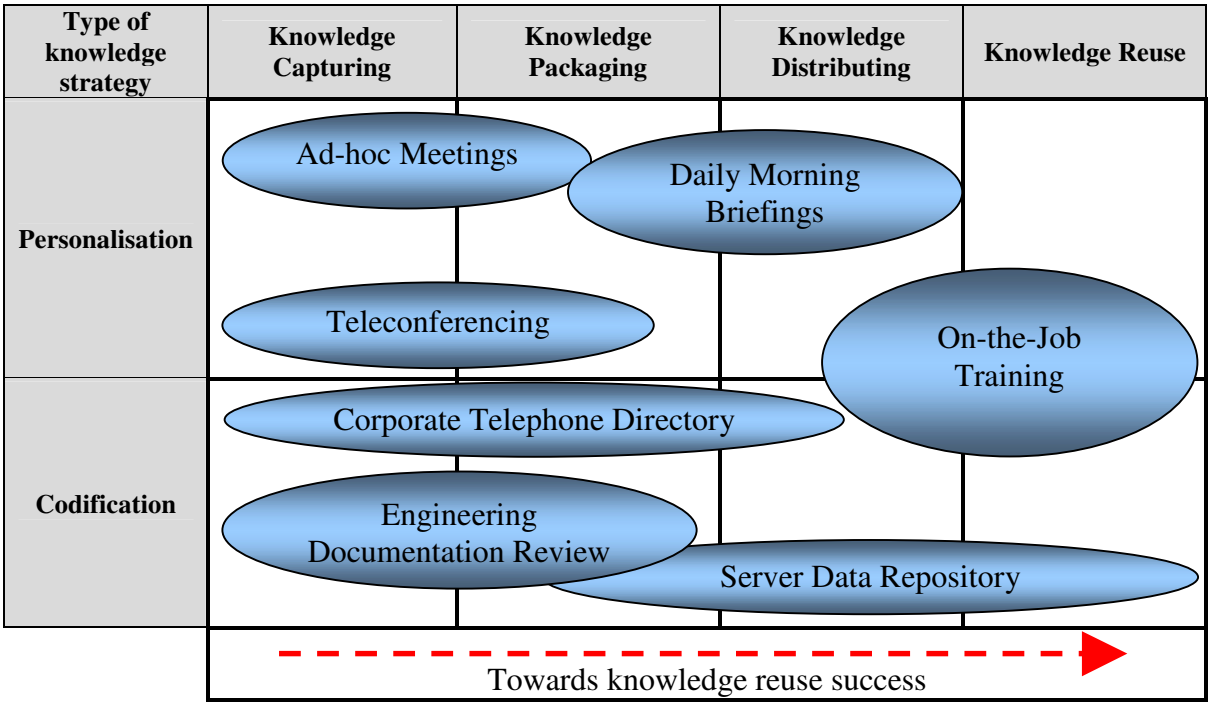

Figure 4.5, A framework of the knowledge management strategy adoption

4.10 Conclusion

This chapter has looked at the research questions and formulated a matrix and framework in order to understand and explain the research observations. Starting with research question 1, knowledge reuse can indeed affect quality issues. From a loose and broad perspective, a robust quality management system will determine the products' quality. If the rule is non-existent or is not enforced, then the organisation's emphasis will be lacking. In order to achieve a greater emphasis of knowledge reuse concepts and initiatives, enforcement will need to come first (top-down management). Enforcement can also come from customers and third party audits, and then the emphasis will have to be taken seriously by the management. Resource allocation can be set up to execute a knowledge reuse system while still fitting to the business model by using codification, personalisation or a mixed of both (Hansen et al. 1999). However, due to a lack of evidence, the quadrant to focus on enlightenment (as in Figure 4.4), will assume that once people are in place, their awareness and motivation to use and continuously update the knowledge (tacit and explicit) will be the key to achieving successful knowledge reuse (Markus 2001).

As for research question 2, the formulated framework was used in order to understand and explain the research observations. It can be concluded that mechanisms and mediums are closely linked, and that their impact on knowledge reuse success is significant. The mechanisms tend to be highly rich in content, consisting of people and document-oriented mediums. A framework was also used to explain the link between the mechanisms and the knowledge strategy used. This framework supports Hansen, Nohria and Tierney's (1999) proposal of adopting 2 strategies when dealing with knowledge management. This research,

while focusing on knowledge reuse in a quality system environment, also indicated similar trends.

To conclude, it has been clearly identified that the research intentions as initially stated out in Section 2.6 could be addresses with the results presented here. Of this these two research questions, it has shown that there is a strong link between quality systems and knowledge management (in this case, specifically in the context of knowledge reuse). The impact of knowledge reuse, as explained by research question 1, is significant and a matrix (as seen in Figure 4.4) was provided to explain the phenomenon. Research question 2 explored the realm of knowledge reuse mechanisms. From a practitioner's point of view, this can help create a better overview of which knowledge reuse initiative should be implemented, depending on the type of organisation and business model. In this case, for Alpha, it is best to use more personalisation while adding codification to support and sustain knowledge reuse in the quality system.

5. Discussions and Conclusions

5.1 Introduction

This chapter reviews the findings of this dissertation study and discusses the implications for both practitioners and academics. The openness of the research questions and the lack of integrated theories called for a case study approach. Consequently, due to the exploratory nature of this work, it is appropriate to view the main contributions of this research as more of a rich, framed and organized collection of new insights rather than a statistically supported set of hypotheses. This chapter commences by presenting a summary of the major contributions of this research and shows how the findings answer the set of research questions formulated earlier. Resting on this synthesis, a review of the implications for practice and theory is provided. To conclude, the limitations of this study and opportunities for further research are discussed.

5.2 Research Findings

In these times, few would argue against the claim that knowledge is considered a central resource upon which companies strive to build a sustainable competitive advantage (Drucker, 1993; Grant 1996). Managing the knowledge that resides inside organisations is an essential constituent of any knowledge management strategy. It has been remarked that organisational knowledge increasingly takes a fragmented form, distributed amongst the employees and entities in firms. A lack of knowledge management initiatives can lead to knowledge residing in the employees themselves.

In the extant literature on knowledge reuse, the phases of capturing, packaging and distributing knowledge are well defined; what is lacking is in the final phase of reuse. Codification methods were often described as the preferred strategy for knowledge reuse, and ICTs were used for this sole purpose (Fruchter & Demian, 2002). Again, the gaps in the review of what type of knowledge exists do not justify the codification methods used for all knowledge reuse situations.

From the literature review, two research questions were formulated:

1. How has knowledge reuse influenced quality issues?
2. What mechanisms in quality management systems influence knowledge reuse?

Those findings from the 4 cases, with reference to the research questions, are summarised in the following sections.

5.2.1 Knowledge Reuse Influence on Quality Systems

The process of knowledge reuse is often described by a few phases, namely capturing, packaging, distributing and then eventual reuse. The examination of the 4 case studies has indicated that knowledge reuse does exist quality systems. The core of this research is not to answer how well the implementation of knowledge reuse had been, but how knowledge reuse can influence quality management systems. The research in this case has revealed several interesting findings. They are summarised in the list below:

- Quality management systems tend to focus on the front end of the process in knowledge reuse. The evidence shows that the capturing, packaging and distribution phases were implemented with some success. However, when it comes to the reuse phase, there was indeed some lacking in the evidence. While referencing to quality management system procedures, there were requirements but these were not sufficiently prominent in the statements.

- Organisations that have implemented quality systems are largely left to their own devices to determine the processes they set up. Even the engineers in the organisation perform the task of documentation purely for the sake of fulfilling quality system requirements, one of the reasons being that there is a lack of emphasis in the organisation. In addition, the execution of the quality system was not carried out systematically. This phenomenon when coupled with the lack of enforcement by external parties (third party audits and customers) results in failure of the implemented quality system.

- The focus on quality is directly related to customer satisfaction. Effort used by organisations to handle quality issues from customer complaints becomes significantly higher when compared to the handling of internal quality issues. The management of the organisation is also noted to have become increasingly sensitive to customer complaints, thereby stressing the importance of good quality.

- Consistency of knowledge reuse initiatives in the process is only possible when it is emphasised by top management, the reason being that maintaining such processes for knowledge reuse requires significant resources. As well, the organisation must also be aware of and willing to utilise the system.

Based on the 4 points observed, it can be said that knowledge reuse can influence quality management systems when there is Enforcement, Execution, Emphasis and Enlightenment. These are the strategies used to adopt processes to achieve knowledge reuse, as suggested by the 2x2 matrix seen in Figure 4.5. There will be a significant influence on knowledge reuse once there is clearer understanding of the four conditions of the knowledge reuse in a quality system.

Nonetheless, the distinctions of the four "E"s are significant. They allow the practitioner to understand the status of the quality system within the organisation and quickly adopt a suitable strategy to achieve knowledge reuse success. This framework is not intended to inform or provide guidance, but as a form of indicator for knowledge reuse success and, eventually, to improve quality.

5.2.2 Mechanisms affecting Knowledge Reuse

The other research question is to understand what mechanisms are used at which phases of the process of knowledge reuse. By investigating these areas, the process of how current systems have been implemented can be reviewed and improved to enhance knowledge reuse success.

Within the mechanisms, many kinds of mediums were found. The mediums can be loosely grouped into two main types: people-oriented mediums and document-oriented mediums. The following are the observations from the research:

- Many mechanisms exist to facilitate problem solving, but most of the mechanisms used centred around people-oriented mediums due to the fast responses needed to resolve customer issues. People-oriented mediums have the advantage of being rich in tacit information and they tend to be the fastest way of transferring knowledge.

- People-oriented mediums are the preferred way when it comes to problem solving. Document-oriented mediums act as a secondary backup when in-depth details are required.

- The use of personalisation strategies is more significant when fast problem solving is required. Codification strategies support the documentation of the knowledge for later knowledge reuse.

From the 3 observations, it can be said that mechanisms can influence the knowledge reuse success. As seen in Figure 4.5, the framework provides an overall view of the mechanisms spanning the process for knowledge reuse. This was coupled with codification and personalisation strategies, which allowed for an easier focus on the strategies used in each process phase of knowledge reuse. This framework provides practitioners with a clearer view on the knowledge reuse as well as on the knowledge mechanisms pertaining to the mediums

used at each phase of knowledge reuse. Ultimately, this framework can also be used as a decision-making guide on knowledge reuse mechanisms for implementers of knowledge reuse.

5.3 Implications for Practice

There are two major contributions of this research in relation to the understanding of knowledge reuse in a manufacturing quality system: the development of a tool-kit comprising of (1) a knowledge reuse framework and a diagnostic matrix and (2) a knowledge reuse mechanism adoption framework.

5.3.1 Knowledge Reuse Toolkit

This tool-kit comprises of a framework and a diagnostic matrix for knowledge reuse. A framework of the process flow for knowledge reuse phenomenon (Figure 4.3) is proposed. In addition, a matrix relating the conditions of knowledge reuse in an organisation with the various levels of knowledge reuse versus the quality issues faced by the organisation (Figure 4.4) was proposed. The implications to management practitioners that stem from the proposed framework and matrix are threefold.

First, the framework provides a basis for managers to map their current processes for knowledge reuse and understand the flow of various types of knowledge at each stage. This enables managers to identify the gaps within the process of quality management systems to the processes of knowledge reuse and understand the level of the knowledge reuse

implementation (i.e. ad-hoc or consistent). In addition, it allows manager to realise the effort and resources of each process phase required for successful knowledge reuse. In the process of doing this, they are able to identify the deficiencies in areas of their quality management system and understand the focus of the management problem at hand. Overall, this framework suggests a clear roadmap for the practitioners of management systems to follow; it also prevents the "myopia" effect, which results when focus on one area becomes too extensive and neglects the others. From the model, it is also understood that, in the process of knowledge reuse, a weak link at any point in capturing, packaging or distributing will result in a broken process for knowledge reuse, thereby leading to possible knowledge reuse failure. The framework also suggests that focus should be placed first on internal quality issues, not only on customer issues. On quality issues, it is better to adopt a preventive stance, rather than a reactive stance.

Second, the matrix highlights the key areas where problems exist. From there, it is possible to identify the weakness using the diagnostic matrix and then focus on the weak areas within the quality management system, as suggested by the 2x2 matrix. For example, the influence of the success in the matrix can be influenced by the "awareness" created within the organisation and the external stakeholders (i.e. third party auditors, consultants, customer audits). If this "awareness" is not available, knowledge reuse cannot be fulfilled, and eventually results in the breakdown, this breakdown can be identified to be at the various four quadrants of the matrix.

Third, the combination of the framework and matrix provides a holistic tool-kit for the implementation and diagnostics of the knowledge reuse systems in the quality management system. Ultimately, it is possible to measure and judge a system's capability based on its process of knowledge reuse. Managerial personals can use this diagnostic kit to evaluate the maturity of knowledge reuse within any quality management system.

In the three implications of the framework as presented in Figure 4.3, the findings can be helpful to knowledge management activities in an organisation. This framework should be used for two purposes, (1) as a diagnostic tool when an existing knowledge reuse process exists, and (2) as a blueprint for implementing new knowledge reuse processes when there is none existing. In the first scenario, by mapping the process of knowledge flow (it can be of any knowledge base) from capturing, distributing, packaging and finally reusing, it is possible to identify the weak links of the process. In order to achieve knowledge reuse success, the links holding the process must be enforced, executed, emphasised and eventually the organisation will gain enlightenment (Figure 4.4). Ultimately, reaping the rewards of a well-managed knowledge reuse process. In the second scenario, practitioners should use this framework also as a platform for the implementation when no knowledge reuse exists. By following this framework as the "roadmap", it is able to allow the managers of the organisation to effectively implement a possible bare minimum knowledge reuse process to successfully manage knowledge for later reuse. Both approaches should be straightforward once the knowledge reuse concept has been understood. However due to limited time in research, the researcher will not further attempt to explain the mentioned concept, Markus (2001) have already provided a well balanced description on the concept of knowledge reuse.

5.3.2 Knowledge Reuse Mechanism Framework

The second major contribution of this research is to the development of a framework pertaining to knowledge reuse mechanisms. The implications of the proposed matrix to practitioners are threefold.

First, the framework indicates which knowledge reuse mechanisms are commonly used in organisations, therefore providing the practitioners with a clear mindset of the type of activities that currently exist within the organisation. This allows them to map the knowledge reuse phases and the mechanisms together, thereby establishing the links between them. Furthermore, from the mechanisms it is possible to identify the type of medium (people or document oriented) being used, as the type of medium is important to facilitate knowledge reuse.

Second, the effect of knowledge strategy (codification and personalisation) is revealed to the practitioners. By understanding this, it allows for a more effective selection of the mechanisms used for each knowledge reuse phase. The co-existence of strategies also reminds the practitioner to be aware of both the people-oriented and document-oriented mediums. This allows effective top-down implementations, as emphasized by upper management.

Third, when practitioners use this framework they should reference the framework on knowledge reuse initiatives (Figure 4.5). This provides a holistic approach to the implementation of knowledge reuse. The mechanisms used can be cross-referenced with the

two different types of quality issues (internal and external issues). This also enables practitioners to match the desired knowledge flow with the proper mechanisms. Although most organisations have their own process for quality resolution methods, it is still important to have mechanisms that link the whole process of knowledge reuse together in order to achieve the best possible results.

An example in the practical application of this framework is in the similar boundaries of the first presented toolkit (Knowledge Reuse Toolkit). When the setup knowledge reuse process have been implemented, it is possible to use the knowledge reuse toolkit to study and enhance the mechanisms used within the knowledge reuse process. In the event of a link weak being detected, this toolkit can be used to identify which is a better strategy to adopt (i.e. codification or personalisation) for each knowledge reuse phase. Therefore, depending on the type of strategy selected, the relative mechanisms can be selected and modelled against this toolkit. Allowing instant understanding and linkages of the several available methods to help effectively manage knowledge for reuse. Also this toolkit can be used to setup new knowledge reuse processes, by following the processes and selecting specific mechanisms as shown in Figure 4.5, the manager can identify which mechanisms is best suited to the organisation while considering the costs involved during the implementation.

Therefore, both the Knowledge Reuse Toolkit and the Knowledge Reuse Mechanism Framework complements each other. It allows simple effective management of the knowledge within an organisation for reuse purpose.

5.4 Implications for Research

Three implications for theories related to knowledge reuse can be derived from the research findings. They are presented as follows:

First, the refinement of the knowledge reuse framework by Markus (2001) is one of the research implications presented. In Markus's knowledge reuse theory, the mechanisms of the knowledge reuse were not specifically identified. In addition, the framework lacked references to real world cases. This research has provided further insights into knowledge reuse in a quality system environment.

Second, the implications of the findings have derived a framework through which knowledge reuse can be developed (Figure 4.3). In the literature review, it is revealed that the focus was often on new product development or innovation type cases (Majchrzak, Cooper, and Neece, 2004). In the literature, the contexts are different but the purposes are the same. This research takes a holistic stance by considering all the different paths with a manufacturing context that extends beyond the knowledge reuse phases.

A third implication for research on knowledge reuse and quality systems stems from the introduction of the 2x2 matrix. It was designed to facilitate the implementation of knowledge reuse from a quality system perspective. By framing and linking a variety of concepts, it was able to develop new and valuable insights for practitioners and scholars. In this case, the matrix is thought to be useful for researchers interested in the effects of ad-hoc or consistent knowledge reuse. Previously, there was no definition of how, when or what knowledge reuse

should take place. In this regard, it is hoped that new and interesting concepts can be derived from this proposal.

5.5 Limitations of this Research and Future Work

From the formulation of the research questions to the analysis of the sub-cases through the design and implementation of the research, the amount of effort, care and foresight have been limited only by the researcher's abilities, resources and time constraints. New insights and a better understanding of the focal issues described above have been gained. The implications for both practitioners and researchers are substantial. However, as with all research, the present work is subject to certain limitations that are worth exposing as they open the way for further promising undertakings.

5.5.1 Qualitative Approach and Generalization of Research Findings

Due to the exploratory nature of this study, a qualitative approach and the use of a single master case (Alpha) was decided. While presenting many fruitful qualities, the chosen research design also has some inherent limitations. The fact that the various cases analysed originate from a similar and unique organisation calls for further studies to be conducted across a larger sample of companies with the objective of reinforcing the external validity the findings. Additionally, the qualitative approach significantly helped comprehend the context, reveal important constructs and identify interesting relationships. A quantitative approach would now be appropriate to test the findings based on a set of statistical tools applied to a broader sample. This undertaking would increase the robustness of the proposed theories.

5.5.2 Practicality of Research Findings

At every stage of the research process, the objective of producing actionable knowledge directly relevant to practitioners was kept persistently well in sight (Thomson and Tymon, 1982). The creation of a knowledge reuse tool-kit and the mechanism framework stemming from this research clearly acknowledge the concern. However, as one may point out, there is still a gap between the implications suggested and the presentation of a practical management tool usable by practitioners. Application of the developed theory into a consulting or audit tool would certainty prove to be better suited for practitioners. As well, applying the derived frameworks and matrix to a greater number of cases could generate rich and stimulating data for scholars.

5.5.3 Time Consideration

As Navarro (2006) emphatically remarked, research in the management field often focuses on the "what", "how" and "why" questions while eluding the "when" issues. This thesis is no exception, as the time component does not appear as a major concern in the research questions. From the 4 knowledge reuse events that were gathered, there were some vague insights to the effects of timeliness (i.e. prompt response to customer's complaint) on the knowledge being reused, as well as some additional clues to how it might have affected the type of knowledge used for the reuse phase. While it would be based on a different collection of cases, further research concerning the way that knowledge reuse is strategized and applied over time may lead to promising results.

5.5.4 External Environmental Factors

This research had the clear purpose of answering two research questions. The first was "how" knowledge reuse can affect quality issues. The second question was to investigate the influence of the mediums used in the processes for knowledge reuse in quality systems. Both answer the larger question of how is it possible to improve knowledge reuse implementations in quality systems without suggesting significant changes to what the organisations are doing now. The proposals that suggested were not to reinvent the wheel, but to improve and change the current systems, thereby shortening the learning curve. While the processes, mechanisms and strategies for knowledge reuse are essential to explain how knowledge reuse takes place, other factors are important to take into account during the development of a robust knowledge reuse theory. These include environmental factors such as organisational structure, leadership, culture, employee motivation and benefits. Market competitive strengths may prove to be complementary and have a significant influence on the research. Hence, these might be worth examining further.

5.6 Conclusion

The ability to promote knowledge reuse within an organisation has become a critical competency for executives evolving in a world where knowledge is one source of a lasting competitive advantage. The review of the extant literature has shown that practitioners are exposed to increasingly distributed knowledge management literature. The most recent research related to knowledge reuse was in areas of new product development and innovation,

of which none looked into the "out-dated" manufacturing quality management systems. This research has resulted in the detection of some gaps in the existing knowledge reuse theories, of which this dissertation hopes to highlight. While the bulk of the research was created from building upon other theories, it has implications for practitioners and academics alike. Instinctively, this research has created links to the original theories that, in this dissertation, has resulted in unique and innovative lines of thinking. The new insights are as follows:

- Quality management systems can effectively support knowledge reuse, but only if the processes are Emphasised, Enforced, Executed and Enlightened (4 "E"s), as seen in the matrix Figure 4.4.
- The 4 "E"s must be supported by the adoption of proper mechanisms and mediums, as reflected by Figure 4.5. Of these, personalisation and codification strategies should be adopted in a mixed formula. This provides a clear roadmap for knowledge reuse success.

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7. Appendix

7.1 Appendix A: Interview Questions

The semi-structured interviews, which have been conducted in Alpha, were based on the set of questions presented below. The exact formulation of each question, the order according to which questions were asked, and the expectations regarding the answers' breadth and degree of detail followed rules of personnel congeniality and depended upon the interviewees' position and on their familiarity with the subject of inquiry. The interviews were conducted in the mother tongue of both the interviewer and the interviewees and questions had been translated from English accordingly, prior to the interviews, it was agree that the interviewees' details were to be kept confidential. In addition, the interview sessions was conducted with two interns from NUS ISE department. It was necessary to keep the interviews free from bias, as the researcher at the time was an employee of the organisation.

Questions on Processes for Knowledge Reuse

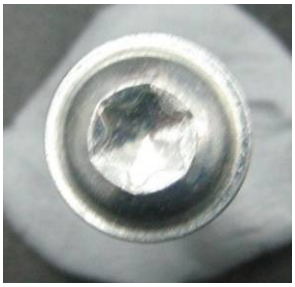
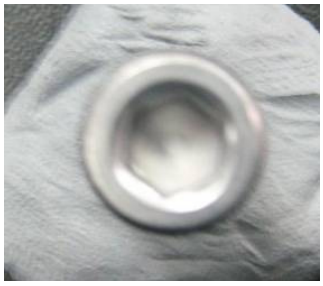
- How did the quality issue happen and who/how was it solved? (Show evidence on the troubleshooting process if any)
- What were the specific corrective actions? Who carried it out?
- Were the corrective actions being documented? Who documented it?
- What documents were packaged for each level of the ISO/TS16949:2002? (Quality manual, Procedures, Operating Instructions, Records)
- Were the corrective actions effective after the implementation? Were the corrective actions disseminated/made known? How was it being done?

- What was used to follow up the corrective actions?
- Were the corrective actions being explained and disseminated?
- Was the corrective action being transferred to other future projects/situations?
- How was the corrective actions feedback into the new projects, to improve quality and reduce future problems?

Questions on the Knowledge Reuse Mechanisms

- What are considered as knowledge reuse mechanisms in your company?
- What about the methods/mediums used to support the mechanisms?
- What mechanisms were used during the problem solving process in face of the quality issues?
- What were the responses of the customer in the face of the quality issue?
- How is the preferred method of mechanisms to use when communicating with customers?
- What other mechanisms are in use within your company, which indirectly supports the problem solving process?
- How have the mechanisms help in your work? Are they effective?
- What are the strengths and weaknesses of the mechanisms?

7.2 Appendix B: Case Study Products Overview

Case	Part number	Top View	Side View	Description
1	40015250			Head: Torx® T30 Pan Head Thread: Delta® PT60 Material: SWRCH 22A (Low carbon steel) Plating: Clear Zinc Trivalent Chrome
2	3016421			Head: Torx® T30 Pan Head Thread: M6.0x1.0-6g with active patching compound Material: SAE 10B21 (Low carbon steel with boron) Plating: Clear Zinc Trivalent Chrome
3	CN05E07.01.05			Head: 5mm Hexagon Socket Head Thread: M6.0x1.0-6g Material: SAE 10B21 (Low carbon steel with boron) Plating: Clear Zinc Trivalent Chrome
4	3013457			Head: Torx® T20 Pan Head Thread: Taptite® II, M4.0x0.7 with CA point Material: SAE 1022 (Low carbon steel) Plating: Clear Zinc Trivalent Chrome

7.3 Appendix C: Supplementary to Quality Management Systems

A breakdown of the available management systems common to the industry at this current time and day (referenced from http://www.bsiamericas.com/IntroToMS/index.xalter) can be seen as follows:

- ISO9000:2000 - Quality Management
- QS-9000 / ISO/TS16949:2002 / VDA 6.1 - Quality Management in the automotive supply industry
- AS9100 - Quality Management in the Aerospace supply industry
- TL9000 - Quality Management in the Telecommunications supply industry

Practitioners have claimed that certification can provide the following benefits to the company:

- Increased market opportunities as customers will see you as more effective and better organized
- Cost savings by improved quality of products (reduced complains and reduced rejects and wastes)
- Improved staff responsibility, commitment and motivation by well managed system
- Stronger reputation in the eyes of stakeholders, through a commitment to doing things right

It can be further identified that there are several quality awards and Total Quality Management systems which is linked to the mentioned management systems, which clearly distinguishes the similarities as seen in Table 7.1, almost all put focuses on knowledge management (to a certain level) as the necessary step for creation of business sustainability and quality improvement.

	Baldrige Criteria	European Quality Award	Shingo Prize	ISO9000:2000
Emphasis	Criteria for performance excellence	Criteria for performance excellence	Manufacturing excellence	International quality standard
Scope	United States	Europe	North America	Worldwide
Purpose 1	Improve everything	Recognize excellence	Facilitate increased awareness	Standardization
Purpose 2	Share best practices	Identify role models	Foster understanding and sharing	Conformity with quality system
Purpose 3	Tool to manage and learn	Share successes	Encourage research	World trade
Value for applicant	Assessment; opportunities to improve	Opportunity for recognition and learning	Learning and recognition	Certification with ISO logo
Emphasis on knowledge transfer	High	Low to medium	Medium to high	Low to medium
Emphasis on knowledge sharing	High	High	High	High
Emphasis on knowledge reuse	High	High	High	High

Table 7.1, Total Quality Management systems with the emphasis on knowledge management

(Source: English M.J, Baker W.H.Jr, 2006)

An Introduction to ISO/TS16949:2002

ISO/TS16949:2002 is an ISO Technical Specification, which aligns existing US, German, French and Italian automotive quality system standards within the global automotive industry. ISO/TS16949:2002 specifies the quality system requirements for the design/ development, production, installation and servicing of automotive-related products. ISO/TS16949:2002 was written by the International Automotive Task Force (IATF) in conjunction with the International Organisation for Standardization (ISO). The IATF consists of an international group of vehicle manufacturers, BMW Group, DaimlerChrysler, Fiat Auto, Ford Motor Company, General Motors Corporation, PSA Peugeot-Citroen, Renault SA and Volkswagen, plus national trade associations, AIAG (America), VDA (Germany), SMMT (UK), ANFIA (Italy) and FIEV (France). Japanese vehicle manufacturers associations (JAMA), have been involved in the development of ISO/TS16949:2002 and are expected to join IATF as full members in due course. Automotive Sector requirements, defining international automotive quality system requirements are contained in ISO/TS16949:2002, which is written injunction and based on ISO9001:2000. Customer specific requirements are required by individual subscribing vehicle manufacturers are provided separately. Along with customer specific requirements, ISO/TS16949:2002 has been accepted as equivalent to the following automotive quality standards of QS-9000 (America), VDA 6.1 (Germany), AVSQ (Italy) and EAQF (France).

Product Realization in ISO/TS16949:2002

In this research, the focus will be on ISO/TS16949:2002; hence, a model of the existing ISO/TS16949:2002 can be seen in Figure 7.1.

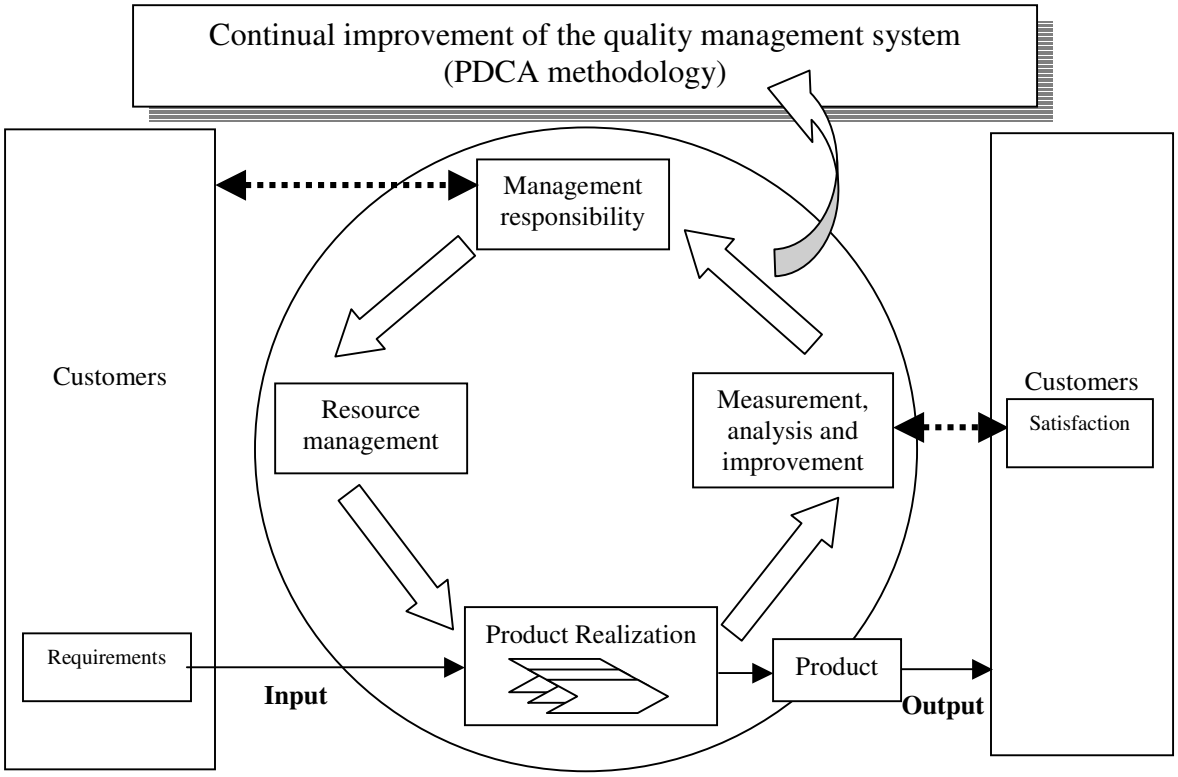


Figure 7.1, Model of a process-based quality management system

(Source: ISO/TS16949:2002 document)

It is specifically a process-based quality management system, where the mention of documentation in the form of Process Flow Diagrams, FMEAs, Control Plans, records, engineering drawings, Manufacturing Process Flow Charts/layouts, Work Instructions, Measurement Data, Methods of Rapid Detection and Feedback for Product Non-Conformities. Such documentations directly points to the storage of explicit knowledge

within the firm as well as the customer (All documents will be submitted to customer for verification and storage). Knowledge in Alpha exists in explicit (documentation) and tacit (communication) form. Of which the directives of the ISO/TS16949:2002 requires the organisation to put in place a team of knowledge holders (senior/managers, engineers and technicians) where it is required to meet and discuss formally prior to the product realization phase, in order to reduce the chances of problem occurrences as well as to create an atmosphere for knowledge transfer. After the success of the product realization phase, the team will require to meet again to prepare for mass production phase. This indicates knowledge reuse initiatives requirement from quality management systems perspective.

One of the key processes in ISO/TS16949:2002 is the Product Realisation phase. This is where the prototypes are developed for customer based on their requirements. In the sense of ISO/TS16949:2002, it comprises of planning, design, development, risk reduction, and measurement tests to determine the product actual realisation efforts. In the whole process, this product is then documented in an Advanced Product Quality Planning (APQP) package. It was initially being created by Ford, General Motors and Chrysler with a sole purpose of being a quality management tool. It has now been widely embraced by the automotive industry as seen in Figure 7.2.

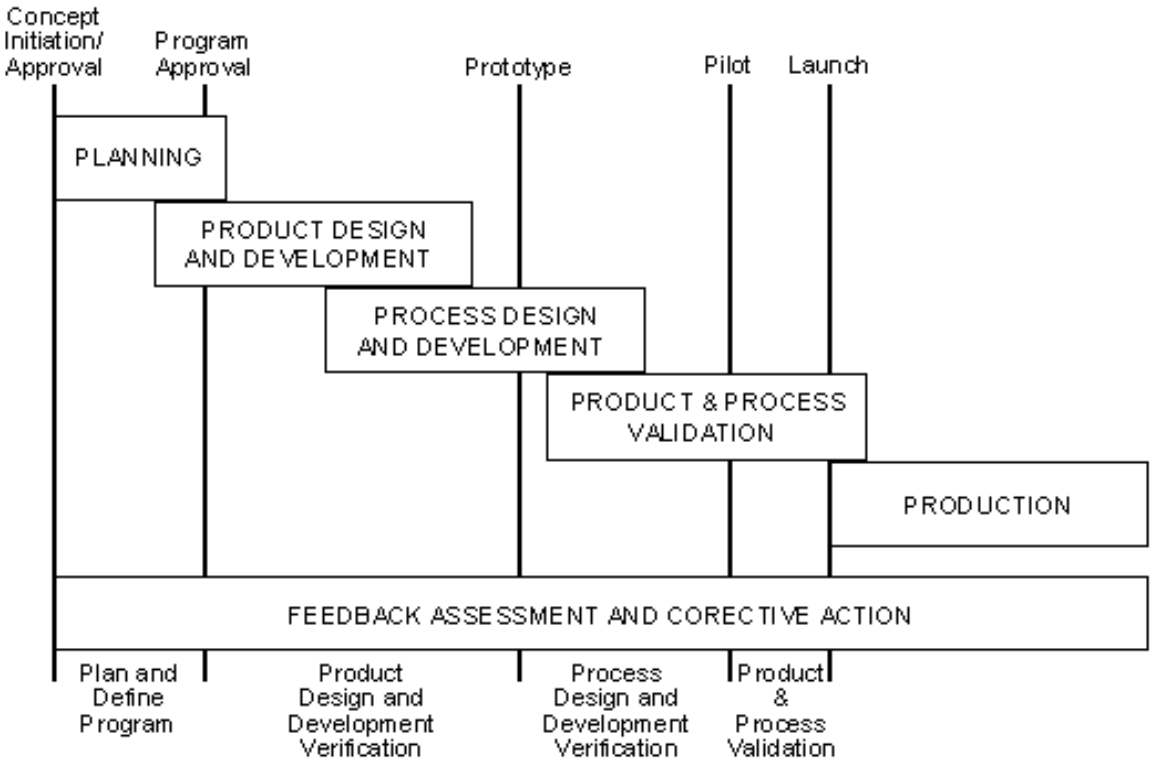


Figure 7.2, APQP workflow timing chart

(Source: http://www.npd-solutions.com/apqp.html)

7.4 Appendix D: Problem Solving Tools commonly used in Quality Systems

The following states the commonly used tools:

- 5-Whys method
- Statistical Process Control methods
- Fishbone diagram
- 8D report

A brief explanation for the tools is explained as follows:

- The 5-Whys method is a form of question-asking thinking process used to explore the cause/effect relationships underlying a particular problem. Ultimately, the goal of applying the 5-Whys method is to determine a root cause of a defect or problem. The common area of the application includes quality issues, management system issues and operation issues. The technique was originally developed by Sakichi Toyoda (founder of Toyota Industries Co., Ltd) and was later used within Toyota Motor Corporation during the evolution of their manufacturing methodologies. It is a critical component of problem solving training delivered as part of the induction into the Toyota Production System. The architect of the Toyota Production System, Taiichi (1988) described that the 5-Whys method was the basis of revealing the root cause, the tool has seen widespread use beyond Toyota, and is now used within Six Sigma.

- Statistical Process Control (SPC) is an effective method of monitoring a process using control charts. Control charts enable the use of objective criteria for distinguishing

background variation from events of significance based on statistical techniques. Much of its power lies in the ability to monitor both process centre and its variation about that centre. By collecting data from samples at various points within the process, variations in the process that may affect the quality of the end product or service can be detected and corrected, thus reducing waste and as well as the likelihood that problems will be passed on to the customer. With its emphasis on early detection and prevention of problems, SPC has a distinct advantage over quality methods, such as inspection, where SPC pre-alerts the problem rather than relying on inspection to detect the problem.

- Fishbone diagram or also known as Ishikawa method is an analysis tool that provides a systematic way of looking at effects and the causes that create or contribute to those effects. Dr. Kaoru Ishikawa, a Japanese quality control statistician, invented the fishbone diagram. Because of the function of the fishbone diagram, it may be referred to as a cause-and-effect diagram. The design of the diagram looks much like the skeleton of a fish. Therefore, it is often referred to as the fishbone diagram. As seen in Figure 7.3, a typical fishbone diagram is the focus of 6Ms, namely Man, Machine, Materials, Method, Maintenance and Mother Nature (environment). For example, a represents Man, and this is linked to the main problem as defined to be q. There are other related e and f which is attached to a, where e and f are the refined causes linking to the Man issues. To use this fishbone diagram, a brainstorming session is required prior to filling up these links (a, b, c, d, etc).

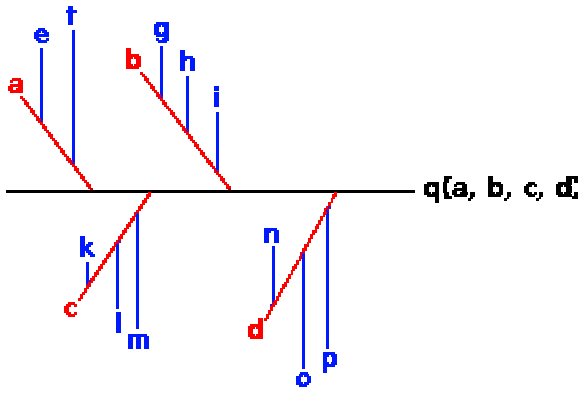


Figure 7.3, A typical fishbone diagram

(Source: http://en.wikipedia.org/wiki/Image:Fishbone.svg)

- 8D method (reporting format) is also known as Eight Disciplines Problem Solving. The U.S. Government first standardised the 8D process during the Second World War, it was later popularised by the Ford Motor Company in the 1960's and the 1970's. 8D has become a standard in the automotive as well as some manufacturing industries that require a through structured problem solving process. The 8D method is used to approach and to resolve problems as in the following:
  - 1D: Assemble a cross-functional team of experts
  - 2D: Define the problem fully
  - 3D: Implement and verify interim containment actions as needed, also known as temporary corrective actions
  - 4D: Identify and verify root cause
  - 5D: Choose and verify permanent corrective actions, also known as preventive corrective actions
  - 6D: Implement and validate permanent corrective actions
  - 7D: Prevent recurrence of the problem/root cause
  - 8D: Recognize the efforts of the team