Understanding Knowledge Creation: A Study of the Processes, Interrelationships and Contributory Factors within Multidisciplinary Project Teams

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Declaration

This thesis is presented in accordance with the regulations for the degree of Doctor of Philosophy (PhD) of the University of Warwick. The work described in this thesis is entirely original and my own, unless otherwise indicated. None of the material contained hereafter has been submitted for a degree at any other university. The interpretations in this thesis are the sole responsibility of the author, and do not in any way represent the views of the case company, the project team members or Warwick Business School.

The following papers based on the findings in this thesis have already been presented or will be presented in due course:

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Abstract

The growing importance of introducing unique products to the market has made firms more conscious of organisational knowledge creation. Knowledge creation is recognised to be important in creating and sustaining competitive advantage as well as in meeting organisational goals in modern societies. Multidisciplinary project teams have gained increased popularity owing to their diversity of knowledge resources, drawing upon different organisational functions and professional disciplines. They are viewed as having high potential to innovate due to their heterogeneous nature. Their activities are fundamental to learning within wider organisations, and not just in the form of temporarily disconnected project units. The research empirically investigates the creation of new technical knowledge and develops a conceptual model of the knowledge creation process. It broadens the organisational knowledge creation theory developed by Nonaka and Takeuchi (1995), into the area of multidisciplinary project teams. This research focuses on three major aspects: the key processes that underlie knowledge creation within multidisciplinary project teams, the interrelationships between these key knowledge creation processes and the factors that influence the processes of multidisciplinary knowledge creation. Empirical evidence was collected from a large property development company, using a qualitative case study approach. Two multidisciplinary project teams, working on infra-structural and residential developments, were selected for the in-depth study.

The research reviews existing theories of organisational knowledge creation and team processes. It seeks to contribute to the theory of knowledge creation within multidisciplinary project teams through technological innovation or problem solving, by providing an explorative account supported by empirical evidence. Secondly, it contributes to the development of the knowledge creation theory within multidisciplinary project teams by adopting a social construction perspective and by focusing on its processes and their interrelationship. In addition, factors are identified that affect these processes. The proposed framework provides not only for future research to systematically examine and test knowledge creation processes against different backgrounds, but it also allows management to continuously anticipate and support knowledge creation activities related to the successful management of collaborative team projects within their particular organisations.

Abbreviations

GFA	Gross Floor Area
HDD	Horizontal Directional Drilling
IT	Information Technology
M&E	Mechanical and Electrical
R&D	Research and Development

Chapter One - Introduction

1.1 Background to the Research

1.1.1 Knowledge as an Important Resource

The increasing importance of knowledge has been proposed as a central feature of post-industrial societies (Bell, 1973; Drucker, 1995; Habermas, 1979; Quinn, 1992; Quinn et al., 1996), with knowledge considered as a primary economic resource. Knowledge is one of the most important resources to an organisation (Drucker, 1993; Grant, 1996a; Nonaka and Takeuchi, 1995; Spender, 1996b), and may be "the only meaningful resource" (Drucker, 1993, p. 42). Intellectual or knowledge-based assets have been distinguished from the more traditional factors of production, such as land, labour and machinery. Unlike traditional factors of production, knowledge assets are intangible, residing within individuals. As a result, they may be more difficult to locate and harness, and may be easily lost.

In order to compete in knowledge intensive industries, an organisation must continuously create, utilise and disseminate new knowledge (Brown and Eisenhardt, 1995; D'Aveni, 1994; Dougherty, 1992; Nonaka, 1994). D'Aveni (1994) reasoned that given the dynamic environments faced by most organisations, those capable of producing a continuous stream of new knowledge are best positioned to achieve competitive advantage. In order to compete, firms must acquire, retain and integrate knowledge and be able to facilitate the creation of knowledge (Nonaka and Ichijo, 1997). Nonaka et al. (2000, p. 2) suggest that the reason for a firm's existence is to "continuously create knowledge".

Attempting to develop and sustain competitive advantage so as to survive intensive competition, organisations are focusing their resources and processes on generating unique knowledge embodied in new and innovative products or services. Although many organisations are beginning to seek more sophisticated organisational structures, or train personnel in many managerial, creative or teamwork skills, many are still likely to have difficulty in being continuously innovative. They may be highly effective in exploiting existing knowledge in the short term, but there is likely to be relatively little long-term learning and knowledge creation, particularly if individuals and knowledge are isolated and fragmented (Dachler, 1992; Isaacs, 1993; Spender, 1996b). Bringing the collective knowledge of members in teams to bear on serving customers or clients is practically important because knowledge is a source of competitive advantage (Barney, 1991; Prahalad and Hamel, 1990; Teece and Pisano, 1994; Teece et al., 1997). Knowledge creating skills in particular are important as they are required to create new products or processes or enhance existing ones (Kogut and Zander, 1996; Leonard-Barton, 1995; Nahapiet and Ghoshal, 1998; Nonaka and Takeuchi, 1995; Prahalad and Hamel, 1990). Learning must be integrated with current tasks, not only to meet present goals, but also to develop and retain knowledge for future organisational needs.

1.1.2 Knowledge Creation and New Product Development

Several researchers have described new product development as a knowledge-intensive activity (Davenport and Prusak, 1998; Iansiti and MacCormack, 1997; Nonaka and Takeuchi, 1995; Song and Montoya-Weiss, 1998). New product development often involves cross-functional linkages, where different participants join a team with differing viewpoints. Such teams are often characterised with risk and synergy resulting from their interaction with other team members (Jassawalla and Sashittal, 1998). Morrison and Kennedy (1996) suggest that this interaction brings in the need to organise, integrate, filter, condense and annotate collaborative data and other relevant information that these team members contribute.

Creating new knowledge and perspectives is fundamental to new product development. A new product can be considered as "a package of features and benefits, each of which must be conceived, articulated, designed and 'operationalised', or brought into existence" (Dougherty, 1996, p. 425). The development of a constructed facility can be viewed as a new product development, with customers or end-users purchasing or using the facility. They would assess their own needs and affordability before they purchase. The development of a new product entails the application of knowledge to new problem-oriented situations, thus requiring uncertainty reduction. The same applies to construction projects, with each project unique in itself in terms of design and construction. With the many constraints the construction industry faces (due to limited space, increasing project complexity, limited budgets, tight programmes and the constant demand for facility innovation), project teams are faced with challenges to utilise diverse, and create new, knowledge in meeting stringent requirements and fulfilling ever changing needs. Project team members have to incorporate new information into their understanding in order to solve the technical challenges they face. Thus, learning is inherent in the work they do (Mohrman, Mohrman and Cohen, 1995). The knowledge gained can be explicit and formal, as when members learn new analytical procedures to deal with a new phenomenon or go to a publication to learn the properties of a new material being used for the first time. Alternatively, their work may lead to tacit learning (Polanyi, 1962), occurring as the individual learns from experience and develops a deep but unarticulated sense of the phenomena at hand. It could also lead to informal learning as members consult one another, taking advantage of each other's personal knowledge stocks (Eraut, 2000). Learning can be personal and remain within the heads of individual contributors, or become public when it is shared with others and perhaps systematised.

1.1.3 Knowledge Creation Activities

In this research, technological innovation and shared problem solving[1] are viewed as knowledge creation activities. In the activity of shared problem solving, employees with different specialisations and problem-solving approaches are brought together so that the diversity of their knowledge and backgrounds can be channelled toward creative problem solving (Leonard-Barton, 1995). According to Leonard-Barton (1995), as people become highly skilled, they develop individual 'signature skills,' formed from their specialisations, cognitive style preferences and preferences for particular tools or methods. Bringing people with diverse signature skills together to work on a problem generates the creative abrasion that, when managed properly, can be a source of innovative solutions. Viewing technological innovation and problem solving this way also follows the framework of Nonaka and Takeuchi (1995) in allowing for the concept of tacit knowledge. Tacit knowledge is a highly contextual and barely expressible knowledge that may be communicated and shared only through socialisation (Nonaka and Takeuchi, 1995). Traditional explanations of knowledge emphasise explicit knowledge in the form of patents or books that may be best

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[1] Leonard-Barton (1995) identifies four main knowledge-building activities carried out in the course of developing new products and processes through which an organisation builds its knowledge and extends or creates new capabilities: (1) shared, creative problem solving; (2) implementing and integrating new methodologies and tools; (3) experimentation and prototyping; and (4) importing knowledge from outside.

considered as the final expression of the knowledge creation process. By acknowledging the tacit elements, the entire process of knowledge creation is included and may be more deeply understood. Anand et al. (1993), emphasise the better understanding of tacit knowledge as a prerequisite for acquiring, distributing and creating knowledge. Eder (1989) suggests that much knowledge in new product development, such as knowledge about the strategic design approach, and knowledge about tactics and methods for designing, is primarily tacit.

1.1.4 Research Implications of the Present Study

The present research has important implications for those project teams that are increasingly investing in knowledge-based co-operative ventures. Many multidisciplinary project teams are involved in collaborative projects, like those examined here. The implications of the findings have widespread ramifications for both theoretical development and managerial practice. As is the case with most construction projects, their raison d'être is creating knowledge to fulfil stakeholder needs, allowing for any constraints that may be imposed. As such, these projects make ideal research material for studying the process of knowledge creation. Senior management also stands to gain substantially from a better understanding of the processes and management of knowledge creation. Successful knowledge creation in the form of better design ultimately leads to economic benefits for the customers that may result in the products meeting increasing demand. Knowledge creation in projects could also lead to the technological innovation that is so desperately needed in the construction industry (Gann, 2000).

While the importance of new knowledge has been demonstrated and widely investigated (Brown and Eisenhardt, 1995; Dougherty, 1992; Kogut and Zander, 1992; Spender, 1996b), research that explores the endogenous knowledge creation process in multidisciplinary project teams is in its infancy and offers fertile ground for study. Multidisciplinary teams are different from traditional homogenous teams in that the diversity of knowledge helps, at least potentially, to maximise the creation of knowledge. The combination of project team processes and knowledge creation - a typical challenge to today's companies whose main thrust is project-based - is still a relatively unknown and novel subject for management researchers.

As organisations shift towards adopting a team-based structure, theories about what makes multidisciplinary project teams productive and innovative are lagging behind (Denison et al., 1996). This research focuses on knowledge creation within multidisciplinary project teams - to empirically examine its processes, the interrelationship between the processes and the significant factors involved in knowledge creation.

For consistency reasons, no distinction has been made between the term 'team' or 'group'. Instead, both words are used interchangeably throughout the thesis.

1.2 Research Scope and Objectives

The main purpose of this research is to improve the understanding, both empirically and theoretically, of the processes that contribute to knowledge creation within multidisciplinary project teams, the interrelationship between these processes and the factors significantly affecting them. Such factors, positively or negatively contributing to knowledge creation, could be cultural, structural, organisational, task-oriented, emotional or managerial. The role of management is to ensure that these conditions are available for project teams (Nonaka and Takeuchi, 1995). This research does not attempt to convey a comprehensive understanding of all the 'right' significant factors for knowledge creation, as we believe these may not be readily prescribed. The purpose is rather to highlight some central themes that project team members emphasised as important.

The research questions, identified from gaps in existing literature, seek to create an understanding of how project teams work and what critical issues they face in their knowledge-creating activities. Due to the lack of existing theories, the research points the way towards an understanding of organisational knowledge creation in a broader sense.

This study focuses on the processes, their interrelationship and the critical issues through which project teams create products and knowledge, with teamwork as the main focus and emphasis. Technology infrastructure, or information technology (IT), has a low priority in this study. This choice does not intend to neglect or undermine its emerging and important role in managing and creating knowledge. As highlighted by Tuomi (1999), if information technology is seen as part of the broader socio-technical systems and includes aspects like tacit knowledge and social capital, information management can probe more deeply into the whole area of knowledge, instead of covering data and information management only.

1.3 Structure of the Thesis

The remainder of this thesis is structured as follows. Chapter Two highlights existing theories and perspectives related to knowledge and organisational knowledge creation. Other issues essential to the inquiry of knowledge creation within multidisciplinary project teams are examined. A conceptual framework, utilising as an initial framework the organisational knowledge creation theory of Nonaka and Takeuchi (1995), is proposed for knowledge creation within multidisciplinary team settings, consisting of knowledge sharing, knowledge integration and collective project learning. Finally, the literature review demonstrates gaps in the literature and identifies researchable questions to be explored in this research.

Chapter Three describes the research process and the methodology utilised to explore the phenomenon of knowledge creation within multidisciplinary project teams. The attempt is to detail the process and the data collection methods in order to provide information and justification of how the case study was prepared and how the major findings emerged and were analysed during the research process. Other issues, such as the philosophical stance and research orientation, are also given as a means of answering the proposed research questions.

Chapter Four presents the case organisation, the two facility development projects and the two multidisciplinary project teams. A detailed look at the case organisation's history and structure will be given. Case descriptions for the two projects, as well as their teams and the organisational and project practices of the case organisation, are described in depth.

Chapters Five and Six are very similar in nature. With the perspective of knowledge creation, they describe the research findings from both case studies - the infrastructure development project and the residential development project respectively. The emphasis, based on the proposed conceptual framework, has been on how the teams share knowledge, integrate knowledge and learn collectively. Other issues pertinent to the processes of knowledge creation are not precluded from the case analyses. These chapters intend to build up richly detailed analyses of how professionally diverse team members created their knowledge during the design process.

Chapter Seven discusses the empirical findings based on the analysis of data collected from the two case studies, as well as drawing comparisons with existing literature and theories. The processes underlying knowledge creation in multidisciplinary project teams, their interrelationships and the significant factors influencing these processes, are identified. A revised model of the knowledge creation processes is proposed.

Chapter Eight concludes the study findings and describes their implications for theory and practice. The limitations of the research, together with future research directions, are given to provide opportunities for further investigation.

Chapter Two - Existing Literature and Theory

2.1 Introduction

This research attempts to fill a significant gap in the literature on team functioning and knowledge creation by exploring the processes of knowledge creation in multidisciplinary project team settings within construction projects. There is a significant amount of literature and research on team processes and teamwork as well as knowledge creation in organisational settings, but very little on how multidisciplinary teams of professionals engage in knowledge creation in projects. Research is needed to explore and understand the processes and dynamics of knowledge creation in multidisciplinary project teams. This gap stems from the dearth of empirical research into how team knowledge is actually created. Accordingly the research focuses on a particular type of team setting, that of multidisciplinary project groups.

The literature review chapter serves three purposes. The first is to demonstrate the gap mentioned above. The second is to place the phenomenon of knowledge creation in a multidisciplinary project team setting within the context of the knowledge creation and team processes literature. This is important to both theoretical development and managerial practice because knowledge, as an important resource, is now seen as a driving force behind organisational goal achievement as well as gaining competitive advantage. The third is to formulate a conceptual framework, research questions and an appropriate data collection strategy addressing the need for further theoretical development.

The concept and theory of knowledge creation have been increasingly discussed in organisational, innovation and economic literatures (Boisot, 1995; Kidd, 1998; Nonaka and Konno, 1998; Nonaka and Takeuchi, 1995; von Krogh, 1998). In addition, a number of innovation researchers have emphasised the importance of a team approach in successful product development (Clark and Fujimoto, 1991; Eisenhardt et al., 1997; Leonard and Sensiper, 1998). There is extensive literature on project or work teams, which contribute to an understanding of the ways in which they operate. For example, Cohen and Bailey (1997) have conducted an extensive review of research on four types of teams, namely work, parallel, project and management, published between 1990 and 1996. However, a focus on the processes of knowledge creation from a multidisciplinary project team perspective is new and compelling, as evident in the increased interest in knowledge creation. Furthermore, research specific to multidisciplinary project teams and the knowledge creation process appears to be very limited (e.g. Newell and Swan, 2000). Yet multidisciplinary project teams are such important vehicles for developing new products and services, with many organisations actively using them to achieve their organisational goals (Bushe and Johnson, 1989).

Most product development is moving towards team-based structures, since teams are believed to increase individual commitment and performance. As Galegher et al. (1990) observe, they seem effective in bringing a new product to the market within a short time frame. As products and technologies become increasingly complex, new product development requires the effective collaboration and integrated skills of several individuals. Many suggest that creating knowledge at the team level is essential for long-term team effectiveness, innovation and productivity (Nonaka and Takeuchi, 1995; Senge, 1990; Watkins and Marsick, 1993). They also point out that, because teams are one of the primary natural and structural work units in organisations, knowledge creation at the team level has the potential to contribute to performance and knowledge creation at the overall, organisational level. However, Dougherty (1992) finds that the varying thinking styles and actions of team members, involved in different aspects of new product developments, can inhibit a team's effectiveness primarily by blocking the collaboration required to develop sufficient knowledge of the technology and market relationships. In addition, Newell et al. (1998) have demonstrated the difficulties of knowledge creation and retention in cross-disciplinary project teams. The objective here is to advance our understanding of the processes that support knowledge creation in multidisciplinary project teams, leading to better theories and practice of knowledge creation, innovation and technological development in collaborative team settings.

The following literature review attempts to cover the major areas of the literature that have fuelled the research. It starts by looking at the origins and meaning of organisational knowledge creation. An intrinsic feature of organisational knowledge creation is knowledge itself. Knowledge is defined, with distinctions drawn between knowledge, information and data. The nature of explicit and tacit knowledge, experience and social capital, discussed and proposed by others, are explored. Organisational knowledge creation from various perspectives is discussed. Finally, this section reviews various existing frameworks proposed by other researchers together with their enabling conditions. The chapter then details three interrelated processes in multidisciplinary knowledge creation - knowledge sharing, knowledge integration and collective project learning. The chapter concludes by providing the conceptual framework as well as identifying the theoretical gaps and researchable questions which this study aims to address.

2.2 Organisational Knowledge Creation

2.2.1 Knowledge in Organisations

2.2.1.1 Knowledge, Information and Data

Before considering the concept of knowledge, it is essential to highlight and discuss some of the distinctions made in the literature between knowledge, information and data. Davenport and Prusak (1997) find it rather difficult to distinguish between data, information and knowledge. Nonaka and Takeuchi (1995) differentiate information and knowledge, with information as a flow of messages and knowledge as something created by that very flow of information, anchored in the beliefs and commitment of its holder. Starbuck (1996) clarifies the distinction by defining knowledge as a stock of experience rather than a flow of information. Thus he suggests that knowledge relates to information in the same way that assets relate to income. The distinction between information and knowledge is thereby understood as the degree to which information is processed and put into a practicable context.

Davenport and Prusak (1997) stress that data are simple observations of states of the world. Data are easily structured, captured on machines, often quantified and easily transferred. They further use Drucker (1988) to define information as data endowed with relevance and purpose. Information requires units of analysis, needs consensus on meaning and also human mediation. Davenport and Prusak (1997) say that knowledge consists of valuable information from the human mind. It includes reflection, synthesis and context and is said to be hard to structure, difficult to capture on machines, often tacit and difficult to transfer. However, it can be embedded in machines (Davenport and Prusak, 1997) as well as in routine or process (De Long and Fahey, 2000).

Brown and Duguid (2000) note that the terms 'information' and 'knowledge' are often used interchangeably in the literature. However, they also note three generally accepted distinctions between the terms. First, they mention that knowledge usually entails a 'knower'. Given this personal attachment, knowledge secondly appears harder to recognise than information that is generally easy to find, possess, put in a database, accumulate or compare. Knowledge, in contrast, is less easy to identify. Their third distinction is that knowledge seems to be something we digest rather than merely hold. Brown and Duguid (2000) assert that it entails the understanding of the 'knower', alongside some kind of commitment. They say that information can be conflicting but knowledge is usually not. Brown and Duguid (2000, p. 119) further state that it is reasonable to say: 'I have got the information, but I do not understand it' rather than 'I know, but I do not understand'. These three distinctions between knowledge and information, they argue, should initiate a shift in emphasis from processes and technology towards people and the assimilating, understanding and sensemaking of information. Unless the social process of shared understanding and sensemaking of information is in place, it cannot be converted to knowledge.

It can be concluded that knowledge may be transferred either directly between individuals through socialisation, or indirectly through delivering information which people can make meaning of and internalise as their personal knowledge. Information, in turn, is data that have been put in context.

After reviewing the various distinctions made in the literature between knowledge, information and data, the next section will examine and discuss the different perspectives of knowledge that provide the theoretical underpinnings for the analysis and the processes of knowledge creation in multidisciplinary teams.

2.2.1.2 The Concept of Knowledge

Polanyi (1962, p. 4) defines knowledge generically as "justified true belief". This rationalistic perspective means that there exists a true reality and people are part of the real truth. The rationalistic and formal perspective is closely connected to the cognitive approach, which has dominated theories of learning within organisations. The cognitive school developed formal models of the brain (or any cognitive system) as a machine for information processing and logical reasoning. Knowledge is seen as something that is possible to encode and store, and easy to transmit to others (von Krogh, 1998). According to this view, organisations can never be perfectly rational due to the limited information processing ability in bureaucratic organisations. This means that individuals are only able to explore a limited number of alternatives and make only adequate decisions (Morgan, 1986).

According to the 'constructionist' perspective, knowledge resides between individuals and is closely tied to earlier experiences. Instead of considering that individuals have certain characteristics, constructionists argue that people act in ways that are unique to each person (von Krogh, 1998) because of the different ways in which they interpret the world around them. From this perspective there is no 'real' world, only individual constructions of that world built through a process of sensemaking during interactions with others. Nonaka and Takeuchi (1995) agree with this, adding that the interpretation of the world depends on a unique viewpoint, personal interpretation and individual experience, but this interpretation is derived from interactions with others, hence it is a process of social construction.

After reviewing the various perspectives on knowledge, the social construction perspective is adopted in this research to provide a useful philosophical lens, not only to understand the nature of knowledge but also to investigate the processes of knowledge creation. The cognitive perspective's assumption that the accessibility and value of organisational knowledge are unconditional and unproblematic appears to be incomplete. From the social construction perspective, knowledge is a set of shared beliefs, constructed through social interactions and embedded within the social contexts in which knowledge is created, whereas the data and information emphases on processes and technology lack the social process of shared understanding and sensemaking. For this reason, only by understanding the dynamics of social interaction and its social context can the underlying meaning of knowledge be understood. In the next section, the literature conceptualising knowledge in organisations is briefly reviewed.

2.2.1.3 Conceptualisations of Knowledge in Organisations

The concept of knowledge has been portrayed by literature as on a continuum of 'articulability', i.e. from easy to difficult to articulate or codify. This distinction emphasises the ease of measurement (articulated or codified knowledge is easier to measure than knowledge that is tacitly held). Empirical research has focused more on knowledge that is codified (Mowery et al., 1996; Szulanski, 1996) than on knowledge that is not codified, though there is growing attention to this latter type, particularly in studies of innovation (Leonard-Barton, 1995; Senker, 1995) and technical work (Barley and Bechky, 1994; Collins, 1974). The implication of this literature is that articulated knowledge is thought to be easier to share and capture. Knowledge that has not been articulated is thought to be more difficult to share and capture.

Thus, the distinction between explicit and tacit knowledge, perhaps the dominant typology in the literature, highlights the dimension of articulability. This distinction was originally drawn by Polanyi (1962, 1966), who captured the essence of tacit knowledge in the phrase, 'we know more than we can tell'. Tacit knowledge is heuristic, subjective and internalised (Nonaka and Takeuchi, 1995) and is learned through personal examples, experiences and practice (Senker, 1995). Tacit knowledge is difficult to formalise, making it hard to articulate, communicate or share with others. Face recognition and bicycle riding are two examples of tacit knowledge. They illustrate activities that many people perform frequently, but have difficulty articulating and explaining. Tacit knowledge is distinguishable from explicit knowledge, which is easily articulated and transmittable in formal, systematic language (Nelson and Winter, 1982). Examples of explicit knowledge include recipes, procedures and explanations.

Winter's (1987) distinction between articulable and observable knowledge follows this logic as well. Articulable knowledge can be expressed through words. Observable knowledge can only be acquired through observation or experience. A swimming instructor can explain to a new swimmer how to float, but that knowledge also tends to be communicated through observation and experience.

The distinction between knowledge that is easier or more difficult to articulate also underlies efforts to differentiate 'knowing what' from 'knowing how' (Ryle, 1949). 'Knowledge what' includes facts, axiomatic propositions and symbols (Kogut and Zander, 1992, p. 386). 'Knowledge how' is defined by von Hippel (1988) as the accumulation of expertise or skill that enables one to perform well. In the context of professional intellect, Quinn et al. (1996) describe 'know-how' as the translation of book learning, or the rules of a discipline, into real-world problems. 'Knowledge what' can be easily articulated and communicated without loss of integrity, while 'knowledge how' or 'know-how' is more difficult to articulate.

The difference between 'knowing what' and 'knowing how' maps closely the distinction between declarative and procedural knowledge, commonly invoked in the literature on artificial intelligence (Simon, 1996). Declarative knowledge consists of a statement that provides a state description. Procedural knowledge consists of statements that describe a process, such as how to determine when a batch of cookies is ready to take out of the oven. Some procedural knowledge, such as recipes, may be articulated. Other procedural knowledge, such as how to negotiate a tense situation in a project team meeting, may be less easily articulated, based more on accumulated experience or intuition that is difficult to explain. Procedural knowledge of this variety is not formulaic.

Scholars who have drawn on research by Rogers (1983) and Winter (1987) to distinguish between codifiable and complex knowledge also differentiate according to ease or difficulty of articulating knowledge. Codifiability refers to the ease with which knowledge can be structured into a set of identifiable rules and relationships easily communicable. Drawing on information theory, Pringle (1951) defined complexity as the number of parameters required to define a system.

A similar distinction is present in Szulanski's (1996) assertion that 'thick' knowledge is complex or rich and Davenport and Prusak's (1998) distinction between knowledge that has high viscosity (rich or thick) and low viscosity (thin). Knowledge gained from a year-long apprenticeship is likely to be thick or highly viscous, while knowledge retrieved from reading a project deliverable is likely to be thinner or have lower viscosity. The 'articulability' of knowledge reviewed here is summarised in Table 2.1.

Table 2.1 'Articulability' of knowledge

Research by	More Easily Articulated Knowledge	Less Easily Articulated Knowledge
Winter (1987)	Articulable	Observable
Pringle (1951); Rogers (1983); Winter (1987)	Codifiable	Complex
Nelson and Winter (1982); Nonaka and Takeuchi (1995); Polanyi (1962, 1966); Senker (1995)	Explicit	Tacit
Kogut and Zander (1992); Quinn et al. (1996); Ryle (1949); von Hippel (1988)	'Knowing what'	'Knowing how'
Davenport and Prusak (1998)	Low viscosity	High viscosity
Simon (1996)	Declarative	Procedural
Szulanski (1996)	Thin	Thick

These typologies emphasise the 'articulability' of knowledge. The distinction between more and less easily articulated knowledge is important, and lends itself to empirical measurement. Many recent studies (e.g. Zander and Kogut, 1995) of organisational knowledge focus on knowledge that is not only articulated, but codified (written down). If knowledge can be articulated, it can be captured in written or spoken words and communicated. Clearly it is easier to observe knowledge that is codified or articulated. This has led scholars to assert that tacit knowledge, in particular, is a source of competitive advantage because it is more difficult for other firms to copy or replicate (Senker, 1995; Teece and Pisano, 1994; Teece et al., 1997). Strangely enough, the characteristics of tacit knowledge making it difficult for other firms to copy also make it difficult to share internally. Although the distinction between tacit and explicit is important, Tsoukas (1996) suggests that tacit and explicit knowledge are mutually constituted. While it is useful to differentiate and delineate knowledge types, it is recognised that their inseparability has to be acknowledged.

In professional work, experience has been seen as an indispensable part of a professional who offers his professional service to the client. Experience as a kind of tacit knowledge, not fully explored in the past, will be examined in the following section.

2.2.1.3.1 Experience as a Sub-set of Tacit Knowledge

Knowledge and experience are gained by continuously engaging in work activities. From Polanyi's (1962) work, it is suggested that tacit knowledge is acquired and maintained through experience. This experience can be either obtained through repeatedly performing a task in a similar way, or through experimentation with new approaches to complete a task. New tacit knowledge is acquired when a familiar task is performed in a new way, or when a new task is performed through experimentation.

Knowledge develops over time, through experience that includes what we absorb from formal means such as courses, books as well as informal learning. Penrose (1959) examined experience and objective-based knowledge, emphasising that 'experience-based' rather than 'objective-based' knowledge created a competitive advantage. Experience-based knowledge focuses on knowledge difficult to transfer and imitate. Experience-based knowledge requires time to create (Penrose, 1959). The value of experience lies in its historical perspective. Experience is the essential bridge between what happened in the past and what is happening in the present. Experience is embedded in every response to a problem or issue encountered on a project. In a very important way, project team members may 're-experience' that which has already been experienced. Experience also is valued for the critical understanding it adds to a new situation. When team members are working on a new project, that experience becomes invaluable, providing insight and direction. In determining the importance of previous experience, it is relevant to consider mistakes as well as success, as Arup (1989, p. 10) states: "mistakes are valuable guides; they should not be forgotten or concealed. Rocks and reefs are chartered on maps as a warning to sailors - shouldn't we do the same with our mistakes and failures?" These experienced-based insights are what firms pay premiums for - they show why experience counts. Nonaka and Takeuchi (1995) suggest that knowledge of experience tends to be tacit, physical and subjective, while knowledge of rationality tends to be explicit, metaphysical and objective.

A study by Marvin (1985) confirms that architects relied heavily on their experience rather than published literature to obtain solutions to problems. The research by Mostow (1985) concludes that experience is the most importance influence on design decisions. Since knowledge is the primary resource for professionals, learning from past experience and applying knowledge in new situations are essential for improving future value creation for clients (Lowendahl, 1997). Experience can be seen as an important sub-set of tacit knowledge, as experience is usually hard to articulate.

Utilising the knowledge and experience of others has been shown to be a crucial part of the professional's knowledge creation process. An element of utilising the experience of others is the exchange of information in the form of meetings. The importance of meetings is considered by Svensson (1990) who believes that knowledge is transferred through conversation. Knowledge that has been gained through direct experience can be indexed to that experience. Knowledge gained through others (knowledge by description) cannot be indexed in such a manner. Yet it is one of the most prominent ways of learning. In deciding how much reliance can be placed on events that are not directly experienced, Russell (1948, p. 29) states:

> "The chief importance of knowledge by description is that it enables us to pass beyond the limits of our private experience. In spite of the fact that we can only know truths which are wholly composed of terms which we have experienced in acquaintance, we can yet have knowledge by description of things which we have never experienced. In view of the very narrow range of our immediate experience, this result is vital, and until it is understood, much of our knowledge must remain mysterious and therefore doubtful."

While experience is an important subset of tacit knowledge in professional work, social capital is defined by Lesser (2000, p. 4) as "the wealth (or benefit) that exists because of an individual's social relationship". It can be seen as an enabler for managing both explicit and tacit knowledge (Lesser, 2000).

2.2.1.3.2 Social Capital as an Enabler for Managing Knowledge

Social capital is broadly defined as an asset that inheres in social relations and networks (Nahapiet and Ghoshal, 1998). Beyond this general definition, researchers have used the term in competing and sometimes contradictory ways. Fukuyama (1995, p. 10) defines social capital as "the ability of people to work together for common purpose in groups and organisations". Fukuyama (2000, p. 3) later defines social capital as "an instantiated informal norm that promotes cooperation between two or more individuals". Putnam (1995, p. 67) sees social capital as "features of social organisation such as networks, norms and social trust that facilitate coordination and cooperation for mutual benefit". Nahapiet and Ghoshal (1998) find that unlike other forms of capital, social capital increases rather than decreases with use. Bourdieu (1986) suggests that interaction is a pre-requisite for the development and maintenance of dense social capital. Adler and Kwon (2000) find that the sources of social capital are embedded in networks, norms, beliefs, rules and trust.

As suggested by Lesser (2000, p. 9), social capital is necessary "to enable the effective management of both explicit and tacit knowledge". Nahapiet and Ghoshal (1998) highlight the influences of the three dimensions of social capital: structural, cognitive and relational in the creation of intellectual capital[2]. They create a social capital framework to show the effects of social capital on the creation of new intellectual capital. Lesser (2000, p. 10) further adds that since technology has been used to capture explicit knowledge by using repositories of different formats, social capital "truly impacts the effectiveness of such efforts". It is found that the role of social capital is even more important in the sharing of tacit knowledge as it is usually transferred through direct contact between parties (Lesser, 2000). Tsai and Ghoshal (1998) find that social capital has significant effects on the way organisations create

[2] Nahapiet and Ghoshal (1998) view intellectual capital in parallel with Coleman's (1988) concept of human capital which includes "acquired knowledge, skills, and capabilities that enable persons to act in new way" (Nahapiet and Ghoshal, 1998, p. 244).

and share knowledge. In addition, Szulanski's (1996) finding suggests that social capital is an essential element in transferring best practices. These are the reasons that support why social capital has been increasingly viewed as an important concept in knowledge creation as well as in managing explicit and tacit knowledge.

Consider the example of applications software and electrical engineering members in a product development team increasing their likelihood of creativity or innovativeness by capitalising on novel task information acquired through their separate external networks. Social capital creates connections between different people, systems and their environments. Social capital is a quality created between people, whereas human capital is a quality of individuals (Burt, 1997). Burt (1997) describes social capital as the contextual complement to human capital. He links human capital with individual ability and social capital with opportunity. Individuals with high social capital are able to add value by coordinating other people and using the right people to develop new opportunities. Individuals with more social capital get higher returns on their human capital because they are positioned to identify and develop more rewarding opportunities.

In cross-functional teams, members have training and experience in a number of specialised areas. Thus cross-functionality increases the likelihood of any team improving performance should members exchange knowledge externally. The breadth of perspective in a multi-functional team can improve the reception and transmission of knowledge within it. Members of cross-functional teams also have more opportunities than members of functionally homogeneous teams because each has ties to people in different domains (Ancona and Caldwell, 1992b). Of course, access to external sources of knowledge alone is not enough to guarantee positive results for cross-functional teams. Team members need to exchange knowledge with their ties outside of the team. This is in line with the argument that cross-functional members can have non-overlapping areas of expertise externally, with members of different functions capitalising on diverse external networks, accessing diverse sources of task information, know-how and feedback.

After examining the various facets of knowledge in organisations, the following section will look into knowledge creation in organisations.

2.2.2 Knowledge Creation in Organisations

Organisations innovate not by simply processing information, from the outside in, to solve existing problems and adapt to a changing environment, as described in classical organisation theory. They rather have to create new knowledge and information, from the inside out, to redefine both problems and solutions and, in the process, to create their environment (Daft and Weick, 1984; Weick, 1995).

Traditionally, organisations were conceptualised as entities that converted inputs into outputs by using essentially well known capital such as land, labour and machinery, so that the production function was pre-eminent in the nature of the competitive advantage of the firm (Grant, 1996a; Prahalad and Hamel, 1990). The introduction of the resource-based view of the firm shifted the attention from the production function to the resource side (Wernerfelt, 1984). In the resource-based view of the firm, organisational competitive advantage is thought to be generated from the resources of the firm, which may be evaluated based on their value, rareness, imitability, and substitutability (Barney, 1991). This shift towards the resource-based view of the firm, and the realisation of the firm's primary role as knowledge creator rather than knowledge applicator, has led to proposals for a knowledge based theory of the firm (Grant, 1996a). The culmination of this research direction is the discovery of the importance of organisational knowledge creation in general and, specifically, knowledge creation in multidisciplinary project teams for sustainable competitive advantage.

Nonaka and Takeuchi (1995, p. 3) define organisational knowledge creation as "the capability of a company as a whole to create new knowledge, disseminate it throughout the organisation and embody it in products, services and systems". Or, more succinctly, "the process that organisationally amplifies the knowledge created by individuals and crystallises it as part of the knowledge system of an organisation" (Nonaka et al., 1996, p. 833). The role of management is to design the structures and encourage the processes that are shown to increase the capacity of the organisation's members to absorb and create new knowledge giving a competitive advantage. It is the creation of knowledge that is organisationally relevant.

The process of knowledge creation has been variously described in the literature as the production of new knowledge by means of the exchange and integration of data, information, knowledge and wisdom within and between individual, team and organisation levels in a company (Nonaka and Takeuchi, 1995; Watkins and Marsick, 1997). These exchanges are best described using the seminal work of Nonaka and Takeuchi (1995) who view them as interactive, spiralling, iterative processes that go back and forth between the explicit and the tacit. By sharing experiences, mental models and skills, people within organisations create tacit knowledge - existing knowledge and skills that are difficult to describe or account for.

Creating new knowledge is critical because it is directly related to outcomes of importance, such as new product development and service delivery. A burgeoning literature focuses on knowledge creation, particularly in technology-based industries (Iansiti and Clark, 1994; Leonard-Barton, 1995; Zander and Kogut, 1995), pharmaceutical companies (Henderson, 1994; Henderson and Cockburn, 1994), biotechnology firms (Powell et al., 1996; Senker, 1995), product design consulting firms (Sutton and Hargadon, 1996), and health care settings (Preuss, 1998).

Schwandt (1995) suggests that there are at least two types of knowledge creation that are relevant in organisations and teams. The first focuses on knowledge about task performance such as manufacturing and production activities, meeting schedules and the development and execution of strategy. The second targets learning, about how organisations, (and the individuals within), learn, grow and transform their assumptions and perspectives to adapt to the current environment, anticipating, and even creating, the future. Both types are critical to organisational success. The second, however, may be the key to true competitive advantage because of its emphasis on developing and maintaining competencies that promote quick identification, understanding, solution and action to novel problems (Nonaka and Takeuchi, 1995). Various theories from different disciplines have formed the foundation for the investigation of knowledge creation. They are examined in the next section.

2.2.2.1 Organisational Knowledge Creation Theories

Leonard-Barton (1995, p. xiii) focuses the organisational knowledge building activities on "the creation and growth of technological capabilities [in] the development of new products and services". Core capabilities give the firm its distinctive competitive edge, because they have been developed over time and are not easily imitated. To create and maintain core capabilities, the organisation needs to understand what dimensions constitute these capabilities, and to know how to manage the activities that create knowledge (Leonard-Barton, 1995). She identifies four main capability-creating activities carried out in the course of new products and processes development through which an organisation builds its knowledge: (1) shared problem solving, (2) implementing and integrating, (3) experimentation and (4) importing knowledge.

For the shared problem solving activity, people with different diversity of specialisations, cognitive style and methodologies are brought together so that different knowledge and backgrounds can be channelled towards creative problem solving. According to Leonard-Barton, as people become highly skilled in applying certain solutions to problems, they develop individual 'signature skills', which are formed from their mindsets or problem-solving biases as a result of their specialisations, cognitive style preferences, and preferences for particular methodologies. Bringing people with diverse signature skills together to work on a problem generates the creative abrasion that, when managed properly, can be a source for innovation and problem solving (Leonard-Barton, 1995).

Through the activity of implementing and integrating new processes and tools, proprietary information and knowledge are introduced into processes and tools that improve internal operation and potentially contribute to core capabilities. Leonard-Barton (1995, p. 110) emphasises that "the implementation of such tools must be managed as an innovation project". To ensure successful implementation, user involvement is essential to create 'buy-in' since the future users of the tools or processes will have critical information and knowledge that must be incorporated during design.

In the experimentation and prototyping activity, the organisation extends its existing capabilities, as well as building new capabilities for the future. Leonard-Barton (1995, p. 114) believes that continuous and widespread experimentation develops "a diverse portfolio of technological options" for the organisation, and that the act of experimentation itself "sets up a virtuous cycle of innovation". Experimentation must be properly managed to ensure that organisational learning does take place. For example, "intelligent failures" which provide valuable lessons for the organisation should be encouraged, and feedback channels that facilitate learning from experimentation (such as project audits) should be established (Leonard-Barton, 1995, p. 118).

In discussing the activity of importing knowledge from outside of the firm, Leonard-Barton (1995) distinguishes between external knowledge that is technological in nature, and knowledge about the market. The key to importing technological knowledge is for the organisation to expand its 'absorptive capacity' by scanning broadly and continuously for technological opportunity, and by identifying employees who can act as technological gatekeepers and boundary spanners. Importing knowledge about the market presents a special challenge when the technological potential outstrips users' ability to understand it. In such situations, the organisation can seek new product opportunities through market experimentation and qualitative techniques such as 'emphatic design'. This is "the creation of product or service concepts based on a deep (emphatic) understanding of unarticulated user needs" (Leonard-Barton, 1995, p. 194). It may be obtained through observing actual customer behaviour, interacting directly with those who understand the organisation's capabilities and potential user needs, and redirecting existing capabilities to new products or markets.

In summary, the central theme of Leonard-Barton's knowledge-building activities (1995, p. 5) is therefore the creation of knowledge by "managing the interaction between activities pursued in the course of developing new products and processes, and the organisation's core technological capabilities".

In their book "Knowledge and Value: A New Perspective on Corporate Transformation", Wikström and Normann (1994) distinguish three types of knowledge processes in organisations: generative processes, productive processes and representative processes. They explain that the generative processes are those in which "new knowledge is created largely in activities which are geared to the solving of problems" (Wikström and Normann, 1994, p. 107). First produced in the course of problem solving, generative knowledge is important for increasing the overall pool of knowledge resources in the organisation, and for generating new business and better products for the organisation. Productive processes are those in which new knowledge is accumulated and used by the organisation to produce "customer-adapted knowledge" or customer offerings (Wikström and Normann, 1994, p. 107). Productive processes thus yield knowledge that is manifest and used - "a drill is manifest knowledge deriving from the knowledge processes of a manufacturing company. A headache tablet is manifest knowledge deriving from the knowledge processes of a pharmaceutical company" (Wikström and Normann, 1994, p. 14). Productive knowledge and processes are also reproductive, in the sense that they are applied repeatedly.

Representative processes are those in which the organisation conveys its manifest knowledge to the customer, so that its knowledge is made available to the customers for their own value-creating processes. For example, "when a machine is sold it becomes a representative outside the company of all the knowledge processes within the company which led to its existence" (Wikström and Normann, 1994, p. 108). Through representative processes, the productive knowledge is used in creating income for the organisation, through the knowledge manifested in the customer offerings, and they have price tags attached to them. The three knowledge processes (generative, productive, and representative) overlap and are to some extent synchronous and reciprocal.

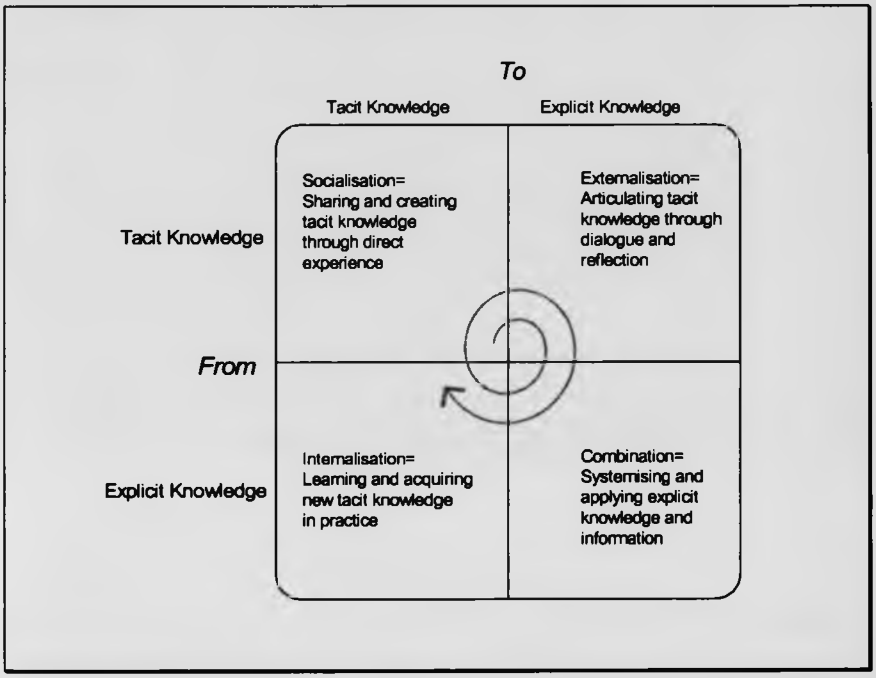
Nahapiet and Ghoshal (1998) assume that knowledge for value creation is created through the two processes of combination and exchange. The combination process comprises of two components: incremental and radical. As observed by Nahapiet and Ghoshal (1998, p. 248), "there appears to be a consensus that both types of knowledge creation involve making new combinations - incrementally or radically - either by combining elements previously unconnected or by developing novel ways of combining elements previously associated". For the exchange process, knowledge is created through social interaction between parties who possess the knowledge. Through social interaction and negotiation, the generative nature of knowledge creation, in which knowledge that is held tacitly becomes more explicit, is realised (Nahapiet and Ghoshal, 1998).

In Nonaka and Takeuchi's (1995) theory of organisational knowledge creation, they depict four knowledge conversion processes, essential to organisational knowledge creation. This is because knowledge, according to the theory, begins as tacit knowledge. This may reside only within an individual and only at an unconscious level. By way of the knowledge conversion processes, this tacit knowledge is made more explicit where it may be codified and transferred among organisational members and re-internalised as shared or organisational knowledge.

The assumption that knowledge is created through the interaction between tacit and explicit can be described as four modes. The first flows from tacit knowledge to tacit knowledge and is termed 'socialisation'. The second, from tacit to explicit knowledge, is called 'externalisation'. The third, from explicit to explicit, is known as 'combination', and the fourth, from explicit to tacit, is called 'internalisation'. As illustrated in Figure 2.1, the processes of organisational knowledge creation give rise to cycles that feed off each other. Nonaka and Takeuchi (1995) talk about the knowledge spiral in which each process leads to the next, unwinding through time and towards greater amounts of organisational knowledge creation.

Figure 2.1 Knowledge conversion processes

(Adapted from Nonaka and Konno, 1998; Nonaka and Takeuchi, 1995)



Socialisation is a process of "sharing experiences and thereby creating tacit knowledge such as shared mental models and technical skills" (Nonaka and Takeuchi, 1995, p. 62). An individual can acquire tacit knowledge directly from others through observation, imitation and practice. The key to acquiring knowledge is experience. Without shared experience, it is difficult for one person to project her or himself into another individual's thinking process (Nonaka and Takeuchi, 1995). One example of socialisation might be brainstorming meetings, where employees from different departments meet to discuss certain issues. Another example of socialisation could be the interaction between producers and customers before a new product development, with tacit knowledge shared and used to create new knowledge. Much organisational knowledge is embedded in technologies, structures and procedures and can be leveraged, as well as shared, through social interaction. Therefore, it is extremely important to provide an environment where socialisation is possible and feels natural, embedded in the company culture (Nahapiet and Ghoshal, 1998; Nonaka and Konno, 1998). Socialisation emphasises that tacit knowledge is exchanged through joint activities, such as being together or spending time in the same environment, rather than written or verbal instructions (Nonaka and Konno, 1998).

Externalisation is a process of "articulating tacit knowledge into explicit concepts" (Nonaka and Takeuchi, 1995, p. 64). It is a knowledge creation process in which tacit knowledge becomes explicit, taking the shape of metaphors, analogies, concepts, hypotheses or models (Nonaka, 1994). The externalisation mode of knowledge conversion can be seen in the process of concept creation and in collective reflection. Metaphors and analogy often drive externalisation. During externalisation, an individual commits to, and becomes part of, a group. The sum of the individual's intentions and ideas fuse, becoming integrated with the group's mental model (Nonaka and Konno, 1998).

Combination is a process of "systemising concepts into a knowledge system" (Nonaka and Takeuchi, 1995, p. 67). According to Nahapiet and Ghoshal (1998), the foundation for economical development lies in producing the means to combine materials and forces within one's reach. Individuals exchange and combine knowledge through the media, such as documents, meetings, telephone conversations, or computerised communication networks. Knowledge creation carried out in formal education and training at schools usually takes this form. This mode can be seen when middle managers in companies break down and operationalise corporate visions, business concepts and product concepts (Nonaka, 1994). Development of new knowledge is created by combining previously unconnected elements or by developing ways of combining elements previously associated (Leonard-Barton, 1995).

Internalisation is a process of "embodying explicit knowledge into tacit knowledge" (Nonaka and Takeuchi, 1995, p. 69) and is closely related to 'learning by doing' (Nonaka, 1994). In this phase it requires the individual to identify the knowledge relevant for him or herself within the organisation. The employees have to find themselves in a larger entity. Training programs in larger organisations that help the trainees understand the organisation, and their role within it, are an example of this. In the trainee programs, training with senior mentors and colleagues can be one way of enhancing this training (Nonaka and Konno, 1998). When experiences through socialisation, externalisation and combination are internalised into individual tacit knowledge bases by shared mental models, only then is the internalisation process complete. For explicit knowledge to become tacit, it helps if the knowledge is verbalised or diagrammed into documents, manuals or oral stories. Documentation helps individuals internalise what they experienced, thus enriching their tacit knowledge (Nonaka, 1994).

From the previous review, it is evident that theories on knowledge creation have been developed, especially from an organisational perspective, but little empirical work has been conducted to demonstrate the validity of the above theories. In addition, little work has been done on exploring knowledge creation in multidisciplinary project teams. By comparing the theories proposed by Leonard-Barton (1995), Wikström and Normann (1994), Nahapiet and Ghoshal, (1998) and Nonaka and Takeuchi (1995), shortcomings or inapplicabilities of these theories to the current research are identified. One common feature of all these organisational knowledge creation theories is that they all stipulate the knowledge-creating processes.

The Leonard-Barton (1995, p. xi) theory focuses on organisations whose core capabilities are technology-based, i.e. "organisations that compete on the basis of technological advantage". In addition, her proposed processes of 'experimenting and prototyping' and 'implementing and integrating new processes and tools' also point to the suitability to technological capability. Furthermore, her emphasis on 'shared problem solving' as the first knowledge-building activity does not fit the current research, as a design situation in the present research does not necessarily refer to as a problem-solving situation - it can simply involve a design issue rather than a problem situation.

Wikström and Normann's (1994) model emphasises using knowledge for value creation. They start the knowledge processes by examining the 'generative processes' in which "new knowledge is generated by activities aimed at solving problems" (Wikström and Normann, 1994, p. 13). This may neglect the fact that knowledge can be possessed already by team members based on past experiences, only needing to be recalled and shared among them. Again, its suitability in the current research is in doubt.

For Nahapiet and Ghoshal's (1998) theory, the combination and exchange processes are less detailed and sophisticated than Nonaka and Takeuchi (1995). In addition, their theory explores the mere recognition that knowledge is important to value creation. In fact, there are similarities between the two theories in terms of the role that combination plays in the knowledge creation process as well as the importance of social interaction in the exchange process. However, the incremental and radical combination approaches proposed by Nahapiet and Ghoshal have extended beyond the framework suggested by Nonaka and Takeuchi (1995).

Nonaka and Takeuchi's (1995) theory is the most widely used and quoted organisational knowledge creation theory in the literature. Their consideration of knowledge creation through the interaction between tacit and explicit knowledge is unique, vital to research into knowledge creation. Furthermore, Nonaka and Takeuchi's (1995) theory was inductively developed using case studies of product development projects so the focus on technical knowledge creation is appropriate for this study. In this respect, Nonaka and Takeuchi's (1995) theory is considered the most appropriate in this research compared with other theories described above.

Among the four organisational knowledge creation theories identified, only three have highlighted the conditions that enable knowledge creation in organisations. They will be highlighted briefly in the next section.

2.2.2.2 Enabling Conditions for Organisational Knowledge Creation

Nonaka and Takeuchi (1995) describe five enabling conditions that support organisational knowledge creation. These are intention, autonomy, fluctuation and creative chaos, redundancy and requisite variety. Intention is the "organisation's aspiration to its goals" (Nonaka and Takeuchi, 1995, p. 74). According to Nonaka and Takeuchi (1995, p. 74), "organisational intention provides the most important criterion for judging the truthfulness of a given piece of knowledge". This philosophy dates back to theories of organisational decision-making (Cyert and March, 1963; March and Simon, 1958) and organisational sensemaking (Weick, 1979). These, and other similar concepts like strategic intent (Hamel and Prahalad, 1989; Hamel and Prahalad, 1990), form the basis for the types of information and knowledge deemed important and truthful. Autonomy refers to the degree individuals, teams and business units can act on their own accord. Inherently risky, autonomy may allow the flexibility needed for creative innovation. It is the concept most prominent in the use of skunk works[3] in organisational R&D design (Gwynne, 1997; Kimura and Tezuka, 1992; Single and Spurgeon, 1996).

Fluctuation and creative chaos represent a more complex and abstract construct in which attempts are made to create situations where crisis leads to renewal. Fluctuation is characterised by "order without recursiveness" (Nonaka and Takeuchi, 1995, p. 78). Creative chaos is fluctuation intentionally introduced by management to increase "tension within the organisation and [focus] the attention of organisational members on defining the problem and resolving the crisis situation" (Nonaka and Takeuchi, 1995, p. 79). The concept refers to the intentional attempt at provoking reflective, double-loop or deutro-learning in organisational members (Argyris and Schön, 1978). In Nonaka and Takeuchi's (1995) research, the concept is made operational as managerially created creative tension. Redundancy refers to overlap in information

[3] 'Skunk works' is a concept where "small groups of scientists, engineers and other personnel who tackle specific problems and try to commercialise the solutions" (Gwynne, 1997, p. 18).

shared by different individuals in the firm and not to unnecessary duplication. It is "the existence of information that goes beyond the immediate operational requirements of organisational members" (Nonaka and Takeuchi, 1995, p. 80). Redundancy allows for greater communication between organisational members who can speak the same language, helping to find solutions to problems that others may be experiencing. Finally, requisite variety derives from Ashby's (1956) cybernetics theory in which "an organisation's internal diversity must match the variety and complexity of the environment in order to deal with challenges posed by the environment" (Nonaka and Takeuchi, 1995, p. 82).

There are overlaps between Nonaka and Takeuchi's (1995) five enabling conditions and Leonard-Barton's (1995) discussion of management strategies to support organisational knowledge building. She emphasises that organisations need to have a clear understanding of their core capabilities and strategic intent; that members be encouraged to experiment continuously; that creative abrasion is an effective way of parlaying members' cognitive diversity and variety of signature skills; and that group boundaries should be kept porous so that information can be broadly diffused.

For Nahapiet and Ghoshal's (1998) model, four enabling conditions for the processes of creating new intellectual capital are listed as: (1) an opportunity to make a combination or exchange, (2) an expectation of value creation by involved parties, (3) an intrinsic motivation behind the actualisation of value creation, and (4) an inherent capability to combine.

Since all these enabling conditions are linked to individual organisational knowledge creation theories, it cannot be concluded which set of enabling conditions is better than the others. They should be viewed together with the organisational knowledge creation theory as they are inter-related. After reviewing the various concepts related to organisational knowledge creation, the following section will be devoted to knowledge creation in a particular team setting - the multidisciplinary team.

2.3 Knowledge Creation in Multidisciplinary Teams

Knowledge in designing a product does not form a complete and coherent body of knowledge that can be precisely documented or even articulated by a single individual. Rather, it is a form of knowing that exists only through the interaction among various collective actors (Gherardi and Nicolini, 2000). Existing literature (Kanter, 1988; Nonaka, 1994; Spender, 1998; Starbuck, 1992) has highlighted a need for the development of a diverse workforce if knowledge creation is to be promoted and sustained within organisations. This literature suggests that a diverse set of resources (experts with different backgrounds and abilities) provide a broad knowledge base at the individual level, offering greater potential for knowledge creation.

Conceptually, a team can be viewed as a socially constructed phenomenon or linking mechanism that integrates individuals and organisations (Horvath et al., 1996). A multidisciplinary team is defined by Nonaka and Takeuchi (1995, p. 85) as "a self-managed, self-organised team in which members from various functional departments, and/or areas of expertise, work together to accomplish a common goal". The primary goal of the multidisciplinary composition is to marry diverse bodies of knowledge in a way that forces out a synergistic knowledge outcome that is innovative, contextualised, difficult to imitate and as such, has strategic value. For the most part, project team tasks are non-repetitive in nature and involve considerable application of knowledge, judgement and expertise.

The advantage of adopting multidisciplinary project teams is that they are quicker in integrating the expert knowledge of different functions, e.g. design, construction, property management, marketing, etc. Cross-functional project teams with mutual accountability and collective work products were found to decrease development time and increase product quality (Ancona and Caldwell, 1992b; Dougherty, 1992; Van de Ven, 1986; Wheelwright and Clark, 1992). Multidisciplinary project teams create a 'task culture', facilitating the necessary close linkages and direct personal contacts between different functions (Cohen and Levinthal, 1990). These close connections are necessary, as new product development by its very nature includes uncertainty about potential market response and about new technology (Henke et al., 1993). This transformation process is a team-level phenomenon. It emerges through 'heedful interrelationships' (Weick and Roberts, 1993), and interdependencies between team members, their actions and interactions and the enmeshment of their individual knowledge paradigms. If creating new collective knowledge is indeed a team level phenomenon, then the multidisciplinary team is considered the greenhouse where such a phenomenon can be best cultivated.

This research views the multidisciplinary project team as an unusual team arrangement primarily because it is composed of professionals from various disciplines who take pride in their fields of expertise. They are committed to the basic assumptions of their paradigms and they perceive their roles in the team as representing their knowledge bases in the best possible way. In addition, a project on which a multidisciplinary team works, can metaphorically be seen as an experiment, a vehicle for knowledge creation with knowledge being created through the process of executing the project.

Through a synthesis of the knowledge creation and team processes literature, three distinctive processes of knowledge creation in multidisciplinary teams - knowledge sharing, knowledge integration and collective project learning - are highlighted.

2.3.1 Knowledge Sharing

2.3.1.1 The Importance of Knowledge Sharing

To enhance competitiveness and meet organisational goals, organisations need to ensure that people share both tacit and explicit knowledge. Increased sharing of knowledge raises the likelihood of new knowledge being created, tending to support valuable innovation (Nonaka and Takeuchi, 1995). Though organisations can codify some of the knowledge people use, it is easy to find cases or examples that do not fit the codified knowledge of the organisation. This unarticulated knowledge requires communication among people. Orr (1996) finds photocopier technicians often searching for solutions beyond their manuals. Orr (1996, p. 2) explains that "the expertise vital to such contingent and extemporaneous practice cannot be easily codified". At one point during his study, Orr (1996) finds technicians joking about the usefulness of their manuals. When documentation proves insufficient, people need to access each other's experience to solve more difficult problems. Orr shows how technicians sometimes use narrative to recount each other's experience. Technicians might use breakfast or lunch meetings to share knowledge. Other accounts of knowledge sharing demonstrate how workers use computer-mediated communication. For example, Constant et al. (1996) show how people use a computer-mediated network to seek help and advice. Similarly, Hargadon and Sutton (1997) explain how product designers search for knowledge by sending out pleas for help over electronic mail. In both cases, communication is the key to sharing knowledge.

Knowledge sharing relies on reaching a shared understanding of the underlying knowledge, not just in terms of the content but also the context of the knowledge, or 'Ba' in Nonaka and Konno's (1998) term. Exchanging information represents only a partial view of the knowledge sharing activity. The essence lies in unveiling and synthesising paradigmatic differences through social interaction.

Many definitions of the word 'paradigm' exist. Neufeldt and Guralnik (1988, p. 979) define it first as "a pattern, example, or model" and secondarily as "an overall concept accepted by most people in an intellectual community, ... because of its effectiveness in explaining a complex process, idea, or set of data". Kuhn (1970, p. 181) who popularised the term, provides two definitions for a paradigm. In the primary sense of the word, a paradigm is a "disciplinary matrix", the ordered elements of which are held by the practitioners of a discipline. According to this definition, a paradigm includes symbolic generalisations (laws and definitions), shared beliefs and shared values. In an alternate use, Kuhn (1970, p. 187) defines paradigms in a more circumscribed manner as "exemplars" or "shared examples". Recent work by Boland and Tenkasi (1995) indicate the use of the concept of 'perspective taking' and 'perspective making' to resolve paradigmatic differences through appreciating individuals' different paradigms. By synthesising the various definitions and insights, a paradigm as used in this research is defined as 'a team perspective or belief which is collectively constructed and accepted by members of the team'. This definition reflects the perspective of social construction as well as the opportunity that paradigmatic differences can be resolved through social interaction between members in collective settings, such as teams or organisations.

Knowledge sharing is not constrained to exchanges within and across employees of a company. It can occur between employees and customers, between organisations or firms in entirely different industries (von Hippel, 1988). Some of the very important knowledge identified in a survey among knowledge-intensive businesses includes customer, competitor and product knowledge (Skyrme and Amidon, 1997). The more knowledge is shared about the needs of current and potential customers among project team members, the better they may understand realistic customer requirements. With such knowledge, greater value for customers may be created because the resultant products might better satisfy customer needs and expectations. Accordingly, the products might have a better chance of success in the market place. In the same vein, shared competitor knowledge could be helpful in developing products ahead of market requirements (getting products to market ahead of competitors, developing products on schedule). It could yield high value to customers (extending any product's success in the marketplace), possibly improving product performance (better overall product performance than that of competitors). In addition, shared product knowledge (product advantage, disadvantage, strengths, history and technologies), may be important to improve development productivity (reducing development costs) and production costs (reducing overall production costs).

It is clear that sharing diverse knowledge can enhance problem solving, as well as creating the culture required for knowledge creation. Communication is the key to knowledge sharing. The following section will examine the interrelationship between communication and knowledge sharing, as well as the more effective means of communication in exchanging the different types of knowledge.

2.3.1.2 Communication Media and Knowledge Sharing Effectiveness

Knowledge resides in people, products or procedures of the organisation. This knowledge can be imitated, copied or transferred through communication (Zander and Kogut, 1995). People within an organisation can use various means of communication, such as face-to-face, telephone, electronic mail or memos. Daft and Lengel (1984) place communication media on a continuum, based on the amount of information the media can carry. The richest form is face-to-face, employing many signals (including facial expression, body language, voice tone) and possibly communicating many levels of messages. Electronic mail is the least rich, due to its lack of discernible signals. Much Information Systems (IS) research has examined how the thickness of the communication medium might affect the transmission of different types of knowledge (Jarvenpaa et al., 1998; Lee, 1994; Ngwenyama and Lee, 1997). The amount of knowledge and information disseminated across the involved parties determines the quality of communication, and this in turn affects the success or failure of innovation (Galbraith, 1994).

Daft and Lengel's media richness theory (1984) suggests that the more complex the organisational phenomena to be communicated, the richer the communication medium needed. They also suggest that, when imparting information of low complexity, less rich or thin communication forms will be better than richer or thicker ones. At times, thick communication can exhibit "too many cues, noise, [and] ambiguity" (Daft and Lengel, 1984, p. 199). This theory suggests a connection between the type of communication used and the type of information imparted. Because tacit knowledge is more complex and personal, people are more likely to use the communication forms containing the most signals, such as face-to-face. Compared with thinner forms of communication, face-to-face communication allows for immediate feedback between the communication sender and receiver. This feedback may be verbal or may be signalled, such as through a facial expression, showing frustration. The sender can sense how the receiver is interpreting the information, whether or not he is accurately comprehending the message. This process of give and take is important in sharing tacit knowledge, possibly requiring several attempts and thorough explanations before the sender can be certain the receiver understands (Polanyi, 1966). The immediate feedback during face-to-face communication also lessens problems of miscommunication. As Goffman (1963, p. 95) points out, eye contact maximises "the opportunity for participants to monitor one another's mutual perceivings".

People could impart explicit knowledge using even the thinnest communication forms, such as e-mail. However, electronic mails can leave much ambiguity. The communicator assumes his target understands the meaning of a particular message, but it is difficult to confirm this. For example, in a study of dispersed teams communicating with e-mail, Cramton (1997) finds that students have difficulty communicating the importance of information and often misinterpret the information they did and did not receive. People seem especially likely to misinterpret sarcasm and humour over e-mail, as the communicator cannot see the target's reaction through the display a facial expression of shock. Therefore, if the receiver misinterprets the sarcasm, the communicator may have no immediate recourse. The thickness of the communication form - the added visual signals of body language, facial expressions, touch and feedback - is where tacit knowledge is stored. E-mail, a communication form stripped of thickness, would appear to create a barrier to exchanging tacit knowledge. E-mail and other thin forms of communication should allow for the efficient exchange of explicit knowledge. People become task-oriented using e-mail (Siegel et al., 1986), and should therefore be able to effectively articulate simple facts and details. Thinner communication should allow the receiver to focus on the bare facts of a message, without being distracted by any peripheral cues of body language or facial expressions.

The theory, however, has been subjected to critical and empirical investigation and newer understandings are emerging. The critical social theory (Habermas, 1987; Markus, 1994; Ngwenyama and Lee, 1997) argues that communication richness not only involves accurate understandings between sender and receiver, but also enables a testing of the validity of the communication claims made by sender. As a result, people are not mere passive recipients of a communication; to a certain extent, they are critical, active interpreters of communications. Communication richness then relies on mutual understanding rather than channel capacity. The effect of active interpretation is to shed light on the simple assumption that channels of decreasing richness mean less ability to process information. In addition to communication media, the diverse profiles of team members are believed to impact upon the effectiveness of knowledge sharing.

2.3.1.3 Knowledge Sharing and Team Members' Diversity

Besides communication thickness, another issue that seems to influence the process of knowledge sharing is team composition. The diversity or heterogeneity of the team membership affects the sharing or acquisition of knowledge. According to Stasser and Titus (1987), diverse teams whose members possess different sets of information due to variations in their backgrounds, training or experience may be more likely to share their unshared information than homogeneous teams composed of similarly typed members. A team's awareness of the distribution of expertise within the team increases the probability that unshared knowledge individually held by team members will be shared (Stasser et al., 1995; Stewart and Stasser, 1995).

Extensive research has been conducted regarding the effect of team composition (especially the heterogeneity of team membership) on dimensions of team performance (Bantel and Jackson, 1989; Moreland and Levine, 1992; Williams and O'Reilly, 1998). Williams and O'Reilly (1998) emphasised that functional diversity generally had more positive effects on performance than other dimensions of diversity. However, some research on team composition has yielded contradictory findings (Bettenhausen, 1991; Ophir et al., 1998).

Nahavandi and Aranda (1994) discuss fluidity of membership as a common and desired state in organisations. When members are moving in and out of the team, less cohesion and complacency can develop, and more dynamism and renewal characterise the team. Along these lines, Ancona and Caldwell (1992b) who studied new product development teams suggested that fluid membership can prove helpful for the team to acquire and process required information. The view of task demands as the dominant consideration affecting team composition decisions points out that members will enter and/or leave the team based on the need for their expertise. Yet as Pasmore and Mlot (1994) argue, team members need a period of time (6 - 18 months) working together to develop and acquire relevant task-related skills and to develop their teamwork knowledge (Rentsch et al., 1994), so as to become effective contributors to team performance. Thus, team membership should be relatively stable. Switching memberships between different team settings is regarded as counter-productive, for an individual member cannot gain from and/or contribute to the team-specific knowledge.

Much advantage in heterogeneous teams would appear to stem from the diverse pool of information and knowledge the team members have access to, for sharing in meetings or discussions. In addition, heterogeneous teams seem also better than homogeneous teams at developing new knowledge. Raghuram and Garud (1996) suggest that focusing on skills or knowledge differences leads to an increase in trust in diverse teams, whereas focus on value differences more easily leads to mistrust and ultimately unproductive teams.

Knowledge sharing among team members is necessary for executing their team task. Past studies have demonstrated the importance of task communication within work teams (Allen, 1977; Katz and Tushman, 1979; Tushman, 1978). For example, Katz and Tushman (1979) found that intra-project administrative and problem-solving communication were positively associated with performance for research projects. Along with helping create a common understanding of the work in hand, internal knowledge sharing can also increase an awareness of who knows what in the team (Liang et al., 1995; Moreland and Myaskovsky, 2000). As work team members share what they know with one another over the course of a project, they should become more efficient at solving problems and allocating responsibilities for the task. Knowledge redundancy (Nonaka, 1990) and common knowledge (Demsetz, 1991) are found to be important issues that enable internal knowledge sharing.

Previous studies on social network structure illustrate how diverse work teams can benefit from external knowledge sharing (Burt, 1992; Granovetter, 1973; Krackhardt, 1992). Social network theories predict that by maximising differences in their external networks, team members can enhance the performance of their team. One reason is that team members often need to discuss the latest work procedures with a variety of former colleagues or potential clients. The non-redundancy or uniqueness of these ties, in turn, can provide non-redundant or unique resources and information that team members could leverage for competitive advantage (Burt, 1992; Friedkin, 1982; Granovetter, 1973; Lin et al., 1981). For instance, team members can bridge areas of knowledge by visiting members of other teams to observe and compare operations. Another reason for enhanced performance is the tapping of non-overlapping expertise, with team members eliciting diverse ideas and insights from others (Ancona and Caldwell, 1992b; Cohen and Levinthal, 1990; Hansen, 1999).

It is clear that knowledge constructed by teams is often embedded within, and inevitably 'protected' by, invisible boundaries (Denison et al., 1996). For knowledge sharing to occur, it is vital to remove or cross such boundaries, allowing the necessary social interaction to take place. The following section will highlight tensions that appear in knowledge sharing.

2.3.1.4 Tensions in Knowledge Sharing

Two issues come together here to describe the importance of extensive collaboration among team members. First is the idea that knowledge is largely implicit, embedded in actions and in interrelationships between members and as such, is hard to articulate (Nelson and Winter, 1982; Weick and Roberts, 1993). Second is the idea that a multidisciplinary team comprises a nexus of interdependencies resulting from the richness and complexity of its task.

But collaboration is not a natural mode of conduct for professionals who are socialised to work individually, to be praised and rewarded for their personal accomplishments, to compete and vigorously defend their knowledge paradigm (Mohrman, Cohen and Mohrman, 1995). Tjosvold and Tjosvold (1995) point to the difficulty professionals have in collaborating with others. Professional education and socialisation may not have prepared specialists to work in the open. Garner (1982) traces the barriers among multidisciplinary team members to their professional training in colleges and universities. In their designated departments, "each team learns the knowledge, skills, values and attitudes of its own profession" (Garner, 1982, p. 13), seldom interacting with professionals in other specialty areas (Garner, 1982). In the job market, the 'invisible barriers' are continued, reinforcing the socialisation of professionals to the perspectives of their respective disciplines (Garner, 1982). Tjosvold and Tjosvold (1995) share Garner's view that professional cultures encourage individuality rather than collaboration and teamwork. The ongoing role differentiation process triggers the emergence of boundaries around individuals' roles and around the team as a whole. The role differentiation process takes place through intensive intra-team interaction, and so this process is driven by, and is further driving, the emergence of collaborative interaction among team members. The interdependent nature of any team task acts as facilitator, with no single member capable of performing the team task individually, but each knowing he or she has enough power to 'pull things off'. The emergent delicate power balance is based on common trust between individuals who know they have sufficient power to sabotage the team's performance individually, but also have sufficient power to 'make things happen' with mutual collaboration.

Team members may exert effort in two directions - producing high quality knowledge and sharing it with other members through dialogue. The additional need to actually work together, as dictated by the interdependent nature of the team task, induces the development of heedful relationships between members (McDermott, 1995). Individual knowledge is transformed, through actions, conversations and reflections, from its localised-implicit form into a collective-explicit one, creating a shared community of practice (Lave and Wenger, 1991). Thus, the emergence of a collaborative communication network facilitates the team management of knowledge sharing tension, by developing individual in-depth knowledge and the intensive collaborative dialogue between members leading to team learning and knowledge creation.

However, since team members of the collaborative network are not governed by traditional hierarchical relationships, the development and maintenance of trust and the deployment of power among members become critical issues (Ring, 1997).

According to Smith et al. (1995), cooperation is encouraged by trust and competition leads to a breakdown in trust. Trust is the confidence one has that other team members will honour their commitments (Thompson, 2000). When trust is established among people, they help each other as they feel it is morally right (Tyler and Kramer, 1996). In addition, trust increases an organisation's potential to cope with complexity and individual diversity (Nahapiet and Ghoshal, 1998). Dodgson (1994), also aware of these social problems of team collaboration, suggests that creating and maintaining personal relationships between the parties is one of the vital aspects in inter-organisational network. Trust can be based on social networks or social embeddedness (Uzzi, 1997). These embedded ties among people encourage cooperation and the development of trust. Newell and Swan (2000) stress the importance of trust in inter-organisational network and they also re-group previous typologies of trust under three major categories: companion, competence and commitment trust. They defined 'companion trust' as "trust that is based on judgements of goodwill or personal friendships", 'competence trust' as "trust [that] is based on an attitude of respect for the abilities of the trustee to complete their share of the job at hand" and 'commitment trust' as "trust stems from the contractual agreements between the parties" (Newell and Swan, 2000, p. 1295).

When team members have repeatedly worked together to achieve mutual goals, they develop mutual trust (Sherif and Sherif, 1953). Anderson and Narus (1990) suggest that the attainment of mutual trust leads to shared knowledge. They find that team interaction builds trust, leading to increased communication and the eventual sharing of knowledge. In addition, von Krogh (1998) points out that when people have good organisational relationships, there will be mutual trust, active empathy, and more help among team members. As a consequence, according to von Krogh (1998), employees will then 'bestow' knowledge on others and not shield knowledge. There is a mutual intent to help others to optimise their task performance and to share knowledge. Bradach and Eccles (1989) report that by alleviating the fear of the unexpected and facilitating interaction and involvement, trust encourages a culture conducive to the sharing of knowledge. Thus at the team level, mutual trust seems to develop over time as a consequence of individual interaction. Previous research findings suggest that some individuals fear that by sharing knowledge, their importance to the company diminishes, thereby increasing their sense of being replaceable and thus more vulnerable (Davenport et al., 1998). In a multidisciplinary project team, with team members having their own area of expertise, this kind of fear is not as evident.

2.3.1.5 Viewpoint of Knowledge Sharing in the Present Study

In this research, knowledge sharing is regarded as a combination of processes sharing and using knowledge directly without language (socialisation) and with language (externalisation). The terms 'knowledge transfer' and 'knowledge dissemination or diffusion' have been used extensively in the context of transferring best practices intra and inter-organisation. The term 'knowledge transfer' gives the impression that knowledge is relatively easily transferred from one place to another, contrary to our understanding of it as dynamic, human, context-sensitive and difficult to transfer. For 'knowledge dissemination or diffusion', they suggest a rather passive role for the receiver. Therefore, the term 'knowledge sharing' is more appropriate in this research.

Knowledge sharing contributes to the accomplishment of a collective task within a team who intend to develop a new product or service, requiring members to share through different knowledge conversion modes. The re-grouping of socialisation and externalisation under the heading of knowledge sharing does not imply that these modes are regarded as the same. Within the knowledge sharing context, socialisation and externalisation will further the understanding of how knowledge is created in a multidisciplinary project team.

Team members will have to integrate the knowledge shared from different disciplines to form a solution that can meet various stakeholders' needs. The following represents the second process in multidisciplinary team knowledge creation.

2.3.2 Knowledge Integration

2.3.2.1 The Importance of Knowledge Integration

A fundamental problem in many organisations - indeed in the economy and society in general - is the integration of fragmented knowledge to accomplish important tasks. Recent research has stressed the importance of integrating or coordinating diverse knowledge both within companies and across its boundaries (Hamel, 1991; Hoopes and Postrel, 1999; Iansiti, 1995; Simonin, 1997). Millar et al. (1997, p. 403) suggest that knowledge interwork in trans-organisational innovation arises from "the need to synthesise product-related knowledge from disparate sources into a coherent product without compromising usability or adversely impacting technical interwork".

A product development team needs input from many sources to complete a task satisfactorily, as does a multidisciplinary project team wishing to design a facility. According to Jassawalla and Sashittal (1999), the most difficult yet important challenges facing product development teams are the integration of markets, products and technologies. There is a heavy reliance on integration of different types of knowledge in the project. Successful product development depends on how quickly project teams capture, exchange and utilise relevant knowledge components (i.e. share knowledge) and integrate them to derive innovative solutions for new products (Iansiti and MacCormack, 1997). Teams with heterogeneous composition are better at integrating multiple perspectives (Gruenfeld, 1995a,b; Peterson and Nemeth, 1996) than teams without conflicting perspectives. The motivation for the use of multidisciplinary project teams is the fact that they are able to combine their knowledge and differing perspectives to produce a solution that no one member, acting alone, would have been able to achieve. Knowledge integration requires the input of at least two persons. Though heterogeneity provides greater input and ideas, these are of little use if lack of cohesion and common direction prevent their implementation (Nemeth and Staw, 1989). Knowledge integration requires the coordination and collaboration of team members. Through integrating knowledge of individual members, teams may not only blend knowledge and insights beyond individual achievements. New knowledge development may also be stimulated by conversations and language based learning in teams (Boland and Tenkasi, 1995; Brown and Duguid, 1991; Weick and Roberts, 1993).

As noted long ago by Hayek (1945), knowledge in an economy is dispersed among many actors. Grant (1996a), in developing a knowledge-based theory of a firm, suggests that the greater the diversity of knowledge within the organisation, the greater the scope for knowledge integration. In a business organisation, knowledge may be integrated from various sources both inside and outside the firm. Knowledge integration means the assimilation of individual knowledge by a team of people. At the level of the knowledge creation process, integration is the merging of new knowledge about the impact of possibilities, with deep accumulated knowledge in the existing knowledge base of the organisation (Iansiti and Clark, 1994). Henderson and Clark (1990) refer to the ability to integrate knowledge across disciplinary and organisational boundaries as architectural knowledge. They argue that architectural knowledge creates the ability to reconfigure knowledge to deal with new situations.

The concept of knowledge integration has varying scope in the literature. For some authors it is only one amongst several issues involved in building strategic capabilities (Leonard-Barton, 1995; Prahalad and Hamel, 1990), in building a 'learning organisation' (Garvin, 1993), in creating a 'knowledge building company' (Nonaka and Takeuchi, 1995) or in developing an 'absorptive capacity' (Cohen and Levinthal, 1990). In contrast, for other authors the integration of knowledge plays a far more central role. It is the basis on which to build dynamic capabilities (Clark and Fujimoto, 1991; Henderson, 1994; Iansiti and Clark, 1994). These authors concentrate more on elaborating the concept of knowledge integration and its different dimensions. Integration is analysed in the context of problem solving activities, considered to be the basis unit of knowledge creation. These authors differentiate between internal and external integration of knowledge. Internal integration refers to problem solving activities that focus and manage internal assets (Iansiti and Clark, 1994). It is basically analysed in the context of project implementation and relates to the linking of existing specialised skills, knowledge bases and technical and managerial systems. Clark and Fujimoto (1991) developed an index of internal integration which estimates the extent to which the different sub-teams involved in development activities are managed and coordinated to achieve a well-integrated, coherent product. This index was critical in explaining performance differentials in the automobile industry.

External integration refers to problem solving activities that span the boundaries between the firm and its external environment. It is basically analysed in the process of concept development of projects, and it is related to the generation of options using external sources of information and to the ability to evaluate those options according to the existing knowledge base (Iansiti and Clark, 1994). External integration includes two dimensions: (i) customer integration, i.e. integration of knowledge of the market and the customer base, and (ii) technology integration, i.e. integration of knowledge of emerging technologies.

2.3.2.2 Knowledge Integration in Team Situations

More information and knowledge are not always the answer. What may be needed is to better integrate the information and knowledge already available within the team. According to Weick (1995, p. 86):

> "... more information will not help them. What will help them is a setting where they can argue, using rich data pulled from a variety of media, to construct fresh frameworks of action-outcome linkages that include their multiple interpretations. The variety of data needed to pull off this difficult task is most available in variants of the face to face meeting."

One example of such an arrangement is the 'thought collective' (Fleck, 1979) in which the insights of a team of specialists are combined to create new knowledge. Dougherty (1992) applies Fleck's idea to a single department of an organisation, claiming that each department represents a different 'thought world'. Fleck's theory was developed in the context of scientific research, in which researchers of a particular 'school' jointly make new discoveries. According to Heisenberg (1971, p.

89), "science is rooted in conversations. The cooperation of different people may result in scientific results of the most significant important". Related to this, the following cybernetic view of scientific collaboration (Wiener, 1954, p. 126), is illuminating:

> "A clear understanding of the notion of information as applied to scientific work will show that the simple coexistence of two items of information is of relatively small value, unless these two items can be effectively combined in some mind or organ which is able to fertilise one by means of the other .... There is a great fertilising and revivifying value in the contact of two scientists with each other; but this can only come when at least one of the human beings concerned has penetrated far enough across the frontier to be able to absorb the ideas of his neighbour into an effective plan of thinking."

In a new product context, Wiener's view supports Hayes et al. (1988) suggestion that members of new product development teams should have a basic knowledge of other functions in addition to an in-depth knowledge of their own specialty. It is suggested that "specialists are inventors; generalists are innovators" (Galbraith, 1982, p. 22) and that people who are willing to cross functional or other boundaries are likely to be more innovative (Kirton, 1988), or to be able to resolve conflicts because of their ability to see both sides (Gregory, 1983). Nonaka and Takeuchi (1995) allude to generalism when they talk about Japanese firms' support of 'information redundancy' or knowledge overlap between people. Although the use of the term 'redundancy' might seem to denote inefficiency, it might in fact turn out to be effective in an innovation situation. This positive effect of knowledge overlap may explain the positive association between the use of job rotation and new product success found in a number of product development studies (Song and Parry, 1993; Souder, 1981; Wiebecke et al., 1987). Wiebecke et al. (1987) proposed that job rotation promotes an understanding of the work of other functions, and facilitate cross-functional 'bilingualism'. Souder (1981) found that in all the cases where 'equal partners' harmony, associated with product success, was attained between marketing and research and development (R&D), the marketing personnel were all technically trained, most having worked in R&D previously. Cross-functional skills learned in job rotation may facilitate the combination of existing knowledge to produce new knowledge. Having considered the importance of integrating knowledge in team situations, the following section will focus on tensions in the process.

2.3.2.3 Tensions in Knowledge Integration

The composition of a multidisciplinary project team poses a demand on the team to manage divergent thinking paradigms and basic assumptions, as well as managing the 'professional ego' of the members (Dougherty, 1992). Diverse, conflict-positive ways are needed to make multidisciplinary teams work. Team members integrate that private knowledge with the explicit knowledge or learned knowledge that can be easily shared to develop a core knowledge base about the product to be designed (Dixon, 1994). The integration of these diverse perspectives based on the tacit or explicit knowledge of the team membership takes place through communication and learning, and is then transformed into the core knowledge base, which resides in the team. Two team issues that occur frequently in any team situation can affect or become tensions in the knowledge integration process. They are the issues of conflict and power.

The causes of team conflicts change during the team's development (Kivlighan and Jauquet, 1990). Conflict has long been recognised as an important dimension of both task and social activities in teams working on decision-making or problem solving tasks (Janis, 1972). The benefits of conflict are that it encourages the team to explore new approaches, motivates people to understand issues better, and encourages new ideas (Robbins, 1974). When opposing views are brought out into the open and are fully discussed, the team makes better decisions and commitment is enhanced (Cosier and Dalton, 1990). However, the two types of conflict - task-oriented and people-oriented (Wall and Nolan, 1986) - cause different kinds of activity to occur. Teams engaged in task-oriented conflict direct their actions towards the task, because the conflict orients team members on, and forces the team to address, issues concerning the task or to be concerned with task functions. For example, task-oriented conflict is often related to team level 'resource tapping' activities - such as exploring the problem in more depth (Tjosvold and Field, 1984), showing more critical evaluation of assumptions and recommendations (Schweiger et al., 1986), using a higher level of reasoning processes (Smith et al., 1985), as well as individual activities such as considering more strategies or finding new solutions on one's own (Nemeth and Kwan, 1987; Nemeth and Wachtler, 1983).

Teams engaged in people-oriented conflict direct their actions towards activities concerning team members' relations with each other because the conflict orients the team towards and focuses the team discussion on the people in the team. At the individual level, people-oriented conflict is linked to showing activities such as low concern for other people in the team or low altruistic behaviours (Wall and Nolan, 1986). These activities include attempting to dominate others and withdrawal (Thomas, 1992).

During a conflict, team members need to comprehend the information being presented by the members who disagree with them and to understand the perspectives members are using to organise and interpret the information (Johnson and Johnson, 1979). When information and insights relevant to solving the problem or making the decision are distributed among team members, there is no guarantee that all the information and insights will be exchanged (Stasser and Titus, 1985).

Two dimensions are related to conflict resolution approaches: distribution (concern about one's own outcomes) and integration (concern about the outcomes of others) (Rahim, 1983; Thomas, 1976; Walton and McKersie, 1965). The goal of managing team conflicts is to develop integrative agreements in which all parties benefit. Integrative agreements help to improve the ongoing relationships among the parties (Pruitt, 1986).

Besides conflict, power is another issue that can affect the knowledge integration process where diverse team members are involved. Power is defined as the ability or potential to influence (French and Raven, 1959). Given that it refers to the potential to influence, rather than the use of influence strategies and tactics, power is fundamentally a social construction that is perceptual in nature (Fombrun, 1983). Individuals develop their power bases through social interaction and individual behaviours which affect the power available in their social environment (Giddens, 1993). Similarly, power at the group level can influence the power of individual members. There are two types of power that an individual can have in a group: personal or soft power and positional or harsh power (French and Raven, 1959; Raven et al., 1998). French and Raven (1959) define personal or soft power as coming from an individual's characteristics or personality (expert, referent and information power), whereas positional or harsh power is based on one's formal position in an organisation (legitimate, reward and coercive power). They see that teamwork should rely on the personal power of team members. Team decision making is better when the discussion is dominated by people who are most expert or who have the relevant information to add, rather than by people who have authority to make decisions (French and Raven, 1959). Interdependence can help a team to perform better by changing the amount of power that team members have over each other (Franz, 1998). In addition, research on power has converged on the following three general categories of antecedents: structural position, network centrality and unit characteristics (Ragins and Sundstrom, 1989). A number of researchers have identified the structural position of a unit as a source of power at the individual (e.g. French and Raven, 1959) and group (e.g. Fombrun, 1983) levels. At both levels of analysis, a unit's own, or even other, mental representations of power are derived from their formal positions within a larger context.

Prior researchers have also noted the important role of less formal interpersonal relations and centrality in a social network as an antecedent of power. Individual power derived from networks (Brass, 1984; Brass and Burkhardt, 1993) and the power of groups in their networks (Franz, 1998; Rowley, 1997) both refer to a unit's informal ties to others. Finally, researchers have addressed the role of unit characteristics as antecedents of power. Although many of these have been noted at the individual level (Ibarra, 1993), group-level characteristics (Franz, 1998) are thought to play a similar role as antecedents of mental representations of power.

Having considered the tensions in knowledge integration, the following section will highlight the knowledge integration perspective adopted in the present study.

2.3.2.4 Knowledge Integration Perspective of the Present Study

Following the above discussion, knowledge integration is defined in this study as a collective process of synthesising different knowledge and paradigms through the social interaction of team members/stakeholders in order to facilitate the construction of new knowledge or combine existing knowledge.

A project where a multidisciplinary team is involved, can be described as a transformation process, superimposed on the regular or cycled activities of an organisation (Beale and Freeman, 1991). In this regard, a project becomes part of a wider venture (Beale and Freeman, 1991), the first part of which is the production of a product or service followed by an operating cycle. The project therefore takes place within a complex corporate, legal, financial and regulatory environment (Fox, 1984). This environment leads to a number of parties having a stake in the project, from internal departments to external regulatory bodies and customers, since the project decisions have a potential impact on all stakeholders (Cleland, 1986).

As Grant (1996b) indicates, competitive advantage does not evolve from knowledge per se, but from the integration of such knowledge that facilitates the construction of new knowledge. The diversity of specialised knowledge involved in the integration process determines its difficulty. Hence, the uniqueness of multidisciplinary teamwork is in its potential to integrate different bodies of knowledge into a new synergy. From an organisation standpoint, the prime purpose of the multidisciplinary team is to function as a knowledgeable entity engaged in creating new knowledge. In other words, the function of a project team is to convert knowledge inputs into new products and processes, bringing together participants with expertise in the right specialised knowledge domains and skills necessary to integrate and coordinate the knowledge of diverse participants.

Having integrated knowledge from diverse disciplines, the following section will focus on collective project learning, the third strand in knowledge creation within multidisciplinary project teams. Collective project learning is vital if experiences gained are to be transferred to other projects.

2.3.3 Collective Project Learning

2.3.3.1 Projects and Learning

The metaphor of projects as learning experiments for the company embraces an awareness of the importance of both exploration and exploitation of knowledge in organisations (Burgelman, 1991; Levinthal and March, 1993; March, 1991). To see an individual project as an experiment means that new knowledge is created and explored among project participants. The project knowledge and experience gained from earlier or current projects can be used to create new knowledge to suit current situations or problems. Projects, as a form of organising work, can be one way to explore new knowledge, project related as well as operational. During participation in a project, team members, through their engagement in the learning process, gain new experience and knowledge that could be used to solve problems. Furthermore, this knowledge and experience could be useful for other projects. In that sense, a project can be viewed as a learning experiment for the companies involved (Drew and Smith, 1995).

Sahlin-Andersson (1998) sees projects as local arenas for knowledge creation, as individuals possessing different experience and skills work together to solve a common task within a limited timeframe. Through collaboration, new technical knowledge and knowledge for organising the project are developed over time. It can be argued that projects should not be seen as vehicles for reaching the stakeholders' re-defined objectives alone, as frequently cited in project management literature. March et al. (1991) argue that organisations learn from experience to improve future performance. By the same token, projects can be used as a media for organisational learning, where knowledge and experience gained in one project can be transferred and utilised in the next. This strategy does not aim solely to save time and money, but also to avoid 'reinventing the wheel' which can occur so frequently in every new project. Penrose (1995) argued that utilising and employing experiences, and the resultant knowledge thus created, make an organisation grow.

In project-oriented companies, learning from projects is the key for building strategic competitive advantage. During a project's existence, a number of decisions are made. Every decision involves a degree of uncertainty. Packendorff (1995), for example, argues that the problems or mistakes that cause this uncertainty are often of a similar character. Yet it is not clear whether this is a global generalisation or whether it depends on the sector or stage of an industry life cycle. Nevertheless, experience to date has shown that once experience is gained in a project, knowledge is created that may be re-applicable. The basic hypothesis of the project learning approach is that learning from projects can reduce the uncertainties that might lead to inefficiencies. The use of project experiences and their integration into the organisation to expand the body of knowledge are important and valuable cornerstones in a project learning approach. Ensuring that people pass on their experience to others is one of the greatest challenges for an organisation and its organisational memory (Morris, 1994). However, learning and projects are not a natural combination (Bartezzaghi et al., 1997) since conflicts of a basic logical character are involved. These conflicts comprise the time aspect, the task orientation, the team structure and the transitional culture of projects (Lundin and Söderholm, 1995).

To carry out their project work effectively, project team members need to develop the capability of managing across boundaries. If learning is assumed as social, learning is engagement in practice and dealing with boundaries (Wenger, 1998). Project-based organisations offer an excellent opportunity to engage in learning and to acquire reflective habits that transcend the boundaries of projects. Not only does the nature of single projects support learning - so does the web of relationships that are created in project management organisations.

Membership in projects is temporary and thus offers individuals the opportunity to belong to multiple communities. In project-based organisations, there is a large number of weak ties that help diffuse knowledge and practices (Granovetter, 1973). In the majority of organisations, project members maintain their links with their primary organisations (to where they will return upon the completion of the project). Membership in multiple existing teams contributes to creating informal webs of people who act as knowledge brokers (Wenger, 1998). Project-based organisations thus enable continuous building and cultivation of relationships, nurturing the development of 'communities of practice' (Brown and Duguid, 1999). Communities of practice are natural internal mechanisms where ideas and practices spread in work settings, although they tend to exist outside the boundaries of the formal hierarchy (Wenger and Snyder, 2000). Project-based organisations may grow into constellations of interrelated communities of practice, offering a web of mutual support for cultivating reflective practices. When projects share members, they are bound together and become embedded in the same social network (Granovetter, 1973). The recursive interaction among projects creates social networks of mutual assistance. Project-based learning looks to augment the natural workings of such social networks and communities of practice as already exist.

When a project is completed, the members either return to their functional units or organisations or move on to the next project which makes project teams unique from any other organisational arrangement. In addition, it is not uncommon for individual team members to be members of several teams simultaneously (Henke et al., 1993; O'Leary, 1996).

2.3.3.2 Individual Learning

In construction, most of the design knowledge does not exist a priori (as in textbooks) but instead is created during the work process. Team members need to be able to learn new knowledge and skills on demand (Fischer, 1991) while they are doing their work. As representatives of various knowledge fields, team members are expected to constantly learn and develop their expertise, so as to provide the team with state of the art knowledge.

The traditional assumption held by many people was that one expert would know all the answers, regardless of any uncertainties (Schön, 1987). Above all, an expert would never reveal any uncertainty. This would give the client a sense of security. A fully cognisant expert would be confidently relied upon to execute any requisite task. In the role of reflecting expert (Schön, 1987), one is expected, like the technical-rational practitioner, to 'know my business', to possess relevant know-how. However one need not know everything, let alone have all the answers. One recognises that others, too, possess relevant knowledge and that people can learn from each other, gaining insights that result in good solutions.

Organisations mainly learn through their individuals and it is therefore necessary to understand the theories of individual learning, in order to comprehend how individual learning is transferred to higher levels. How the individual learns and what is learned in different situations depend to a large extent on the mental model that each individual has (Edmondson and Moingeon, 1996). According to Senge (1990) mental models represent a person's view of the world including explicit and implicit understanding. Mental models help us interpret and view material in any given situation, to isolate things that are important and also determine what kind of knowledge is being stored. The basis for learning is found in an individual understanding of his or her work. The way we interpret a certain learning situation depends on what kind of learning approach we undertake. The learning approach in turn is to a large extent influenced by the mental models that are a result of our experiences and the way we view our surroundings and reality.

Lewin (Kim, 1993) describes learning as a cycle where the individual cycles through a process of having concrete experience, making observations and reflections on that experience. Based on those experiences and the reflections, the individual forms abstract concepts and by testing those ideas in new situations, he gains another concrete experience.

The levels of learning, the operational and conceptual level, can be related to mental models. Operational learning represents learning at the procedural level, where individuals learn the steps in order to complete a particular task. This learning is connected to what kind of 'know-what' is necessary to complete the task and the actual learning takes place through action. The 'know-how' is captured as routines and recommendations. Conceptual learning has to do with thinking about why things are done in the first place and may lead to new frameworks in the mental models (Kim, 1993). As Quinn et al. (1996) argue, the understanding of our work, the 'know-why' aspect, gives the possibility to articulate a conceptual understanding of an experience. New learning is created through the transformation of experiences, but the learning is not leveraged before the understanding of the experience and task is established (Kolb, 1984).

Reflection is a necessary component in being able to 'know-why'. It is important to not just focus on the interpretation, but also on the process that leads us to the interpretation, the way that people generate what they interpret. Through this reflection individuals open up the possibility to render what is tacit and subjective to something more tangible. 'How can I know what I think till I see what I say' is a sentence which creates a thoughtful perspective on what Weick calls sensemaking. As Weick puts it, sensemaking is to consider reality as an ongoing accomplishment, that takes form when people make retrospective sense of situations in which they find themselves and their creation (Weick, 1995). But what is really reflection? According to Senge (1990), reflection concerns slowing down our thinking processes so that we can become aware of how we form our mental models and the ways they influence our actions. When we become aware of our mental models, and how they influence our actions, we are also open for new knowledge. Learning has to be linked to a change in an individual's interpretations of event and action (von Krogh and Roos, 1996).

The basic assumption is that insight and innovative ideas occur to individuals, not organisations. However, an exclusively individual focus runs the risk of neglecting the social context of learning within which individuals are embedded, as well as overlooking the need to institutionalise what individuals and teams have learnt (Crossan et al., 1996).

2.3.3.3 Team Learning

Individual learning is a prerequisite for team learning (Senge, 1990). If the individual team members do not learn, then the team as a whole cannot learn (Senge, 1990). There are a growing number of studies that examine learning and transformation in a shared group experience (Taylor, 1997) as well as collective learning by teams (Davenport and Prusak, 1998; Nonaka and Takeuchi, 1995).

Project participants frequently engaged in team learning activities to create new understanding or transform existing knowledge into new understanding. This type of team learning has been described in Senge's (1990) work. In it he shows how generative team learning is supported by collaborative sharing of knowledge for building the intellectual capacity of the whole team.

Dixon (1994) states that explicit and tacit forms of knowledge are complementary and, when communicated, can contribute to team or collective learning. The design process may be considered a mutual learning process in which all participants are both teachers and learners, and the design situation itself is a source of new knowledge. A client or user seeks to grasp and understand the situation together with the professional project team, calling for a greater measure of participation in developing the design (Gray et al., 1994; Kernohan et al., 1992; Lipman and Harris, 1998; Margolin, 1997; Reich et al., 1996).

Horvath et al. (1996) view team learning as a collective endeavour to make sense of actions and experiences. Dechant and Marsick (1993, p. 40) describe team learning in this way: "members must put together an integrated body of team-held knowledge and skills and then use it as a basis for thinking and acting". They go on to describe the relationship between individual and team learning based on their research into team learning: "team learning is different from individual learning because it is a shared experience with shared outcomes" (Dechant and Marsick, 1993, p. 40). According to Senge (1990, p. 236), the definition of team learning is "the process of aligning and developing the capacity of a team to create the results its members truly desire".

Purser et al. (1992) introduce the idea of deliberation to capture the reflective and communicative behaviour that appears to be characteristic of team learning. Cross-functional teams are fertile grounds for learning, although they vary greatly in the extent to which they are able to establish the dynamics to support it (Purser et al., 1992). Takeuchi and Nonaka (1989) find that learning can potentially occur within a project team along two dimensions: across different levels (individual, team, and organisational) and across multiple functions or disciplines. Team learning occurs when knowledge is shared among team members and incorporated into collective practices; it primarily emerges either from collective work or from team efforts to import knowledge in order to solve problems and/or achieve goals. The same forces drive learning across teams. Cross-team learning or inter-team learning can also occur when teams share their internal approaches with one another.

Team learning is viewed as a combined process of action and reflection that results in collective and observable outcomes of new knowledge, beliefs and behaviours (Watkins and Marsick, 1990). Team learning theory actually draws on concepts from both individual and organisational learning (Nonaka and Takeuchi, 1995). Concepts from organisational learning, such as interpretative systems and sensemaking, have been translated into team learning theories, although their application is not well developed (Horvath et al., 1996). Weick (1979) suggests that learning at the collective level requires that organisations be seen as interpretative systems where individuals and groups make sense of and adapt to their environments. When this is applied to the collective, the interpretation rests on the social exchange of individuals (Gioia and Sims, 1986) and occurs as retrospective sensemaking (Daft and Weick, 1984). By focusing on the learning role of a group or team, it should be possible to reveal the potential contribution that team learning can make to organisational learning as a whole. This is consistent with Senge's (1990, p. 5) observation that "team learning is vital because teams, not individuals, are the fundamental learning unit in modern organisations". This is where "the rubber meets the road; unless teams can learn, the organisation cannot learn" (Senge, 1990, p. 5).

Even if people are the basic learning unit, it is essential to understand the collective process that links them to each other and to their organisation (Crossan et al., 1996). Team learning implies that some persons or teams co-operate in order to accomplish something, which might have been impossible for one person. When individuals work together, they contribute their individual and specific knowledge, but they also develop a collective learning, of no use to a single individual. It is rather how the team works together that constitutes the collective knowledge. This means that the sum of individual knowledge is different to that of collective knowledge (Cohen and Levinthal, 1990). Team learning could thus be defined as the process whereby knowledge is created through the transformation of experience, increasing the team's capacity to accomplish a common objective. It is possible to distinguish individual and team learning as the transfer and transformation process through which individual learning is retained by a team - when new knowledge is developed by an individual and transmitted to another individual in the same team (Timlon, 1997).

The above literature review attempts to cover most of the literature that fuels the research. The next section of this chapter develops a conceptual framework for knowledge creation in the particular setting of multidisciplinary project teams.

2.4 Conceptual Framework and Research Questions of Knowledge Creation within Multidisciplinary Project Teams

The above literature review has made references to the literature on team processes and knowledge creation. A large amount of contributing literature has also been touched on but is not the main focus of this research. In this section, key issues identified in the literature review are summarised and synthesised in order to identify theoretical gaps, leading to the identification of major research questions to be explored in this thesis. The current research examines the underlying processes, their interrelationships and the critical factors enabling or inhibiting these individual processes in knowledge creation in multidisciplinary project teams. Due to resource constraints, it is not possible to cover all theoretical gaps identified in this single study. In addition, it is found that not all the theoretical gaps identified can be researched. This study accordingly chooses to select researchable questions that are of conceptual significance.

The issue of knowledge has been debated for several centuries. Knowledge has only recently been viewed as a collective phenomenon in organisational contexts. Two conflicting theoretical perspectives about knowledge emerge during the course of this research. The first perspective, as highlighted by Prahalad and Hamel (1990) and Wernerfelt (1984), focuses on the resource-based view where knowledge is professed as a set of strategically important commodities that exist independent of their creators and are context-independent, i.e. the firm's primary role is as knowledge applicator. The second perspective from Berger and Luckmann (1966), Kuhn (1970) and Nonaka and Takeuchi (1995) perceives knowledge as a set of shared beliefs that are constructed through social interactions and embedded within the social contexts in which knowledge is created, i.e. the firm's primary role is as knowledge creator. This view on knowledge elaborates the social construction perspective held by this study of trying to understand knowledge creation processes and investigate the phenomenon of knowledge creation in multidisciplinary project teams. The literature on knowledge creation at team levels is rather limited, particularly in relation to multidisciplinary project teams. This recognition has led this research to emphasise the multidisciplinary team context, in order to fill a major theoretical gap.

The present framework for examining the knowledge creation processes within multidisciplinary project teams is based on Nonaka and Takeuchi's (1995) organisational knowledge creation theory as discussed previously. Nonaka and Takeuchi's theory is utilised because it is one of the few knowledge creation theories available that examines the interrelationships between explicit and tacit knowledge. Furthermore, Nonaka and Takeuchi's (1995) theory was inductively developed using case studies of product development projects so the focus on technical knowledge creation is appropriate for this study. While all knowledge creation theories are, by nature, process-based, Nonaka and Takeuchi's theory, along with describing the processes of knowledge creation, describes the factors, designated as enabling conditions, that enable these processes. Other knowledge creation theories are not adopted in the current study due to reasons as stipulated in Section 2.2.2.1 above.

How organisations view knowledge creation seems to be dependent on their organisational culture. Nonaka and Takeuchi (1995) explain that the superiority of the Japanese continuous innovation has been due to their strong emphasis on socialisation, i.e. sharing tacit knowledge directly and internalisation, i.e. individuals' own participation in learning-by-doing. In contrast, the Western focus is more on externalisation, i.e. heavily emphasising explicit knowledge and combination. This is due to the epistemological difference where "Westerners tend to emphasise explicit knowledge and the Japanese tend to stress tacit knowledge" (Nonaka and Takeuchi, 1995, p. 243). Moreover, in the Japanese society, knowledge is mainly created on a group level through dialogue, whereas in Western organisations the link between individual learning and organisational learning is less obvious. This stems from the ontological difference between their focus on individual and group where "Westerners are more focused on individuals, while the Japanese are more group-oriented" (Nonaka and Takeuchi, 1995, p. 243). Nonaka and Takeuchi (1995) add that in the West, work at group-level is devoted to carrying out pre-defined tasks rather than maintaining dialogue through which tasks are newly defined and further developed. Conversely, Japanese firms are less adapted to managing large complex systems, requiring extensive articulation and transfer of knowledge to the environment through products, patents and people. Though project team members are of various nationalities and have gained a variety of experiences abroad, they have been embedded in Hong Kong society anyway, which suggests that, in the setting of this research, the cross-cultural aspect could be argued to be pretty much irrelevant in any case.

However, Nonaka and Takeuchi's (1995) knowledge creation model has some limitations that lessen the model's suitability for the study of knowledge creation in multidisciplinary project teams. Their primary distinction between tacit and explicit knowledge is problematic as tacit or unarticulated knowledge is always a precondition for explicit knowledge (Engeström, 1999). Tuomi (1999) also criticises the model for taking culture and language for granted. The difficulty to discuss the role of language as a "repository of culturally shared meaning" (Tuomi, 1999, p.340), critical for any knowledge creation theory, may make its use difficult for multidisciplinary project teams. It is also not clear what happens when the knowledge-creating spiral expands outside a team: is knowledge still created the same way (Tuomi, 1999)? As pointed out by Tuomi (1999, p. 328), "there is no model of social activity within the [knowledge creation] model - the motives for knowledge creation, and their relations to individual or organisational needs, remain obscure. Why some knowledge is created, and why some knowledge is not, remains an open question". Furthermore, Tuomi (1999) finds that though Nonaka and Takeuchi (1995) stress that the process of knowledge creation is 'social', their underlying focus is on individual and intra-personal knowledge. He adds that "as their concept of knowledge is intra-personal, truth becomes a necessary aspect of knowledge, grounding intra-personal knowledge into interpersonal reality" (Tuomi, 1999, p. 333).

In order to overcome some of the shortcomings in Nonaka and Takeuchi's knowledge creation model, if one accepts the social construction perspective of knowledge as a set of shared beliefs constructed through social interaction amidst certain social circumstances, then both individual and social levels require acknowledgement and integration. Specifically, we have distinguished three modes of knowledge creation. They are 'knowledge sharing', 'knowledge integration' and 'collective project learning'. In this study, we regard knowledge sharing as a multitude of processes taking place directly without language (socialisation) and with language (externalisation). Designing a facility requires collaborative interaction of individuals from different professional backgrounds. Their diverse expertises represent different interests and issues. Those different experiences, mental models and motivations can be expressed only partly in explicit language. Thus, socialisation is a valuable mode of sharing knowledge in teams without language through imitation, observation and sharing experience face-to-face. Nonaka (1994) emphasises that socialisation is also an important way to further trust between partners. Saint-Onge (1996) refers to socialisation as a way of creating a sufficient level of congruence to enable individuals to understand each other and work together towards their common goals from different perspectives. Besides sharing without language, sharing work-related expertise requires the use of language. Social constructionists regard language as coordination of action (Burr, 1995) and therefore a fundamental tool in knowledge creation. The commonly employed tool in externalisation is dialogue. Dialogue triggers the unconscious elements of knowing and not-knowing as well as revealing gaps in knowledge compared to what the community knows (Ayas, 1996).

An important aspect of knowledge integration is the willingness to combine knowledge from within and outside the team. The more differentiated the knowledge inputs needed in a task are, the higher the knowledge diversity and the greater the scope for knowledge integration. Design, involving art, engineering, finance and business, is a process of knowledge integration and a facility's design emerges from the collaboration of project participants and stakeholders. Leonard-Barton (1995) views creation of new knowledge by combining previously unconnected elements or by developing ways of combining elements previously associated.

Innovation teams are likely to engage in effective knowledge sharing and integration to achieve their predefined goals, but do their processes include activities to ensure the future creation of knowledge as well? Nonaka and Takeuchi (1995) claim that large Western organisations are not good at internalising learning from their activities at team level. There is a strong emphasis on converting tacit knowledge to explicit knowledge, but less is done to support the further generation of tacit knowledge. Learning usually has a more open-ended and long-term focus.

Knowledge is a very general concept, relating to a firm's capabilities to create sustainable competitive advantage. One most obvious source of knowledge that can lead to sustainable competitive advantage is the creation of new products or processes by technological innovation or problem solving. Leonard-Barton (1992) asserts that knowledge creation may involve problem solving, though problem solving need not involve knowledge creation. This is so because problems may be formulated and solved based on well-known knowledge without the need for creation, or even learning, to take place. Due to our common use of the term 'problem solving' in almost every situation, it is likely to downplay the tacit elements of knowledge creation and emphasise the explicit. Problem solving suggests that the necessary parameters of the 'problem' are known and the solution may be formed from determining the right combination of parameters. Thus new knowledge is created, or existing knowledge is combined, in those circumstances. Project design involves problem solving on many levels. A building project can be seen as a gap between an existing state and a desired state. The project delivery team members bring their experience and skills to bear on the problem of diminishing this gap. Problem solving is "the generation and selection of discretionary actions to bring about a goal state … creative thought represents a form of problem-solving" (Mumford et al., 1994, p. 3). But design solutions are only a part of the design process, since permutation of team members, budgets, taste, priorities and values, for example, are also integrated. When taken together, the building appears as a collaborative effort created by, and within, the design process.

Technological innovation can be viewed as a form of problem solving (Dailey, 1978; Dailey and Morgan, 1979). That is, the solution to a problem is discovered after some amount of physical or mental exploration. Technological innovation as a result of knowledge creation in projects is claimed to be desperately needed in the construction industry (Gann, 2000). Viewing technological innovation and problem solving as knowledge-creating activities also follow the framework of Nonaka and Takeuchi (1995) in allowing for the concept of tacit knowledge. By acknowledging the tacit elements, the entire process of knowledge creation is included and may be more deeply understood (Anand et al., 1993).

A number of innovation researchers have emphasised the importance of a team approach in successful product development (e.g. Clark and Fujimoto, 1991). Project team members with diverse skills, knowledge and experiences are required to work together to resolve issues or problems encountered in a project. Though there is an extensive literature covering teams (e.g. Cohen and Bailey, 1997) and the benefits they can bring to organisations (e.g. Ancona and Caldwell, 1992a), a focus on the processes of knowledge creation from a multidisciplinary project team perspective is compelling as research specifically addresses this issue appears to be very limited (Newell and Swan, 2000). Senge (1990) suggests that creating knowledge at the team level is essential for long-term team effectiveness, innovation and productivity. In addition, a team can be viewed as a socially constructed phenomenon or linking mechanism that integrates individuals and organisations (Horvath et al., 1996).

On the one hand, existing literature has highlighted a need for the development of diverse workforce if knowledge creation is to be promoted within organisations (e.g.

Starbuck, 1992). Kirton (1988) finds that people who are willing to cross functional or other boundaries are likely to be more innovative. On the other hand, researchers (e.g. Newell et al., 1998) have demonstrated the difficulties of knowledge creation in cross-disciplinary teams. These conflicting findings, regarding individual team members with distinguished knowledge and experiences interacting to create knowledge, need to be re-examined. Therefore, two of the most fundamental research questions are:

- How do team members with diverse knowledge bases interact?
- What are the critical issues influencing such interaction?

To enhance competitiveness and meet project goals, team members need to share both tacit and explicit knowledge. Increased sharing of knowledge raises the likelihood of new knowledge being created, tending to support valuable innovation (Nonaka and Takeuchi, 1995). Though organisations can externalise some of the knowledge in use, it is easy to find cases or examples that do not fit the codified knowledge of the organisation. Orr (1996) uses an example of photocopier technicians to support the fact that unarticulated knowledge requires communication among people. Knowledge sharing relies on reaching a shared understanding of the content as well as the context or 'Ba' of the knowledge (Nonaka and Konno, 1998). Besides exchanging information, knowledge sharing unveils and synthesises paradigmatic differences through social interaction. Knowledge sharing does not only allow exchanges among project team members, it facilitates customer, competitor and product knowledge to be shared. Individual tacit knowledge is shared through socialisation, (for example, through observation, imitation or practice) and through the development of trust (Nonaka and Takeuchi, 1995). The result is manifested in shared mental models that are tacit. In addition, individuals take part in communication networks through which their tacit knowledge is articulated and captured in ideas, concepts and models that can become explicit and externalised. Various means of communication exist: from the richer or thicker one such as face-to-face to the thinner form such as e-mail. Together with active interpretation of communications, different communication media offer merits to different forms of knowledge, i.e. explicit or tacit knowledge (Habermas, 1987).

From the diversity of team membership, Stewart and Stasser (1995) find that a team's awareness of the distribution of expertise within the team increases the probability that unshared knowledge individually held by team members will be shared. Along with helping create a common understanding of the work in hand, internal knowledge sharing can also increase an awareness of who knows what in the team (Moreland and Myaskovsky, 2000). In addition, previous studies on social network structure illustrate how diverse work teams can benefit from external knowledge sharing (e.g. Granovetter, 1973). The uniqueness of these ties can provide non-redundant or unique resources and information that team members could leverage for competitive advantage (Burt, 1992). Another reason for enhanced performance is the tapping of non-overlapping expertise, with team members eliciting diverse ideas and insights from others (Cohen and Levinthal, 1990). However, collaboration is not a natural mode of conduct for professionals who are socialised to work individually, to be praised and rewarded for their personal accomplishments, to compete and vigorously defend their knowledge paradigm (Mohrman, Cohen and Mohrman, 1995). Tjosvold and Tjosvold (1995) point to the difficulty professionals have in collaborating with others. Since team members of the collaborative network are not governed by traditional hierarchical relationships, the development and maintenance of trust and the deployment of power among members become critical issues (Ring, 1997). Newell and Swan (2000) stress the importance of trust in inter-organisational network. Anderson and Narus (1990) suggest that the attainment of mutual trust leads to shared knowledge. They find that team interaction builds trust, leading to increased communication and the eventual sharing of knowledge. According to Pemberton and Stonehouse (2000), knowledge sharing is vital to knowledge creation and competence development. Two questions that surface from the concept of knowledge sharing are:

- How do multidisciplinary project team members share knowledge with other team members?
- What critical issues influence knowledge sharing among project team members?

In addition to acquiring knowledge by sharing knowledge or experiences already possessed, what would happen when issues or problems are encountered with no relevant knowledge or experience available in the team. In this respect, two research questions emerge:

- How do members acquire or seek knowledge to address shortcomings or problems if no one in the team has the relevant experience?
- What are the critical issues that influence the knowledge acquisition/seeking process?

As noted long ago by Hayek (1945), knowledge in an economy is dispersed among many actors. Without exception, projects usually take place within a complex corporate, legal, financial and regulatory environment (Fox, 1984) with a number of parties having a stake in the project - from internal departments to external regulatory bodies and customers. Project decisions have a potential impact on all stakeholders (Cleland, 1986). Grant (1996a), in developing a knowledge-based theory of a firm, suggests that the greater the diversity of knowledge within the organisation, the greater the scope for knowledge integration. Knowledge integration is the base on which to build dynamic capabilities (Clark and Fujimoto, 1991). According to Jassawalla and Sashittal (1999), the most difficult yet important challenges facing product development teams are the integration of markets, products and technologies. Successful product development depends on how quickly project teams capture, exchange and utilise relevant knowledge components (i.e. share knowledge) and integrate them to derive innovative solutions for new products (Iansiti and MacCormack, 1997). Gruenfeld (1995a) finds that teams with heterogeneous composition are better at integrating multiple perspectives than teams without conflicting perspectives. The motivation for the use of multidisciplinary project teams is the fact that they are able to combine their knowledge and differing perspectives to produce a solution that no one member, acting alone, would have been able to achieve. According to Weick (1995), more information or knowledge may not be desirable, whereas a setting wherein people can argue and include their multiple interpretations is found to be more effective. One example of such an arrangement is the 'thought collective' (Fleck, 1979) in which the insights of a team of specialists are combined to create new knowledge.

Conflict has long been recognised as an important dimension of both task and social activities in teams working on decision-making or problem solving tasks (Janis, 1972). The benefits of conflict are that it encourages the team to explore new approaches, motivates people to understand issues better and encourages new ideas

(Robbins, 1974). When opposing views are brought out into the open and are fully discussed, the team makes better decisions and commitment is enhanced (Cosier and Dalton, 1990). In addition, individuals develop their power bases through social interaction and individual behaviours which affect the power available in their social environment (Giddens, 1993). French and Raven (1959) suggest that team decision making is better when the discussion is dominated by people who are most expert or have the relevant information to add, rather than by people who have authority to make decisions.

As Grant (1996b) indicates, competitive advantage does not evolve from knowledge per se, but from the integration of such knowledge that facilitates the construction of new knowledge. The diversity of specialised knowledge involved in the integration process determines its difficulty. From Demsetz (1991) and Grant's (1996b) work, knowledge integration serves the coordination function, critical in knowledge creation. Based on the above synthesis, two questions arise:

- How do team members integrate multiple knowledge perspectives in the project?
- What are the critical issues that influence the integration of knowledge?

In project-intensive companies, learning from projects is the key for building strategic competitive advantage. During a project's existence, a number of decisions are made. Every decision involves a degree of uncertainty. However, the problems or mistakes that cause this uncertainty are often of a similar character (Packendorff, 1995). Penrose (1959) argues that utilising and employing experiences and knowledge created makes an organisation grow. Takeuchi and Nonaka (1989) find that learning can potentially occur within a project team along two dimensions: across different levels (individual, team and organisational) and across multiple functions or disciplines.

Project team members have to incorporate new knowledge into their understanding in order to solve the technical challenges they face. Thus, learning is inherent in the work they do (Mohrman, Mohrman and Cohen, 1995). In the role of reflecting expert (Schön, 1987), one is expected, like the technical-rational practitioner, to 'know my business', to possess the relevant know-how. However one need not know everything, let alone have all the answers. One recognises that others, too, possess relevant knowledge and that people can learn from each other, gaining insights that result in good solutions. New learning is created through the transformation of experiences, but that learning is not leveraged before an understanding of the experience and task is established (Kolb, 1984). Learning has to be linked to a change in an individual's interpretation of events and actions (von Krogh and Roos, 1996).

Individual learning is a prerequisite for team learning (Senge, 1990). If the individual team members do not learn, then the team as a whole cannot learn (Senge, 1990). There are a growing number of studies that examine learning and transformation in a shared group experience (Taylor, 1997) as well as collective learning by teams (Davenport and Prusak, 1998; Nonaka and Takeuchi, 1995). Project participants frequently engage in team learning activities to create new understanding or transform existing knowledge into new understanding (Senge, 1990). Dixon (1994) states that explicit and tacit forms of knowledge are complementary and, when communicated, can contribute to team or collective learning. Horvath et al. (1996) view team learning as a collective endeavour to make sense of actions and experiences. Purser et al. (1992) find that cross-functional teams are fertile grounds for learning, although they vary greatly in the extent to which they are able to establish the dynamics to support it.

Membership in projects is temporary and thus offers individuals the opportunity to belong to multiple communities. In project-based organisations, there are a large number of weak ties that help diffuse knowledge and practices (Granovetter, 1973). Cross-team learning or inter-team learning can occur when teams share their internal approaches with one another. Collective learning can be considered as a vital mechanism (Huber, 1991) and a final product of knowledge creation (Argyris and Schön, 1978; Senge, 1990). Three questions are identified relating to the issue of collective project learning:

- How do team members learn from experiences in projects?
- How do the experiences gained from the current project influence other projects or vice versa?
- What are the critical issues that influence learning in projects?

Despite the growing recognition of the importance of knowledge creation in organisations, the underdevelopment of this concept in team situations is evident in the review of current literature. Furthermore, the lack of a comprehensive theory, with empirical evidence in the knowledge creation research area, has worsened the situation. Accordingly, this research seeks to explore the processes of knowledge creation and to generate a theoretical account of those processes applicable to multidisciplinary project teams. The above discussions point to various perspectives on the processes of knowledge creation and the critical issues that affect these processes. However, one major area has not been covered in the literature previously: the interrelationships of the various processes. Therefore, the last question to be dealt with in this research is:

- What are the interrelationships between various multidisciplinary knowledge creation processes?

After exploring all research questions vital to the examination of multidisciplinary knowledge creation processes, the following chapter, covering research methodology, outlines various issues relating to how the proposed research questions can be answered from empirical evidence.

Chapter Three - Research Methodology

3.1 Introduction

In this chapter, the study's methodological approach adopted is discussed and justification is provided for using the epistemological approach. Two extensive in-depth case studies were conducted in order to address the research questions. The empirical material derived from these two cases was analysed using an interpretative approach rooted in constructivism (Alvesson, 1995; Denzin and Lincoln, 1998). Stake (1998, p. 86) states that a case study in itself "is not a methodological choice, but a choice of object to be studied". I chose to study two multidisciplinary project teams, engaged in design and problem solving work during the design phases of two facility projects, in order to understand the processes of knowledge creation, the interrelationship of these processes and their contributory factors in those particular processes. A reputable property development company in Hong Kong was identified with a significant commitment to a high standard product[4]. Two of the company's multidisciplinary teams, working on two different projects, were selected for study.

In Section 3.2, the chosen methodological approach is detailed, together with the ontology and epistemology adopted. Section 3.3 discusses how the research was designed, including the selection of the research cases and negotiating access. Section 3.4 deals with the research strategy. Various data sources used to collect the evidence are highlighted, including project documentation and organisational records, interviews and direct observation. The ways in which the data were analysed are discussed, highlighting the interpretative methods used. Issues, regarding the

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[4] Product - a construction project can also be treated as a product because at the end of construction, a facility will exist, with consumers using it to fulfil their needs.

generalised nature of the research and the inevitable limitations of the fieldwork, are discussed in Section 3.5 of this chapter.

3.2 Methodological Approach Chosen

The case study approach proposed by Yin (1994) is rooted in positivism. Yin (1994) emphasises that this approach is well suited to research questions that focus primarily on the 'how and why' form. Influence over behavioural events is not required, attempting to ascertain casual relationships between particular phenomenon and context. He suggests that many critics do not believe the case study method as methodically valid, with those who conduct case studies often allowing

> "equivocal evidence or biased views to influence the direction of their findings and conclusions" (Yin, 1994, p. 9).

Acknowledging such criticism, Yin (1994) proposes adopting a scientific approach that thoroughly tests and substantiates data using natural science methods of experimental design. Through embracing reliability and validity testing, 'problems' associated with case studies can be overcome. Many researchers (e.g. Eisenhardt, 1989; Leonard-Barton, 1990) promote the use of natural science methods when designing and analysing case studies, highlighting that constructs such as external validity and reliability are of importance if the theory development is proposed. Positivist approaches to case study design and research believe that organisational reality consists of dependent variables and independent variables and that the relationships between them can be tested, leading to the verification of the hypothesis. This approach tends to fundamentally discount the idea that the world (including the research world) is socially constructed, which is the characteristic of the constructivist paradigm (Denzin and Lincoln, 1998).

Those qualitative researchers who strive to achieve such an objectivistic, scientific approach, are labelled by Alvesson (1995) as 'data collectors'. He differentiates this research approach and an interpretative approach, in which personal frames of reference and values are allowed to influence the interpretation of data. He denotes this second group of researchers as 'interpreters'. Burrell and Morgan (1979, p. 28) describe the interpretative paradigm as seeking "explanation within the realm of individual consciousness and subjectivity, within the frame of reference of the participant as opposed to the observer of action". They add that

> "in its approach to social science it tends to be nominalist, anti-positivist, voluntarist and ideographic[5]. It sees the social world as an emergent social process which is created by the individuals concerned" (Burrell and Morgan, 1979, p. 28).

The main emphasis of the interpretivist approach lies in the researcher's own subjectivity in the analysis, arguing against claims that biased views intrinsically lead to invalid research findings. Alternatively, interpretative research acknowledges that there are some organisational phenomena that cannot be empirically validated but at the same time can be understood in an interesting and meaningful way. In short, Alvesson (1995) finds that the interpretative approach focuses on developing hypotheses and theories rather than testing and verifying them. Alvesson (1995, p. 42) states explicitly that the interpretative approach recognises

> "there is no such thing as ready-made data waiting to be collected up by the researchers ingenuous research methods ... The researcher's frames of reference language and other elements in the prestructured understanding strongly affect that which he or she sees, how it is interpreted and how it initially becomes a research text."

[5] The ideographic approach stresses the importance of developing "first hand knowledge of the subject under investigation" (Burrell and Morgan, 1979, p. 6).

In addition, Deetz (1992, p. 66) supports this claim and states that

> "theory is a way of seeing and thinking about the world. As such it is better seen as the 'lens' one uses in observation than as a 'mirror' of nature".

Deetz (1992) suggests that in theory development, researchers can never hope to develop a 'true' representation of reality as they can only rely upon their subjective observation.

Deetz (1992, p. 70) argues that the positivist approach, with its emphasis on hypothesis testing, dependent and independent variables, etc., helps create only applied and highly specific knowledge, based on the researcher's own "arbitrary structuring of the world". He adds that it fails to direct our attention to significant aspects of reality. Stacey (1996) finds that teams and groups in intensive information processing and knowledge discovery processes are necessarily complex chaotic environments, not well suited to traditional quantitative methodologies. Provided that interpretations are well supported by empirical evidence, supporters of the interpretative approach suggest that it provides for an analysis that permits conceptualisation, rather than strict definitions. It aims not to generate one worldview of ordering reality within the context studied, but it facilitates multiple representations of the organising and ordering of events, which offer scope for alternative thought and courses of action. As such the interpretative approach aims to encourage critical debate around the area studied rather than offering any answers.

The analyses of the cases will focus on many aspects of organisational 'reality' and phenomena such as knowledge sharing. These phenomena, I suggest, can only be understood and analytically represented by adopting the interpretative approach.

These are not aspects of organisational reality that can be tested or measured accurately. Nor can they be categorised in verifiable, objective terms, particularly within the organisational context studied. These phenomena can only be subjectively perceived by those who experience them. Hence their potential influence on the processes of knowledge creation within any social group can only be subjectively interpreted. Their influence cannot be subject to testing and verification against an externally defined social reality. Even more tangible organisational attributes, such as team configuration, cannot be reduced to crude objective variables, existing as stable, discrete, definable entities. Individuals need not necessarily agree, for example, on the level of trust existing within a team. This again can only be subjectively perceived. It is the work of the researcher to gather empirical material from a variety of sources and, acknowledging one's own subjectivity, interpret the level of trust within the team, using the multiple sources of evidence to justify that interpretation.

Rather than attempting to demonstrate that the approach chosen satisfied such criteria as internal and external validity or reliability, which is the characteristic of the positivist paradigm (Yin, 1994), this research is similar to the constructivist paradigm. It assumes a critical ontology and a subjective epistemology. The data analyses will therefore be essentially critically reflective. The aim is to develop an analysis that, whilst aiming to establish criteria such as trustworthiness, credibility, confirmability and transferability as suggested by Denzin and Lincoln (1998), also reflects tensions, unresolved issues and contradictions that intrinsically represent organisational 'reality'.

The way in which the research was designed, especially the way in which cases were identified and selected, is discussed together with how access to the cases was negotiated and granted. Consideration is given to the temporal perspective of the research and reference is made to the lack of substantive, empirical research in the field generally.

In addition, the number of respondents who would be involved, relative to the range of variables under investigation, was small (approximately 15 in each case) which made a more standardised statistical treatment of the data impossible. To explore particular themes, open-ended questions became the appropriate means of obtaining the requisite data. A more pragmatic reason for employing the case study approach was that full familiarity with the types of circumstances encountered could not be assumed. An openness and awareness of the peculiarities of the practical design process were deemed essential. It was also recognised that the range of possible situations could not be adequately anticipated, given the lack of familiarity with circumstances found in construction. In other words, an understanding of the full context of social interaction seemed to be of central importance (Van Maanen, 1988).

An explorative case study would enable the researcher to examine assumptions in the literature while remaining open to new explanations and evidence. It is "an explicit attempt to interpret the narrative but also to link emerging conceptual and theoretical ideas inductively derived from the case both to stronger analytical themes within the case and wider theoretical debates in the literature" (Pettigrew, 1990, p. 280). Bell (1987, p. 7) points out that the strength of the case study method is in allowing

> "the researcher to concentrate on a specific ... situation ... and the various interactive processes at work. These processes may remain hidden in a

> large-scale survey but may be crucial to the success or failure of systems or organisations."

Bell (1987, p. 7) concludes that "a successful study will provide the reader with a three-dimensional picture and will illustrate relationships, micropolitical issues and patterns of influence in a particular context". Bryman (1989, p. 172) has a similar finding that "case studies should be evaluated in terms of the adequacy of the theoretical inferences that are generated. The aim is not to infer the findings from a sample to a population, but to engender patterns and linkages of ... importance".

The main focus of this research is to explore the underlying processes of knowledge creation in a multidisciplinary project team setting, together with determining the interrelationships of these processes and their contributory factors. Taking into account the explorative nature of the study and the complexity of the issues, a more holistic approach has been adopted towards the study of specific phenomena. As a result, two in-depth case studies were used to obtain as thorough a picture as possible of the attributes and practices affecting knowledge creation in multidisciplinary project teams.

Similar to Bresnen's (1986) research into project organisation and matrix management in the UK construction industry, the present research adopted a longitudinal approach to study the processes of knowledge creation in each case. In contrast to the longitudinal approach, a cross-sectional approach could produce a snapshot view, neglecting change and development, which were of paramount importance in this study. In addition, as suggested by Bresnen (1986), the methodological consideration related to the recurring nature of the research problems favoured the longitudinal approach, minimising the issues associated with regulating points of entry in inter-case comparison as well as an excessive reliance upon retrospective commentary. As a result, based on such methodological and pragmatic considerations, this study chose a more dynamic longitudinal study over a static cross-sectional approach. The following section will highlight the research design.

3.3 Research Design

Fieldwork was carried out within two multidisciplinary project teams, employed by a leading Hong Kong property developer to develop two island based infrastructure and residential projects. The choice of construction and real estate sectors for a study on knowledge creation was influenced by their huge effect on the local economy. Table 3.1 tabulates the Gross Domestic Product (GDP) of construction and real estate between 1990 and 1999. Projects in the construction industry are prime generators of knowledge creation. Through past successes and failures, they are continually great resources for construction professionals to learn from. They also provide an ideal environment for new and unproven ideas and concepts to be considered as long as health and safety issues are not compromised. Altogether they harbour appropriate conditions to actively promote knowledge creation.

Table 3.1 GDP by detailed economic activity, 1990-1999

Year	Construction		Real Estate	
	% Distribution to GDP	HK$ million	% Distribution to GDP	HK$ million
1990	5.4	30,220	9.7	54,068
1991	5.5	34,659	9.5	60,181
1992	5.1	37,337	10.3	75,558
1993	5.2	43,089	11.0	91,581
1994	4.9	46,325	12.4	117,698
1995	5.4	54,761	9.9	100,480
1996	5.8	65,058	10.2	115,326
1997	5.8	71,650	10.9	134,186
1998	6.0	69,937	9.7	112,842
1999[@]	5.8	66,111	7.6	86,241

[@] - Figures are subject to revisions later on as more data become available.
Source: Census and Statistics Department (2001)

The choice of case organisation was primarily driven by the consideration of what the company represents to Hong Kong within the construction and real estate sectors. It is one of the most high profile firms, a leader in Hong Kong's construction and real estate markets. During the financial year 2000/01, the company completed over 400,000 square metres of attributable gross floor area, with a total property sales amounting to over HK$19 billion. As one of the Hong Kong's largest private landowners, the company currently has a total land bank exceeding 5 million square metres. Its property development portfolio is one of the largest, with a great number of on-going projects at different stages of development. Furthermore, during the period of study, the company was undergoing significant stress due to the financial turmoil in Asia and fierce competition within the construction and real estate sectors. Although, for the purpose of this study, the recession and competition themselves are not explicitly put under scrutiny, they nonetheless have to be considered as significant background influences to knowledge creation. The resultant need for dynamic flexibility, streamlining the design and construction processes or lowering the development costs, and innovation provided fertile opportunities for the observation of knowledge creation and collective learning processes. Finally, the selection of the two fieldwork projects was aimed at introducing variations in context when they were examined by the research questions. The rationale for the selection of the cases is explained in detail in the next section.

3.3.1 Selection of the Research Cases

Two project teams - infrastructural and residential - with diverse design concepts, discipline and knowledge bases, skills and possibly attitudes towards knowledge creation, were considered. Both cases shared common involvement in the construction of two large-scale projects on a 'green field' site. In addition, the nature of the work is information and knowledge intensive, requiring the teams to develop new or utilise existing technologies, techniques and processes to achieve their work goals. Further details of the nature and scope of work will be given in Chapter Four. The nature of project team at work is both intellectual and interactive. It is intellectual in that it requires the team to find novel or hidden solutions to complex problems, and it is interactive as it requires constant co-operation between all participants in the design development process. However, these two projects differed in many respects. The nature of the tasks was different, as were the personnel involved and the ways in which design knowledge was created. The selection of the cases hoped to gain further insight into the multiple and divergent phenomena fuelling the different modes of knowledge creation during design development. All the while, the study views knowledge as a dynamic phenomenon.

The selection of the residential development project recognises the large reservoir of idiosyncratic knowledge developed by the company over the years. It also recognises the crucial innovating dynamics behind the need to compete on the market with other residential developments. The infrastructure project presented alternative opportunities for knowledge creation and learning, unique in several respects. Firstly, it was a complex operation, distinguished by an extraordinary multiplicity of consultants being employed. Secondly it was rare to find such a project, usually managed by government, in private hands. Finally, the technical challenges presented in this project made it an interesting arena for knowledge creation and absorption within the team.

3.3.2 Negotiating Access

Initial access to the company was provided after contacting the head of Project Management - the 'gatekeeper', to use Becker's (1970) term - to express an interest in learning more about the processes of knowledge creation within the setting of a multidisciplinary project team. After an explanation of all research details, he became interested in the proposal to host a doctoral candidate within the firm. He emphasised the confidentiality of company information, stressing the need for strict anonymity. My need was expressed for formal interview access to a wide cross section of project team members, with all interviews to be recorded and transcribed. I requested observer status in any meetings, events or planning sessions that involved the project teams. Other organisations approached had found this very sensitive as it approved unfettered access to their discussions, possibly of a very sensitive and confidential nature. In terms of secondary data sources, I requested access to any relevant project documentation and archival records.

In negotiating access, it became clear that such extensive, all consuming research would only be acceptable within the confines of one company, because of a considerable anxiety within the industry about the risks of communicating confidential knowledge to competitors. Additionally, by focusing on comparative analyses between two different projects within the one firm, any possible ambiguity could be avoided that might arise from company differences. A deep understanding of the dynamics of knowledge creation in the two project teams could be developed and through this, a foundation possibly established for future cross-organisational studies of firms that might differ in terms of strategic objectives and underlying economics.

The senior project manager was nominated to familiarise me with the research environment and to introduce the participants in both developments. He provided advice on practical, organisational and project-related issues, suggesting whom to consult when wanting to study project team members. He proved to be a key informant throughout the project and gave me access to a rich variety of internal documents. In particular, he helped furnish the background history to both projects and he detailed the strategic transformations his company was going through. He listed the project team members, which assisted selecting personnel for interview.

All participants provided immense help by giving access to the relevant project documentation. Over the 14-month period, full licence was extended to visit the projects and to attend all team meetings whenever needed. The collaborative attitude of both management and team members ensured ample opportunity to fine-tune and regularly check the results emerging from the study, responding to any gaps in the findings as perceived. The resultant close connection with the two teams was critical in view of the challenging and complex research topic. Table 3.2 highlights some pertinent aspects of the case projects and details the sources made available by each of the projects.

Table 3.2 Sources of evidence

Source of evidence	**INF Project Team**	**RDA Project Team**
No. of interviews	16	15
Av. Length of interview	80 minutes	100 minutes
Meetings attended (team meeting observation)	Formal - 12 Informal - 15	Formal - 16 Informal - 19
Access to company data	Open	Open
Access to project documentation	Open	Open
Informal discussions	3	5

3.4 Research Strategy

The research addresses the issues - the key processes that underlie knowledge creation within multidisciplinary project teams, the interrelationships between these key knowledge creation processes and the contributory factors that influence the processes of multidisciplinary knowledge creation. The analysis is aimed at providing a detailed account of the organisational 'activity system' (Blacker, 1992; Engeström, 1987) through the actions and words of participants. Specifically, it observes relevant events, visible behaviours and artefacts and selects domains in which knowledge creation potentially occurs. The above-defined items are conceived as selected features of a situation, constraining or inducing intentional performances or at least falling to the actors' attention. The situation is set where people engage in the processes of knowledge creation. A key resource is the team members' accounts of their own activities within the situation, that is the "language, concepts, categories, practices, rules, beliefs and so forth, used by them" (Van Maanen, 1988, p. 13). Thus, two phenomena stand out - observed behaviour and the participants' interpretations of events and situations.

3.4.1 Data Sources

Evidence for the case studies relied on three main sources - documentation and organisational records, interviews and finally, direct observation.

3.4.1.1 Project Documentation and Organisational Records

Internal documents and archival records were collected throughout the duration of the research project, both on site and from the team members' companies. Archival data were primarily used to reconstruct the organisational context in which the study was being performed. Accordingly the necessary background detail was provided (company history, business activities and organisational structure and characteristics) for the description of the case studies.

Project documents were used to record the design progress, certain major decisions and the resolution of particular problems. Items viewed included tender documents, company manuals and procedural guides, meeting minutes, design sketches and drawings, specifications, project correspondence files, press coverage of developments (articles from newspapers, magazines, professional journals and other media coverage), project programmes and photographs, cost estimates and the project management information system. The documentary evidence led to approaching individual team members about how knowledge was created during the design process as well as how learning was activated in pursuance of novel or unusual ideas. Information from project documentary sources was used to supplement the more 'factual' material obtained and to enable information cross checks. Overall, organisational records and project documentations were extensively utilised within the empirical chapters of this research.

Collecting documentary evidence began at the onset of fieldwork. Many weeks were spent gaining in-depth knowledge of how the projects and individual consulting organisations operated and in understanding their antecedents. Immediate and continuous access was given to glean documentary material in written or electronic form until the data collection process was complete. Throughout the duration of the project, regular visits were made to the project team members' offices to collect documents and background information. During those visits, several informal conversations were held with numerous employees.

3.4.1.2 Interviews

The bulk of empirical material was collected through semi-structured interviews with key participants. Interview was favoured as a data collection method because it assisted an in-depth understanding of people's interpretation of phenomena and their interconnections. According to Burgess (1982, p. 107), interview provides "the opportunity for the researcher to probe deeply to uncover new clues, open up new dimensions of a problem and to secure vivid, accurate inclusive accounts that are based on personal experience". The quality and credibility of the interview was enhanced, by conducting it in person. This approach sensitised the researcher to observe verbal and non-verbal signals such as voice tones, gestures and facial expressions. The aim was to generally structure the questions to provide the interviewee (or informant) with the opportunity of giving additional information, perhaps not necessarily anticipated by the interviewer (Whyte, 1997). This potentially enriches an interpretative analysis.

To ensure that the interview questions were well designed, they had to be put to the test. The piloting of questions was vital in the preparation for data collection, enabling the researcher to put them on trial within a safe environment. In this way, issues were tackled, such as the questions' clarity and precision. Previously unanticipated problems, (such as actual interview lengths), were identified and improved. Thus, the interview questions for the main study were guided by the pilot study and validated by several sensitising concepts, i.e. alerting the researcher to central issues without committing him to reproducing the initial set of concepts. Sensitising concepts included boundary issues, knowledge sharing, knowledge seeking, knowledge integration and collective project learning. These sensitising concepts were developed from the researcher's contextual experience of the teams through extensive observation prior to interview as well as through extensive literature review. To ensure that the comments, resulting from piloted interviews, would reflect the views of actual interviewees, team members from other projects within the case organisation were used. They were selected because they worked in similar fields but were not subjects for the data collection. Another aim was to give the researcher practice in honing interview techniques, promoting confidence to conduct successful and well recorded sessions.

Overall, 31 people were interviewed at the two field sites. 16 belonged to the infrastructure project and 15 to the residential. Interviews embraced a variety of profiles, including seven architects, one quantity surveyor, four project managers, one structural engineer, two landscape architects, two environmental consultants, two civil engineers, two lands consultants, three interior designers, one sewage treatment plant consultant, four mechanical and electrical consultants, one pier consultant and a submarine pipeline consultant. The duration of the interviews varied between 45 to 180 minutes, with an average of about 90 minutes.

When structuring the interview, Whyte's (1997) approach was followed. Having initially ascertained a certain amount of demographic detail, the questioning then focused on how the team was organised and managed, with more specific attention later paid to the processes of knowledge creation during design development. The approach worked well, with the majority of interviewees remarkably candid and open when describing their way of working. This is reflected in the quotes used in the analyses of the cases.

All the interviews were tape-recorded and transcribed. The transcripts were summarised and sent to the participants to verify their accuracy and my interpretation of the interviews. Additional informal conversations were not recorded.

3.4.1.3 Direct Observation

Direct observation served as a useful tool for assessing situations and gaining familiarity with the procedures and processes that occurred in facility design development. It also yielded useful pointers, worth pursuing in actual interview sessions. Observing group interaction and discussions provided valuable information about the processes of knowledge creation in these teams, as well as facilitating the design of the study. Becoming a connoisseur (Eisner, 1991) of each team's process illuminated the conditions where each type of phenomena occurred. It also provided guidance to refine studying these phenomena as well as informing the interview process. The advantages from observation are outlined by both Creswell (1994) and Patton (1990) and include:

1) the researcher obtaining relevant first hand experience and understanding the context in which actions take place.
2) information being recorded as it occurs.
3) not relying on self reported data as is the case in interviews.
4) the opportunity to notice unusual events or recurrent features.

5) utility in quietly observing scenarios that may be uncomfortable for informants to discuss.

The work within the researched field is so dynamic and contextually based that no individual team member can accurately relate what happens in the team, or even simply describe their work activities. Because of the spontaneous and self-organising nature of the teamwork in both projects, actual observation was necessary, to help understand any individual's description of activities. First hand experience and appreciation of the environment facilitated asking focused questions and helped make sense of individual responses.

Direct observation covered both ordinary behaviour and disruptive phenomena occurring in team meetings. Direct observation implied taking detailed and descriptive field notes during the proceedings. Not only linguistic, but also non-verbal and spatial, behaviour was noted (Franfort-Nachmias and Nachmias, 1996). I recorded the context in which meetings took place - including such information as seating arrangements, team members present, room layouts, times of arrivals and departures, people's reactions to discussions and decisions, alternatives put forward, communication patterns and other important environmental conditions. I also took extensive written notes throughout these meetings with regard to my perceptions of the following:

- the project team at work - the way the participants work, what they do, the way they interact.
- design development and problem solving with the team.

- decision making within the team - who made the decisions, how they were reached?
- any relevant issues other than those identified above.

The senior project manager was present at most meetings. As a major sponsor of the research, he frequently reaffirmed my commitment to confidentiality and non-participant objectivity, encouraging attendees to ignore my presence. It is, however, difficult to assess whether my presence at any meetings significantly shaped or altered the discourse that occurred. There is always the risk that the researcher's presence might be seen as intrusive (Patton, 1990). Sensitive issues were discussed in meetings - new concepts or features to be added to the projects or potential selling prices for the residential development. Being privy to such confidences, one could assume that the meetings I attended were typical of those occurring regularly. In addition, regular attendance should have familiarised team members with my presence, possibly maximising the validity of the findings. Eisner (1991) points out that repeated observation may sensitise the researcher to phenomena that might be missed over a less rigorous schedule. Finally, the observation period was long enough to witness many informal, spontaneous interactions between team members. This was important since it provided opportunities to follow the unfurling of knowledge creation, outside the formal or informal meeting settings.

Permission to audiotape team meetings was refused by the senior project manager as he felt that meetings often contained sensitive and confidential discussions and issues. In addition, the client was afraid that the recording could become intrusive, possibly inhibiting open exchanges among team members. Notes from each meeting were transcribed shortly after each meeting.

Such observational data not only reflected the processes of knowledge creation but they also helped shape and focus the interview protocol. Observing interaction and discussion often identified areas to be probed during subsequent interviews. These, in turn, validated the data generated from observation.

With respect to both projects, meeting observations took place for a lengthy period of time before interviews were conducted. Many informal conversations were also held with team members. This gave rise to a good grasp of the issues and problems they faced as well as familiarising them with my presence, helping to alleviate any sense of unease they may have felt. A constant presence in all sectors was obviously not possible, given the temporal and physical constraints. Nonetheless, the level of access and support guaranteed by the case company guaranteed abundant interaction across both projects, enabling mutual trust to develop with the observed, albeit retaining an observer-observed relationship. Generally, the researcher assumed the identity of 'participant as observer' (Denzin, 1989), witnessing real life situations evolve during team meetings and beyond.

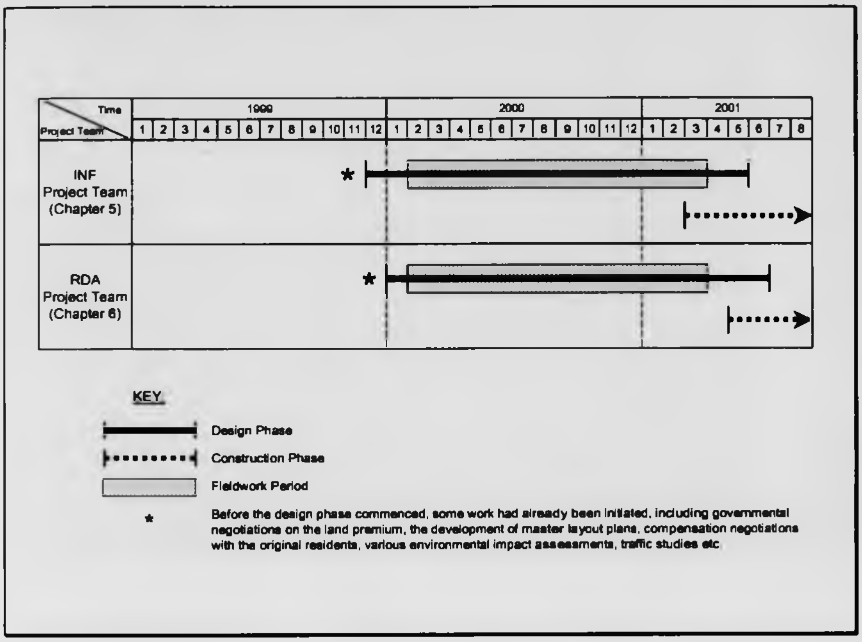
Overall, 62 formal and informal meetings on both projects were attended, with the detailed breakdowns of these tabulated in Table 3.2. The observed formal or informal meetings were conducted in person over substantial periods. A meeting lasted 150 minutes on average, each ranging from 90 to 270 minutes in length. Team-meeting observations served as an important forum to investigate issues such as the development of trust, knowledge sharing and collective learning practices. The nature and frequency of the meetings are listed below:

- Formal design team meetings occurred once every fortnight in the senior project manager's office. The INF project met on the first and third Tuesday mornings, with the RDA assembling on the second and fourth Tuesday mornings.
- Informal, design sessions occurred fortnightly in the architect's office. The INF project met on the first and third Wednesday afternoons, with the RDA conferring on every second and fourth Wednesday afternoons.

3.4.2 Data Collection

From similar start dates, both case projects ran concurrently over a similar time frame, further reducing problems of comparability. Bresnen (1986) suggests that the longitudinal approach served to reduce the impact of disparity as a result of cross-sectional designs. Not only did the two projects overlap during design duration but their actual development proceeded at an integrated pace on the island. Both the infrastructure and residential development projects closely shared design durations, with similar start and finish dates for the design work, each contributing to part of the integrated development on the island. The completion of the residential development had to coincide with that of the infrastructure development. The length and timing of the projects studied, together with the period of fieldwork involved in each, are given in Figure 3.1.

Figure 3.1 Project durations and periods of fieldwork



The key advantage of interpretative case research lies in its ability to capture complex interdependencies by handling rich sources of data and multiple forms of data collection (Easton, 1995). Fieldwork for both projects spanned February 2000 through to March 2001. The time period for this research was extensive, ending only with patterns and issues beginning to repeat themselves, becoming predictable. The unit of analysis under investigation was the total project itself, rather than the work undertaken by merely one of the professional service firms involved as part of that project. Compared with other more stable and static settings, such as manufacturing or any one organisational group or department, the boundaries for projects are more problematic, with a degree of consistency by no means guaranteed. In fact, the case study approach recognises this possibility by being responsive to the types of changes that can, and indeed do, occur over time.

For the purposes of this study, the 'boundaries' of the project tallied with the design phase of the facility. Due to the highly erratic involvement of team members, the 'boundaries' included those individuals most directly involved in the design phase, using them as key informants. From them, data were obtained on attributes and practices with some direct or indirect bearing upon the processes of knowledge creation. In both cases, these project teams appeared not easy to identify, as people joined and exited them at different times or phases of the projects. A more flexible approach was needed regarding the project team boundaries so that this variation could be allowed for. Typically, data collection would entail the following:

- prior to any encounter with project team members, it was essential to study project documentation and organisational records, gaining an initial understanding of the project, the team members involved, a history of the project and issues or challenges faced.
- the study had to be introduced and presented to the project team.
- direct observation was essential in both formal and informal team meetings.
- semi-structured interviews needed to be conducted.
- a second round of direct observation had to take place in both formal and informal team meetings.
- project documentation required detailed study.
- the project team had to be informed of preliminary findings, so that these could be validated.

Similar data collection processes were employed for both case studies. Due to the different meeting times, the researcher was able to study both cases concurrently. If any issues or problems arose, ad hoc meetings were also arranged. The senior project manager's secretary proved invaluable in informing the researcher about meeting dates, times and venues. After nine months of observing the project teams, individuals were interviewed at their own offices. Also the design concepts of the projects were reconstructed retrospectively using archival data and interviews with project team members.

3.4.3 Data Analysis

Following Huberman and Miles (1994), data analysis was devised as a dynamic, recursive process, occurring before, during and after data collection, entailing three linked sub-processes: data reduction, data display and conclusion drawing/verification. Data reduction activities involved selecting relevant data throughout the research process. A preliminary source of reduction was provided by the specific conceptual framework, research questions and study design, which guided the data collection process. During the data collection phase, interim analyses were performed drawing on the evidence and preliminary findings that emerged from the fieldwork. Interim analysis was crucial in keeping the amount of data collected under control. At the same time, it provided the criteria for further, more focused rounds of data collection. In fact, fieldwork was an ongoing process that lasted until being written up. Even then last minute details might require confirmation. Finally, with the bulk of information available, data reduction implied a set of activities aimed at further data selection and condensation. These involved combing through the transcripts of interviews and field notes to select foreground/background relationships according to the research questions, coding and clustering data by listing relevant themes and subsuming them under knowledge categories. The data reduction process employed the cross-site pattern comparison and clustering approach suggested by Miles and Huberman (1994), which included re-reading the field notes and transcripts, highlighting anything of relative interest to the research questions. All the excerpts were collected and identified by the positions and professions of the respondents. They were laid on a big surface, 'reducing' through pairing the similar or different highlights in the two research sites, as in Miles and Huberman's technique. Using matrix display, individual items were put into matrices headed by tentative 'themes'. Key multidisciplinary knowledge creation processes, generated from the clustering, were compared, and the contributory factors, influencing the processes in one or both of the sites, were also evaluated. A column was also reserved for those random items that did not seem immediately pertinent but that might be useful at a later stage. The matrix display was left in a formation where it could remain undisturbed. In that interval, the researcher gave careful consideration to the research questions - the conceptual framework as well as the ideas - regrouping the items or rewording the themes until connections or additions to the literature were seen. The categories under which the data was filed were not extant, but were developed over time.

Data display, defined as an organised, compressed assembly of information (Huberman and Miles, 1994), was performed on a reduced set of data and served as a preparation for conclusion drawing and/or action taking. It mainly implied writing descriptive reports to link emerging themes in a coherent account. Writing proved fundamental to making sense of material throughout the analytical process. Finally, drawing and verifying conclusions involved deriving meaning from displayed data through a variety of tactics suggested by the literature on qualitative methodologies.

These included pattern recognition, comparison and contrast, data clustering, use of metaphors and triangulation between different data sources. The above activities should not be seen as a sequential, but rather as a recursive, process linking induction and deduction cycles. As Huberman and Miles (1994, p. 431) have pointed out, inductive and deductive analyses are mixed:

> "When a theme, hypothesis, or pattern is identified inductively, the researcher then moves into a verification mode, trying to confirm or qualify the finding. This then keys off a new inductive cycle."

At the overarching metalevel, data analysis followed a two-level framework which linking description and interpretation. This turned out to be an exercise in making sense, aimed at progressively framing the complexity and equivocality of the data into structures of signification. In this respect, data analysis can be seen as a cognitive endeavour unfolding according to the distinctive data management and analysis methods described above.

Any particular issues highlighted as significant by interviewees, together with any anomalies or ambiguities that emerged, were further explored using data triangulation techniques (Burgess, 1991; Denzin and Lincoln, 1998; Yin, 1993). These techniques were used across interviews, with additional support for interviewees' comments being sought from a number of other sources - secondary data, observation at team meetings and informal conversations. After the data analysis had been triangulated and checked by members of both project teams, the next step was to compare the findings with existing literature to reveal and explain similarities and differences. As Eisenhardt (1989, p. 545) states

> "Overall, tying the emergent theory to existing literature enhances the internal validity, generalisability and theoretical level of the theory building from case study research ... because the findings often rest on a

very limited number of cases."

The names of the projects have been replaced with pseudonyms to ensure anonymity and to protect the confidentiality of participant views and opinions. Further promoting anonymity has been the omission of information concerning the project's actual location. In both cases, references were linked to team members' quotes to reflect their disciplines and positions within their respective organisations.

In the present study, findings from the data were compared with existing literature on team processes and knowledge creation in order to strengthen the theoretical scope and validity of the study.

The inter-case analysis is centrally concerned with exploring the patterns and processes involved in each project's knowledge creation within the context of issues described in the previous chapter.

All research procedures are highly context dependent and are shaped by the skills and expertise of the researcher. An interpretivist approach in particular does not strive for exact compliance between empirical reality and research results because it is acknowledged that data is as much constructed by the researcher as collected.

3.5 Generalisability of the Research and Limitations of the Fieldwork

Whilst acknowledging the inherent subjectivity of the research approach, the major findings derived from this analysis are expected to hold true for other project teams, focused on the design development of facilities that required a genuine multidisciplinary approach. Recognising that the broader considerations of societal, institutional and industrial effects have not been included in this research, the generalisability of the findings may not be extended to other industries or countries.

It was assumed, a priori, that it was not a matter of chance or accident, but rather by design, that project team members would actively attempt to facilitate processes of knowledge creation. However, the research aimed to develop a critical analysis that would stimulate debate about the possible processes occurring in the formulation of knowledge. In addition, the major findings aim to highlight the interrelationship of these processes together with the contextual influences upon the processes of knowledge creation that need to be noticed to be successful. It is important to emphasise that knowledge creation is inherently problematic and to a significant extent unpredictable. It relies on the interaction among project team members and we must understand that outcomes cannot be predicted and most importantly, to accept that success cannot be guaranteed. The major findings do not act as a positivist recipe for success. They aim to provide exploratory power for at least some of the processes, their interrelationships and issues that influence, but not determine, the processes of knowledge creation within multidisciplinary project teams.

It is also acknowledged that the results of this research could be further refined by conducting additional case studies in similar contexts. When negotiating access with this particular case organisation, the senior project manager mentioned a possible additional study to include the theme park development. Unfortunately, because of time constraints, it was not possible to conduct another case study. At the start of the data collection, there was little design activity in the theme park and this further dissuaded me from pursuing that project.

The 14-months spent conducting fieldwork on both development projects is the minimum time required to undertake a study of this scope and complexity. Whilst a lot of this time was not spent on the research site, the longitudinal approach contributed significantly to an understanding of the design processes as the projects progressed towards completion. An extended time period presented the researcher with the opportunity to observe changes in the way team members organised and worked. Despite the benefits of an extended research period, the analysis could have benefited from the conduct of additional case studies. At least two further case studies of multidisciplinary project teams plan to be executed in the near future.

Throughout this study, the researcher was confronted with a number of methodological challenges. These were mainly caused by the complex multidisciplinary nature of the study. There were two main methodological difficulties, attributable to the wide ranging literature available and the large amount of data collected and not utilised.

As the topic of knowledge creation encompasses a broad literature review, by implication the analysis in this study may be broader than in most other similar studies. Inevitably, the review and even the data analysis have provided a wider platform for discussion of this multi-faceted and context-dependent study and have also limited the depth of the analysis that this study could provide.

The amount of data collected from the study was vast - transcriptions of interviews, personal field notes, organisational and project documents and archival records were in the order of thousands of pages. As mentioned in the data analysis section, data reduction was a necessary and exacting task. It is likely that the potential of the data collected was not fully explored and exploited, partly because of the limited rationality of the researcher in handling the full data set, and partly because of the time constraints imposed by the PhD study. Potential themes overlooked for the above reasons will be addressed in future publications.

In the following three chapters, the case organisation and case study project teams are described and analysed. The analyses are structured according to the main objectives, which were to identify and characterise the processes of knowledge creation and their interrelationships - and to consider and reflect upon the issues influencing these processes.

Chapter Four - Facilities Development and Project Teams in the Case Organisation

4.1 Introduction

This is a case study investigating the processes of knowledge creation, their interrelationships and the issues influencing the processes within the multidisciplinary project teams of a large property development company. Its history and structure are presented in Section 4.2. For the sake of clarity, this company may henceforth be referred to as the **case organisation**. Section 4.3 outlines the two multidisciplinary project teams employed by the case organisation. The strategic design development concept is described in Section 4.3.1. Sections 4.3.2 and 4.3.3 are devoted to the background of the two infrastructure and residential development projects, located on a sparsely inhabited island. The organisational aspects of their project teams are detailed. Again for clarity, henceforth these projects may be referred to as **case projects**. Their interrelationship is described in Section 4.3.4. Section 4.3.5 highlights the various organisational and project practices of the property development company, the case organisation. Section 4.3.5.1 provides a detailed account of their construction and design expertise. Section 4.3.5.2 focuses on the selection of professional service firms to the case projects. Section 4.3.5.3 describes in detail the recruitment of project team members. Section 4.3.5.4 discusses the ramifications of working on single or multiple projects. Section 4.3.5.5 examines the characteristic features of both project team meetings, identifying the most commonly employed interactive mode of generating and creating knowledge. A summary of this chapter is provided in Section 4.4.

The data is collected from internal documents of the case organisation, the company's website, in-house corporate magazines and newspapers, annual and interim reports. Interviews were held with a senior manager from the Project Management department, as well as project team members from the two case studies. The independent observations of meetings serve as another source of evidence. The following section will detail the history and structure of the company.

4.2 The Case Organisation

4.2.1 History of the Case Organisation

Like many successful business entrepreneurs in Hong Kong, the founder of this particular company rose from humble beginnings and through sheer effort forged a career that ultimately helped drive the development of Hong Kong society. He began his career during the Second World War, trading in imported goods. At that time, Hong Kong was an entrepot serving mainland China. In 1937, he left his home-town in Guangdong Province, China, moving to Macau because of the Sino-Japanese War. There he set up a company with his friends, selling goods such as garments, textiles and medicinal balms, to the mainland market, relieving those shortages caused by the war.

The turning point in the founder's career came in 1954 when he became the sole agent for a Japanese brand of zippers. Hong Kong's garment industry was just taking off in the 1950s and zippers - a low-cost, quality item - gained popularity quickly. Sales boomed and his company went from strength to strength. Through the zipper business he became known to factory owners all over Hong Kong, building up a client base that would serve him well in his future forays into industrial property.

As the population grew, so did the manufacturing sector. Hong Kong experienced unprecedented economic growth, with thousands of new factories in operation by the end of the 1950s. Recognising the enormous potential of the local property sector, he joined forces with several like-minded peers (some also destined to become prominent property developers in Hong Kong) to establish a property development company.

Over a period of about ten years, starting with the Shek Kip Mei fire in 1953, Hong Kong was plagued by a number of severe typhoons and fires that robbed countless people of their homes. These misfortunes intensified the general desire for safe and comfortable living environments. As the local population continued to grow, further swollen by a stream of illegal immigrants from mainland China, a huge demand for residential properties was created.

The founder, together with his two colleagues, made his formal entry into the property sector in 1963, establishing an earlier development company. The founder owned 40% of the company and was its chairman, with the other partners each owning 30%. Upon the company's formation, the partners were known in the industry as "The Three Musketeers", a tribute to their seamless cooperation.

The growth of industry in Hong Kong generated a strong demand for industrial buildings, especially with the toy, plastic flower, wig and garment industries gaining international recognition. In time, the company was able to assume a leading position in the industrial property market, while also laying solid foundations in the remaining sectors.

In 1967, as the Cultural Revolution swept through mainland China, serious riots erupted in Hong Kong. This civil unrest triggered a severe drain on capital and the property market plummeted, with average prices for residential properties dropping to about HK$300 per square metre. Doubt and uncertainty reigned throughout this difficult period, but the founder retained his vision of the bright future that awaited Hong Kong. Recognising the opportunity to 'pick up what others discard' the company bought land at low prices. After the storm clouds dispersed, the property sector began to recover. In 1969, the average price of urban residential properties rose to some HK$800 per square metre.

The partnership between the three friends broke up in the early 1970s. The other two partners both went on to set up their own successful enterprises. In 1972 the founder began to restructure the original company, becoming its first corporate chairman.

In the early 1970s it became clear to management that the land supply in urban areas was limited, far below what would be needed to satisfy future growth in market demand. Upon this realisation, the company began the large-scale acquisition of both land and exchange entitlements for land in the New Territories. Despite a slump in Hong Kong's economy between 1973 and 1975, under the influence of global stock and oil crises, the company continued to purchase land in Hong Kong, paving the way for its future expansion.

In 1974, the completion of nineteen residential buildings and shops, became the prototype for future large-scale housing estates in the New Towns. Its completion also heralded a general move away from single residential buildings to extensive, well-equipped housing estates.

By the 1980s Hong Kong had already become a leading international centre in finance, trade and shipping. Local Chinese enterprises developed rapidly, with buoyant property and stock markets attracting an influx of international capital that helped launch the economy. By 1980, the company became one of the ten largest publicly traded companies in Hong Kong.

From 1982 to 1984 the crisis of confidence in Hong Kong caused by uncertainty over the transfer of sovereignty led many major companies to relocate their domicile overseas. The company resolved to stay in Hong Kong, purchasing more land and developing further residential projects, regional commercial complexes, hotels and other investment properties. Despite a weakened property market and poor investment environment, the company boldly broke ground by committing to a new residential development in the New Territories. Working alongside government in developing the New Towns, the company became the first corporate investor of note in Hong Kong's New Territories.

The founder of the company passed away in 1990, at the age of 79. He left a powerful legacy. His goals of 'speed, quality and efficiency', and his pragmatic, risk-averse approach to business, had long since become integral parts of the company's corporate culture. In November that year, the board of directors convened a meeting to address personnel changes, and voted to pass the torch on to the second generation of the founder's family. His eldest son, was appointed chairman and chief executive, while his second and third sons, were each appointed vice chairman and managing director. Under the new leadership, the company's strategy remained the same, with investment in the Hong Kong property market the main focus of operations. In recent years the company has also begun to venture into transportation, telecommunications and infrastructure projects. In 1992, the company began the gradual development of its business in China, with representative offices established in Shanghai and Beijing coordinating mainland operations.

4.2.2 Structure of the Case Organisation

The case organisation selected for this study is one of Hong Kong's largest developers of premium-quality properties. Listed on the Hong Kong stock market in the early 70s, it has about 18,000 employees. At the core of the company is its development of properties for sale and investment. They possess enormous expertise in land acquisition, architecture, construction, engineering, sales and marketing and property management. Complementary businesses include hotel ownership and management, insurance and financial services. Investments are widely placed in local transportation, infrastructure and logistics, as well as in information technology and telecommunications. Quality services and customer satisfaction rank as their top priorities, with award-winning property management subsidiaries overseeing their after-sales service.

The corporate structure is divided into Hong Kong and mainland China operations. The Hong Kong operation embraces Property Development, Property Investment, Property-related Business, Information Technology and Telecommunications, alongside Transportation, Infrastructure and Logistics. The mainland China sector focuses mainly on Property Development and Investment.

The company receives much world wide recognition, reflected in awards bestowed upon it as the best property company Asia-wide, additionally being applauded for its sound corporate governance and Internet site. Further honours cite it as Hong Kong's best managed company of the decade, resulting from excellent quality of service in the real estate sector. These honours were granted by Asian and international magazines, and through surveys conducted by local and international professionals and financial analysts.

4.3 Facilities Development and Multidisciplinary Project Teams

4.3.1 Strategic Design Development Concept

The island, where the construction projects were located, was formerly a tiny fishing village, with industries including fish farming, shrimp-paste manufacturing and a few seafood restaurants. It was covered with bamboo thickets, banyan trees and small banana plantations.

As advised by the senior project manager, there were three core concerns underpinning development: environmental issues, children's growth and welfare and healthy living. An environmental consultant was appointed when the project was first conceptualised. Extensive environmental impact studies were conducted throughout the design process and beyond, well into the construction phase of this massive project. A 200,000 square metres theme park comprising twelve thematic zones is to be built on the island, with the first phase scheduled for completion towards the end of

2002. The first phase of the residential development is to be completed mid 2002. The senior project manager stated that there had been a sudden upsurge in theme park developments during the year 2000, with developers now increasingly eager to include such parks in their residential projects. He added that financial analysts expected theme-park developments to not only encourage tourism, but also increase the value of the properties concerned. Such developments were likely to become a trend.

4.3.2 The Infrastructure Development Project (INF)

4.3.2.1 Background of the INF Project

This particular case study monitors the introduction of a complete system of infrastructure servicing an entirely new, small town on a hitherto underdeveloped island. The scope of the project embraces the construction of a new water supply system, with a submarine pipeline bearing water from the mainland to the island and a new water mains catering for the increased water supply. Also provided will be a service reservoir, water mains throughout the development and a private flushing water system. Storm water drainage and sewage systems (including sewers, sewage treatment plant and pumping stations/rising mains) will be also required. With regards to transportation, a new road system, including a slip road to an existing bridge, toll buildings and plaza and ferry piers for passengers and goods, will be constructed. The estimated passenger distribution would be 75% travelling by ferry, with the remainder using a bus service as agreed to by the government. Other ancillary services to be provided include a refuse transfer facility, gas installation, electricity, telecommunications systems, fire and police stations, as well as landscaping. Essentially the island will be transformed from its present underdeveloped state to one moderately developed, with modern facilities serving a new town, residential centre and ultimately a theme park.

4.3.2.2 Organisational Aspects of the INF Project Team

When the infrastructure project was first conceptualised, the case organisation (alternatively termed as '**the client**') started to look for professional service organisations within the construction industry to provide consultancy services to the project. The workforce of the infrastructure project team is generally educated, with professionally qualified construction personnel. They rely on their expertise and knowledge, rather than equipment or systems, to offer their services to clients. The professional consultancy services required for the infrastructure project were related to civil engineering, structural engineering, architectural design, quantity surveying, landscape architecture, mechanical and electrical engineering and environmental consulting. As there were a few special features within the infrastructure project, the necessary knowledge and expertise were beyond the normal range of the consulting firms. Consultants in the sewage treatment plant, in pier development and submarine pipeline design were later recruited to supplement the services required. The client organisation had in-house project managers to act as representatives on the project - as well as to act as a communication channel between senior management and the consultant team. In addition, they also closely monitored the work carried out by the external consultants to ensure that they were on the right track - as well as offering quality services to the client. From Table 4.1, it can be seen that all project team members except one had at least a Bachelor's degree in a professional discipline. All had extensive professional experience ranging from 3.5 to 22 years. Numerous consultants on the project had higher postgraduate degrees or had taught postgraduates in a technical or business related discipline. This high academic and professional profile reflected an expert workforce. The youngest team member was 27 years old, the oldest 47. They had served in their respective companies for periods ranging from 6 months to 15 years. Only one team member had worked in the same company throughout her professional career. The rest had had exposure to different organisational practices while working for various companies. In terms of length of service in their current position, the shortest had worked for one month, the longest for 10 years. The range of consultant seniority spanned from director to project staff level. Within the project team, the senior quantity surveyor was the only female. Most professionals involved in the project were members of their respective professional institutes, both locally and sometimes overseas. A number of team members had experience beyond their own countries.

Through professional education and training, all project participants had very specialised skills and knowledge. Such expertise placed them into very distinctive roles within the project.

The INF project team was diverse with regard to background, ethnicity, expertise and skills. The senior project manager and the architectural director, commenting on the diversity of staff and teamwork, stated:

> "Despite differences in professional backgrounds, everyone seems to get on well."
>
> "We have a diverse group of professionals working on the project and the knowledge and experience each possesses will be beneficial to the project."

Thus the INF project team appears to have pulled together a diverse team considered necessary for promoting knowledge creation (Nonaka, 1994; Spender, 1996a).

In addition, the project manager paid this compliment:

> "We got a good team of people - though we have no control on team members participating in the team."

This is a very common phenomenon for project teams in the construction industry, with professional service firms having full autonomy over their resources, i.e. who and how many represent their companies on different projects. In addition, each professional consulting firm often had their own supporting staff to assist their member(s) on the project team.

In fact, the INF team was self-managed, free to use whatever methods to achieve the project goal. Everyone interviewed agreed that consultants from different disciplines worked together in project teams, bringing together a multiplicity of expertise.

Team members shared their knowledge freely with each other, enlarging and amplifying their own knowledge base with a new awareness from different professional disciplines. At the same time, as observed in meetings, the team jointly created new knowledge in the form of problem solving and innovations to meet customer and end-user needs. This was manifested on many occasions. Examples included the joint effort in designing the police and fire stations, as well as the innovative idea of creating a distinctive infrastructure. In addition, the design of the infrastructure project would need to blend into the environment alongside the residential development and the theme park.

Due to the high demands of work and the diminishing fee level, consultants were required to expend considerable effort in applying their expertise and knowledge across multiple projects for different clients at the same time. Unless the clients changed their requirements dramatically during the course of the project, the professional fee remained relatively fixed.

It was not easy to identify who were members of the project team as people joined the team at different times or during different phases of the project. Table 4.1 revealed that some team members joined the project team as early as in 1992 whilst others joined as recently as 2000. The reasons for some team members becoming involved at such a late stage were either that they were replacing departing colleagues or that work was now at maximum output, thus requiring extra personnel. In this infrastructure project, there were so many components, from those above ground such as the police and fire stations, roads, etc., to those below ground like the submarine pipeline.

For other infrastructure projects, mostly procured by government, the principal consultant would be appointed to design everything in relation to the civil nature of the project - compared to this project, where specialist consultants were appointed to deal with different aspects or components. Each government facility would be designed individually, by separate teams of professionals. However, in this instance, the current client treated them all as part of an integrated project.

Table 4.1 INF project team

Nature of Job/Title	Gender	Age	Nationality	No. of years in present position	Length of service with present company	Length of service in own profession	Education	Professional qualification	Member of project team since
Architectural Director	M	43	British	4 years	11 years	14 years	Bachelor degree in Architecture	HKIA, RIBA, ARCUK, Registered Architect	Jun 1997
Associate Civil Engineer	M	43	Chinese	4 months	2.5 years	18 years	Masters degree in Transportation	MHKIE, MITE	Apr 1998
Chief Architect	M	38	British	6 months	3.5 years	10 years	Bachelor degree in Architectural Studies	RIBA, ARCUK	Mar 1997
Civil Engineer	M	31	Chinese	3 years	3 years	10 years	Bachelor & Masters degrees in Civil and Structural Engineering	MHKIE, MICE	Jul 1998
Deputy Architectural Director	M	39	British	2 years	8 years	12 years	Bachelor degree in Architecture	RIBA, ARCUK, HKIA, Authorised Person (Architect)	Apr 1994
Electrical Engineer	M	34	Chinese	4.5 years	6.5 years	10 years	Bachelor degree in Building Services Engineering	ACIBSE	Dec 1996
Executive M&E Engineer	M	43	Canadian	6 years	6 years	20 years	Masters degree in Business Administration	MHKIE, Registered Professional Engineer, (Ontario)	Jun 1997
Landscape Architect	M	27	British	3.5 years	3.5 years	3.5 years	Masters degree in Landscape Architecture	MHKILA	Jul 2000
Pier Consultant	M	47	Chinese	6 years	15 years	22 years	Bachelor degree in Structural Engineering	MICE, MHKIE, Chartered Engineer, Registered Professional Engineer	Jul 1999
Project Manager	M	35	Chinese	1.5 years	3.5 years	13 years	Bachelor degree in Civil Engineering	MHKIE, MICE, Chartered Engineer, Registered Professional Engineer	Jul 1997
Senior Architect	M	32	British	1 year	4.5 years	6 years	Bachelor degree in Architecture	RIBA, ARB	Mar 1996
Senior Environmental Consultant	M	33	Chinese	9 years	9 years	10 years	Masters degree in Environmental Studies	MIEnvSc, MIOSH, MIMgt, MInstE	Mar 1992

Nature of Job/Title	Gender	Age	Nationality	No. of years in present position	Length of service with present company	Length of service in own profession	Education	Professional qualification	Member of project team since
Senior Project Manager	M	41	British	10 years	10 years	20 years	Masters degree in Civil Engineering	MIStructE, MHKIE, Registered Professional Engineer, Chartered Engineer	Jan 1992
Senior Quantity Surveyor	F	N/A	Chinese	1 month	11 years	11 years	Diploma in Surveying	MRICS, AHKIS	Jan 1998
Sewage Treatment Plant Consultant	M	31	Canadian	6 months	6 months	10 years	Bachelor degree in Civil Engineering	MICE, MHKIE, Chartered Engineer, Registered Professional Engineer	Apr 2000
Submarine Pipeline Consultant	M	36	Canadian	2.5 years	2.5 years	10 years	PhD in Geotechnical Engineering	Professional Engineer	Jun 1998

N/A - Not Available
ACIBSE - Associate Member of Chartered Institute of Building Services Engineers
AHKIS - Associate of Hong Kong Institute of Surveyors
ARB - Architects Registration Board
ARCUK - Architects Registration Council of the UK
MRICS - Member of Royal Institution of Chartered Surveyors
HKIA - Hong Kong Institute of Architects
MHKIE - Member of Hong Kong Institute of Engineers
MHKILA - Member of Hong Kong Institute of Landscape Architects
MICE - Member of Institution of Civil Engineers
MIEnvSc - Member of Institute of Environmental Science
MIMgt - Member of Institute of Management
MInstE - Member of Institute of Energy
MIOSH - Member of Institute of Occupational Safety and Health
MIStructE - Member of Institute of Structural Engineers
MITE - Member of Institute of Transport Engineers
RIBA - Royal Institute of British Architects

Besides all the team members, the project was influenced one way or another by external and internal stakeholders, with major or minor stakes in the project which could affect the design outcomes and decisions. External stakeholders in the infrastructure project included the Marine Department; the Regional Services Department (now the Food and Environmental Hygiene Department); the Geotechnical Engineering Office, Civil Engineering Department; the Police Department; the District Lands Office, Lands Department; the Water Supplies Department; the District Planning Office, Planning Department; the Highways Department; the Environmental Protection Department; the Fire Services Department; the Metro Group, Planning Department; future end-users (represented by various government departments) and various consultants.

Internal stakeholders for the project included the client as well as various functional departments within the client's group. With some of the internal departments responsible for the maintenance of those portions retained by the client, their needs and requirements also had to be attended to. It could be seen that within the infrastructure project, the number of stakeholders represented was significant, requiring a constant and careful balancing of interests.

4.3.3 The Residential Development Project (RDA)

4.3.3.1 Background of the RDA project

The residential development is located on the north-eastern shore of the island, covering a site area of 130,000 square metres. Residential units will enjoy panoramic sea views. The development comprises 280,000 square metres Gross Floor Area (GFA). 8,000 square metres have been set aside for various commercial uses. There will be approximately 5,000 residential units ranging from about 50 to 200 square metres, with a choice of one to four bedrooms. The total investment is estimated at HK$15 billion. A seaside commercial complex along a beachfront has been planned to create an improved shoreline and promenade. Two recreational clubhouses and an idyllic landscape of paths, parks, gardens, plazas, sculptures and water features are also provided for the residents of this development. The interplay of architectural and natural elements lends the community cohesion, variety and a distinct identity, designed to boost property sales. It is intended to present this development as a resort-style, partly because of the location and partly, with such a distinctive image, to attract potential buyers. A similar development elsewhere proved to be successful in attracting a lot of expatriates and residents returning from overseas. It is hoped that the development will provide a sense of tranquillity and innovative living, away from the more frenzied pace of Hong Kong.

The development will span four phases over 5-6 years. The first phase of the development will be completed in mid 2002, with the first batch of 800 units (5 blocks) put up for sale in March 2002. The price is established at between HK$40,000 to HK$48,000 per square metre. Layouts and unit sizes will vary, ranging from 50 to 150 square metres. About three quarters of these units will have one or two bedrooms, the rest having either three or four. A limited number of 150 square metred, four-bedroom flats, with a balcony or rooftop, will also be available. The developer will launch the development in March 2002, coinciding with the near completion of the Phase One units. By then, the exterior of the property, with comprehensive facilities, landscaping and land and sea transportation systems, will all be ready for potential buyers to investigate. The completion date of Residential Phase One will be slightly ahead of the first phase in the theme park development.

With environmental concerns as central to the development, it will be the first town in Hong Kong free from car pollutants. The development will provide a 24-hour shuttle bus service using battery and liquefied natural gas as energy sources. A jetfoil service is planned to take residents to Central on Hong Kong Island in a 20-minute journey. Besides the sea approach, a slip road will be built to an existing bridge, along which residents can take public bus transportation to the nearby railway station.

The design evolution of the residential development was not a linear process. The project evolved, sensitively responding to shifting market needs. The gross floor area increased from the original 300,000 to 375,000 square metres, from 6 or 7 to 20 storeys. The number of flats also grew, from over 2,000 initially to the current number of 5,100. The number has almost doubled with a new design concept offering fewer large, luxury flats alongside a broader range of smaller apartments. The recent financial turmoil led to the developers opting for a variety of sizes to suit the market's altered circumstances and requirements. These changes influenced the site's layout and block arrangement significantly. Over 40 different layout plans were considered - some drawing on past experience, others responding to current needs.

The number of units and apartments should be established now with the construction work already underway on site. However readjustments could be made dependent on market requirements. If an economic upturn is suggested, the developer might favour larger flats being constructed. These in turn could be broken down into smaller flats should the economic outlook appear less favourable. Up to 200 units could be created or withdrawn pursuant to the perception of market sentiment. However, generally, with the construction of Phase 1 well in hand, previous planning needs to be adhered to, thereby minimising any risks in construction. The design of Phase Two will be influenced by the sales executed in Phase One.

In October 2000, the government announced a series of incentives to promote environmentally friendly architecture. It was hoped that a culture conducive to safer and greener designs would be encouraged within the community and building industry. Suggestions ranged from the greater use of wind to reduce air-conditioning demands, to larger window areas that could save on lighting costs, alongside the use of solar energy. Incentives would be introduced encouraging developers to exempt balconies and other 'green facilities' from the gross floor area in calculating any apartment's price. The vice-chairman of the company said that this particular residential project would be one of their first featuring green designs.

In order to compete within the industry, the case organisation created competitive advantages within the development that would appeal to the end consumer. Porter (1985) classified competitive advantage into three categories: cost advantage, differentiation and a combination of both. The client in this case could definitely not adopt the cost advantage strategy as their properties demanded prices consistently higher than those managed by their competitors in similar locations. The higher costs were usually the result of better quality construction as well as additional design concepts and special features. Thus management elected to engage the differentiation strategy, producing for their customers unique and valuable properties of superior product design, with high quality after-sale service and sound property management.

In terms of quality, the client was established as a leading developer in the property market in Hong Kong. In several recent sales, their property development had received high acclaim from customers, despite the recent economic recession in Hong Kong. Needing to woo urban dwellers from their high rise complexes and with a competitor also developing an island retreat, the project managers had to constantly encourage the team to include special and distinctive features that would raise the profile of the development and ultimately enhance its saleability. It was continually evident that all team members had this focus firmly in mind throughout the project's progression. Central to this fresh and distinctive appeal lay an overriding commitment to environmental concerns, child development and healthy living. Several interior designers had also been appointed to create special décor, not seen before in Hong Kong, throughout the project.

As promoted in the local press, the development had the further distinction of having no other proposed residential sites nearby. Thus the views enjoyed at the opening of the complex would not be obstructed. There would be no more development after the completion of the 5,100 units, with no reclamation or further construction encroaching upon the island as it was surrounded by important sea channels.

The architectural director stressed that the project team had invested substantial amounts of time and knowledge to produce the current layout plans.

> "We have developed or we've considered over 40 different types of residential layout plans - some were used in the past and others are new to this project. The experience and knowledge gained from this project will also be channelled into future projects."

Other team members echoed the view that past experiences and knowledge, gained from other developments, had been channelled into this project.

4.3.3.2 Organisational Aspects of the RDA Project Team

The team members in the residential development project team were all experienced construction professionals. The professional disciplines encompassed project management, interior design, architecture, building services engineering, structural engineering, lands consulting, environment consulting and landscape architecture. Due to the scope and size of this project, some consultants appointed were unique to this residential project. The client also engaged independent specialist consultants whose expertise could be beneficial to the project, rather than relying on the key consultant to provide these additional services. These included the interior designers and the landscape architect. It was not uncommon in projects of a smaller scale for the architects to also be responsible for designing landscaping as well as interior design. In addition, the client also appointed a property consultant with specialisation in land matters to oversee lease interpretation, lease modification, etc. For the project management service, the case organisation used their in-house Project Management Department. They played an active role in the development by attending most of the meetings, constantly monitoring the project's progress and having direct discussions with government officials on various issues affecting the development.

Since the residential development relied heavily on offering aesthetic value to the customers, this project had engaged several interior designer firms for different aspects of the development. The scope of the interior design was substantial and by having more than one interior design consulting firm, resources were increased with the design concepts and creativity enhanced. There were separate interior designers for the clubhouse, for the floor lobbies and main entrance lobbies as well as for toilets and kitchens.

> "Since this project is very large, it is not feasible to have just one interior designer to deal with all the interior design work." (Associate Interior Design Director - Residential Blocks)

She suggested that there needed to be multiple and shifting involvement in the interior design division.

> "Seven years ago, the client did not use external interior designers. They either used in-house or freelance designers - or the architect on the project would do the interior design. They later changed their approach by using interior designers for upmarket residential projects."

The current appointment of the interior designer for the residential blocks resulted from previous working relationships over a number of years. This applied to most of the interior design companies appointed to the project. The interior designers responsible for kitchens and toilets had to conclude this work, having been asked by senior management to concentrate rather on floor lobbies and main entrance lobbies. The work taken from them was later given to another interior designer.

The appointment of interior designers for the clubhouse was based on their reputation for designing resorts in the West Palm Beach in California, USA. With a very small office in Hong Kong, they tended to relay work back to their US office where they had more resources and experience. It was mentioned during a team meeting that this company was also carrying out some interior design work for one of the company chairmen.

From Table 4.2, it is revealed that most project members had at least a Bachelor's degree in a professional discipline, except for the interior designers and the assistant building services engineer. Several team members had obtained Masters degrees related to their own specialisations. They all had extensive professional experience ranging from 3.5 to 20 years. Their ages spanned 27 to 54. They served in their respective companies from 1 year to 12. Two team members had worked in the same companies throughout their entire professional careers. Their present lengths of service extended from 1 month to 10 years. There were quite a number of female team members including two lands consultants and two interior designers for the residential blocks. The majority of team members had earned professional memberships from institutes both locally and overseas. A small number of team members also had overseas work experience. This would allow them to bring different experiences and perspectives to the project. Team members joined the project at various times, some as early as in 1991, the most recent arriving in 2000. The later appointees were usually replacements for predecessors who had left their respective companies. The job titles of the team members ranged from those at director level to assistant project manager or assistant building services engineer. In fact, the title tended to reflect the experience and seniority the team members had in their respective companies.

Though team members all had very diverse knowledge, skills, experience and expectations of the project, the architectural director described the team as working well with one another.

> "This project team is friendly and people do understand others' concerns. Some good examples of teamwork in this project are - that there is a good mix of personnel on the project, they have common goals, with no major conflicts in personal characters. The project has been running for a long time, we have come to know each other. We know each other's characters after so many meetings." (Architectural Director)

Table 4.2 RDA project team

Nature of Job/Title	Gender	Age	Nationality	No. of years in present position	Length of service with present company	Length of service in own profession	Education	Professional qualification	Member of project team since
Architectural Director	M	40	Chinese	4 years	12 years	14 years	Bachelor degree in Architecture	RIBA, HKIA, Registered Architect	Oct 1991
Assistant Building Services Engineer	M	36	British	6 years	11 years	11 years	Diplomas in Electrical Engineering	---	Jul 1999
Assistant Project Manager	M	30	Chinese	1 month	6 years	8 years	Bachelor degree in Building Surveying	AHKIS, MRICS, Registered Professional Surveyors	Jan 1995
Associate Architectural Director	M	40	Canadian	3 years	8 years	14 years	Bachelor degree in Architecture	HKIA, RAIC, AIA, Registered Architect (Hong Kong) Registered Architect (New York)	Oct 1999
Associate Interior Design Director (Residential Blocks)	F	36	Chinese	2 years	11 years	14 years	Diplomas in Interior Design	---	Feb 1996
Associate Structural Engineer	M	39	Chinese	4 years	11 years	12 years	Bachelor & master degrees in Civil Engineering	MHKIE, MIStructE, Registered Professional Engineer	Jan 1999
Building Services Engineer	M	54	Chinese	3 years	3 years	20 years	N/A	N/A	N/A
Clubhouse Interior Designer	M	28	British	1 year	1 year	10 years	Bachelor degree in Construction Studies	Architectural Technician	Sep 2000
Development Surveyor	F	N/A	Chinese	2 years	2 years	4 years	Bachelor degree in Surveying	AHKIS, MRICS	Sep 1999
Interior Design Manager (Residential Blocks)	F	N/A	Chinese	3 years	3 years	N/A	Diplomas in Interior Design	---	Jan 1998
Lands Consulting Director	F	N/A	Chinese	3 years	3 years	14 years	Bachelor degree in General Practice Surveying	AHKIS, MRICS	Jun 1999

Nature of Job/Title	Gender	Age	Nationality	No. of years in present position	Length of service with present company	Length of service in own profession	Education	Professional qualification	Member of project team since
Landscape Architect	M	27	British	3.5 years	3.5 years	3.5 years	Masters degree in Landscape Architecture	MHKILA	Jul 2000
Project Architect	M	31	Chinese	1 year	1 year	6 years	Bachelor & master degrees in Architecture	HKIA, Registered Architect	Oct 1999
Senior Environmental Consultant	M	33	Chinese	9 years	9 years	10 years	Masters degree in Environmental Studies	MIEnvSc, MIOSH, MIMgt, MInstE	Mar 1992
Senior Project Manager	M	41	British	10 years	10 years	20 years	Masters degree in Civil Engineering	MIStructE, MHKIE, Registered Professional Engineer, Chartered Engineer	Jan 1992

N/A - Not Available
AHKIS - Associate of Hong Kong Institute of Surveyors
AIA - American Institute of Architects
HKIA - Hong Kong Institute of Architects
MHKIE - Member of Hong Kong Institute of Engineers
MHKILA - Member of Hong Kong Institute of Landscape Architects
MIEnvSc - Member of Institute of Environmental Science
MIMgt - Member of Institute of Management
MInstE - Member of Institute of Energy
MIOSH - Member of Institute of Occupational Safety and Health
MIStructE - Member of Institute of Structural Engineers
MRICS - Member of Royal Institution of Chartered Surveyors
RAIC - Royal Architectural Institute of Canada
RIBA - Royal Institute of British Architects

The interior designer of the clubhouse worked closely with the architects, finding them to be very open, resulting in close co-operation.

> "The good thing about the architects is that they're very receptive to ideas and they're always willing to give an opinion. So if we do have a problem I'd go to them and say 'we've done this, and this, does that work in with your plans?' ... We work very closely with the consultants to try and solve the problem so that everyone is happy with the result." (Clubhouse Interior Designer)

Besides the project team members and the client, there were other stakeholders involved both externally and internally. Internal stakeholders included the various functional departments of the case organisation such as marketing, property management, etc. External stakeholders included the future buyers and consumers, along with the various government authorities such as the Buildings, Lands and Fire Services Departments, etc.

4.3.4 Interrelationships Between the Two Case Projects

Both projects share an integral link. The infrastructure project provides facilities that serve the residential development in terms of transportation, fresh water supply, sewage collection and treatment, public utilities, etc. Without the infrastructure support, the residential development would not be habitable. Without the residential development, the infrastructure project would become meaningless. With such interdependence, the completion time of the projects must be closely monitored and co-ordinated. Because of this interrelationship, a senior project manager straddled both projects in order to address any interfacing issues. This joint appointment was authorised early on in the design development phase, minimising the risk of problems or issues arising in the construction phase. Careful monitoring of both projects was instituted, aimed at minimising negative knock-on effects. The senior project manager had thorough knowledge of both projects, acting as a communication channel between the two teams.

4.3.5 Organisational and Project Practices

The following sub-sections will highlight the organisational and project practices of the case company in terms of facilities development. They cover its expertise in the design and construction of facilities, its selection process of professional service firms, its recruitment of project team members working on single or multiple projects and the project team meetings. Practices common to both projects are covered under the following sub-sections, otherwise they will be described separately in later chapters.

4.3.5.1 Expertise in Construction and Design

The senior project manager attributed one unique feature of the organisation as having its own construction department carry out general construction work. For specific work, such as piling or foundations that require a special licence, joint-venture companies are usually formed with reputable externally contracted companies.

Because of their wide-ranging expertise, they have become more flexible than their competitors in the fields of design and construction. Generally speaking, during the construction stage, all design work is frozen, otherwise substantial claims from the contractor could be involved. However, since the property market in Hong Kong is very dynamic, this freezing of design prior to construction may not meet evolving customer needs. The end product may not entirely satisfy the consumer's altered perception. However, with vertical integration, the company can respond to sudden shifts in the market, making changes quickly to reflect new customer needs. In-house construction teams permit high manoeuvrability in delivering optimal products to the market. The senior project manager suggested that the company had an edge over competitors because they were more able to accurately predict customers' needs. Their corporate vision emphasised the importance of retaining pre-eminence through continuous improvement, innovation and meeting the needs of all stakeholders. The senior project manager felt further that the company realised its competitive strength to be in the effective and swift implementation of product launches. Once on the market, their competitive knowledge could be adopted by other developers. Thus there is an imperative urgency to be innovative in each individual project.

As general construction work is carried out in-house, the work is not tendered. The pricing is usually set by in-house quantity surveyors. Because the construction department is part of the development company, there tend to be fewer disputes on contractual issues or pricing, sharing management at the top of the hierarchy. The senior project manager stressed that these in-house contractors are very willing to participate in the early stages of design development. The contractors' input can ease some of the difficulties in construction caused by unnecessarily complicated design. Practical issues will be studied together with the project team. During construction, they will raise issues and make suggestions to help simplify the process. The senior project manager suggested an additional benefit to be that the quality of materials and workmanship is consistent with the standards outlined in project documentation. He suggested that contractors winning jobs through competitive tendering, may try to cut corners in order to realise profit despite an unrealistically low tender price. Potentially this was more likely in the current strained economy. Having their own construction workforce to realise the design work could well be a prime factor in the consistent success of the company projects, was his repeated conviction. However, he warned that the success of this formula depended on having a constant property development portfolio to sustain the costs of maintaining an in-house construction team.

The senior project manager found that knowledge accumulated extensively by the company contractors from past projects proved beneficial to future ones. He acknowledged shortcomings of this approach, with tender prices not necessarily as competitive as they could be in open contest with other contractors. Furthermore, by serving the overall company alone, the contractors may lack a full exposure to wide ranging projects as well as the latest technological and managerial developments in the industry. The senior project manager later added that, with his company well connected to the industry at various levels and disciplines, the issue of loosing touch with advances should not be of key concern.

Besides in-house construction capability, the senior project manager explained that the company also boasted their own in-house professionals including architects, structural engineers, quantity surveyors, mechanical and electrical engineers as well as project managers. Prior to becoming project managers, they have diverse educational/professional backgrounds ranging from architecture, civil engineering, structural engineering to building surveying. When a certain specialisation is required, an appropriate project manager will be assigned accordingly - e.g. the infrastructure project is looked after by a project manager qualified in civil engineering - whereas the residential development project is looked after by a project manager trained in building surveying. He would be well-versed in government submission and approval procedures, found to be important in residential development projects. He added that for modest projects, his company would use in-house consultants to carry out all the design work. However, on more complex projects, they would seek professional input from external consultants. These may have a more diverse portfolio of projects, with exposure to differing experiences by their professional staff. Such knowledge and insight should surely be of benefit. In addition, external consultants are used to working under tight schedules and heightened pressure and they can be more flexible in responding to a suddenly increased workload. In-house consultants may have more limited project exposure, affecting their commercial sense as well as design flair.

In terms of access to a vast knowledge bank fed into by a full range of professionals, the senior project manager asserted that the company had the overall advantage. He further suggested that to rely on sub-consultants could be less than optimal as they might have a more narrow supply of resources and skills to draw on. Independent and impartial professional advice could be compromised as sub-consultants might feel obliged to work according to the lead consultant's ideas.

The senior project manager explained that external consultants are used in both residential developments and infrastructure projects. It tends to result in better independent professional input from the various consultants appointed. However he stressed that conflicts or disagreements among them could be greater as they are all directly accountable to the client. Generally they would not solely focus on architectural ideas whilst ignoring other perspectives. As they are independently appointed, their aim is to protect the client's interests, offering design alternatives to suit the client's needs. The senior project manager felt this, from his experience in both the infrastructure and residential development projects, to be a better approach, with all consultants sharing an equal status. He said that though disagreements may arise on certain issues during the design stage, these could be resolved quite easily through dialogue amongst themselves and/or with the project managers. He did note some minor disadvantages, with consultants occasionally frustrated by the lack of commitment evident in some of their counterparts. He quoted an example of one consultant being consistently elusive, not easily contactable, frequently absent from meetings and unreliable in adhering to commitments.

4.3.5.2 Selection of Professional Service Firms

The senior project manager explained that in both cases, professional service firms were selected based on two criteria. His department has a regularly updated list of professional service firms eligible for future projects. Most were selected based on experience or expertise in particular fields - e.g. a firm of architectural specialists in residential projects had a greater chance of being awarded a specific job than other less experienced competitors. Firms were selected based on previous work relationships with the client. Over and above expertise and knowledge, past working relationships can be an important consideration. Former connections enable the consultants to know what it is like to work with particular clients, being already familiar with their standards and expectations. As revealed in team meetings and interviews, it proved important to know the client's preferences in terms of design or material selection. Most importantly, knowledge of those materials to be avoided, owing to poor past performance, is often not written down anywhere. Such practical knowledge is assumed through experience and through communicating well with client based personnel. Interviewees affirmed that former work relationships could shorten the learning curve required in any current project, with every property developer having distinctive methods of managing and conducting business. The senior project manager felt that previous work associations could accurately reflect company competence in any given field.

Several professional service firms in the infrastructure project simultaneously work elsewhere for the case organisation - there is the example of a pier consultant working on another project as a structural engineering consultant. This could further point to previous partnerships influencing the acquisition of future contracts.

Table 4.3 Professional services firms appointed for the INF and RDA projects

Professional Service Firms Appointed for the Infrastructure Project	**Professional Service Firms Appointed for the Residential Development Project**
Architectural	Architectural
Civil Engineering	Building Service Engineering
Electrical and Mechanical Engineering	Environmental Consulting
Environmental Consulting	Interior Design (Clubhouse)
Landscape Architecture	Interior Design (Floor and Main Entrance Lobbies)
Pier Consulting	Interior Design (Toilets and Kitchens)
Quantity Surveying	Lands Consulting
Sewage Treatment Plant Consulting	Landscape Architecture
Submarine Pipeline Consulting	Structural Engineering

4.3.5.3 Recruitment of Project Team Members

Having selected the professional service firms and after agreeing on the fees, individual companies will decide which and how many staff they will assign to the project. As suggested by the senior project manager, this is very much an internal staffing policy issue of the professional service firms, dependent entirely on the fee proposal submitted. The case organisation, in most instances, has little say in the selection of team members unless some serious personality clash had arisen between personnel in previous projects. Interviews with varying consultants indicated that two principal criteria appear to be used in selecting members to the project team. The first criterion relates to past and similar experience. For example, if a civil engineer has previous experience in sewage treatment plant design, he or she would be a logical choice for appointment to a team where this is a key requirement. However, there is a possibility that candidates suitable for certain teams may be irrevocably engaged elsewhere and unavailable for immediate involvement in any new project. With such scenarios in mind, some companies prefer not to allow too much specialisation since this can limit staffing flexibility. Moreover, should specialists leave, they take away a wealth of knowledge and experience that may be lost to another, rival consultancy. Some companies prefer to establish wide-ranging diversity in staff members so that certain employees have similar, mutually interchangeable capabilities and skills.

The different roles professionals play in a project also affect the knowledge required. For example, the client's infrastructure project manager had previously worked as a design engineer in a professional service firm. Technical ability became very central to this role, being required to use university and work expertise to design the projects assigned to him. Now in management representing the client, a more critical need arises for organisational skills, having to strike a balance between time, design, quality, cost, commercial or stakeholder issues, over and above the technical concerns alone. His focus has shifted, becoming broader. All technical matters in the project have the professional attention of the many and diverse consultants appointed to the team.

The second criterion used to select team members was that of availability. The associate architectural director termed this a 'pool system of managing staff resources' - whoever is available will be allocated to the team. Team members working on a particular in-house team on one occasion might not necessarily be on the same team in the future. He added that a consultant, at the final stage of project completion, could be transferred into a new team while trying to complete the current commitment. This consultant may or may not have the appropriate and relevant experience. In most situations, the company would not place staff into unfamiliar settings. The professional fee structure would agitate against any steep learning curve that could result, with low initial productivity as a potential consequence. From the company's point of view, preference would be given to those with previous and specific experience. Some companies prefer to have the same consultant serve the same client in order to maintain the client/consultant relationship. Such an association can be hard to hand on to other colleagues.

Most team members interviewed suggested that while still graduates undergoing training in their respective professional institutes, they had greater opportunity to gain wider experience. Once qualified, either they had been placed in a specialisation according to their interest and abilities, or they had been appointed to positions according to company demands. Of course, specialisation can build up a solid bank of knowledge and experience in certain types of project work. However, as voiced by several interviewees, boredom for the staff concerned can also result.

4.3.5.4 Working on Single or Multiple Projects

Except for the project architect, dedicated full time to the residential development, all other personnel interviewed - in both teams - had concurrent and part time commitments to several projects. These were located both locally and in China. Some shared common features, others were totally different. Numerous interviewees agreed that the wealth of knowledge, gained from current or past projects, could be recycled through similar projects. The ability of a team to share both positive or negative experiences and pool extensive expertise was further confirmed in team meetings. For example, the building services engineers in the residential development project suggested having a double wall construction to create a passage for maintenance personnel in the swimming pool area. This would have taken up more space, while significantly increasing the pool's building costs. The architect had worked on a similar project and shared his former experience and insight with the present building services engineers to tackle the issues of sustainable maintenance and costs. Knowledge gleaned from past projects was seen to benefit the present. In the end, a shallow trench design was settled on for the services installation, eliminating substantial costs that could have resulted from the proposed double wall construction.

4.3.5.5 Project Team Meetings

Throughout the two projects, there were a variety of formal meetings, such as project work, presentation, coordination and team meetings. Minutes were recorded. The names of the different meetings are self-explanatory. At the other end of the spectrum, design working sessions were used to generate informal discussion among consultants and clients. Both case projects adopted similar structures for meetings. Formal meetings were held once every fortnight in the client's office, with all project team members expected to attend and report on progress as well as any major issues affecting operations. Informal meetings were held once every two weeks in the architect's office. Those team members with design issues or conflicts to present to the team for discussion were requested to attend. As observed, while both project designs evolved, increasingly more team members were required to get involved in meetings. The duration of the meetings became longer.

Formal meetings for both projects were usually held in the client's office on a regular basis. They occupied the same large assembly room in the client's office each time, with quite a number of team members attending. The meeting atmosphere was usually formal, with minutes being taken generally by the civil engineering consultants in the infrastructure project or by the architects in the residential development project. Who actually recorded the meeting's progress depended on the nature and emphasis of the projects under discussion. The duration of the meetings ranged from 2 - 4 hours. The meeting usually examined previous minutes, then discussed issues arising, with new items added in as required. Formal meetings proceeded according to the different sections of work. Each covered costs, programme, submission, etc. The minutes recorded the design issues discussed and reflected the final decisions made.

Formal meetings were usually more structured than informal ones, with two-way communications between two or three parties. There were not many cross-disciplinary discussions in those meetings. The main discussions focused on the status of approval under lease, status of planning approval conditions, main contract preparation schedules and statutory submission schedules. The purposes of the formal meetings were to establish goals and targets for the project teams, e.g. when flats were to go on sale, so that team members could maximise their efforts to meet the target date. Milestones and goals were set for the project teams, making them fully aware of the major issues and providing an overall focus. The formal meetings tended to appraise the projects from an overall and more elevated perspective. Table 4.4 highlights the differences between the formal and informal meetings in terms of tasks and people attended.

Table 4.4 Formal vs informal meetings

Meeting type	Tasks	People attended
Formal Project team meeting/ design meeting	• Reporting • Global issues • Programme, government submission, approval	Management level - all professional disciplines were expected to attended
Informal Design working session	• Discussion and problem solving • Small issues • Technical issues	Working level - attended as required

All the meetings were conducted interpersonally as team members were located within Hong Kong. Occasionally team members were absent if other projects they were simultaneously working on were urgent or if they were out town. There were some consultants whose in-house team members were located in different countries. Examples included the submarine pipeline consultant in the infrastructure project and the clubhouse interior designer in the residential development project. They employed various media for communication purposes - including e-mail, fax and video-conferencing.

The informal meetings were used to discuss design issues and promote co-ordination among team members. No minutes were taken. However, people did take personal notes as a record of decisions made or as a prompt to investigate or clarify something. Occasionally, agendas were set in these meetings to guide discussion. Usually people were fully aware of the issues to be discussed as uninformed parties would not take part. At times with several issues to be discussed, individual team members would arrive at an agreed time to discuss their issues of concern and then depart. In some regards, the informal meetings were very free, with team members tending to discuss issues openly. Issues were tabled to get consensus and input from other parties.

In both projects, most informal meetings were held in the architect's office. Occasionally, they were held elsewhere, such as the landscape architect's office if the focus of that particular meeting was to discuss landscape issues. This flexibility as to locations was necessary in that often heavy materials were required for comment and discussion.

In informal meetings, it was very common for several discussions to take place at the same time. The meeting room and table, round which people would be gathered, were large enough to accommodate simultaneous conversations. Primed in advance, people would openly discuss different issues. No one would lead or dominate the meetings. People were not necessarily seated. People would come and go freely. The atmosphere was usually very relaxed with lots of occasional laughter.

Informal meetings tended to be less confrontational, with an emphasis on problem solving and dialogue. As explained by the senior project manager, the purpose was to facilitate the goals agreed upon in formal meetings. Since most professional disciplines were represented in formal meetings on global issues, the informal meetings were the more appropriate arena to resolve current and specific issues in smaller groups. In this way other disciplines' time was not wasted.

4.4 Summary

The history and structure of the case organisation have been described in this chapter, detailing the background of how the company was established together with their current business operations. The infrastructure and residential development projects, together with the organisational aspects of their respective teams, are clarified. The size and scope of the projects are revealed, along with the diversity and structures of the teams involved. The integral nature of both projects highlights the delicate relationship between them. Since both are initiated by the case organisation on this sparsely inhabited island, they hold organisational and project practices in common. These include their construction and design expertise, selection of professional service firms, recruitment of project team members and characteristic features of project team meetings.

In the following two chapters, analyses of the knowledge creation processes and their contributory factors in the infrastructure and residential development project teams are discussed respectively.

Chapter Five - An Analysis of the Knowledge Creation Processes Throughout the Infrastructure Project Team

5.1 Introduction

In this chapter, the knowledge-creating phenomena occurring within the infrastructure project teams (INF) during the design development are presented. The analysis is structured according to the theoretical literature and conceptual framework presented in Chapter Two, highlighting the processes of knowledge creation. When analysing the INF project team, the way team members interact to maximise knowledge sharing, knowledge integration and collective project learning is considered. However, other processes supporting knowledge creation in multidisciplinary project work will also be explored. The main goal of this case study is to illustrate the dynamic interaction of multidisciplinary team members - to gain a better understanding of the critical underlying processes faced, along with possibly a deeper insight into the contributory factors, pivotal in facilitating or inhibiting the creation of knowledge. The chapter concludes with a summary discussion of the processes of knowledge creation within this multidisciplinary project team.

5.2 Interactive Design Process

The team members found that the design process demanded optimally a high level of interaction through regular and ad hoc team meetings, both formal and informal, with consultants working together to resolve difficulties and develop innovation. They recognised that no one professional possessed all the requisite knowledge and so co-operative effort was needed to produce a favourable outcome. As illustrated by the civil engineer, this infrastructure design was very much a team effort drawing on diverse disciplines.

> "We need to work interactively on this project as no single discipline has all the knowledge required to design it."

A few members did suggest that certain past projects had been distinguished by a sequential design process, with one party completing a task before handing it on to other team members. The current project demanded a more integrative approach. The submarine pipeline consultant assessed the sequential design approach as less than ideal, with professionals pursuing their own perspectives without due consideration for others. He illustrated this by saying that he could have designed the submarine pipelines without regard for the contractor or other parties' requirements. He might have achieved optimal design in his own field but possibly not beyond. Other considerations could be overlooked in this rather singular approach.

The client had employed most of the consultants before design commenced. The senior environmental consultant considered this early appointment, together with the integrative approach, to be in the project's best interests. It was preferable for the expertise and knowledge of the individual consultants to be identified and integrated as early as possible.

> "In other small developments, once the input of other professional disciplines is established, we would be then asked to look at the environmental aspect ... For this project, with so many factors involved, most consultants considered an earlier involvement in the interactive process to be better." (Senior Environmental Consultant)

To achieve the most favourable outcome, it appeared that consultants should assume knowledge and awareness of fields other than their own.

> "We find that like many other professionals, environmental consultants need to step into other people's territories. ... For the sewage treatment

plant, there might be overlap with civil engineering." (Senior Environmental Consultant)

Some project team members were completely new to the field of infrastructure development whilst others had had some past experience. Some confirmed that the nature of this project was similar to ones previously engaged upon, with now ample experience in hand. In team meetings, it became evident that those experienced team members provided a fair degree of design input as well as extending advice, ideas or materials to other team members. The nature of this privately funded infrastructure project was unique, with many components joined together and as such, the problems and issues ahead might be highly specific and often unanticipated. Previous designs could be inappropriate. However, any team member with related experience had a less steep learning curve ahead, with a reduced risk of making errors.

In addition, different projects would have included shifting permutations of team members. This was no exception as it involved specialists in traditional roles, (for example civil engineering), as well as those in non-traditional roles, (such as submarine pipeline, pier construction or sewage management). This is in fact an important variable as different personnel present with a wide range of interpersonal skills. In many interviews, alongside professional expertise, social relationships were attested to as very important in any project's success. As highlighted by the architectural director,

> "Besides professional knowledge, good working relationships among team members are a must for the success of a project."

Some team members made very particular contributions to this project over a limited period of time, e.g. the submarine pipeline consultant. Other team members tended to operate throughout its progression. Appointing a wide range of consultants was designed to ensure that a solid bank of knowledge be devoted to its development. This was borne out by the contribution of their professional knowledge to different parts of the infrastructure project, with no consultants' expertise stretched beyond their professional arena. Team members confirmed that often in smaller projects, with costs in mind, specialists could not be employed. Team members would have to adopt these more specific roles. Thus an architect might assume responsibility for landscape design, with no specialist appointed to the project. Such a scenario holds a degree of risk. For example - had no specific appointments been made to the design and construction of the submarine pipeline, the designated civil engineer, lacking a more detailed awareness, might have laid the water pipes in a more costly, time consuming and less environmentally friendly manner. As the associate civil engineer confessed

> "We have limited in-house knowledge on submarine pipelines. Having a specialist consultant allowed us to have the right expertise in dealing with this unique task."

Team members found it necessary for all individuals to co-operate fully in order to understand the behaviour of designs more completely. They used this pooled knowledge to obtain a more holistic understanding of the infrastructure project. As observed in team meetings, integrated design input was often recorded in design objects such as drawings, sketches or models. In addition, joint design decisions were minuted in meetings.

Following the interactive design process, the following sub-section examines the possible hierarchy existing between client, consultants and contractor in this project.

5.3 Hierarchy of Client, Consultant and Contractor

With the design still in progress, the company's construction subsidiary had started to participate in meetings to advise on feasibility issues, such as whether or not it would be feasible to pursue particular designs as proposed by the consultants. This approach ran contrary to the more sequential tradition of design and construction where design work preceded construction work. The contractor's contribution in the design stage resulted from substantial expertise in construction, as well as an integrated perspective on design and construction. As revealed in a team meeting, the contractor's involvement in the design of a concrete retaining wall next to a slope of a proposed school site had resulted in the design being simplified which would eventually benefit the construction process. In addition, it was observed in several team meetings that system formwork[6] had been considered by the project team, requiring good coordination in the design details before the concrete formwork could be systematised. This proposed construction would enhance modularisation and standardisation as well as the resources used. By adopting this approach, the hierarchical barrier could be broken down between consultant and contractor teams. Below, the project manager summarised the changing emphasis in terms of their relationship and hierarchical distinction.

> "Present (name of the case company's) values to all the consultants and make them aware of the company culture. Both consultant and site teams need to learn how to overcome tensions as the site team belongs to developer. They understand the principle of 'speed, quality and efficiency'. When the site team sees something that can be improved, they will speak out and not give any face to the consultants. The consultancy team is not superior to the site team. They need to collaborate. As project manager, I need to explain to the consultants about our culture. We are a 'design and build' company. Design and construction are of equal status. This involves some attitudinal change. Mutual respect and understanding are the only paths to success - that's the way to deliver a quality product."

[6] Formwork is usually constructed of timber or metal where it will be fixed in position before concrete is poured into its desired shapes, based on the shapes of the formwork.

Generally it was evident that the client was very receptive to ideas, especially new ones. They welcomed input from the consultants, believing that different team members possessed different strengths beneficial to the project. In addition, they believed that new ideas to the infrastructure design would make it distinctive from others as well as enhance the image of the whole development on the island.

While interviewed, the senior architect commented that he still saw the architectural profession assuming a lead role in the building portion of the project.

> "There are buildings within this infrastructure. They are as important as the civil engineering portion. Anything involving buildings will see us as lead consultants."

This in fact reflected the difference in status among consultants, as perceived by some personnel who viewed the architectural profession as possessing higher status than other construction professions.

5.4 Previous Work with the Client, Other Consultants and on Similar Projects

Table 5.1 tabulates the data of individual consultants, their previous working experience with the client and other consultants, or similar projects being currently undertaken. Though about half the consultants stated they had no previous dealings with the current client personally, they asserted that their companies might well have provided professional services before. Team members occasionally mentioned projects in meetings that their companies had shared with the current client. One team member found the current involvement was due to a previous engagement with the client on another project. Both sides knew how they had performed earlier on which was especially important for consultants as they learnt the client's standards and requirements. The literature confirms that effective team building requires individuals to share experiences of working together (Eurich, 1990; Goodman and Associate, 1986; Guest, 1986). For example, the pier consultant stated:

> "I believe this is one of the reasons that we were appointed. We had worked with them on other projects before, not related to piers. They were quite satisfied with our performance. For this critical project, they were confident that we could do it, so they contacted us."

Because individuals have a work history they develop a high level of trust between each other. They know each other's strengths and weaknesses. This allows them to leverage their strengths to tackle the tasks at hand (Carnevale et al., 1990).

Table 5.1 Previous work with the client, other consultants and on similar projects

Consultants	Previous experience with client	Previous experience with other consultants	Previous relevant experience
Associate Civil Engineer	✓	✗	✓
Chief Architect	✗	✗	✗
Civil Engineer	✓	✗	✓
Deputy Architectural Director	✗	✓	✗
Electrical Engineer	✓	✗	✗
Executive M&E Engineer	✗	✗	✗
Landscape Architect	✓	✗	✓
Pier Consultant	✓	✗	✗
Project Manager	✓	✗	✓
Senior Architect	✗	✗	✗
Senior Environmental Consultant	✓	✓	✓
Senior Project Manager	✓	✗	✓
Senior Quantity Surveyor	✗	✗	✗
Sewage Treatment Plant Consultant	✗	✓	✓
Submarine Pipeline Consultant	✓	✗	✗

The landscape architect explained that the good social relations acquired in a previous project had familiarised him with the working style of team members whom he was to work with again on this project.

> "When I first joined the company, I was put on a project that worked with the current project manager. We know each other, especially understanding each other's working style."

In addition, the consultants' previous work experience enabled them to understand the client's main priorities, especially when matters of some urgency arose.

The pier consultant discovered many positives in having had previous work experience with the current client.

> "Our experience with the client guided us as to what the client's views would be on major issues as well as minor ones. Their major focus is to have the pier completed by July 2002. We know their deciding and most pressing factor is time and not anything else in this task."

This project differed from others through its private nature. Most infrastructure projects would fall under the jurisdiction of the government. This gave rise to certain distinctions that project team members needed to be aware of.

Only a small number of consultants had prior shared work experience on the team. Even with previous exposure to a particular firm, the personnel of that firm might have been different. Such experience, however, did engender a certain familiarity with specific company practices and outlook. Generally, because of the many diverse consulting firms on board, there tended to be several consultants who had not worked together. Most team members found there to be more advantages than disadvantages in sharing previous experience.

> "If you worked on a similar project before, you'd know how to approach the design and what elements need to be included. What are the scopes of the project? It's useful experience. On the negative side, the previous design solutions may restrict your thinking. But I think there are more positive influences than negative." (Landscape Architect)

Though some team members had no infrastructure project experience before, they found that even experience obtained elsewhere was useful in this instance. The chief architect found that though he had had no experience relating to piers and commercial complexes, his previous retail design, both in Hong Kong and the UK, was relevant to the development of the beach's commercial complex. His knowledge of food court design proved especially useful.

Several team members agreed that knowledge transcended specific projects, with the senior project manager saying:

> "Knowledge is not project-specific. It is indeed a methodology. It can be used in other projects."

In summary, some consultants shared prior work experience, possibly even with the client, whilst this was the first time for others. Those with previous client experience felt it helped them understand client expectations and standards. Familiarity with multiple working styles also facilitated the transfer of knowledge and ideas within the team.

5.5 The Process of Knowledge Sharing

5.5.1 Socialising with Other Project Team Members

> "Socialising can generate and promote insight into projects." (Project Manager).

And yet, as related by many interviewees, not many social activities were organised for project team members during lunch or after work. This mild criticism of the project's operation is surprising when one considers the strong body of evidence promoting social systems within the workplace.

Socialisation is a valuable mode of creating knowledge within organisations (Nonaka, 1994). It is a way of creating sufficient levels of congruence to enable individuals to understand each other and work together towards common goals but from different perspectives (Saint-Onge, 1996). Team members shared the benefits of socialising with other members within the team:

> "Through social activities, in mentioning a particular and currently pressing problem, colleagues may provide suggestions to me, similar to brainstorming. It depends on whether you are willing to ask and discuss." (Civil Engineer)

The executive M&E engineer found that:

> "It is possible to share knowledge during social interaction - usually people are willing to respond by offering global concepts as solutions. For fuller details you will find these out in due course."

Communication and social interaction were considered as important components of design development. Team members developed contacts with people in a number of formal and informal ways. They indicated that socialising was a good way of networking. These activities allowed one to get to know other people and interact on a more casual basis. They found that a basis of friendship was invaluable if ever requiring new information or advice.

It was invaluable that consultants came from different backgrounds and different projects, that they offered different perspectives on any one situation - in this case, paving areas. From the landscape architect's experience and general observation, he said that most developers in Hong Kong used 'stone' material for paving except one developer who used 'spray paint' on concrete surface. Such competitor knowledge was important in giving advice to the current client without divulging his clients' identities and hence retaining customer/client loyalty.

In team meetings, members were not embarrassed to admit a lack of knowledge, especially if in another discipline. Most team members said they were quite prepared to offer suggestions and solutions to people in other disciplines. By the same token, they were generally happy to receive counsel from others. When interviewed, one team member did admit to guarding his professional boundaries very seriously as he saw himself as the expert in that discipline within the team. He considered himself professionally qualified in the field, with proper education and training as well as many years experience. There were others who considered it impossible for one specialist to possess all the requisite knowledge. The overall conclusion was that the various team members each brought to the project a range of information and experience. When pooled and combined, these proved to be extremely helpful and productive to the development of the project as a whole.

5.5.2 Sharing Positive as well as Negative Experiences

All the team members interviewed agreed that personal experience was a most important element in construction consulting. They shared a common reliance on personal experience to facilitate the resolution of current problems or issues. For them, experience was tacit knowledge, stored in an individual memory until replaced or modified by new experiences. The senior project manager summarises:

> "Experiences gained in the past must be used - as you know whether they work or not."

It concurred with the findings of many interviewees who proposed that should they lack experience on a certain type of project, they could often transfer principles or knowledge gained from other project types.

The submarine pipeline consultant commented that experience was accumulative, increasing with age.

> "I think you have to remember everything, as much as you can from your past history, and bring it all in. That's what makes us valuable, more and more valuable as we get older. We have all this experience in our minds of what works and what doesn't." (Submarine Pipeline Consultant)

Experiences gained by each team member could be both positive as well as negative. Negative experiences were also vital for individuals, reminding them not to repeat certain things in the future. Many interviewees agreed that failures or negative memories tend to be retained more keenly than positive ones. This was echoed in the personal observations of the electrical engineer and the sewage treatment plant consultant. Consequences inevitably ensue that caution a person against repeating the mistake.

> "I remember all the good experiences. For those projects with mistakes, the impression left is very deep. For the good experiences, I feel proud when I see the building completed. For the bad ones, I will remember them deeply." (Electrical Engineer)

> "The successful cases I do not remember, but failed cases I always remember deeply." (Sewage Treatment Plant Consultant)

The pier consultant stated that he employs negative experiences to reflect upon and learn from:

> "In engineering, actually past experience is very important, very commonly drawn on. For negative experience, we will make sure that it will not to be repeated. In a way, the negatives encourage you to think

> about the reason for the failure. After knowing the reason, one will not repeat it again. It is very natural for engineering practice to be based on past experience."

He tended to use a negative experience as a lesson. Through considering the reasons for any failure, one could avoid a recurrence in the future. This, he felt, could be applied to all walks of life, not just the engineering profession.

5.5.3 Contributory Factors

5.5.3.1 Openness

Openness implied a willingness among team members to communicate and interact with one another. It has been stressed numerous times that construction design is a multidisciplinary task involving many professional disciplines. It heavily relies on the sharing of knowledge among team members, eventually resulting in a workable design to satisfy all or the majority of stakeholders' requirements. Openness influences the transfer of knowledge between partners (Lane and Bachmann, 1998). The open attitude of the project managers towards new ideas and contributions across professional boundaries set precedents for all consultants to open up themselves. Again, openness also related to whether team members were willing to contribute knowledge and experience learnt in other professional disciplines within previous projects. By the same token, such receptivity should be prevalent when encountering ideas or experiences unheard of before.

> "As a team, if anyone has a contribution, they need to speak out. I don't want people to contribute within their own professional boundaries only." (Senior Project Manager)

Team meetings revealed members to be open in sharing their ideas, knowledge or experience. Examples in this project included personnel openly sharing their knowledge and opinions on the pier design though not many of them had actual experience. This was especially noticeable in informal meetings like the design working sessions, when team members came to the architect's office, with the common goal of problem or conflict resolution. The atmosphere in the meeting was generally very relaxed. The informal work environment meant that people were free to move around in small cluster groups, to discuss issues that required input and coordination. References and materials were shared. These meetings were used as a forum for resolving issues and avoiding potential problems. In addition, the tight design schedule also had some positive impact on the openness of team members as time constraints agitated against duplicating information or carrying out unnecessary design work. Any shared work experience, if positive, could further enhance openness (Lane and Bachmann, 1998; Rotter, 1980).

Openness seems to impact more on the sharing of tacit, rather than explicit, knowledge. In the INF team, members indicated that openness was essential for sharing experiences, particularly tacit as this often resides in people's minds.

Explicit knowledge sharing, on the other hand, seems to be less dependent on openness and more dependent on technology. Team members noted that technology helps transfer and exchange documents (technology supports the open flow of explicit knowledge). Findings from this case would suggest that an open environment is the key for experience and in-depth knowledge to be shared. The case organisation was experimenting with a project intranet in-house that could be extended to all project team members from different organisations. When interviewed, the senior project manager foresaw the benefits of having such a system for managing the project as well as sharing knowledge. His greatest concern, causing the system to be not yet available to all team members, was security as confidential information, to do with pricing or finances, could be divulged to competitors.

The project manager's office held departmental meetings once every fortnight. Each session a topical issue of recent interest would be covered. A nominated person would collect and present all relevant information and chair the meeting. Any persons attending the meeting could share their experiences. Information collected as well as experiences shared would be recorded and placed in the department's library for future reference. These meetings demonstrated that openness was important for knowledge sharing to be successful.

5.5.3.2 Motivation Linked to Sharing of Knowledge

In a project team linked to infrastructure, generally it was expected to share expertise and knowledge with other team members without reward. Any reward system for knowledge sharing in a multidisciplinary project team would be rather difficult, with individual incentive schemes eroding teamwork and trust, potentially setting people against one another (Pfeffer, 1998).

Team members found other ways of motivating themselves to share knowledge with others. Their sense of professionalism spurred them on greatly. This in fact could agitate against an incentive system as much satisfaction was generated from the pursuit of knowledge and excellence for their own sakes.

Comments were made by various team members as to how they derived rewards for their sharing of knowledge and experiences:

> "Reward of sharing knowledge - being very happy if people listen to you." (Project Manager)

> "If you share an idea with someone and they listen to you and do something your way, it's a kind of reward. At least you have convinced him to follow your way, to take up your idea." (Executive M&E Engineer)

> "People find you have experience to resolve a particular problem - and they respect you - it is a kind of professional status. That is in some sense a kind of reward." (Deputy Architectural Director)

These sentiments seemed to express a certain personal satisfaction resulting from the sharing of knowledge with others. This was often achieved through their professional expertise being recognised and utilised by others. Further gratification could result from praise and expressions of respect, as well as from the intrinsic satisfaction of resolving a problem others found difficult. In addition, the deputy architectural director found sharing knowledge to be contagious, with such open practices influencing others to follow suit.

> "When you share ideas or experience with somebody first, you will influence him or her and they will also start sharing."

Since the consultants were monitored constantly by the project managers, any positive contributions would be relayed to their seniors within their respective companies. Thus career prospects could be considered as important motivating factors in the sharing of knowledge and expertise.

All team members said that not one company had performance evaluations that acknowledged helping and sharing knowledge as valuable. This could be because such a practice was assumed to happen naturally among professionals.

5.5.3.3 Trust

The literature on trust in self-managed project teams and between professionals suggests that high trust relations are characterised by altruistic and help-seeking behaviour, demonstrating the existence of affect-based or unconditional trust (Jones and George, 1998; McAllister, 1995). Team members on the infrastructure project were constantly engaged in help-seeking behaviour. The nature of infrastructure design work meant that knowledge from a broad range of professional areas was often required.

As trust was built up among the team members, it enhanced the knowledge base available to the project, potentially enhancing the knowledge sharing process. Trust is seen as a vital 'lubricant' of knowledge sharing (Scarbrough and Swan, 1999). Through observations, team members were found to freely share their knowledge with others in cooperative and collaborative ways, even though at times there might be debate on design issues.

The senior project manager commented that trust and friendship were built up on the project, often with lasting effect.

> "We have known each other for a long time through the project and have built up trust - like friends."

> "I got to know other team members through this project. The friendship and links will maintain."

It could be seen that trust grew through the working process, enhancing work relations among team members.

5.5.3.4 Time Pressure

"It is easy to share knowledge but not time." (Project Manager)

The interviews indicated that the major barrier to knowledge sharing was time. Most team members agreed they generally trusted people in the team. Since the project had a very tight design programme, team members were trying to cope with their own work whilst exchanging experiences and knowledge. Any delay would have adversely affected the tendering process and the eventual start date on site, along with the progress of construction. In addition, the infrastructure project was interlinked with the residential development on the island. Both projects needed close monitoring, as the delay in one would have tremendous impact on the other. As each consultant was hard pressed, the amount of time they could make available for sharing knowledge was significantly reduced. In addition, the human resources on the project were thinly spread. On the establishment list, the architect team appeared to be the only one with several personnel attending meetings. Manpower being so stretched, team members sometimes came to meetings with previously assured deadlines not fulfilled. Occasionally, the project managers would remind consultants to put more staff on the project as the design work was in full swing. It was later found that, despite several reminders on staffing levels, consultants occasionally still made no improvements, resulting in the senior project manager threatening to speak to their relevant managements. It could be frustrating for other team members, often waiting for inputs from elsewhere which affected the progress of their work.

Team members were working concurrently on several projects for their companies. The time that they could devote to this project was qualified by their other demands. This multiple team membership could drive the consultants beyond their work limit.

Some mentioned during interviews that it was not because they did not want to have new improved design solutions, but time constraints had forced them to rely on previous designs for the current project. With the very competitive professional fee level among firms and the number of projects each consultant was involved in, the associate civil engineer expressed the opinion that consultants quite often worked on projects with very limited human capital. He used one consultant working on the project to illustrate his point. This appeared to affect the design of the project as well as the performance of the team.

5.6 Joint Site Visits as Collective Experiences

Several aspects of the infrastructure project, usually the preserve of government departments, were new to team members. Accordingly several site visits were organised to newly completed and fully operational police and fire stations, along with reservoirs. It was thought that this could facilitate design experience from witnessing the finished products. All team members saw site visits as a way of acquiring new design knowledge. The joint events contributed to a collective experience, helping build up knowledge redundancy within the project team.

> "The architect arranged for us to visit police stations, fire stations and reservoirs as the design team did not have experience in designing these. They are usually designed by government departments themselves." (Electrical Engineer)

The traffic control and management were particularly new to the client project manager, dealt with by government in other infrastructure projects. He organised a site visit to a similar project belonging to a competitor. The willingness of this rival firm to share knowledge was due to the fact that they did not have to divulge anything confidential - the field trip was purely technical.

> "For the traffic management, we went to another island development (belonging to a competitor) for a site visit. We learned things we didn't know from that project." (Project Manager)

The architect had organised a site visit for other consultants to a neighbouring pier. The aim was to learn how the pier was designed and constructed. Photographs were taken to capture design details serving as a reference for the current project. The project team also obtained information about the pier's operational details.

> "We had site visits to existing piers to learn how other consultants designed them." (Electrical Engineer)

They further identified possible deficiencies and thus areas for potential improvement within the current design. Beyond existing requirements, the new pier placed emphasis on environmental issues and amenities, resulting in landscaping on the rooftop, to be used as a leisure venue, unlike existing piers with restricted roof access.

5.7 Generating New Knowledge

As each new facility would pose new challenges, team members generally needed to generate new solutions to situations they had not encountered before or find new solutions to related problems. As each design problem was unique, it was seldom for existing solutions to be re-used totally without any amendments.

The case organisation constantly demanded innovative insights from the project team in order to create a distinctive image of the development by using non-standard designs. Though some sectors of the infrastructure project, such as the police and fire stations, the submarine pipeline, the sewage treatment plant, roads, etc. would be handed over eventually to various government departments for maintenance, the combination of fresh insights and complementary resources might generate a unique infrastructure development that matched other developments on the island such as the residential development and the theme park. It appeared that sustainable competitive advantage might accrue to an organisation able to combine its resources in particularly valuable and not readily imitated configurations. The ability of the firm to generate new combinations of existing knowledge and to exploit its knowledge of the unexploited potential of technology is what Kogut and Zander (1992) describe as 'combinative capabilities' and what Grant (1996b) describes as 'organisational metaflexibility'.

There were several novel areas in the infrastructure design. The first was the pedestrianisation concept:

> "Government has just started to look into the issue of pedestrianisation and they have conducted a fair amount of research. As one of our major clients, with good working relationships, we were able to obtain some information from them as well as drawing on the overseas experience of the landscape architect. We blended past experiences together to produce the scheme for the current project." (Civil Engineer)

The second was the sewage treatment plant:

> "Most sewage treatment plants are designed and built by the government. Most consultants and contractors in the market are usually involved in small sewage treatment plants. For this island project, we need a medium size as we have a fair sized population - there is no similar one in Hong Kong. They are either large sizes for a new town or small sizes for a housing estate. With no past experience, the design team needs to spend time and effort to source information and knowledge - how to design it so that it will be accepted by government. (Project Manager)

The third, widely agreed among project team members as technologically innovative, was the submarine pipeline. The consultant spoke of his experience using the horizontal direct drilling method (HDD) for the water mains as

> "... state-of-the-art crossing as it is the longest in the world into hard rock, as well as the largest diameter."

It could be concluded that new ideas had been generated to resolve design issues and problems as well as make the infrastructure design unique from others.

5.7.1 Contributory Factors

5.7.1.1 Time

Again, time was a critical issue in the generating of knowledge. Faced with a pressing project, team members might not be able to source all possible knowledge before reaching a final decision. They might rely on previously applied solutions, lacking the necessary time to discover more suitable remedies. The senior environmental consultant illustrated that time constraints could preclude a thorough search to identify the most appropriate information.

> "Generating new knowledge to this project depends on how much time you have. If you have no time, even if you want to, you may not be able to do a good job. I can say that we are very willing to generate new knowledge but time is a major problem." (Senior Environmental Consultant)

5.7.1.2 Motivation

> "My company demands new ideas." (Senior Project Manager)

The motivation behind the search for knowledge includes the most obvious drive to identify and develop new ideas for the project. Another source of motivation appears to be the resultant satisfaction from meeting new challenges:

> "My thirst for new challenges and new knowledge." (Submarine Pipeline Consultant)

> "When you come across something that you don't fully understand - e.g. the lighting for the covered walkway shining from the bottom rather than the top - having no such knowledge, you need to then search professional journals on completed design/projects both in Hong Kong and Britain and even talk to the landscape architect. Through using these sources you may get solutions, and the satisfaction from this would be great." (Electrical

Engineer)

5.8 Knowledge Sources

INF team members indicated that they used their own personal and extended networks to acquire relevant information and knowledge. Individuals generally sought out the information and knowledge needed to get their work done and develop their expertise. They had a wide range of strategies for achieving this. Some team members suggested that knowledge generated by outside experts, through lectures or similar channels, was one avenue. Some maintained contact with old classmates, ex-colleagues or friends working at other companies. They would contact them whenever they needed advice or a new perspective on an issue. These personal and professional contacts created a network of knowledge resources that team members could draw on to generate new knowledge. Team members found that it was easier to go directly to an expert than to struggle in isolation. The submarine pipeline consultant sought information and knowledge both internally and externally, drawing on his personal network,

> "Actually I try to draw on a lot of expertise from around the region - within the company, but also outside it. For example, I would contact the contractors with very good experience but possibly no association with the project, to see what they think is a good approach. This project is a bit of an art but it is also a bit of a science. So there is no correct, or at least probably the best, answer, but there is also probably a range of answers. Answers that depend on the situation may work as well. So I try to draw on people within the company but also outside of the company."

> "I think it is good to talk to people. Even if they have the same experience, they may have another opinion."

Many team members had extensive career contacts, having met different professionals on different projects, which they continued to draw from. It was common for team members to gain the information and knowledge they needed from old colleagues and professional contacts. Some companies also organised a range of educational and training activities to advise staff members on the latest issues and technology facing their profession. It was up to individuals to decide how they would further their knowledge of latest developments.

Comments on the diverse knowledge sources used were wide ranging:

> "Make some phone calls to connections in the profession to solicit knowledge and information." (Senior Environmental Consultant)
>
> "You never know whether it will be useful, but I will wander about and get ideas of possible use in the future." (Senior Environmental Consultant)
>
> "Our purchasing department can be a major source of new materials. They learnt from previous experience which materials failed - for example marble as a flooring material needed regular repair. Though they do not have a list of unsatisfactory materials, you can source that knowledge by meeting with them." (Project Manager)
>
> "Trade shows and overseas visits, whether for leisure or business, are good sources of knowledge." (Senior Project Manager)
>
> "Having connections with somebody is better that being able to read sources yourself." (Associate Civil Engineer)

It could be seen that team members generally drew on external knowledge sources such as personal connections and observations of facilities, both locally and overseas.

Behind individual team members, there lay a wealth of knowledge and experience derived from the companies for which they worked. This vast knowledge pool comprised people, organisational routines and procedures as well as project documentation. Team members constantly drew on this knowledge source by talking to their colleagues in-house. Through this they could collect insights and experiences not accessible anywhere else. They could also access past project knowledge through codified formats, such as written forms or drawings. In addition, the knowledge captured in those formats could be an integration of various disciplines' knowledge, rather than belonged to a single discipline.

The senior environmental consultant mentioned the organisational memory he drew on during the design process:

> "Regarding the sustainable development design, our parent company in America had the experience which we used in the current design."

Informal project meetings also provided an opportunity among team members to generate knowledge in an informal way. Published information and references provided explicit knowledge to aid the design process. These could be used as a fresh knowledge source or to counter-check the accuracy of other sources.

The role of connections through one's personal network is considered to be particularly important when trying to acquire knowledge or in solving specific difficulties. Guan xi, often referred to as 'connections' (Lockett, 1993), can be defined as a relationship combined with reciprocity, a special relationship two persons have with each other.

The deputy architectural director saw that one's network could be expanded through utilising other people's networks.

> "If you ask somebody a question for which he has no answer, he may refer you to another person."

In this sense, if a person's social network was exhausted, connections could be established through utilising others' social networks.

5.9 The Process of Knowledge Integration

5.9.1 Multiple Stakeholders and Perspectives

The senior environmental consultant suggested that the architect's predominance in any construction project could be gradually fading away as various issues, other than simply architectural, appeared to influence design. With greater emphasis on environmental protection and the growing power of the Environmental Protection Department, a proper balance among all perspectives was required.

> "For example, five or six years ago, an architect's decision was final and their status among the consultants ranked the highest. What they said, everybody followed. Now attitudes have changed. After all, we all want the final product to obtain government approval and there are a lot more factors involved nowadays to gain that approval." (Senior Environmental Consultant)

The client invited various internal and external stakeholders to participate in meetings as they had vested interests in the project. Their experience could result in useful input. Examples of internal stakeholders included the ferry operator as well as their property management subsidiary.

Ad hoc meetings were held among various stakeholders, to facilitate the smooth design of the project, adjusting it to their specific requirements. In addition, occasional meetings with government officials were also arranged so that informal understanding and properly integrated knowledge could be achieved prior to formal submission. Those team members with experience of working alongside government officials usually found these meetings a valuable resource, facilitating the knowledge integration process.

The following quotes from various team members would highlight the delicate balance of the different perspectives.

> "We still feel the road on the island is heavily influenced by engineering concerns but the civil engineer said the Highways Department would not accept any changes in design. We need to seek a compromise with government, to see if we can beautify it at reasonable cost. In this case, we will present the options to the project manager, along with all the pros and cons, and let them decide from policy level." (Deputy Architectural Director)

> "Because the infrastructure project needs to be handed over to government for maintenance, we need to look at their standards and take into account their maintenance operations. ... Though the idea may work, if out of, say, 100 jobs, 99 use asphalt and concrete, but this project uses special paving materials, the government will have to specially store materials for this particular purpose. And so there is one extra consideration: how to hand over the finished product to government and minimise their problems in maintenance." (Deputy Architectural Director)

> "When designing the sewage treatment plant, we need to satisfy all the technical requirements of the Drainage Services Department. The architect also wants to beautify the design as it affects the surrounding environment and the structural engineer needs to make sure it is structurally adequate." (Sewage Treatment Plant Consultant)

During interviews and team meetings, it was evident that when diverse perspectives arose among team members, usually the project managers were consulted to obtain their opinions. They would be relied upon as mediators because they represented the client organisation, who had the final say in the decision-making process. Because of their more neutral (i.e. non-professional) orientation, they could see things from multiple as well as global perspectives. Often after taking into account the various perspectives, including stakeholder requirements, a more balanced view would be struck. Such neutrality was crucial to the role of project manager, regardless of any earlier professional affiliation. The landscape architect was among many attesting to the role of mediator played by the project managers.

In the INF design development phase, team members gave serious consideration to the entrance plaza as it represented a focus within the development as well as the first point of contact for the incoming public. It could also be used as a venue for special events and festivals. Tight budget constraints by the quantity surveyors generated some fairly heated debate among the team regarding the selection of materials. Colours and patterns were energetically discussed, bright colours often coming in for criticism - some saying they could result in designs that would resemble government walkways. Others felt that vivid colours were difficult to maintain, becoming dirty and staining too easily, with often weathering diminishing their brilliance. The landscape architect suggested that concrete or brick paving could get stained and broken easily if not adequately laid. He advocated the use of more expensive materials. Some team members criticised the materials proposed by the landscape architect for possibly becoming too slippery when wet. Others said that the materials did not adequately mirror the desired resort-style image. Throughout the discussions, team members placed their various emphases on the different issues, some also considering the vital issue of practical maintenance - critically important in this large open area. During the energetic debate, the project manager fulfilled his role of neutrality, balancing all arguments in terms of cost, maintainability, durability, aesthetics, and eventually reaching a consensus agreeable to the majority of interests. A final decision was reached to use granite patterns with pebble infill.

5.10 The Process of Collective Project Learning

5.10.1 Individual Learning

Team members explained that their professional education required them to work independently, as well as collectively, to get all knowledge and resources. Part of their training was learning how and where to access the information and knowledge they would need. They had to learn how to learn independently, to learn from direct experience, or they would not graduate. So by the time they joined the infrastructure project team, they had advanced first hand experience in developing their own self-directed learning strategies. Professional development readily becomes an integral part of the work environment (Schön, 1987). The sewage treatment plant consultant viewed learning as taking place at all levels within a project, no matter how senior or junior.

> "No one can know everything. We have many facets, civil, structural, processing, technical. We are very broad minded. We are always learning. From graduate engineer to director, we are constantly all learning."

Individual team members have to constantly learn new technologies and techniques in order to do their job. The professional services industry is changing rapidly and business competition requires companies as well as individuals to maintain a high level of expertise. The deputy architectural director described the negative impact of a professional who was not able to offer his expertise.

> "When the client approaches you to do something and you reply that you do not know how, how will that client be able to trust you? People are buying your professional knowledge and expertise. As professionals, we need to keep up with current developments."

Besides carrying out the design work, team members also need the desire to learn new things, new technologies and techniques. When knowledge is not readily available, they are expected to learn and discover it for themselves. Self-directed learning is an essential pre-requisite in modern professional development.

Several team members also cited learning from failures or mistakes. Critical reflection on problems and their revision is required. Argyris (1991) has argued that professionals need to reflect critically on their behaviour and assumptions and then change the way they act or do things. The submarine pipeline consultant spoke of the ways in which he avoided repeating mistakes from the past.

> "Well, I think I just try to reflect on a particular situation and I try to learn from my mistakes in past projects. So I think that whenever a decision comes along, I fully debate it and think back to historic experience in similar situations. I try not to repeat those mistakes through reliving old experiences. I also read case histories revealing other people's errors and I try to avoid those as well."

In terms of not 'reinventing the wheel', he added

> "Well I try to look at efficiency. If I've done something before and it has worked, I may start with that particular solution, but I may still try to come up with a better one. I get very bored if I'm not challenged, so in applying one solution to another, that's actually a sure way of making me very bored. So I want to try and improve as I move from problem to problem and keep perfecting things. So I guess that's my internal desire - to be challenged, resulting in not reapplying old solutions - but in trying to improve them."

Another characteristic of individual learning in the project team was that it occurred in a free and open work environment. As suggested by the landscape architect, learning could lead to improvements in the next project with similar situations being encountered. This learning experience not only related to technical knowledge but it was also applicable to interpersonal skills.

> "This time we employed a specialist in large-scale water features. Next time we will have the experience of who to employ or we could do it ourselves, having learnt a lot from this consultant. In addition, future communication with other consultants will be more effective, in terms of our mutual expectations." (Landscape Architect)

Extensive interviews confirmed that individual team members had considerable skills and experience in self-directed learning, of learning independently without a teacher. This learning was frequently motivated through specific problem solving activities but it was also driven with an eye to continuous professional development. In construction, the task-oriented approach to solve a problem made team members eager to collect all relevant information. The pier consultant shared his deep insights into learning specifically within his own profession. However, such insights could easily be transferred to other professions within construction as well.

> "As an engineer has to complete a task urgently, the task-orientation forces you to know how to search for knowledge and information and apply it to the situation. This learning process cuts a deep impression in your memory."

> "Everybody reckons this is an ever-learning profession, everyone pays more attention to what's going on around them. Those who do not have the experience, will know where to go to learn about it."

> "The interest to learn is driven by two needs. The first one is the need of professional interest. The second is the need for continuous development education."

The executive M&E engineer had the following viewpoint regarding learning in project situation:

> "A lot of people learn when they are interacting with others. Nobody will have knowledge of everything. Sometimes during meetings, you learn that a new building regulation has just been released. Or sometimes when talking to the architect during meetings, you learn why some particular feature needs to be like that. I feel good about it."

He added:

> "You often don't have so much time to read about things, so when you are in contact with people, you absorb the knowledge from somebody who has read and digested certain information. And it becomes your personal knowledge, becoming very useful in other projects too, even though it might not benefit the current one."

The submarine pipeline consultant spoke of a situation where he related an experience learnt from life to the project.

> "Drilling is rotating a drill pipe. Here is an experience on a construction site one time, with the drive shaft of the truck. While the drive shaft was turning, it failed. And I brought that experience to this project and actually commented on it to the contractor when he was suggesting

something. He acknowledged it and said he had forgotten about the possibility."

As the horizontal directional drilling for the water main was unprecedented, the submarine pipeline consultant arranged for photographic as well as video footage to record this portion of the work. Because of his newly acquired insight and skills, he was asked by another engineering consultant to help them with this technique on one of their projects. In addition, he was asked by colleagues in different offices to make comments and provide guidance on a few smaller pipeline crossings in Canada, USA, as well as in Australia. He himself discovered the deep satisfaction and benefits of independent learning.

> "Of course the HDD was a technically challenging project, but I also gained in patience and confidence. I learnt how to deal with a variety of people, how to work as a productive team. I developed an ability to think on my feet, how to solve challenging situations. So I think I learnt a variety of useful lessons".

Most project team members did keep personal files, recording lessons learned or mistakes made as reminders for the future. Some also relied upon their own memories to record such mistakes. Portfolios were kept also as positive records, for future reference. An architect might keep a file containing photographs of completed projects and design sketches. Design professionals, as an ongoing learning experience, would visit different places and take photos to refer back to.

A lot of time in construction projects one would come across new things that one had not dealt with before. One of the M&E consultants explained that he learnt what a fire station or police station looked like and what they contained. One thing was to learn from colleagues or team members when coming across something new. Holding discussions with them was one way of learning.

Team members also mentioned that sometimes the office environment provided a good forum for gathering new knowledge. Often colleagues could be talking in the corridor about an issue that someone else found something interesting. This newly gained knowledge might not have any immediate use but it could be of help in future projects.

The pier consultant illustrated that knowledge was not purely contextual. It could be used and applied. In other situations

> "We should look at similarities. For example, in a previous project, if workers have to work without solid ground, on scaffolding or on a gondola that will move in the wind, the workmanship might not be good in those circumstances. Now an engineer needs to design a pier with fixings needing to be installed externally. The engineer knows that scaffolding might not work, neither a gondola nor a barge. The engineer is already drawing the inference that the chance of the good workmanship is not great. He needs to reconsider whether the fixings have to be installed from outside. Can it be done from the inside where the structure of the pier has already been completed? This thought process enables him to transfer the knowledge gained from one situation to another."

The pier consultant used this real life illustration during a discussion among team members. Someone less experienced picked up on the interchange and took the conversation further. Learning thus continued apace - far from any lecture hall or formal setting.

Various people suggested ways in which they generally learnt during a project's development. From their points of view, individual learning could occur even across disciplines.

> "For example, when we work with the architect, from time to time we could learn some special requirements as noted in the Building Ordinance. We are usually not familiar with such areas. From structural engineering,

we may learn that we need to design things in certain ways - for example, where we need a beam and its practice as well as its function." (Landscape Architect)

"Open mindedness makes you always learn something new. For example, I had not encountered horizontal directional drilling before. I only learnt of it during this project." (Project Manager)

The senior quantity surveyor on the project experienced a growth in knowledge expansion through having meetings with other team members beyond her professional parameters. Through such interaction, she learnt about new procedures for submitting building plans and obtaining approvals and consents. The expected duration for these she could then factor into her planning when submitting draft tenders.

"As a quantity surveyor, nobody will tell you the various submission procedures, to obtain approval and consent. Nor did I know about the length of the statutory period. Through meetings with the architects, you learn about these things and now when we draft the front part of the tender document, we can allow for the time these procedures may take. Often you are not supplied with this information." (Senior Quantity Surveyor)

5.10.2 Collective Learning

Team members collaborated with each other in order to get the work done. They would form their own small groups, of 3 - 5 people, as needed. As revealed in meetings and interviews, some of the reasons these sub-teams formed was to: 1) share information and experiences, 2) pool skills for problem solving, 3) brainstorm new ideas and concepts and 4) review information and designs relevant and of interest to members.

As observed in meetings, the small groups were the most common type of collective learning centres. These meetings also revealed that these small collaborative groups were very dynamic pools of learning and knowledge/experience transfer. Smaller groups could informally cluster, discussing intensively pertinent issues. The life span of these groups varied - some were very short, others lasted till the set task at hand was completed.

This pattern seemed to confirm the literature on team or collective learning, where small groups of individuals organised themselves for specific tasks. Zuboff (1988) has described how professionals self-organise into small focused groups for specific problem solving activities that require a specific blend of expertise. The nature of technology and information intensive work require the individual expertise to negotiate collaborative work activities as the situation demands (Wheatley, 1992).

The project team members were far more enthusiastic and dynamic in forming spontaneous, collaborative groups than anything more structured and formal. Individual team members constantly came together to self-organise into new sub-teams, interacting as their work and professional needs demanded.

The project team as a whole followed stricter and more formal project management processes, with more rigid procedures for sharing and interacting. For small sub-teams, collective learning could take place easily, as stated by the senior architect:

> "No one discipline has all the knowledge. Design work must rely on a team. Every time a consultant resolves a new problem, we all learn something. It happens everyday."

The chief architect felt that by working together with other professionals:

> "There is definitely knowledge expansion. Everyone has limited knowledge but in meetings we have so many experts surrounding us and everyone has ideas which they explain very carefully - why they want to do this or that. So you learn a lot from it. When a design is proposed, we can comment on it from a professional or lay point of view - the latter is

> also important as we can think of it as a consumer's perspective. Everybody wearing two hats!"

The project manager felt that:

> "If another colleague tells you he's got a problem, in some sense, it pushes you to learn one extra thing. It is like doctors, the more patients you diagnose, the more knowledge you get and the more experience you accumulate. Therefore, share more - have nothing to lose - pass on some good stuff to others. We learn new things each day."

Though no official meeting took place for reflection on this project, learning from experience did happen inside project meetings, with team members reflecting on past practices and on how they could achieve a better design this time.

5.10.3 Inter-project Learning

A civil engineering consultant found that he could use and transfer insights to this project from another he was currently involved in. He cited the example of learning about pedestrian paving in a simultaneous project. The project manager said learning could take place through being inquisitive, in learning about projects unrelated to yours. Information could be picked up through conversation, questioning and listening. He used the example of paving problems within another major residential project. The same difficulties could have arisen in this more recent development. Through such an alert, potential solutions were put in place and all related problems were forestalled. The project manager and the civil engineer had some involvement in concurrent or earlier developments - providing this pertinent example of inter-project learning.

5.11 A Summary of Knowledge Creation in the Infrastructure Project Team

This chapter has considered the organisational modes within the infrastructure project, in relation to the existing literature on team processes and knowledge creation. The analysis suggests that the INF team embraced all the processes considered in the conceptual framework, with some new insights projected. The analysis also identified several contributory factors facilitating or constraining some of the processes of knowledge creation.

The infrastructure project involved a diverse combination of professionals, merging solely for this project's specific knowledge requirements. The team was characterised by the necessary requisite variety (Nonaka, 1994), with no one professional possessing all the relevant knowledge. The early appointment of most team members allowed the individual expertise and knowledge to be identified and integrated as early as possible. The interactive design nature served as an important mechanism, motivating team members to actively share and integrate their specialised knowledge during project work. Interface communication between team members across different professional disciplines was relied upon. Team members commonly worked on several projects at any one time with varying degrees of involvement.

Because of the differences in professional training, knowledge and experience, expertise boundaries did exist among team members as they had different mental models about design. In addition, perceived hierarchical boundaries existed between client, consultant and contractor. These were tacitly acknowledged by some team members but never articulated in the formal project management structure. Such perceived hierarchical boundaries reflected concealed status among team members.

All the team members had considerable previous experience in working with other professional disciplines. In some cases, they had worked with the client or other consultants before. Since the project was privately funded, usually falling into governmental jurisdiction, not many team members had direct and relevant experience. Experience obtained elsewhere, however, was found to be also useful in this instance.

For the process of knowledge sharing, team members found that socialisation was a valuable mode of creating knowledge (Nonaka, 1994), as through communication and social interaction, tacit knowledge could surface to help solve design problems. In addition, socialisation is a way of creating sufficient levels of congruence to enable individuals to understand each other and work together towards common goals but from different perspectives (Saint-Onge, 1996).

From the outset, all team members had been expected to share freely their knowledge and expertise, generally on a face-to-face basis during the design development. The sharing of successful experiences gained by team members could encourage good practices to be re-used. On the other hand, the sharing of negative experiences was also vital for team members, reminding them not to repeat certain things in the future. Team members agreed that failures or negative memories tend to be retained more keenly than positive ones. Several contributory factors were identified from the research that could facilitate or inhibit the sharing of knowledge. These included openness, motivation, trust and time pressures.

The INF team did not appear to be a self-contained and self-sufficient unit with regard to knowledge creation. In situations where members did not have knowledge on certain aspects, they were keen to tap external information and knowledge sources in order to acquire and generate knowledge not available within the project team. They used extensively their own personal and external networks. This project also utilised joint site visits to help team members gain design knowledge that could contribute to a collective experience, helping build knowledge redundancy within the project team. Two contributory factors influencing the generation of knowledge were time and motivation. Time pressures could be intrinsic to working in knowledge-intensive assignments, possibly constraining the processes of knowledge creation, as consultants could rely on standardised problem solving for the sake of expediency (Starbuck, 1992).

The next process identified was that of knowledge integration. Due to the various internal and external stakeholders having their own vested interests and perspectives, a balanced view had to be struck to satisfy as many needs as possible. The willingness to work collaboratively and to integrate individual disciplinary knowledge with other team members or stakeholders is fundamental to the processes of knowledge creation (Nonaka, 1994; Spender, 1996a). More often than not, INF members needed to rely on group problem solving and decision-making within the project team to solve design issues/problems for the client. This approach is important in integrating diverse disciplinary knowledge for complex tasks (Grant, 1996b).

Project team members occasionally came across new or revised experiences during the course of design. Through their self-directed learning, they actively learned from these experiences, transforming them into personal knowledge. This learning could happen in both their own disciplines as well as others. In other situations, team members would learn together when required to resolve and reflect upon common problems. Due to multiple team memberships, personnel could refocus learning from a base project to the current one. This situation facilitated learning across projects or knowledge being transferred from one to the other. Working with colleagues of different backgrounds and expertise provided ample opportunities to enlarge and amplify team members' individual knowledge bases. This process is entitled collective project learning.

Chapter Six - An Analysis of the Knowledge Creation Processes Throughout the Residential Development Project Team

6.1 Introduction

This chapter, as with the previous discourse on the INF team, investigates the knowledge-creating processes that occurred within the residential development team (RDA). A detailed analysis of the project team is presented, in terms of the processes of knowledge sharing, knowledge integration and collective project learning, (highlighted in the conceptual framework in Chapter Two). Other processes and contributory factors supporting knowledge creation in the project work are also considered. The chapter concludes with a summary discussion of the processes of knowledge creation within this team.

6.2 Interactive Design Process

It appeared that the work of one professional was frequently contingent upon, or affected by, the work of another. The multidisciplinary nature of the RDA taskforce was characterised by a wide diversity of professionals involved - long considered fundamental to the processes of knowledge creation (Nonaka, 1994). People working on the project confirmed that effective teamwork involves engaging with the different knowledge brought to a team by its various members. They found that knowledge work involves the identification and articulation of information and insight relevant to one's disciplinary perspective but it is further related to the ability of individuals to absorb and conceptualise. The design was constituted by the interfacing of the different knowledge domains and modes of practice as represented by team members, with the aid of design objects like drawings or sketches. They realised that the project's well being would be largely dependent upon the team members' abilities to articulate their own discipline-based knowledge and then collectively and effectively manage the intersection of such diverse knowledge. The various professionals were required to work together on the design, addressing issues as encountered. Team members suggested that they would expend time discussing critical issues before attending to their individual disciplinary input. This interactive design process resulted in personnel working to realise all the team needs, as well as those of the client and other stakeholders. Any change in one discipline's design might adversely affect the output of others.

Most consultants on the project team were appointed when the initial design concept commenced, except the interior designers who were selected at a much later stage. The senior project manager indicated that the consultants' early appointment enabled expertise and knowledge from the different disciplines to be shared and combined in the initial stages.

During team meetings, crossing professional boundaries to disseminate information seemed a pre-requisite for sharing knowledge held by individual team members. It was found that they needed this mutual exchange of expertise to optimise their output. They would cross professional boundaries in trying to solve a joint design problem or issue. Examples included the joint effort of several team members to resolve dimensional conflicts in several layout plans of different flats. Dialogue was most commonly used to do this.

> "We cross professional boundaries through informal discussion."
> (Associate Interior Design Director - Residential Blocks)

Team members voiced that crossing over other professionals' boundaries was critical to the success of problem solving:

> "We always cross boundaries - all consultants do, most of the time." (Clubhouse Interior Designer)
>
> "It is very common to cross into another discipline's territory - for example, air conditioning - we make a suggestion to the M&E engineer and ask them to investigate whether it would work. We get them to comment whether it works or not." (Associate Architectural Director)
>
> "Some architects did not design the toilet appliances appropriately and we advised them that they were not the best, possibly giving rise to problems in the future." (Building Services Engineer)
>
> "We need to cross boundaries, to challenge consultants' judgment by asking them "why?" When consultants offer their services to clients, they need to cross into the project management field all the time too." (Assistant Project Manager)

The senior environmental consultant suggested that environmentalists always stepped into other people's jurisdiction. In terms of building design, he would often step into the architect's terrain. He also advised other consultants, in helping them fulfil statutory requirements as well as produce appropriate designs.

Due to the multifaceted nature of the project team, very often solutions would be proposed that transcended the professional boundaries of other team members. Reactions regarding such encroachments were:

> "We always do such things! All consultants do! In the majority of cases, we would say if we can do this before, why can't we do this again? I don't think any past consultants I've ever worked with would have been so proud as to say - "If he's not the designer, what does he know?" We tend to very much interact with other practices and professions and everybody's very receptive to new ideas." (Clubhouse Interior Designer)

He further added that

> "However, you can step into someone's territory, but don't go too far. You have to respect that a person is professionally qualified in a particular

> field. I wouldn't expect an architect to say - "why are you using this make of ceramic tile when we could be using something else?" - This kind of attitude could lead to an argument. You have to be sensitive. Generally it's very much a brainstorming thing, with everyone pooling ideas but respecting everyone's special interests." (Clubhouse Interior Designer)

The assistant project manager said since the consultants had worked on the project for some time, they had built up good, long-term relationships and had become well acquainted with the practices of each team member. In terms of acknowledging mistakes made, he would invite people to be open about their errors, rather than trying to hide them. He added that all the current consultants had been working intermittently with the client for some time. This established relationship was very important in Chinese firms, with rather complicated processes at work.

Since most team members had had extensive experience of residential projects, no great design difficulties presented themselves. In team meetings, it was observed that instead of just re-employing previous knowledge, considerable effort was expended to incorporate new ideas. Customers would be attracted to these new features, adding value to the project. Conscious of the fierce competition amongst property developers, team members were also putting constant effort into improving the design. From the client's point of view, a competitive strategy based on price alone was not sufficient. New and special design features and facilities were needed to enhance the saleability of the properties and accordingly were among the client's prime objectives.

6.3 Hierarchy of Client, Consultant and Contractor

There was no hierarchical relationship between project managers and consultants. However, individual team members appeared to still view the architect as the leading consultant.

> "Generally speaking, the architect will take a leading role, a macro view of the project, and balance all the points of discussions." (Architectural Director)

As architectural and aesthetic knowledge dominated the residential development, the architects were generally regarded as principal co-ordinators, with their contribution often considered as the most valuable by other team members. This could be because their output was more visible and therefore more qualitative, possibly inducing a popular perception of greater merit.

The senior project manager had expressly told the consultant team that they were not valued above the construction team, unlike the more traditional view held of contracting relationships. He added that instead of confronting the construction team, they would collaborate with them to build up mutual respect and understanding. That was the only way to succeed and deliver a quality product. He explained that this was the main reason why other developers could not aspire to what this developer achieved. They did not have an in-house construction team, and so the end product could differ a lot from the intended original design. He encouraged team members with any contributions to the project to speak out, even if beyond their professional boundaries.

6.4 Previous Work with the Client, Other Consultants and on Similar Projects

The architectural director found that technical experience from other residential projects could be used as references and benchmarks for solving current problems. He illustrated this by saying how he had re-cycled a past and positive outcome on piping arrangements within bathrooms and kitchens, to increase efficiency in this project, as well as ease future maintenance issues.

When interviewed, the senior project manager suggested that prior experience with a particular consultant or project team member was also an important asset. He had learned previously that the services consultant and the interior designer were slow to respond to other team members' requests. This historical insight enabled him to ensure that they would have drawings ready by presenting them with earlier deadlines.

Those team members who had dealt with the client before, in particular the project managers, felt that they had helpful knowledge about their style of working. One consultant had become familiar with the client's business procedures. He knew that pre-approval for any changes to the original budget was required from ultimately the client chairman himself and that this involved a substantial time frame, not to mention rigorous documentation. Lacking this awareness could have resulted in awkward difficulties for the consultant if urgent changes needed to be implemented.

Most team members had had previous experience in residential development, except for the project architect and the development surveyor from the lands consultancy who were experienced in other types of development.

The following quotes detailed the responses from various team members about the effects of previous experience with the client and other personnel:

> "When you have previously worked with the client, you at least know what their standards require. You know what the client needs. What their major concerns are. You can satisfy their needs from different angles." (Associate Structural Engineer)

"My previous experience with the client allows me to know their procedures and requirements." (Interior Design Manager - Residential Blocks)

Moreover, previous interaction with various government officials was useful in the approval process. The knowledge of their working styles could help them decide whether or not they could take risks on some controversial issues in the submissions.

"I build up knowledge about the way various government officials work which is useful when I submit documents for their approval." (Development Surveyor)

Table 6.1 Previous work with the client, other consultants and on similar projects

Consultants	Previous experience with client	Previous experience with other consultants	Previous relevant experience
Architectural Director	✓	✗	✓
Assistant Building Services Engineer	✓	✗	✓
Assistant Project Manager	✓	✗	✓
Associate Architectural Director	✗	✗	✓
Associate Interior Design Director (Residential Blocks)	✓	✗	✓
Associate Structural Engineer	✓	✗	✓
Building Services Engineer	✓	✗	✓
Clubhouse Interior Designer	✗	✗	✓
Development Surveyor	✗	✗	✗
Interior Design Manager (Residential Blocks)	✓	✗	✓
Lands Consulting Director	✓	✗	✓
Landscape Architect	✓	✗	✓
Project Architect	✗	✗	✗
Senior Environmental Consultant	✓	✓	✓
Senior Project Manager	✓	✗	✓

From the data collected through interviews, Table 6.1 summarises individual team members' previous work experience on similar projects, with the client and/or with other consultants. A large number had worked with the client before. They expressed this knowledge and experience to be advantageous. Only one team member in the RDA project had worked with other consultants before. These findings mirrored those of the INF project in that though team members had no past experience of working with other consulting firms, their colleagues within their companies might have.

Compared with the INF project, more RDA team members had had previous and similar residential experience. They confirmed the importance to the present project of having relevant experience.

6.5 The Process of Knowledge Sharing

6.5.1 Socialising with Other Project Team Members

In the Residential Development project, the opportunities for team members to socialise with each other appeared limited.

> "So far we haven't had any lunches with other team members." (Associate Structural Engineer)

> "I have met colleagues socially on previous projects but not yet on this project." (Clubhouse Interior Designer)

This was probably due to the fact that some team members, like the interior designer above, had been appointed to the project only recently. The structural engineer, hitherto uninvolved in the project, had suddenly found himself appointed to it upon his predecessor's departure. When the senior project manager was interviewed about the team's social activities, he started to realise that not enough had been done. He realised that the development's fast pace put enormous time pressures on all the consultants who were working simultaneously on several projects. This made people very focused on their tasks, neglecting to foster relations within the team. Some suggested that social events would help improve team interaction so that knowledge could be exchanged more naturally. They believed that social events could enhance relationships, decreasing the distance between team members. This in turn would lead to improved knowledge sharing.

> "Socialising with other project team members is not common and usually not done intentionally - mostly people have lunches together. Social activities are good for the success of projects since interpersonal relationships are very important." (Associate Architectural Director)

He felt that informal conversation could help one understand issues not dealt with before. The architectural director supported his associate by saying "we tend to meet other team members over lunch as we reserve evenings for our families."

The interior designer of the clubhouse also thought it important to maintain social contact, developing relations on a more relaxed level.

> "... You establish a kind of rapport ... We are all in the same boat. It's nice to talk about something else, to find out more about the person than just knowing them purely on a professional level."

He saw socialising beyond the professional working relationship as very important in moving a project forward. Some team members found that during social events, they would talk about work-related issues in a relaxed fashion. Others preferred not to discuss the project, purely using the occasion to get to know one another. Some team members suggested that while socialising, they sometimes developed unexpected insights or solutions from the more informal discussions. The building services engineer echoed others in saying that when people aired an issue during social events, everyone was generally more willing to exchange their views.

The senior project manager found that using the telephone to contact other team members was more personal than e-mail. Telephone conversations tended to be more interactive, dynamic and instant than typing out e-mail messages which took time and seemed more clinical. He suggested organising social activities where team members would avoid talking about the project, using these occasions purely to build relationships.

6.5.2 Sharing Positive as well as Negative Experiences

From the outset, all project team members had been expected to freely share their knowledge and expertise, as this appeared to be the norm in professional appointments. This willingness to behave cooperatively and integrate individual knowledge with other team members is fundamental to the processes of knowledge creation (Nonaka, 1994; Spender, 1996a). The assistant project manager confessed that there was personal bias as to what was important to be shared.

The senior project manager found that team meetings were a good platform upon which to trade knowledge. He added that one characteristic of construction projects was that multiple meetings were necessary as each profession's work was affected by everybody else. He observed that generally it could be awkward for people to reveal bad experiences, but within the project team, because of its relaxed nature, people found ways of unburdening their errors. He found that the act of sharing knowledge was not difficult - but that finding time was a key issue.

The associate architectural director confessed that no one person could solve all the problems encountered in any given career. They needed to learn and exchange ideas in the office, even with their junior staff and with the project team. He found that team members often quoted projects in meetings, either through personal experience or through insights gained from friends. The client might also reveal information from previous projects that would be usually precise and relevant to other team members.

Similar to the INF project, RDA team members saw personal experience as critical in their offering of professional services to clients. The client's organisation, especially the Project Management Department, had a very open culture of sharing knowledge and experience. They revealed their successes as well as failures, reasoning that no single team member could have full exposure to all different project situations.

> "In our in-house debriefing sessions, we share mistakes as well as successes." (Assistant Project Manager)

It appeared, partly due to the open culture of the client organisation and partly due to the already established knowledge sharing culture within consulting firms, that team members generally traded both their positive as well as negative experiences. The negatives served to remind team members not to pursue the same paths as they did. The positives acted as models of reference for others to follow.

> "We build up long term relationships with our consultants and they know our practice. Regarding mistakes, we invite them to share rather than hide them." (Assistant Project Manager)

> "I can see the knowledge from one project can be applied to another project quickly. It is due to project experience shared." (Associate Architectural Director)

Knowledge shared and experience gained by a team member on one project enhanced overall learning. As some team members suggested, this was extremely important in construction consulting, with not all team members exposed to the same depth of knowledge and experience from projects previously worked on.

Ad hoc brainstorming sessions were observed in several team meetings, involving anyone with some contribution to problem resolution. One session was used to generate ideas about features to be provided to the clubhouse. Team members shared their knowledge and experiences from projects they had worked on before, from the latest sales brochures or new trends in Hong Kong and overseas.

6.5.3 Shielding Knowledge Sharing

Due to the confidential nature of the design information and the special project features, the consultants were asked not to have the same in-house teams working on key competitors' projects. Accordingly, consultants' in-house teams were advised not to have direct communication with other in-house teams working for different clients in case confidential information was leaked. Both the architects and interior designers were specifically reminded of this. The main reason for the client's concern was that there were distinctive features of the design that would make the product sell. Leaking those features could mean losing the competitive advantage. The client's fear was that if confidential information about this project were leaked, their competitors would possess knowledge that would distinctly disadvantage the case organisation. Competitors could adopt the special design features, apply them to their projects and then launch these hi-jacked developments ahead of time.

The architect and interior designer explained the system used to avoid the spread of knowledge across in-house teams.

> "We have different teams in the office working for (name of another island development) and the current project. Some developers prefer to keep their development secret. We respect their privacy and thus may not

> use those ideas in their competitor's projects." (Associate Architectural Director)
>
> "I only work on this client's projects or on joint-venture projects with other developers. Other teams work with other developers' projects." (Associate Interior Design Director - Residential Blocks)
>
> "Some project managers will remind us not to have the same team working on arch competitors' projects due to the extreme sensitivity of such competition. We also try to avoid having communication with other in-house teams that work for different developers." (Associate Interior Design Director - Residential Blocks)

In addition, the clubhouse interior designer suggested that there was secrecy in their profession about the projects currently worked on. They usually did not let interior designers from other firms know what projects they were working on until the project had already started on site. The two interior designers working on the tower blocks made similar comments. They all stressed that they did not contact other professionals for knowledge or advice. They would rather rely on professionals within other disciplines, or on suppliers or contractors.

> "No, what we don't want to do in the early stages of the project is let anyone know that we're working on it. Even though we've signed a contract and have paid a retainer, if word gets around that there's work available on a particular project, then other companies might try to take the deal away. But at the initial stages, yes, we very much have to rely on our in-house knowledge and sources." (Clubhouse Interior Designer)
>
> "We try to avoid telling the suppliers, because they might mention us in conversation to someone. Normally most design firms are very shrewd and they'll say we have a project but they won't specify what project exactly. If they have to write to a supplier requesting something - they will just say something like "club house" project or "hotel" project - something open ended, giving no clues. We're very aware of it. It's always been the case since I first started working in interior design - that people are quite protective about their project list. We don't discuss anything until we're actually going on site. We're then free to talk about it to suppliers." (Clubhouse Interior Designer)

The interior designers for the tower blocks stressed that they seldom contacted colleagues in the same profession. The clubhouse interior designer agreed that the industry was highly competitive and accordingly, there was a profound lack of trust.

6.5.4 Contributory Factors

6.5.4.1 Openness

The project managers consistently delivered the message that communication was vital and stressed the importance of knowledge sharing, encouraging team members to adopt this open culture. Some team members described themselves as having very open personalities, not shielding any knowledge. Team members indicated there was no lack of trust, nor was there a secretive culture. A successfully integrated design relied on all team members who were transitory, coming from different organisations purely to get the project completed. There was no reason to withhold their knowledge and experience, as they were not in competition with each other.

> "From what I've seen so far, there's been no lack of trust or any secrecy between the individual consultants. Everyone has his own area of expertise and is quite willing to talk about it to solve problems - the way to produce a better result, by taking a different approach." (Clubhouse Interior Designer)

> "It is different from university life where students will hide some secret weapons. In the reality of this industry, people are willing to share. Through sharing, others may comment on your ideas and you will learn even more. There is no secret about knowledge; it is different experience and exposure." (Associate Architectural Director)

> "Sharing knowledge is kind of self-initiating. It very much depends on personal character. Some people like to talk to people and some don't." (Architectural Director)

The remarks from various team members generally reflected a willingness to communicate and interact with one another, to exchange knowledge and experience.

The formal and informal meetings served as channels for team members to discuss issues and problems openly, with the prime objectives of resolving them expeditiously, to get the project going. Due to the very tight programme, team members could not afford to dwell on any issue for too long. The clubhouse interior designer found that informal meetings generally facilitated open discussion.

> "I have to say that informal meetings are probably more productive ... Formal meetings have to be minuted and nobody wants to be seen saying something which could later backfire. Informal meetings are where you can get down to the bones and with not being minuted, you get a much better idea of what people are looking for."

During an informal meeting, the building plans for the top two floors in each residential tower were discussed. These were more luxurious than the other units. The flats were round 120 square metres. Team members started to discuss the size and layout of the living room and bedrooms, wondering how to maintain a 4-metre distance between the television and the sitting areas. Parallels were drawn with a previous project. The architectural director raised the issue of 'feng shui', with some bedroom doors facing the main entrance door to the flat, which meant that wealth and luck could escape from the unit. The senior project manager saw this as a personal preference but complimented the architect for sharing it openly. In conclusion, team members were found to share their design knowledge, experience and ideas openly. This was important, given the array of experience possessed by the team as a whole.

6.5.4.2 Motivation

Like many multidisciplinary situations, team members were not rewarded for sharing their knowledge or experiences, as this was part of their professional duties. The following quotes by various team members highlighted their motivation for exchanging knowledge. The simple reason, as reinforced by an interior designer, was that the nature of project work required collective wisdom and teamwork.

> "We need to share knowledge, as we cannot deal with the project alone.

> We need teamwork."

> "Project work requires the collective wisdom of the team. Unlike fine art, which is an individual masterpiece."

The architectural director perceived that motivation to share knowledge stems purely from personal interest.

> "Motivation to share knowledge is driven by personal interest."

The clubhouse interior designer saw helping others as a gratifying experience.

> "It's nice to be able to help someone out. If they have a query or a problem that they can't solve and they come to you, and you've had that problem before and you can solve it, it's very gratifying to know that you can rely on each other to solve problems."

Overall, team members seemed highly motivated to share their expert knowledge and experience with others during the design process.

6.5.4.3 Time Pressure

All the current consultants indicated that they needed to strictly account for their time spent on projects - typical of the consultancy sector in general.

Hence, within the project's fixed time frame established by their respective companies, consultants tended to have the least time in which to maximise profits. Some team members expressed that this was a common measure that companies used to gauge their employees' performance. This approach was considered to potentially constrain both individual and collective knowledge bases, possibly stifling creativity. It was in the consultant's interests to complete project work successfully and quickly, with little incentive to contribute towards creative solutions.

The time pressures experienced by team members tended to be largely imposed by the client and their companies and were considered to constrain processes of knowledge creation. Instead of experimenting with or exploiting new ideas, team members might adopt existing solutions to new problems.

The associate architectural director saw time pressure as two sides of a coin, both facilitating as well as inhibiting knowledge sharing. He found that people shared when they were pressed to resolve an issue but equally, they might not share when lacking time.

> "One thing that facilitates knowledge sharing is a deadline to resolve an issue." (Associate Architectural Director)

> "The major barrier to sharing knowledge is lack of time. We already expend all the time on projects." (Associate Architectural Director)

Team members were asked specifically about barriers to knowledge sharing. They all cited lack of time as the only major issue since the design programme was very pressing and team members could not dwell on an issue or problem for very long. Secretive culture or lack of trust appeared not to be an issue in the knowledge sharing process among multidisciplinary project team members.

6.6 Generating New Knowledge

The 'not invented here' syndrome was not present in the RDA project as team members did not resist solutions from each other or from elsewhere. They stated that they often used other suggestions after quickly verifying their viability. Since safety and the structural integrity of the design were crucial, some team members were cautious about embracing new ideas, favouring the re-use of tried and proven ones.

When interviewed, there appeared to be a general consensus that consultants preferred to ask colleagues or friends rather than spend time searching through previous project work for relevant information.

Most team members suggested that the only way to avoid 'reinventing the wheel' relied on individual memory. Indeed, they suggested that 'reinventing the wheel' could be inevitable as different problems called for different solutions. In addition, innovation or new insights were required or else all designs would be the same. They found it very rare for a solution to be re-used without modification. They would improve and refine earlier solutions to suit the new circumstances. The finding here suggested that reinvention was considered to be important for innovation and creating knowledge, highlighting the fact that redundancy promoted knowledge creation (Nonaka, 1994).

Some project team members went to Singapore for a site visit to examine a housing design. Of particular interest were the use of architectural fins to break up the monotony of residential block elevation and the use of pitched roofs for high-rise buildings. They used Singapore as a study example as there was some similarity between the projects - the towers ranged from 16 to 20 storeys. In Hong Kong, most residential projects are over 30 storeys. In addition, they wanted to generate some fresh ideas from other high-rise residential projects in the South East Asia region.

During the design phase, a rival residential development came on the market, selling out immediately. The chairman of the case organisation asked the project team to view the flats, to learn from their elevation design and plan layouts as the project appeared so successful.

The architectural director commented that every construction project represented a unique situation. Team members needed to generate new knowledge for each project in order to draw distinction between current and past projects. This was especially important for building elements that were exposed to view. Such visibility was a prime reason for those team members involved in architectural, landscape and interior design to possess a certain degree of creativity - more than in the structural, electrical or mechanical disciplines.

Different team members discussed reasons and rationales for generating new knowledge in each project.

> "You wouldn't want to follow the same design as you've done elsewhere. You want to create variety but yet retain a certain [company name] identity. If you start thinking about what you used in previous hospitality projects, companies might stop using you after some time because originality would be lacking. And they might lose faith in you if they find out that all you've done is copied someone else's design and ideas. The hotel trade in particular want something different each time." (Clubhouse Interior Designer)

> "Because of new government regulations, new ideas or market competition, we need to think of something new for the client. Like last year, when the Chief Executive (of the Hong Kong Government) in his policy address, called for greener designs and more sustainable development in building design. Our client then wanted to be the first developer in Hong Kong, within a short timeframe, to incorporate these new ideas into the design development as a sale attraction." (Senior Environmental Consultant)

> "Developers are competing with each other. The project team and the client need to generate new ideas all the time." (Associate Architectural Director)

The interior design manager overseeing the tower blocks found that interior design had to adapt to the grade of the development. The same design could not be easily applied to all grades of development. The assistant project manager found that new knowledge was required in this project as it was very complex and they needed to find ways to run it more effectively.

Though to a certain extent existing knowledge could be re-used in projects, new knowledge was also required to make the project unique as well as more efficient.

6.7 Experimenting

The clubhouse was planning to include spa and health treatment rooms, a new venture for the case organisation. It was feared that the proposal might be opposed by the Lands Department as within a residential complex, the installation of facilities with potential commercial value might not meet with approval.

The project team had spent considerable time discussing an appropriate name for the spa and treatment facilities as it might negatively present a commercial image to the approval authorities. Some team members went to a famous resort in Thailand for an inspection visit but they could not directly adopt the clubhouse design, as it served a different purpose. They also referred to a top hotel in Hong Kong to gain ideas from their spa and treatment rooms. They made reference to a lot of in-house as well as external project information. The architectural director saw any off site visits by the project team as a way of gaining common experience and insights.

> "The client also paid for the project team to visit some projects overseas that they wanted us get ideas from - this is then a common experience that we can all discuss."

Eventually the joint input by the land consultants, client and architects resulted in an experimental idea being approved by the various government authorities, including the Lands Department.

6.8 Knowledge Sources

The RDA team appeared to be not adverse to outside ideas. When team members were asked about external knowledge sources, they seemed quite open about the need to look beyond their own mindsets in order to acquire and create new knowledge. A few appeared to have quite limited personal networks, relying generally on internal sources of information. However, most team members expressed openly that a system of external networks was one of their most frequently sourced knowledge bases.

> "I seldom contact friends, relying mainly on suppliers with whom I have very close contact and contractors." (Interior Design Manager - Residential Blocks)

> "If I have problems that I think my superior has better experience in, I will discuss them with her. For architectural issues, I will contact my friends who are architects. In quantity surveying (QS), I will talk to my QS friends." (Development Surveyor)

> "My personal network is mainly from university. I graduated not too long ago, about 3 - 4 years. Most people I contact are my friends from university, my relatives and my ex-colleagues as well. This is a great benefit of continuing to socialise with ex-colleagues." (Development Surveyor)

Team members when interviewed said it was quite common to approach other projects within their organisations to gain enlightenment on, or seek solutions to, certain issues or problems. This usually resulted from personal connections and did not reflect company policy. In acquiring knowledge from outside one's company, team members revealed that people in the industry generally could make the distinction between professionally exchanging knowledge and the need for company confidentiality. Sensitive information, like professional fees and tender prices, would not be shared out. The strategy used by the associate architectural director in seeking knowledge beyond the project was that he would ask friends in other architectural practices. They would not discuss sensitive issues but they were willing to share their technical knowledge. He admitted that in reality, if one willingly shared ideas and information, others might have further insights to add. This would add depth to the learning cycle.

Since most RDA consulting firms were large, they had a wealth of knowledge and a variety of in-house projects to draw on.

> "Large companies have much project experience as well as personal experience." (Assistant Project Manager)

As revealed in meetings and interviews, a lot of new knowledge was retained in people's memories, filed or diarised. Unless explicitly shared with others, it very much remained the personal property of individual team members. Since there was no project or team memory bank, and recall very much resided within team members, any newly gained experience could be lost should team members be assigned to different projects, or in fact leave the company.

Many team members found it quicker to ask around the office, the team or external contacts for information or knowledge rather than search through records or project lists to locate relevant projects or documentation. The clubhouse interior designer used a similar approach:

> "We very much rely on suppliers. I might ask them for products of certain specifications. Or I might approach friends who are very competent architects and engineers. Often they don't even charge me. I've also 50

> people in the US office to turn to. I rely on all these contacts for their opinions and ideas."

Team members revealed that when they found themselves in a new situation, or one they were unsure how to deal with, usually they would contact colleagues in the same profession who might be working for a competing firm. This, however, was not the case for those in the interior design industry.

> "No! I would never talk to a competitor! What I would tend to do is talk to architects or contractors I've worked with previously. But not interior designers! The people who know how to solve the problems with contractors are more likely to be on site everyday. I have a very good friend who works in Hong Kong for a contractor. He's very knowledgeable. Or I might go down to happy hour in the evening and I'll sit with friends who are architects, mechanical engineers or whatever. We'll discuss problems, sometimes even sketching them out on the bar mat!" (Clubhouse Interior Designer)

The senior environmental consultant said that he would contact colleagues within the company, or friends working in another firm, to solve a problem if they knew each other well or if they were known experts in that particular area. He would often approach senior colleagues to tap their knowledge and experience. He added that compared to the construction industry, the environmental industry was newly established. A lot of products were very new and not proven over time, but people in the field were willing to try out something new.

The assistant project manager realised that in reality, one could have the best solution for design problems - but not the perfect solution. His senior cited several ways to help solve design problems - liasing with the purchasing department who, accessing a vast tacit knowledge of at risk materials, were a major source of information, attending trade shows, drawing on overseas visits as well as closely monitoring local realities.

When trying to generate knowledge for the project, the lands consulting director usually approached connections, mostly ex-government officials, enquiring whether any precedence existed for proposed solutions to any grey areas in the lease conditions. Government officials had wide exposure to a variety of applications or submissions from different developers. She added that if there were a precedent, they would use it as a reference to support their application. She said they were usually willing to co-operate as they were now in the same profession. Friends or ex-colleagues were also helpful. In land matters, she found that there was a lack of written or published guidelines, which meant that they mainly relied on accumulative experience. She further added that in seeking knowledge:

> "When you realise you've got something you don't know, something you've not carried out smoothly, something you're uncertain of, you ask people around you. Somebody will give you an answer and if you have any further doubts, you'll then find someone else to clarify the whole thing." (Lands Consulting Director)

It would appear that a variety of knowledge sources was employed by team members in generating new knowledge. Contacting people was the most frequently used.

6.9 Market Knowledge and Intelligence

In a residential development, market knowledge is very important, with the completed product competing alongside other developments. The senior project manager explained that the ever-increasing expectations of customers are crucial in motivating new ideas or knowledge for any product. He illustrated this by explaining a new feature of the project, known as the 'sunshine ambassador' concept. This more rounded and improved property management function was called for in previous satisfaction surveys and was a reflection of the company's determination to provide unique service to their customers. This changed the traditional role of security guard to a more proactive role within property management. He suggested that it would be implemented on all future residential sites developed by the case organisation as it offered residents an improved package that considered their daily needs more fully. Additional services included laundry and dry cleaning, newspaper and magazine delivery, the discounted purchase and delivery of moon cakes, organising sightseeing tours for residents, etc.

To meet customer needs, the project managers needed to be knowledgeable of and sensitive to the market. They revealed that market knowledge could be generated through various means. Viewing other developments, especially new ones and those abroad, was an important contributor to market evaluation. Their selling points could be included in present and future designs.

> "Knowledge of and sensitivity to the market are important. It is most useful to view other projects, noticing any market responses as well as comments from people in the field." (Senior Project Manager)

> "We need to be sensitive to market knowledge and the end users requirements. We need to view other new developments. We then ask ourselves: "Do they sell and why?" "What selling points do they offer their customers?" We try to adopt the good features, even if from an overseas project." (Assistant Project Manager)

In terms of meeting the ever-increasing consumer demands, the project team had to continue to bring new features to the development:

> "For this clubhouse, how can we keep the current framework and yet break new ground? The entertainment of people keeps on changing. It is an incremental increase with no end. For example, 20 years ago, golf was not a popular sport. Now there need to be multiple practising facilities within any clubhouse design." (Architectural Director)

The associate interior design director of the residential blocks treated the residential development like a product design,

> "While designing for the residential development, I approached it as a product that had to sell. The interior design for a residential project resembles cosmetics. People can see it visually. Other team members' contributions may be hidden inside."

The senior project manager further added that after each sale, market research, conducted by the Marketing Department of the case organisation, would provide very quick feedback about customer taste, what they liked or disliked up to and during the period of property transfer. This information would act as a focus and reference for improvements to future or current projects. Though the company had developed residential projects over many years, building up substantial expertise, each project was still viewed as a potential arena for improving past practices.

In this project, knowledge of competitors and customers was examined seriously by the case organisation, the former being important from the selling point of view, the latter important in understanding and meeting customer needs. All the while the project managers would act as needs communicators, between the consultants and the various functional departments within the case organisation. They might liase concerning the size and location of the property management office, where to park the patrol cart, what retail shops should be leased and where, etc. In addition, the project managers needed to know what the market needed and tried to cater for it, rather than be constrained by certain project parameters.

> "The project manager needs to read the market - to interpret what the market wants rather than stay rigidly within budget. In some cases, we need to exceed the budget if that fits the image of the project." (Assistant Project Manager)

The senior project manager revealed that the client's Marketing Department had conducted a previous survey, finding that besides flat sizes, buyers were also concerned about the elevations of the residential blocks. Resulting from the survey, they tried to choose colour(s) for these elevations to make them more in keeping with a resort, which was the development's main theme. For ideas, they referred to other sales brochures of both in-house and competitive projects, as well as to architectural manuals. The senior management asked for pictorial forms of reference from the project team to support the colour scheme(s) being chosen.

The client's marketing team also accepted comments from a focus group selected from a residents' club, formed by the case organisation to better understand market needs. The senior management specifically asked the project team to listen to the Marketing Department's ideas, especially with regard to customer knowledge.

Various team members found that market knowledge had played a major role in the residential design:

> "According to current market dictates, a design needs to suit the majority, rather than the niche, market." (Architectural Director)
>
> "The client needs to be very flexible, needing to catch the market tide and not miss opportunities. They need to be extremely resilient and adaptable to market needs." (Associate Interior Design Director - Residential Blocks)

In summary, the client and the project team need to develop global knowledge to deliver a product that will be appreciated by the customers.

6.10 The Process of Knowledge Integration

6.10.1 Multiple Stakeholders and Perspectives

During team meetings, there were occasional debates about selecting alternatives and integrating outputs from the various disciplines. Project work was characterised by individual and team effort. Often, debates would arise about ways to proceed when problems presented themselves. This was very characteristic of the intellectual conflict necessary for processes of innovation (Leonard and Sensiper, 1998)

It was through such dynamic interaction that the team built and shared a deeper project understanding. The multiple knowledge bases increased the team's problem-solving capacity, further enhanced by combining all relevant knowledge. Blending the different areas of expertise is an important aspect of problem solving and innovation processes, recognising the need to promote diversity and redundancy (Nonaka, 1994).

Extensive discussions, centred upon the design of the residential clubhouse, were conducted in several informal meetings, with different team members offering different opinions on the sizes, facilities and locations of the various functional areas. They also needed to consider the interior design theme as well as the selection of materials. The meetings discussed a range of issues that included predicting how consumers would perceive the layout, what and how different functional areas would be used, their sizes, etc. After a series of exchanges, a final design emerged, based on the integration of knowledge from various team members. Users' perspectives were constantly considered during all the discussions.

The following quotes illustrate the knowledge integration process by the team members during the project's design phase:

> "For example, the structural engineer may find a workable solution but the column sizes are too big. After several rounds of discussions, all the consultants will come up with a unified solution, not based on compromise. The architect will work hand in hand with the project manager in order to control the balance." (Architectural Director)
>
> "We need an open mind to accept new ideas. We learn how to strike a balance between what we and other consultants believe to be right." (Assistant Project Manager)
>
> "We can't say there is no new design in this project as design is a combination - a combination of different design decisions." (Associate Architectural Director)
>
> "Design innovation is the assembly of 100 appropriate design solutions rather than invent 100 untried solutions. We aim for combination rather than innovation." (Architectural Director)

Team members expressed their ideas and the best one(s) would be selected, evaluated and combined. They found that design decision-making was cooperative rather than unilateral. Usually people would present their ideas and then let the team settle upon the best alternatives after considering all the relevant issues. All professional disciplines had their stakes in the project. They were very willing to air their comments and concerns so that these would be considered in the final analysis.

Drawing on their individual strengths and perspectives, some team members might offer solutions of a global nature, others might be more specific. In this respect, the project managers, after listening to all viewpoints, would strike a balance to accommodate the stakeholders' interests, including those of the team members as well. As described by the senior environmental consultant, all parties actively contributed to the decision making process along the way:

> "During the design process, we considered many issues - for example how to design the internal layout of the buildings with respect to railway noise or to maximise the sea views which customers always enjoy."

The assistant project manager found that the criteria he used to make decisions included (1) whether the design under selection was appropriate for the project, (2) whether they had the requisite resources and (3) whether it was feasible for their construction arm to tackle the task. If he considered that the proposal cost money but did not add value to the project - they would not do it. This was echoed by the senior project manager, who asked, whenever an alternative was chosen, whether the market would like it and what extra costs would be incurred. Whenever the senior project manager made a decision, he would turn to his company's slogan of 'speed, quality and efficiency'.

The associate architectural director saw the team's multiple diversity as a way to produce a marketable design. Most of the time, they needed to work within constraints and to aim for compromise among solutions. From the architect's point of view, they needed to consider and balance all the stakeholders' perspectives and advise the client accordingly.

6.11 The Process of Collective Project Learning

6.11.1 Individual Learning

> "Resolving problems during the design process was also a learning process." (Associate Architectural Director)

It was found that problem resolution generally resulted in positive outcomes and the individual consultants' knowledge base was generally amplified and enlarged. The following highlight the importance of individual learning in a project-based industry like construction:

"You're always learning in the industry. You have to search for knowledge because the trends change. Fashion changes. The type of available materials changes. You'll have to change or otherwise you'll stagnate. You can't sit still. I may go into a hotel somewhere and see some fantastic feature that I feel is worth adapting. I'll then want to learn more about it, to see how it's been done. Such chance discoveries help us. We're also quite lucky in that we've a lot of suppliers who bring us new products to consider or try out." (Clubhouse Interior Designer)

"Learning through engagement, receiving publications, attending seminars, being in internal meetings, but most of all, keeping one's eyes open - these are all good forms of learning. As a professional, we need revitalisation. We have an urge to learn, to keep alert and to learn from good or bad examples seen. This learning may not directly relate to any current project but it will enable us to build upon our experiences." (Architectural Director)

The building services engineer found that motivation often came from when he encountered something unknown which triggered a learning desire within him. The senior project manager echoed other team members, that searching for knowledge was a personal quest to perform well and fulfil his responsibilities.

It could be seen that different team members had different learning channels, all absorbing diverse information in vastly variant ways. Learning could occur within the learner's own discipline:

"Sometimes amongst ourselves we chat about our own projects and you find somebody's project is interesting. At that precise moment you may not find it useful but later on, you may come across a similar case and then you will want to refer back to that person and get his or her advice." (Lands Consulting Director)

In addition, cross-discipline learning could happen when diverse team members worked together to resolve an issue.

"We don't have a lot to do with landscaping but since going to the landscape architect's presentation, we think what they've done there is really good. We could use that somewhere else or a variation of it. Also what the architects do gives us an insight into different designs, new products and new technologies." (Clubhouse Interior Designer)

"Sometimes by working along with the architects, we subconsciously absorb a lot of knowledge and information - say for example, the means of escape in buildings. Next time it is mentioned, you know what they are talking about. In fact, you often learn something from other professionals." (Lands Consulting Director)

"We learn things everyday, but if you were to ask me how much I have learnt on any one day, I wouldn't know how to answer you. But examples of how you learn could include relying on the architects for their advice on how to present things to the Building Ordinance Office for approval. They will know how it should be done. And once told, it is easy to absorb for use another time. And so, when you are approached by another organisation to help them in future submissions to the Building Ordinance Office, you will have this past advice and experience to fall back on. We learn so much information subconsciously. In my field I tend to lead others so they end up learning from me. But I have to admit that I do learn from other professions. That knowledge can be really useful." (Lands Consulting Director)

The lands consulting director demonstrated ways in which that she also learned. For example the architects informed her of the building regulations to do with the ratio of kitchen to restaurant. This was something she had not known before and considered it useful for the future. She confessed that she selectively absorbed knowledge as some technical knowledge from other disciplines was beyond the professional services that she could offer. Her subordinate also shared the same learning insight:

"If I hear of information I've never heard of before, and I know that it may be useful in the future, I will absorb it." (Development Surveyor)

The senior environment consultant's learning strategy was to be sensitive to things around him. Every time he went somewhere, he would look for anything new or interesting. Knowledge absorbed in this way could be useful. He termed this habit a kind of 'career disease'.

The assistant project manager found that through discussion with consultants, he could learn new technical knowledge about designs or materials. For those projects outside of this particular development, the senior project manager would spend time in viewing these flats. The associate architectural director had a similar practice of viewing other new developments to keep abreast with current trends:

> "We visit new developments to find out the current trends in design."

The architectural director said there were lots of buildings in Hong Kong where one could evaluate the problems in designs or materials used. The most important strategy was to pay attention to fine detail. Personally, he found that observing products on overseas trips contributed to learning how to create a resort type atmosphere. He saw learning from other developments, either in or out of Hong Kong, as one way of broadening his perspective.

The associate architectural director found that most of the knowledge in construction is learned from live projects

> "University textbooks are now outdated in terms of a lot of new technology. Most knowledge is learned from live projects."

Team members found that everybody on the project was learning at the same time as a lot of designs or concepts were new to everyone, including the client.

> "Experience learnt is a personal benefit. Everybody in the project learns different things." (Architectural Director)

It was through healthy discussion that much information could be discovered.

> "When I share my experience with other team members, they will also reciprocate with things they have encountered. I definitely learn from dialogue." (Project Architect)

The architectural director considered interacting with people as a good learning exercise in considering other professionals' needs.

In conclusion, team members were motivated to learn when encountering unfamiliar situations. This could happen both within or across their own disciplines.

6.11.2 *Inter-project Learning*

While working on the residential development project, some team members were involved concurrently in other projects assigned by their respective companies. The consensus was that knowledge and experience gained on one project could be applied to others.

The following quotes by team members highlighted that learning could happen across projects when they shared some similarities:

> "Experience learnt from other projects was applied to this project and this project's experience will be applied to those in the future." (Architectural Director)
>
> "We can use other ideas proposed in discussions for future projects. These ideas can be from other people and you can quote them for future use." (Assistant Project Manager)
>
> "My knowledge and experience gained from Conduit Road can also be applied to this project." (Associate Architectural Director)
>
> "When working on several similar projects, the knowledge and experience gained from one project could be applied to others." (Assistant Building Services Engineer)
>
> "Learning from other client's projects, we can avoid repeating the same mistakes." (Architectural Director)

In conclusion, team members from different disciplines found that knowledge gained or learned from a project could be re-used in other projects. This was especially important for a project-oriented industry like construction where most of the professionals were project-based.

6.12 A Summary of Knowledge Creation in the Residential Development Project Team

In this chapter, the processes of knowledge creation in multidisciplinary project team have been analysed in relation to the conceptual framework and existing literature in team processes and knowledge creation.

The literature suggested that fundamental to the processes of knowledge creation was a diverse work force (Spender, 1998). The RDA project team did exist as a diverse team of professionals. The project team environment was characterised by diverse expertise and redundancy resulted from previous relevant experience, considered to be important for the processes of knowledge creation (Nonaka, 1994). Project team members generally worked closely together, relying primarily on face-to-face communication. Team members often worked on a number of projects simultaneously, with the exception of one junior member. Knowledge and expertise were significantly valued in the RDA project team. The design was constituted by the interfacing of different knowledge domains and modes of practice, as represented by team members. This reflected the autonomy and expertise of individuals and is an important aspect of knowledge work (Alvesson, 1993).

Disciplinary knowledge and experience differences had created expertise boundaries among team members as they had different mental models about design. Some team members perceived the architect as the lead consultant, which created a high-low status among project participants. As architectural and aesthetic knowledge dominated residential development, the architects were generally regarded as the principal co-ordinators, with their contribution often considered as the most valuable by other team members. This could be because their output was more visible and therefore more qualitative, possibly inducing a popular perception of greater merit. On the other hand, the traditional view held of contracting relationships between the consultant and contractor had influenced the build up of mutual respect and understanding. They had created hierarchical boundaries among team members.

In the knowledge sharing process, team members believed that socialising could improve relationships, decreasing the distance between team members. This in turn would lead to the better sharing of knowledge. Because of the open culture of sharing knowledge and experience within the team, together with the encouragement from the project managers, participants were not hesitant to share positive as well as negative experiences. They realised that not all team members possessed the same depth of knowledge and experience exposure from projects that they had worked on.

The project managers had asked the architects and interior designers not to have the same in-house teams working on key competitor projects. The main reason for the client's concern was that the design held distinctive features that would make the product sell. Leaking those features could mean losing the competitive advantage.

Openness, motivation and time pressures were found to influence the process of knowledge sharing during the project work. The time pressures that were imposed on the project team were generated from the tight design programme as well as the demand of the client to have some flats ready for sale by a certain date.

Though majority of the project team members had ample experience in residential development, they were requested to generate new knowledge from time to time, as a way to make the development distinctive from others. Project participants experimented with some new concepts in the design that required trial and error like the spa and health treatment facilities. Team members also extensively used their own personal networks, external to the team, to acquire and generate information and knowledge relevant to the project. However, for a small minority, these appeared to be quite limited. There was then a general reliance on internal sources of information and knowledge, such as from their own organisational memories. In addition, knowledge of competitors and customers were examined seriously by the project team, the former being important from the selling point of view, the latter important in understanding and meeting customer needs.

Owing to the diverse perspectives held by the stakeholders within the project, blending the different areas of expertise is an important aspect of the problem solving and innovation processes (Nonaka, 1994). Debates among themselves were a characteristic of the intellectual conflict necessary for processes of innovation (Leonard and Sensiper, 1998). Striking a balance to accommodate the stakeholders' interests, including those of the team members, was at the very heart of the process of knowledge integration.

Working on the project resulted in the amplification of individual knowledge and generated significant amounts of explicit collective knowledge. Individual team members expanded their knowledge bases through individual learning. In addition, team members straddling similar and concurrent projects could have their learned experiences transferred to other projects, or vice versa.

The results of both case analyses will be considered in Chapter Seven, to further refine the analysis and lead to conceptual developments and theories that provide explanatory power for the way in which the processes of knowledge creation, their interrelationship and the contributory factors can be sustained.

Chapter Seven - Knowledge Creation Processes - Their Interrelationship and Contributory Factors in Multidisciplinary Project Teams

7.1 Introduction

The empirical findings and conceptual developments discussed in this chapter aim to explore the research into knowledge creation within multidisciplinary project teams, through addressing the processes behind knowledge creation, the interrelationship among the processes and the significance of those contributory factors affecting the processes.

Existing literature in the field of knowledge creation and team processes has tended to focus primarily on three of the five processes identified in this research - namely, knowledge sharing, knowledge integration and collective project learning. This chapter hopes to contribute to the theoretical debate in the literature concerning the nature of knowledge work and the management of knowledge creation within multidisciplinary project teams. The processes of such knowledge creation are discussed by using the conceptual framework highlighted in Chapter Two.

The evidence from the two case studies suggests that several processes are important to create knowledge. Table 7.1 compares the infrastructure and residential development project teams based on major criteria such as diversity, past experience, boundaries, etc. Project teams need to create knowledge because not every situation encountered can re-cycle existing knowledge without modification. Some design problems are unique. Team members have to pool their individual expertise and knowledge so that decisions can be reached. Even though the problems or situations may present as the same, the different knowledge and experiences the team members possess may alter the eventual knowledge created.

Table 7.1 Key comparisons between the infrastructure and residential development project teams

	Infrastructure project team	**Residential development project team**
Diversity	Diverse team of professionals.	Diverse team of professionals.
Past experience	Not many team members had direct and relevant experience.	Most of them possessed relevant previous experience.
Boundaries	Expertise boundaries existed among team members. Perceived hierarchical boundaries existed between client, consultant and contractor.	Expertise boundaries existed among team members. High-low status existed among project participants, creating hierarchical boundaries among team members.
Socialising	Team members found that socialising was a valuable mode of creating knowledge.	Socialising was found to improve relationships as well as decreasing the distance between team members.
Sharing knowledge	Both positive and negative experiences were shared.	Both positive and negative experiences were shared. Architects and interior designers were asked not to have the same in-house teams working on key competitor projects as divulging those features could mean losing the competitive advantage.
Seeking knowledge	External information and knowledge sources, through team members' personal and external networks, were accessed. Joint site visits were arranged to help team members gain design knowledge that could contribute to a collective experience.	New knowledge, to make the development distinctive from others, was generated. External and personal networks were employed to acquire and generate relevant information and knowledge. Knowledge of competitors and customers was examined seriously by the project team.
Integrating knowledge	Various internal and external stakeholders' interests and perspectives were integrated.	Various internal and external stakeholders' interests and perspectives were integrated.
Learning in projects	Individual learning was self-directed. Team members learnt together when required to resolve and reflect upon common problems. Inter-project learning took place through multiple team memberships.	Individual learning was self-directed. Team members, straddling similar and concurrent projects, could have their learned experiences transferred to other projects.

In section 7.2, the areas of expertise and the hierarchical boundaries that exist within multidisciplinary teams are examined. Also identified are the mechanisms of crossing such boundaries. Once boundary crossing has occurred, interaction can take place, initiating the process of knowledge creation among team members from diverse professional backgrounds. Information and individual experiences are exchanged so that problems can be identified and solutions found. Various conceptual developments and issues of knowledge sharing among multidisciplinary team members are explored in section 7.3. Many participants may not have relevant experience or pertinent knowledge to draw on. They have to generate knowledge through collective action, in collaborating, interacting and using a wide range of knowledge sources to resolve problems. This is covered in section 7.4. Otherwise, team members can resolve the issues or problems encountered, through sharing the knowledge or experiences they possess. The next process is to integrate knowledge (section 7.5). Once knowledge has been generated or shared by team members, it must be combined into a collective product. It resembles a jigsaw puzzle, with the different team members holding various, vital segments of knowledge. The last major feature of knowledge creation (section 7.6) is collective project learning, with individuals internalising the problem solving experiences so that in future, they can rely on the additional knowledge and experience acquired. Collective project learning may occur throughout the knowledge sharing, generation and integration processes. Emphasis is made here that these five dynamic processes of knowledge creation in multidisciplinary project teams do not appear in a linear and unidirectional way, even though they are analytically separate. Instead, they are highly interwoven. The dynamic interrelationships between the five processes are highlighted in Section 7.7.

The implications of these conceptual developments will be considered in relation to existing theory. Thus, knowledge creation in a multidisciplinary situation involves processes through which team members (1) cross boundaries, (2) share knowledge, (3) generate knowledge, (4) integrate knowledge and (5) learn collectively from the project.

7.2 The Process of Boundary Crossing

The term 'boundary crossing' refers to the process through which team members transcend various boundaries to share, generate, integrate and absorb relevant information and knowledge. Two types of boundary crossing from the case studies are described. Both existed at the outset of the two projects. The first boundary existed as a result of the specialist expertise of team members, initially defined by varying expertise expectations. The analysis of this is provided in section 7.2.1. The second boundary is analysed in section 7.2.3. It exists because of very distinct, hierarchical levels that lead to distancing and negative attributes. Typically this boundary occurs at the interface of client, consultants and contractor. The discussion then highlights the processes used in crossing each boundary. Both boundaries were found to inhibit knowledge creation in multidisciplinary project teams.

7.2.1 Expertise Boundaries within the Project Teams

Both the INF and RDA projects were complex, demanding input from different disciplines as no one professional was able to manage the whole development process. Both project team members appeared to possess distinctive knowledge, professional competence and specialist skills and seemed highly regarded by the general public. They generally co-operated fully with each other to ensure that the objectives set by the client were fully met.

The expertise boundary exists in project team members across disciplines. Expertise tended to be associated with specific individuals and labelled accordingly - for example, architect, structural engineer, quantity surveyor. Thus, an expertise boundary refers to whatever delimits the perimeter - and thereby the scope of a role. In both projects, the different expertise possessed by the team members resulted in knowledge gaps and created boundaries to build a shared understanding between team members. Some team members in both projects were accustomed to the traditional sequential design process, with one discipline completing a task before handing it over to another, with little team interaction or discussion aggravating the expertise division. Furthermore, the clear expertise barriers could create a design that was less than ideal, as each discipline pursued their own perspectives without due consideration for others. They might achieve optimal design in their own field but possibly not in terms of the overall, finished product. As illustrated in the INF project, the partial or complete absence of knowledge redundancy, due to a lack of familiarity with infra-structural design among team members, could create boundaries inhibiting knowledge development in a multidisciplinary team setting. This was due to the fact that the infrastructure project was funded and designed by a private property developer, whereas most installations would be under government jurisdiction. Previous work by Hutt et al. (1995) propose the concept of 'interpretive barriers' by referring to the difficulties created by participants' diverse knowledge backgrounds when making decisions. However, they do not advance further to explain how the diversity of knowledge influences the creation of barriers.

With the presence of expertise boundaries, team members could dwell in their own disciplinary knowledge without due regard for other disciplines' needs and perspectives. Previous research finds that team members usually create and maintain boundaries as a means of simplifying and ordering the environment (Michaelsen and Johnson, 1997; Nippert-Eng, 1996a,b; Zerubavel, 1991). They erect "mental fences" around people that appear to be similar, functionally related or otherwise associated (Zerubavel, 1991, p. 2). The boundaries are real in the sense that team members perceive them as such, acting as though they are real (Weick, 1979). These boundaries enable project team members to concentrate on whatever domain is currently salient to them, focusing less on other domains. Thus, crossing boundaries has been described metaphorically as taking a cognitive leap between categories (Zerubavel, 1991).

In the INF case, the submarine pipeline consultant could have designed the pipeline unilaterally, without looking into other team members' requirements. If this expertise boundary were maintained, he might achieve optimal design in his own field but possibly not beyond. In the RDA project, the same applied to the work between the environmental consultant and the architects or engineers. They could each go their own way but whether the building design could meet with the stakeholders' requirements would be seriously in doubt. In this project, some residential blocks were close to an existing railway line. Noise migration measures were of top priority in order to fulfil statutory requirements, especially environmental ones, as well as minimise any adverse effects to future sales and the well being of residents. Without crossing the expertise boundaries, the design could hardly satisfy the requirements of the stakeholders, including various regulatory authorities.

7.2.2 Observed Methods for Crossing Expertise Boundaries

The crossing of the expertise boundaries was in the form of connections with other team members. These could be the result of joint design activities, shared problem solving or knowledge redundancy among team members. Several different disciplines might have jointly developed a design. Often the expertise of one discipline overlapped with another. These situations required closer interaction than simply sharing information, knowledge or results, as no one professional discipline possessed all the requisite knowledge. Numerous examples could be found in both projects. Various INF disciplines were required to work together on the design of the pier and all the related team members were consulted. Other examples included the team of environmental consultants, architects and various engineers, in designing a sewage treatment plant that could fulfil statutory requirements for the different regulatory authorities. In the RDA project, resolving dimensional conflicts in the layout plans of different flats called for closer interaction among the architects, structural engineers and building services engineers.

In these particular case studies, some degree of knowledge redundancy between participants could have broken down the boundaries inhibiting cross-functional knowledge transfer. Team members suggested that knowledge overlap was achieved through prior knowledge acquired while working with other disciplines in previous projects, as well as experiences gained from working in similar facilities to the current ones. The INF team had fewer members with actual experience in infrastructure projects whereas most RDA employees had had experience in previous residential design. In other words, there was little knowledge redundancy in terms of relevant experience amongst the INF participants. Under the normal infrastructure projects procured by government, consultants would be appointed separately to work on them rather than working interactively. The unique private nature of this infrastructure project had caused team members to lack the relevant project experience. In addition to possessing relevant project experience, it seemed advisable for team members to have some knowledge of professional disciplines other than their own. To understand the assumptions and theoretical models underpinning someone else's work appeared pivotal in helping build connections. The research findings echo Nonaka's (1994) concept of knowledge redundancy. He explained that a degree of overlapping expertise, or what Demsetz (1991) labels 'common knowledge' between team members, not only provides a platform to build shared understanding amongst them but also helps them acquire new knowledge. The requirement of members of product development teams to have some knowledge of the work within other functions has been identified in the organisational behaviour literature (Nonaka, 1994; Trist, 1977), as well as in the new product literature (Souder, 1988; Wheelwright and Clark, 1992). These scholars stress the benefits of cross-functional experience and knowledge breadth in facilitating effective cross-functional relationships.

During this stage, the team's collective knowledge was based on an aggregation of results and findings developed independently within the various disciplines. The discipline boundaries established points where information, knowledge and conclusions were transferred from one discipline to the next. This sequential cross discipline interaction seemed not particularly effective. The designs produced by the preceding team members might have acted as a constraint to the succeeding participants.

In both cases, there was other evidence of crossing the expertise boundaries. The catalyst was often a technical hurdle requiring multi-disciplinary problem solving. The interaction sometimes began when a team member risked stepping beyond his own role and boundaries to challenge the work or logic of someone else. In the INF project, boundary crossing, or stepping into another person's territory, was necessary when shared problem solving, specific to infrastructure design, was required. For example, the sewage treatment plant design specifically called for a high level of collaboration among various team members. Boundary crossing was observed within the RDA team, when a team member offered insight previously gained from within a colleague's knowledge domain. This facilitated the crossing of the expertise boundaries.

When people develop a level of comfort within a group setting, they are able to question each other without anyone becoming defensive. During informal meetings, it became evident that team interactions were relaxed and spontaneous, characterised by little pretence. Such environments were conducive to transcending boundaries and entering other people's disciplines. Should a team make it through the expertise boundary crossing, the level of integration and knowledge creation changes. The basis of interaction shifts from an evaluation of another perspective to valuing and exploring multiple perspectives. This allows other ideas to expand one's own understanding. Knowledge creation in this mode requires time in which to discuss issues, along with patience to hear and fully appreciate another person's perspective. An example of this could be seen when the project teams faced technical hurdles. Both teams would collect as many facts about the problem as possible and through discussion, they would aim to identify the core issue, be it technical, aesthetic or regulatory. Through such crossing of individual expertise boundaries, they were able to offer and receive insights from other team members and resolve many key issues.

Identifying core problem areas and knowledge gaps is a primary advantage of this level of cross-disciplinary integration. Considerable time and resources can be wasted if team members pursue peripheral notions. Team members in both projects had opportunities to interact across expertise boundaries during formal and informal meetings. They were able also to communicate the information and knowledge needed for the projects through the use of boundary objects. All project team members did work beyond their role, extending into multiple disciplines. Crossing into an outside domain requires boundary work (Fisher, 1990). Boundary objects help people to cross boundaries and come together to solve a problem by inhabiting "several intersecting social worlds" and satisfying "the information requirements of each of them" (Star and Griesemer, 1989, p. 393). As observed within the project setting, boundary objects could be concrete or abstract, including sketches and drawings, reports, correspondence, tender documents, specifications or conversations. They would have to be tangible to all team members, with the capacity to support translation across boundaries. Generally, concrete objects are a pivotal feature of crossing disciplines, often shared between different professions and sometimes brought together for discussion when requiring input from other disciplines. Boundary work is the cooperative pursuit of tasks in spite of boundaries that could prevent separate social worlds from achieving goals (Gieryn, 1995). Boundary objects may also be critical in highly interactive situations, as in both case studies. The project teams accomplished important boundary crossing through team conversations with the aid of boundary objects. The objects had different meanings within different disciplines but shared a common structure, making them recognisable to all team members. As a result of their flexible structure, they served as a means of translation between the various disciplines.

Drawings were a legitimate means of communication in the project teams. Activities presented for tendering and construction purposes, and for approval by the various regulatory authorities, were often supported by drawings. The sociology of science literature offers several reasons for the legitimacy and primacy of drawings as communication devices. Both Ferguson (1992) and Latour (1986) point out that drawings allow visual information to be reliably transferred across space and time. Team meetings illustrated the way in which drawings could be used and interpreted, embedded in the language spoken within the group (Henderson, 1995). Participants used drawings as a primary means of communicating, often pulling documents out in the course of conversation. Alternatively, they might have prepared free-hand sketches during a discussion to support their case. Since creating and interpreting drawings was an important aspect of the project team's work, they shared a common understanding through this boundary object. This does not imply, however, that they shared a complete understanding of one another's work, as each discipline possessed a specialist knowledge domain.

The study found that the abstract boundary object, the successful project, served as a common denominator for all team members. At a more subtle level, a shared understanding of the project's limitations and constraints, e.g. set budgets in both projects, also served as boundary objects among project participants. Boundary objects tended to be persistent features at the intersections of team members.

Participants were required to cross professional boundaries, at least to the extent that boundary objects collectively helped resolve the problems.

Evidence from both cases confirmed that boundary objects are representations or artefacts that embody particular aspects of knowledge-in-practice, yet have a shared or understandable character across different discipline settings, making them useful for mutual or cross-functional problem-solving.

7.2.3 Hierarchical Boundaries within the Project Teams

The research findings suggest that hierarchical differences could easily become boundaries separating participants in the knowledge creation process from non-participants. The implication for cross-functional knowledge creation is that hierarchical boundaries create barriers that restrict communication as well as various knowledge-creating activities. Manifest in both case studies, the difficulties created by hierarchical differences need not be related only to the willingness of team members to share their knowledge with others. Just as important is the issue of whether a shared understanding can be achieved among team members.

The hierarchical differences, although seldom voiced openly, did affect behaviour in boundary crossing, with most team members consciously drawing distinction between the client, consultant and contractor. The interview process revealed that these types of hierarchical boundaries did exist in both project teams. Some team members may have been reluctant to openly share ideas with the client, possibly fearful of appearing unintelligent or assuming that the client, as an experienced developer, probably had all the answers regarding facilities development. Consultants may have been reluctant to acknowledge the participation of contractors during the design process, as they are presumed to be only concerned with ease of construction without due regard for aesthetic considerations. In addition, they may perceive the architects, or the architects perceive themselves, as the lead consultants on the projects, with their contributions valued higher than other team members. This in fact could be the consequence of the construction industry's current procurement practice of having a clear divide between design and construction, as well as a distinction between the different professional status of consultants.

As Argyris (1995) demonstrates in his research, these attributions typically go untested. Participants in any given situation behave based on their beliefs. The fact that they hold particular beliefs and assumptions is not open for discussion. This self-fulfilling sequence erected an even higher boundary in both project teams between client, consultants and contractor.

Because of the positional power of client versus consultant versus contractor in the decision making process, high and low status members were identified and acknowledged in both teams.

7.2.4 Observed Methods for Crossing Hierarchical Boundaries

Top-down boundary crossing implicated the client's project managers with a need to gain the full collaboration of the consultants and contractors involved in the project teams. The negative impact of these distinct boundaries lies in their potential damage to knowledge creating opportunities among project team members, possibly limiting their contributions when they have so much to offer. In meetings, it was evident, through the dialogue between the consultants and the contractor team, that team members began to recognise and acknowledge their construction expertise in related areas as the project manager emphasised the changing company culture regarding design and construction. Examples in the INF case included the joint design effort among the consultants and contractor for the system formwork and the concrete retaining wall next to a proposed school site for the project. The consultants also were reassured that problems during construction, possibly created by a complicated design, could be resolved at a much earlier stage. All the while, the project managers served to reinforce the importance of removing hierarchical boundaries. Inviting the contractors to participate in formal meetings meant that construction knowledge could be accessed constantly. It also acknowledged their expertise and served to lower the boundary barriers. The RDA project managers had unceasingly encouraged project team members with any contributions to the project to speak out, even if outside their professional boundaries. Their constant invitation in having new ideas from team members reflected their open attitudes towards ideas that could make the project distinctive as well as lessen the effect of professional segregation.

The active participation of the project managers also sent a positive signal to all team members that they were part of the project. The managers were keen to work together with team members to resolve design conflicts and issues rather than just leave them on their own to deal with the design.

7.2.5 Summary of the Boundary Crossing Process

The study describes two types of boundaries affecting the progress and success of multidisciplinary knowledge creation in both projects. The importance of boundary crossing is reflected in the notion of 'solving the boundary paradox' (Quintas et al., 1997) where team members are able to exchange and combine knowledge (Nahapiet and Ghoshal, 1998). The interpersonal interactions across these boundaries can either foster or hinder knowledge creation. In considering the case studies, the first boundary was between team members of different disciplines. The second boundary existed between client, consultant and contractor.

As described above, the expertise boundaries could be crossed not only through shared problem solving and knowledge redundancy among team members, but also through boundary objects. The most prominent project boundary objects were drawings and personal conversations among team members. The second hierarchical boundary could be crossed by the conscious effort of team members to break down barriers by valuing the expertise of others. The example set by the project managers was also helpful in this regard. It must be stressed that crossing boundaries does not necessarily ensure that knowledge will be created. Four other knowledge creation processes also play key roles.

7.3 The Process of Knowledge Sharing

The following discussion illustrates three aspects of knowledge sharing: competition, communication thickness and knowledge sharing from different knowledge domains. In discussing each aspect, the actions of the two project teams are highlighted and compared with current literature. Lastly, influences on the knowledge sharing process are identified and explained. One essential point to be stressed here is that the previously described boundary crossing is a pre-requisite for the remaining knowledge creation processes to occur. Without this, individual team members will be very much working in their own disciplines, with little knowledge cross-fertilisation occurring.

7.3.1 Competition and Knowledge Sharing

The RDA project illustrates that knowledge sharing could be a double-edged sword in attempts to foster competitive advantage. When competitive advantage partially depends upon non-imitability of knowledge used in product strategies, and when knowledge sharing comes at the cost of increased knowledge leakage to competitors, thereby facilitating imitation, the company's competitive position could well be eroded rather than improved. It is tacit knowledge - and not explicit - that most accurately fits the description of resources to which sustainable competitive advantage and associated returns confer (Grant, 1996a; Leonard and Sensiper, 1998; Spender and Grant, 1996). In contrast to easily traded and widely accessible resources, idiosyncratic and scarce knowledge qualifies as a strategically significant resource (Winter, 1987).

In the RDA project, sharing in-house knowledge among the architects or interior designers could yield potential losses through unwanted knowledge diffusion, should company designs be imitated elsewhere. This could result in restrictions being considered on knowledge sharing among in-house members. Knowledge once articulated and codified may be easier and less costly to replicate and leverage internally. Simultaneously, however, codification and easy access to shared knowledge increases the risk of imitation outside the company. Consequently, companies have to weigh the potential for, and the speed of, internal replication against the threat of expropriation through imitation (Kogut and Zander, 1992; Nelson and Winter, 1982; Sanchez, 1997; Winter, 1987).

Out of the two projects, the residential development is more susceptible to competition, more sensitive to customer needs and more vulnerable to market forces. The infrastructure project would generate little competitor interest in adopting its design, despite its many unique features. A lot of the knowledge had already been codified and published by government in design standards and guidelines. Consider, for example, the performance requirements and the spatial arrangements of the police and fire stations or the design details of the roads. More pertinently, an infrastructure project generally has little market value, with no potential buyers. As a rule, privately developed infrastructure is not common in Hong Kong, making it less vulnerable to imitation. The residential development, on the other hand, will face fierce competition. Each year tens of thousands of residential units, both new and second hand, move onto the market.

Acutely aware of this market vulnerability, the case company had a further security risk to consider. The heavy competition in Hong Kong's construction industry results in energetic bidding for projects by professional service companies. They cannot afford to serve one particular client alone as the returns would not be sufficient. Accordingly, they often end up working for clients who may be in competition with each other. This was very much the case in the RDA project, with both the architectural and interior design firms working for the client company and its competitors. The project managers had explicitly requested the designers not to have the same teams serving both the project and any rivals. In this way, the risk of confidential information and design details being leaked to competitors could be minimised. They were advised, furthermore, to have totally separate in-house teams providing professional services to the client and their competitors, with absolutely no direct communication. Teams were simply not allowed to share knowledge. At the same time, the sharing of information and insights across teams and professions would appear to be important in stimulating knowledge creation.

This would seem to run contrary to the knowledge sharing principle of employees being encouraged to share their knowledge. All team members from the architectural and interior design firms were fully aware of this constraint. They seemed to appreciate that their input and discretion were both critical to the success of the product launch. It is interesting to conjecture whether such shielding of knowledge may in time erode the working culture within companies, with colleagues communicating less to avoid divulging confidential information.

Furthermore, several interior designers revealed that they would never contact colleagues in other firms to share or seek knowledge. The competition among interior designers was intensely fierce. This lack of knowledge cross-fertilisation might result in some 'reinventing of the wheel'. Negative work experiences might also be needlessly re-enacted, given the potential scarcity of cautionary advice. There is also the risk of self-complacency or stagnation. Design creativity can be triggered through sharing knowledge with professional peers. Interviews with members of other disciplines did not reveal similar levels of knowledge hoarding. It is possible that this tendency could curb knowledge advancement in the interior design industry.

7.3.2 Communication Thickness and Knowledge Sharing

Because of their specialist professional knowledge, team members had to share both tacit and explicit knowledge to meet a general deadline most effectively. The process of creating knowledge in teams consistently begins with communication between individuals.

This study revealed a connection between the medium of communication and the type of knowledge shared. Thicker communication was associated with the sharing of tacit knowledge among team members in both projects. This result is consistent with the critical social theory (Habermas, 1987; Markus, 1994; Ngwenyama and Lee, 1997) which suggests that thicker communication media are preferred for sharing more complex information and knowledge. Most particularly personal experience or personal tacit knowledge is shared through active interpretation of the sender and receiver. This is in line with Nonaka and Takeuchi (1995) who suggest that Japanese corporations have invested in expensive corporate retreats to withdraw to when complex decisions need to be made. In both cases, thicker communication enables complicated ideas, opinions, social cues and emotions to be exchanged and interpreted.

Individuals from both teams possessed expertise and knowledge relevant in varying degrees to their project work. This did not guarantee that they would necessarily share their knowledge. Before this could take place, team members needed to recall any relevant information or knowledge - and also be motivated to share it. The negative consequences of failing to share critical knowledge during the design phase could result in substandard or faulty design, possibly causing fatalities, injuries or simply mere discomfort. In the RDA project, the failure of the architects to convey their intention of creating a clear span for the roof structure above the swimming pool had resulted in the structural engineer designing the roof using columns, beams and a flat roof structure. This situation was later rectified during an informal meeting and the engineer had to resolve the situation by using a much more expensive solution of a structural steel, lattice roof structure to accommodate the large, unobstructed span. The failure of the INF civil engineer to share critical knowledge, on the future access of vehicles to part of a paved area, resulted in the landscape architect having to re-design the base material and the thickness of paving blocks to be strong enough to support the vehicular traffic. Whatever the scenario, the impact on the projects could be considerable and would be best avoided. The more conducive an atmosphere is to knowledge sharing, the more likely problems would be addressed and corrected.

All project team members were located within Hong Kong, enabling them to interact frequently in person through the scheduled formal and informal meetings. Ample opportunities were available to share explicit as well as tacit knowledge, allowing hidden knowledge to be exchanged. Personal interaction is regarded as the richest form of communication because it provides multimode communication with immediate feedback. Though such interaction provides more opportunity for knowledge sharing, it does not necessarily imply that it will happen naturally and automatically in every team situation. Opportunities for project team members to interact with and observe one another are better mechanisms for transferring tacit knowledge than electronic media which is often relied upon so heavily to coordinate geographically dispersed teams (Nonaka, 1991). Both project teams would have used electronic communication solely for transmitting project-related information like drawings or documents to other team members. It would not have been used as a forum for knowledge sharing or problem solving. E-mail messages are restricted to the printed word and are mono-directional.

As Souder (1987) suggests, new product development team members need to share perceptions and feelings as well as factual data. When they use rich communication media, new knowledge is more likely to emerge (Nonaka, 1994). There is no evidence in either project that e-mails were used extensively to replace face-to-face dialogue. Attachments to e-mail messages enabled design inputs to be incorporated but these were difficult to implement and were not freely used. Its principal advantage was being able to send information to several team members at the same time and quickly. It was seldom used for social and informal discussion. It was found that not every team member had a personal e-mail address. Electronic messages are not as rich as those personally delivered, with the risk of misunderstanding therefore higher (Canney-Davison, 1994; Romme and Dillen, 1997).

Generally it appeared that face-to-face communication in both projects enhanced the understanding of pertinent issues and problems. Visual aids such as free-hand sketches, or drawings, photographs and pictures from references, were used to facilitate dialogue and aid further comprehension of concepts. Both project team members tended to use objects to promote visualisation of issues. In addition, knowledge sharing through discussion embodies more of the 'human moment' than writing. Team members evidently valued interpersonal discussion and anecdotal exchange to promote knowledge and social interaction.

Both project groups held formal and informal meetings on a regular basis. Formal meetings focused more on broader issues affecting all team members, such as setting goals and deadlines. Informal meetings enabled interrelated team members to resolve design issues that were affecting each other. They were less formal, with team members speaking openly on issues of mutual interest. The vigorous nature of the meetings, and the detailed discussions that flowed, gave rise to a more thorough comprehension of other people's opinions. Such conditions enabled tacitly held knowledge to be converted into explicit knowledge, where team members explicitly shared previously gained experiences in order to facilitate working on the current projects.

Team members were repeatedly observed as not hesitant in sharing the knowledge they possessed once the boundaries mentioned previously had been crossed, irrespective of being within their own domain knowledge or not. The sharing happened so naturally, as part of the discussions. Team members shared knowledge gained from concurrent or previous projects. Some were able to share project knowledge, not from their own domain but from the organisational memory embedded within their companies. Others were able to offer knowledge acquired through inspecting other facilities. Some of this knowledge was acquired during weekends or on vacation overseas. The shared knowledge came from a range of sources and experiences. Communication was the key to sharing knowledge in both project teams.

7.3.3 Knowledge Sharing from Different Knowledge Domains

Through training and experience, team members may acquire information and knowledge that others do not possess. Knowledge sharing within multidisciplinary project teams can unlock diverse material possessed by different professional team members.

Personal discussions, at work or during social activities, with other project team members were used extensively for knowledge sharing, to assist the problem solving and decision-making process. Socialisation is a valuable mode of creating knowledge within organisations (Nonaka, 1994). It enables individual team members to understand each other and work together towards common goals but from different perspectives (Saint-Onge, 1996). Team members had diverse backgrounds, training, expertise and experience. They contributed their different histories, skills and knowledge to the project, all uniquely fashioned through years of individually distinct experience and training. Team members appeared to be comfortable in sharing their information and knowledge, not at all reluctant to offer their insights to colleagues. An example in the INF case was the sharing of knowledge on the different paving materials commonly used in Hong Kong. RDA team members openly shared their insights about the clubhouse features, based on projects they had worked on before, latest sales brochures or new trends in both Hong Kong and overseas. Besides sharing positive experiences, team members in both projects candidly shared negative experiences gained from previous projects so that they could be currently avoided. Only a small number of team members were cautious when needing to 'trespass' into another professional arena. Generally it was found acceptable during brainstorming meetings or informal discussions to enter someone else's domain and accept different suggestions and solutions from their peers. They all agreed that even after many years, they still stumbled upon things they did not know. They seemed to perceive each project as a new learning experience. By pooling the expertise and knowledge of various departments, knowledge sharing enables organisations to reduce uncertainties and to achieve synthesised benefits exceeding the sum of benefits produced by departments individually (Clark and Fujimoto 1991). As Moenaert and Souder (1990) point out, through collaboration and knowledge sharing, between marketing and research and development (R&D) functions, an organisation as a whole is able to reduce consumer, technological, competitive and resource uncertainties. These cannot be reduced simply by knowledge held by one function alone.

Research by Stasser and Titus (1987) matched the finding here that members of a diverse group, each with different information to give, may be more likely to discuss uniquely held information than groups comprising similar, like-minded members (Wittenbaum and Stasser, 1996). People from diverse groups are less likely to have information in common and will therefore have that much more to exchange. The advantage of heterogeneous teams stems from the diverse pool of accessible information and knowledge that can be shared in meetings or discussions.

In addition, the team's awareness of the distribution of expertise increases the chance that unshared knowledge uniquely held by members will be shared (Stasser et al., 1995; Stewart and Stasser, 1995). This was evident in both projects. The INF civil engineer's extensive experience in roadwork design and submission procedures to the Highways Department attracted other team members to seek his advice. A lot of his knowledge was not codified in regulations or design manuals. The RDA architectural director possessed immense expertise in design matters. This attracted team members to approach him directly for advice as well. As a general rule, expertise within a team helps validate the credibility of uniquely held information or knowledge as team members are more likely to accept and remember information contributed by a recognised expert (Stewart and Stasser, 1995). Various team members, when interviewed, openly praised the architectural director for his knowledge and expertise in design matters, automatically valuing his advice.

It could be said that knowledge or information provided by an expert might determine the team output more than knowledge provided by someone not perceived as expert in that field. This finding also relates to the knowledge integration process, discussed later in this chapter. The following section highlights several contributory factors, identified from the research as influencing the knowledge sharing process.

7.3.4 Contributory Factors Influencing the Knowledge Sharing Process

The knowledge sharing process appears to be moulded by four different influences - namely openness, motivation, trust and pressure of time. They are detailed below.

7.3.4.1 Openness

Once project team members were able to cross the expertise and hierarchical boundaries, they were generally willing to communicate and interact with one another. This openness enabled individual knowledge to be shared.

The openness seemed particularly evident in team meetings, with open discussion taking place concerning issues and problems. Such openness allowed team members to voice potentially useful ideas without fear of ridicule. RDA team members explored the issue of 'feng shui' in the luxury flats, fearing that this could affect the layout design and ultimately, influence the decisions of potential buyers. INF team members openly shared knowledge related to pier design though not many had actual experience in designing piers. Through knowledge they had acquired in past projects, or through reading design reference materials, their ideas were pooled to enable team members to consider possible alternatives before a final decision was made. Lane and Bachmann (1998) find that openness between partners positively influences the transfer of knowledge. Since some team members on both projects had previously worked with other team members, positive experience of working with colleagues elsewhere could further enhance openness (Lane and Bachmann, 1998; Rotter, 1980).

It was apparent that team members were open enough to share knowledge and experience from other professional disciplines, observed during previous or concurrent projects. In this way knowledge was shared across professional boundaries. It was seen as an opportunity to listen to opinions or solutions gained in other projects through the participation of current team members.

7.3.4.2 Motivation

In both teams, participants seemed motivated to share their knowledge and experience since they managed to overcome the various boundaries that existed within the project teams. No financial or other reward was given to team members to share their expert knowledge. There appeared a general expectation that multi-disciplinary project teams were paid to share and create knowledge for the clients' benefit. Due to the distinctive knowledge bases of project team members, it could be difficult to measure whether the knowledge shared by one professional discipline would be better than another.

Team members in both projects found that sharing knowledge provided personal satisfaction and gratification. A lot of time and effort could be expended searching through professional journals and manuals and this often could be circumvented through the knowledge sharing process. In tight design programmes, parties could ill afford to waste time. Knowledge collaboration frequently precluded this, firmly motivating participants to share expertise and ideas.

7.3.4.3 Trust

Another influence identified was trust. Team members did not hesitate to share their knowledge in the project teams, given the case organisation's open culture and the frequent efforts of project managers to allay any anxiety that could arise through sharing new ideas. Nam and Tatum (1992) suggested that without any contractual obligation between professionals, respect and trust appear to be strong motivators of cooperation.

Trust refers to a belief in people's capability (Szulanski, 1996) or 'competence trust' (Newell and Swan, 2000), which is a belief in people's competence. Team members may have derived a level of trust based on the client's reputation for recruiting the best consulting firms, constantly evaluating the professional competence of all their listed consultants. This trust was further enhanced by their mutual work experience which tended to confirm that other team members were highly capable.

When people trust each other, they also help one other because they feel it is morally right (Lewicki and Bunker, 1996; Tyler and Kramer, 1996). Team members appeared willing to engage in exchanging knowledge in a cooperative manner, possibly reassured by the sentiment of trust.

In practice, the time needed to develop trust might be too long should participants be of temporary status, with little time to engage in the usual forms of team building or other trust building activities. Therefore, many temporary systems act as if trust were present, even though their histories seemed to preclude its development (Meyerson et al., 1996). Meyerson et al. (1996) call this phenomenon 'swift trust'. To transfer the individual expertise of strangers into interdependent work, people must reduce their uncertainty of one another through activities that resemble trust. This could have been reflected in both projects, as interviewed team members did not highlight trust as such an important issue in knowledge-based work, despite the numerous literature claims. This could suggest that trust had developed swiftly or that people took a 'leap of faith' or they simply presumed that performance needs were imperative. Since some team members had previous collective work experience, Sherif and Sherif (1953) referred this to the benefit of building up mutual trust.

It was revealed that the establishment of trust or friendship in both projects would guarantee personal ties for the future. It was felt that the relationships could extend beyond the current project, into people's informal personal networks.

7.3.4.4 Time Pressure

Time pressure can act as a double-edged sword in the process of knowledge sharing. Time pressure on both projects had been due to insufficient human resources, team members' commitment on multiple projects, the client's tight programme as well as the corporate focus on profit maximisation. On the one hand, time constraints can restrict the opportunities for sharing knowledge (Starbuck, 1992), with participants rushed to get their work done. Members could quite easily resort to adopting previously workable solutions if time were really pressing. This was evident in the INF project as one team member opted to use an existing design for the current project. However, construction design should require innovative and freshly creative input, in order to attract customers and improve previous products.

On the other hand, team members recognised that deadlines could stimulate knowledge sharing so that time could be effectively managed, with the risks of error possibly diminished. It was evident in both projects that team members did share their knowledge by lending previous drawings or designs to other team members for reference. This often helped reduce the design time by minimising preliminary investigations and highlighting any past imperfections or pitfalls.

7.3.5 Summary of the Knowledge Sharing Process

This study suggests that competition could be detrimental to the knowledge sharing process. Sharing important market or design knowledge can facilitate imitation by competitors, possibly even resulting in a project being poached by another consulting firm. In addition, it proposes that the type of communication was more important in the transfer of tacit knowledge than explicit. For tacit knowledge to be transmitted, interpersonal communication was of utmost importance as team members shared tacitly held personal experiences through dialogue. Orr (1990) demonstrates how narrative, in the form of stories, facilitates the exchanging of practice and tacit experience between technicians. The emergence of shared narratives within a team enables the creation and transfer of new interpretations of events facilitating the combination of different forms of knowledge, including those largely tacit. Marwick (2001, p. 815) finds that "through conceptualisation, elicitation, and ultimately articulation, typically in collaboration with others, some proportion of a person's tacit knowledge may be captured in explicit form". He suggests several activities that will enable the sharing of tacit knowledge including dialogue among team members, response to questions as well as through storytelling.

Evidence from both cases also revealed that team members of differing knowledge domains were more likely to discuss their uniquely held information and knowledge than those who held information in common. It was an advantage to have a diverse pool of knowledge that team members could access and share in meetings or discussions. It is also clear that four influences appear to encourage the sharing of knowledge. They include openness, motivation, trust and time pressure. They all seem to affect knowledge sharing positively as well as negatively.

If knowledge possessed by team members is not sufficient to resolve the situations or problems, or new and emergent knowledge is called for, it needs to be generated through various means. Knowledge generation can be viewed as the third process in knowledge creation in multidisciplinary project teams.

7.4 The Process of Knowledge Generation

The third process of knowledge creation abstracted from the data analysis has been termed knowledge generation. This process was not anticipated in the original conceptual framework but it was found to be important in the knowledge creation process. The term 'knowledge generation' refers to knowledge being generated through interaction and communication both inside and outside the team, where no individual team member possesses prior knowledge or experience. In addition to acquiring knowledge through sharing knowledge already possessed, project teams also generate new or 'emergent' knowledge through interaction and communication. 'Emergent' refers to knowledge not possessed before group interaction, but resultant from that very interaction. Thus new or emergent knowledge not held before discussion can develop through group discussion and interaction (Kogut and Zander, 1992). In addition, new knowledge can be acquired from outside the project teams through the social networks of individual team members. The development of emergent knowledge is vital for teams engaged in tasks demanding creativity and innovation, examples being project teams, research and development teams or product development teams. Both projects saw knowledge emerging, with comments from one team member stimulating another and so giving birth to new ideas. Different professionals in a team might hold conflicting views that lead another to develop an alternative, reconciling the differing viewpoints. Cook and Brown (1999) describe the process of collective knowledge generation, as a 'generative dance' since communication within a group does not result in knowledge simply being internalised within individuals. It can be collectively compounded and processed into new forms. In the RDA project, team members modified or built on solutions proposed by others to overcome the dimensional conflicts in several types of residential flats. Since the problems were interwoven, the resolution of one conflict could trigger other conflicts. The collective knowledge generation process resembled a 'generative dance'. In the INF project, when problems concerning the expansion joints to the vehicular bridge connecting the toll plaza surfaced, team members conducted a small brainstorming session to elicit possible solutions. Some team members proposed completely new solutions, while others offered ideas that built on ideas suggested by other members.

Speed in the process of knowledge generation can be influenced by the degree of external versus internal knowledge sourcing. Through external knowledge sourcing, the variety of a team's knowledge-structure may be broadened and new external perspectives in the design process may lead to useful cross-fertilisation of ideas. In addition, external knowledge sourcing may speed up the design process through accessing external competence or past experiences. For internal knowledge sourcing, communication and exchange within a team can evoke novel associations, connections and hunches so that new meanings and insights are generated. In other words, communication not only affords the exchange of knowledge but also the generation of collective knowledge and new ways of using knowledge. The following sub-sections consider these findings in more detail by providing qualitative illustrations from personally conducted interviews and team observations.

7.4.1 Social Networks

One way in which new knowledge was generated in the project teams was through the use of personal contacts. It would be rare for any single team member to solve all the complex problems. Most team members agreed that the important skill was in knowing how to find and apply the relevant information and knowledge efficiently. They considered this to be more practical than trying to master vast amounts of knowledge.

There was general consensus in both project teams that social networks were the most important vehicle for information and knowledge exchange. Team members in both projects developed their own networks of communication, creating a complex network of relationships. Networks included colleagues, friends or ex-colleagues and were rich resources of information and knowledge. The disparity and diversity in the project teams generated a large variety of external networks that seemed to provide more effective and productive results than individual efforts did (Ancona and Caldwell, 1990). Efficiently yielding quality results, not only were social networks valued for consultative purposes, team members were also relied upon heavily for keeping abreast with current professional developments. They suggested that conversations across social networks were found to be important methods of exchanging news, getting feedback on work performed or seeking solutions to specific problems. Team members discovered that in multidisciplinary work, feedback from knowledgeable sources was crucial, especially if venturing into less familiar situations. By conversing with people in allied fields, team members were alerted to their knowledge gaps. Some team members relied heavily upon outside knowledge resources to accomplish tasks as they found this saved time. They engaged in deliberate interactions of knowledge exchange with those identified as relevant knowledgeable constituencies. These may have included suppliers, other teams, consultants and contractors.

In the INF project, personal contacts from outside fields were called upon to determine the viability of a new design or materials, as was evident when fixing roof tiles onto the proposed concrete pitched roof, not a common practice in Hong Kong. Various social networks had been sourced locally, to locate a similar construction and finally a proprietary system, designed for this situation, was sourced. Team members sometimes received advice that they wanted to verify and validate, by contacting their personal networks. Such validation often persuaded team members to assimilate the newly acquired information and turn it into usable knowledge. Some RDA team members used their personal networks to seek out past performances of proposed materials, as well as to interpret grey areas in statutory regulations. In addition, the lands consulting director used her connection with ex-government colleagues to solicit precedence cases on the proposed spa and health treatment facilities.

Rogers (1995) finds that people usually rely upon a network of relationships for information and advice. Rather than turning to databases or policy and procedure manuals, they seek information from trusted and capable colleagues. Observation of both projects confirmed that team members were more likely to turn to friends or colleagues for information than to other sources. In short, whom you know significantly affects what you eventually know. Team members stressed that personal relationships often developed after working in a project team, with previous team members becoming part of their social network. Two important features could be considered useful for building social networks. Firstly, time spent on interacting at work establishes a sense of reciprocity and trust among colleagues or friends. This was identified in both projects, that people had established trusted relationships in their social networks. In addition, there was an unwritten reciprocity between parties in the network. This social capital encouraged team members to turn to colleagues for useful assistance or advice about future initiatives. Secondly, by working closely together, colleagues build an understanding of each other's particular strengths. In the INF case, the civil engineer had exceptional knowledge in highway design. In the RDA case, the architectural director's expertise in design matters was highly renowned. Knowledge of colleagues' strengths allows team members to source appropriate contacts in the future.

It was found in both cases that a person's network of human relationships often determined the knowledge they accessed. Team members usually took advantage of published sources only when colleagues directed them to a specific point in the published source. Rather than engaging in an extensive search through an organisation's repository of knowledge, team members turned first to friends and peers to learn where to find the relevant knowledge. The INF civil engineer had adopted this approach to identify published materials on pedestrianisation from governmental contacts. The RDA architect sourced published information on green designs through friends. They found that learning from the experience of others and reusing materials effectively employed elsewhere, improved the quality and speed of problem solving, especially when time was pressing.

It was not surprising to find that most team members also established contacts in fields other than their own professional disciplines to promote cross-disciplinary understanding and knowledge generation. Example in the RDA project includes the clubhouse interior designer who had contacts in his social network that embraced architectural, engineering as well as contracting. The electrical engineer in the INF project maintained connections with people in diverse fields other than his own. Cronin (1982, p. 224) does not specifically address generating knowledge, but he notes that informal communication "facilitates boundary spanning", helping transmit ideas across disciplines. Project participants consulted with contacts from different backgrounds to explore the various ways problems could be approached, to grasp long-term hopes for a solution, and to verify a solution once proposed.

It was also established that the members of a social network functioned as filters and interpreters. They were the most effective information filters because they were highly customised to an individual's needs and activities. Connections based on shared interests tended to include trusted colleagues and friends with the authority to provide or evaluate information or knowledge.

E-mail is a welcome form of communication for managing the exchange of information within social networks. Among all the interviewees, about 50% did not have personal e-mail addresses. It was felt that this impeded the use of e-mail as a way of eliciting help within the social network. They had to rely on phone calls or face-to-face exchanges. However, generally such channels were preferred as they added a human dimension to the dialogue. Team members said they would not use the corporate e-mail for contacting social networks, as it lacked privacy.

Compared with all the other types of boundary objects used in both projects, people were the most vital among all. They played a critical role by acting as information and knowledge transfers in social networks, and performing other critical boundary-crossing functions.

7.4.2 Print as Sources of Knowledge

Generally, the use of written data in the design process of both cases is limited. Team members saw this as a time-consuming activity. Some team members used the written references mainly to counter-check solutions offered. The written material consulted included statutory regulations, trade literature or past and current project information. Generally they had too little time to consult printed information so they relied heavily on their ingrained knowledge or knowledge gleaned from their social networks.

There was evidence in the RDA project that published design and technical information or references were used more extensively than in the INF project. Some published materials were brought into informal meetings as references when team members tried to generate knowledge for a design concept or idea. Take the example of colour schemes for the external elevations of the tower blocks. These were deliberately selected to promote the resort theme but all the while it was vital not to deter potential buyers who might not like the colours chosen. Both considerations had to be weighed and the team relied heavily on published materials to guide their decision making. Printed information could be used as evidence to support the previous application of a design concept or idea. Printed materials served to give inspiration to team members in generating ideas or new knowledge for the projects by referring to other design works. Within the INF project, a lot of design details had to follow established government codes or standards. Team members had to refer to them for guidance as well. Team members in both projects seldom mentioned books or articles as referral sources as the information or explicit knowledge might not have been so practical or contemporary.

Due to the vast amount of printed information available, team members also used their social networks to identify the most relevant and appropriate sources, approaching people who had used them for their opinions. This could significantly reduce the time spent in accessing research.

7.4.3 Knowledge Generated from Customers and Competitors

In the RDA project, the case organisation drew on satisfaction surveys or customer feedback surveys to identify the needs of potential customers so that this information could be used in the design of current residential projects. Compared with the INF project, the RDA project tended to be more sensitive to market or customer needs. In addition, since the residential development was a private investment, there were fewer constraints, with a freer hand in the design as long as the client and prospective buyers would accept it and provided all relevant regulatory requirements were fulfilled.

Besides the customer feedback survey conducted by the marketing department, the client also relied on a residents' club, which included all their customers on their residential properties. This wide membership was regularly referred to for fresh ideas. Through these channels, the client could assess the latest needs and tastes of existing buyers in order to tailor the new developments to meet the requirements of potential new buyers. In addition, the chairman of the client's organisation also encouraged project team members to visit their competitors' residential developments, to look for improvements, new ideas and designs.

Sale brochures or knowledge absorbed from viewing competitors' developments were shared in team meetings as a way of generating new ideas for the project. The frequent sharing of in-house or external project knowledge by the RDA team was intended to stimulate new knowledge for the current project through assessing the good or bad lessons learnt from those projects.

Several INF visits were conducted to completed facilities, including the police and fire stations, the pier and reservoir. The project team members visited other completed facilities as an important source of design information and as a mechanism to acquire knowledge to solve operational problems. The visits were arranged either through personal contacts or through the relevant government department. Team members not only acquired design knowledge from those completed facilities, they could also assess any operational problems that existed due to design faults or design oversight. These excursions provided the project team with valuable insight to avoid certain pitfalls.

7.4.4 Contributory Factors Influencing the Knowledge Generation Process

The influences identified in both case studies that had direct impact on the knowledge generation process included both time and motivation. Both factors can affect whether new or emergent knowledge can be generated to satisfy design and consumer requirements.

7.4.4.1 Time

Unfortunately, time is the resource most likely to be begrudged by team members in generating new or emergent knowledge. It is the scarcest of all resources, the one impossible to replicate and yet most essential to genuine knowledge generation.

INF team members found that if they were hard pressed for time, they would be unable to investigate alternative knowledge that might improve the design. Accordingly, they might copy previous designs from other projects to meet the time constraint. An example in this project included the electrical engineer re-using an existing design for the current project. This is not ideal as every project is unique. User requirements might change over time or technological advancement might have rendered the current design not as effective. Previous flat layouts were used to establish the current RDA system because these workable designs had established a certain space efficiency that could not be overlooked. The project team then spent their time improving on these. Generally, many team members stressed that it was very rare to copy a design directly from a previous project without the slightest modification.

Previous research suggests that product development often builds upon an existing base product and rarely begins from scratch (Iansiti and MacCormack, 1997; Song and Montoya-Weiss, 1998). The same finding also applies to the design of facilities unless the project is so unique that no previous reference exists in organisational memory or other means.

In both projects, there was always the chance of new products or equipment coming onto the market periodically. If team members did not search for this new knowledge, the product or equipment selected, based on past projects, might not be the best for the client or future consumers. Again, time plays a significant role in allowing team members to generate new knowledge in projects.

7.4.4.2 Motivation

In both projects, motivation for knowledge generation was found to come from the need for fresh ideas, from dealing with unfamiliar situations as well as continual improvements in technological advancement.

Without this motivation, team members might resort to existing designs that might not meet the future requirements of the new facilities. Evidence shows that the client, through the project managers, encouraged team members to generate as many new ideas as possible for further consideration. Even though the infrastructure was not for sale, the client still demanded new ideas and knowledge to make the project distinctive, matching other developments on the island. Knowledge needed to be generated to create such ideas. In addition, project team members very often encountered unfamiliar situations and the resultant challenges could be motivating in themselves.

Some team members mentioned that there was always room for improving design methods, even if one were well experienced. Technological developments or changes in user requirements all demand newly emergent knowledge to improve current practices. Even in familiar situations, team members needed to examine whether there were better ways of designing a facility than past experience would have suggested.

7.4.5 *Summary of the Knowledge Generation Processes*

The above discussion has highlighted the importance of knowledge generation in relation to multidisciplinary knowledge creation. In addition to acquiring knowledge by sharing the knowledge that team members already possess, project teams also generate new or 'emergent' knowledge through interaction and communication. New or emergent knowledge that no team member possessed before discussion can develop through group discussion and interaction (Kogut and Zander, 1992). The development of emergent knowledge is vital for teams engaged in tasks that involve creativity and innovation. Research suggests that new or emergent knowledge was generated for both projects through various means, including social networks, through printed sources as well as feedback from customers and competitors.

Social networks are identified as the most important vehicle for information and knowledge exchange in both projects, with team members using networks of colleagues, friends and ex-colleagues as rich resources to generate information and knowledge for design situations. The use of written data in the design process was limited because team members found it time-consuming. Written references were mainly used to counter-check solutions offered. Social networks were relied upon to share experiences and knowledge, to recommend published materials, to reduce research time and enhance usability. The final knowledge generation source is through the comprehension of customer needs, insight into competitor products and an appreciation of completed facilities. The two influences identified from the findings that mainly impact on the knowledge generation process are time and motivation. It is interesting to note that both issues promote the sharing of knowledge (as described previously), as well as the generation of new knowledge.

Boundary crossing, knowledge sharing and knowledge generation are the first three of five identified processes of multidisciplinary knowledge creation. We shall now turn to consider the fourth process: knowledge integration.

7.5 The Process of Knowledge Integration

Because of the complexity of their work and diverse disciplines, the project teams interacted in multiple and complex ways. The integration of knowledge from different design disciplines depends upon a marriage of differing perspectives in design decision-making. But this cannot readily be achieved without the development of common design perspectives, requiring a re-conciliation of the differing priorities and values held by professionals of varying backgrounds and experiences.

In both projects, individual team members offer their values or positions on issues and the interaction between them influences the positions they assume. Interaction is the integration of social order, and more specifically, the integration of thought processes, understanding and thoughts themselves.

Central to Rittel's theory of communication, the knowledge relevant to any design problem is distributed among a number of individuals who have conflicting requirements. The best design solution is the one which best fits the patterns of conflicting requirements (Rittel, 1964). These characteristics can be treated as conditions for knowledge integration. Nemeth (1992) examined the effect of conflict on the stimulation of divergent thinking in groups. The term 'divergent thinking' refers to the process of considering an issue from multiple perspectives. Nemeth's (1992) finding shows that conflicting views within teams can create new knowledge.

Knowledge integration represents the extent to which ideas are shared, discussed openly, challenged constructively and built upon by team members. This is the motivation behind the use of multidisciplinary project teams - the fact that they are able to combine their knowledge and differing perspectives to produce a solution that no one member, acting alone, could have achieved. Knowledge integration requires the input of at least two persons. The disciplinary specialisation of each project team member accumulates different knowledge bases within the teams, so it is necessary for team members to integrate knowledge, to strengthen the knowledge creation process and be able to build up strategic capabilities. Knowledge integration requires the coordination and collaboration of team members. Knowledge integration seemed significant to the knowledge creation processes within both projects.

During team meetings and discussions, team members needed to experiment with a variety of strategies. They tended to consider the constraints imposed by the situations, together with the needs of various stakeholders, such as consumers, the client, regulatory authorities or contractors. Then they would formulate the most appropriate solution. The constraints imposed on the tasks could be physical, cost and time related, as well as constraints imposed by other disciplines.

7.5.1 Integrating Multiple Stakeholders' Perspectives

Both project facilities operate in many domains, which must function structurally, environmentally, economically, aesthetically and technically for the users, owners and the general public. It was found that project team members had to make wilful choices about solutions that would have repercussions on the overall design. They used their professional and practical knowledge and other types of knowledge in the design process, to negotiate a design to suit the needs of various stakeholders. In both cases, the evaluation of a design for a facility involved a number of people who design, discuss, calculate, approve, contest and disapprove of the form. These participants have differing interests, knowledge and goals with regard to the facilities. Their combined influence upon the process then affects the way the problem is solved and the facilities that result. Thus there is a distribution of influence across participants.

For different parts of the facilities, the distribution of influence will be different.

For example, in the RDA project, when considering the external elevations of the tower blocks, the knowledge input of the architects and client was more dominant than other team members, due to aesthetic reasons. In the foundation design, the structural engineers took a more prominent role in the knowledge integration process when they integrated their knowledge input together with other team members also taking part in the foundation design. Further evidence of knowledge integration among team members was during the design of the residential clubhouse where different opinions on the sizes, facilities and locations of the various functional areas were negotiated.

The ferry pier consultant, the architects and the electrical and mechanical consultants had all pooled their knowledge to arrive at a final design satisfying the various requirements for a pier in the INF project. This included structural integrity, the wave and impact load, spatial layout, aesthetic elements as well as the delicately controlled artificial environment. Without the proper balance and integration of knowledge input from the various team members, the design would have fallen short of user expectations, possibly not obtaining approval from the relevant authorities. Another example from the INF project was the entrance plaza, where team members held some fairly heated debate on selecting the suitable paving materials for this large open area. Various issues, such as cost, maintainability, durability and aesthetic appeal, were evaluated. Knowledge from different perspectives was negotiated and integrated before a final decision was reached. Beyond the input of team members, various stakeholder requirements were also addressed. Without considering these, the design would not have been satisfactorily completed. It was found in both cases that effective design decision-making integrated knowledge contributions from project team members and stakeholders, reconciling disparate values to a common purpose. The quality of this increasingly depended on the effective integration of knowledge from a range of sources.

Design problems are non-routine and complex and, despite their resemblance to past problems, are necessarily time and context specific. Project team members are knowledge workers. The range of skills and knowledge required to effect successful design outcomes or projects is increasing. Facilities design requires multidisciplinary skills and knowledge input, but team members from different backgrounds bring to the design situation different sets of assumptions about the best ways to proceed and prioritise different values in considering what is desirable. Muller and Pasman (1996) suggest that design situations are unique. No homogenous set of knowledge can be generally applied.

The knowledge integration process also subjected the design to checks by various statutory authorities like the Buildings Department or the Fire Services Department. There is statutory legislation concerning safety and accessibility standards, subjecting the project team's decisions to external determinants. The attention paid to consumer satisfaction and participation also led to the increase in client and consumer input in the design process. In the RDA project, though, there was no direct user participation as the residential blocks were not yet ready for sale. The client had used the knowledge gained from consumer satisfaction surveys, conducted by their marketing department on other recently completed residential buildings, to collect feedback from end-users. The survey was a standard instrument, including macro-level items like design, quality standard and clubhouse facilities. At the micro level, it included questions on satisfaction with the units' layout, design and provisions. For example, one specific item asked for opinions on the residential blocks' external elevation design, the materials and colours used. From the feedback collected, they could verify whether the users liked a particular design, material or colour. With a positive result, that knowledge could be re-employed for other projects. If not, it should be avoided. RDA team meeting observations suggested consumer responses, as well as general public opinion and the appearance of the completed buildings, were valued highly by the client. Any negative comments regarding their properties could have adverse effects on their sale. Post-occupancy evaluations indicated consumer taste and requirements, of utmost important to residential developments. The input of the property management department as another key stakeholder to the project was also important because they would be responsible for all the daily administration and future maintenance of the property. Their experience in managing other residential properties, as well as current design problems encountered, confirmed that their input to any design was valued highly.

Perhaps one could argue there would be no customers to buy the infrastructure project. However, there are stakeholders in it who need to be considered - most obviously being the government authorities who would take over the infrastructure and carry out its future maintenance. From their point of view, the value criteria of the infrastructure system should relate to low maintenance. The users of the road system would value a safe design, one that would ensure comfortable motoring. Through the team members' involvement in the client's past project, professional knowledge and experience were used to integrate their knowledge input and strike the best balance between stakeholder interests and the reputation of the client's products.

The vast array of expertise, knowledge and tacit know-how in the context of an organisation can have a bearing upon design success. A key lesson to be drawn from their work is that teams typically do not make full use of their knowledge resources in the design process and that oversights can subsequently prove costly. For example, functional managers in the case organisation can possess crucial know-how concerning the facilities which technical specialists in the project teams can neglect. Grant (1996b) has proposed that knowledge integration capability is the key to organisational survival and prosperity in dynamic environments. This capability is especially crucial to the design process. It is the process of combining knowledge from different disciplines that invariably leads to developments that could not be compatible with any single discipline.

Nonaka (1994) finds that many potentially exciting new developments are founded upon the successful integration of technical knowledge inputs from different fields. He calls this process 'combination', in the context of his spiral model of knowledge creation. It was observed in both projects that the integration of knowledge from different design fields depended upon a marriage of differing technical perspectives in design decision-making. But this could not be readily achieved without the development of common perspectives on design, requiring a reconciliation of the differing priorities of values which specialists of different backgrounds and experiences hold.

When team members use rich communication media like face-to-face discussions, it is more likely that new knowledge will emerge (Nonaka, 1994). This may be understood by viewing knowledge integration as a fusion of information and knowledge. The greater the range of information that can be shared, the more likely it is that effective knowledge integration will occur. In addition, since the interactive nature of rich communication allows for immediate feedback, team members can participate in a multi-stage adaptive exchange of views in which each builds on the other's ideas to produce an integrative solution.

7.5.2 Project Documentation and Design Objects as Integrative Tools

The main purpose of the project documentation was to have a final product comprising the knowledge pooled from the knowledge input of various team members. It was a necessary and useful tool to coordinate activities and to make these known to all participants.

Project documentation, like drawings and meeting minutes, had an important role in integrating knowledge from different discipline sources. Tuomi (1999) observed that documents represent attempts to convert some aspects of underlying tacit knowledge in a written linguistic or graphical form. In both projects, meeting minutes tried to capture the knowledge discussed in written format, with drawings combining the pooled knowledge into a design solution format. This enabled the contractor and subcontractors, using this portfolio, to turn them into reality. Since drawings could not relay all the tacit knowledge from the project team to the construction team, project team members needed to interact frequently with the construction team during the construction stage in order to make their final intentions known.

During discussions, various project team members would use such items such as drawings, sketches, models, perspectives or other design objects to support the case they might be presenting. As observed in team settings, these often were the result of knowledge integrated from various team members. They gave rise to collective reflection during the design process, allowing different knowledge input and negotiation to take place before decision-making was finalised. These design objects were useful in the knowledge integration process as team members could visualise the situations under question, as well as examine the effect and impact of the proposed solutions on the overall design. These design objects were used frequently throughout both projects, as could be seen when split air conditioning units were being considered in the RDA project. Freehand sketches were employed by a range of personnel to discuss design, location and maintenance details. Various knowledge inputs were accessed before the final decision was reached. In the infrastructure project, a design model for the pier was even built, enabling the various team members to assess how different variables could impact on the design. This stimulated the integration of knowledge from several project participants.

7.5.3 Summary of the Knowledge Integration Process

Knowledge integration is a critical process within knowledge creation as it allows the integration of knowledge from different disciplines by marrying their differing perspectives in the design decision-making. It enables different stakeholder thought processes and perspectives to be incorporated so that they can be considered and integrated.

Facilities design requires multidisciplinary skills and knowledge input. Differing team members bring to the design situation different sets of assumptions about the best ways to proceed, prioritising different values about what is desirable. By integrating the knowledge input of various stakeholders, differing perspectives may be taken into account, best meeting their requirements as well as resulting in satisfactory design solutions. The research suggests that project documentation, as well as various design objects used during the design process, can be used as tools to integrate the different knowledge inputs from project participants.

In the following section, the last process examined in team knowledge creation is collective project learning. It must be stressed that this process should not be viewed as linear. In fact, collective project learning is found to occur in knowledge sharing, generation and integration.

7.6 The Process of Collective Project Learning

A large part of learning takes place contextually in design and construction - that is, actually on the project. This is true of those who may be formally educated in various disciplines but who nonetheless still have to learn the realities of their job through experience. Accordingly, the design process may be considered a mutual learning curve, in which all participants are both teachers and learners and the design situation itself is a source of new knowledge.

Learning is defined as the process whereby knowledge is acquired. It also occurs when existing knowledge is used in a new context or in new combinations. Since it also involves the creation of new personal knowledge, the transfer process remains within this definition of learning. In this research, 'collective project learning' is defined as the acquisition or mastery of knowledge existing outside the individuals or teams in project-based situations. Collective project learning is likely to provide enough resources to accommodate various issues including customers or end-users, market and competitors. In both case studies, this proves to be very important as no one party or discipline possesses knowledge in all three different areas. In Ferry and Ross-Gordon's (1998, p. 107) view, "the key to expertise does not seem to reside in merely gaining experience, but in how the individual uses experience as a learning mechanism".

The research indicates that collective project learning embraces learning both within the project team as well as within individual professional disciplines. It can also happen across projects through the interaction of different team members. Table 7.2 summarises the differences among the three types of learning.

Table 7.2 Various types of learning that occurred in projects

	Individual learning	**Team learning**	**Inter-project learning**
Structure	Individual activity.	Team activity.	Individuals with multiple team memberships.
Involvement	Project team members who want to capture the knowledge/ experience.	Project team members jointly involved in the tasks.	Project team members involved in the base/past project and the new project, concurrently or sequentially.
Outcome	Individual learning from the project, captured in an individual's memory or personal files for reference in the future, resulting in new knowledge for individual team members. This includes learning from mistakes made.	Team members learn together from a task disregarding the functional boundaries, resulting in new knowledge for the team.	Successful practices/solutions from one project transfer to other projects.

7.6.1 *Individual Learning*

Both the residential and infrastructure developments required complex multi-disciplinary work. This can be seen from the number of professional disciplines involved in both projects. Both project teams seemed quite free to accomplish their professional work and projects' goals. The multi-disciplinary teams of professionals were self-organised to meet any unpredictable problems and knowledge needs throughout the design processes. From the outset, the project managers had maintained an informal work environment, encouraging individual professionals to pursue work relationships as their work permitted. Individuals and teams were further enabled to pursue learning as the need arose. This created a complex work and learning environment in which both the individual and teams developed their skills and abilities.

Individual learning occurred in both teams and consisted of either self-directed or collaborative activities, with individuals helping each other. In either case, individuals shared their learning experience. It became clear that individual and team learning are interrelated and need to be understood together as a whole. Nonaka and Takeuchi (1995, p. 80) confirmed that "every individual should strive for staying knowledgeable in their respective fields, accessing the latest state-of-the-art proficiency that can provide a forward vision".

Project participants concluded overall that individual on-the-job learning is the way for professionals to learn and achieve competency. They found that professional construction consultancies required in-depth professional knowledge and experience, with clients paying professional fees for specific expertise. Team members did rely on individual learning to absorb the new knowledge they encountered on the project, or revise the knowledge already possessed. Both projects demonstrated a high degree of individual learning. They usually learned within their own discipline or occasionally across disciplines. These learning opportunities were self-directed or self-planned, with no intervention from any other party. They were free to learn whatever they liked or found useful. Generally, there was no one to direct them about how to acquire the knowledge needed to complete their job. However, some senior project team members would help junior staff acquire the skills and experiences needed. Individual learning was a way of updating personal knowledge in order to serve current and future clients better. Individual learning also benefited one's personal project experience, highly valued in the construction industry.

Team members explained that professional training required them to independently access knowledge and resources. A major part of their professional training was learning how to obtain requisite information and develop independent learning skills. Even after qualification, they still needed to undergo professional development, to keep updated. So by the time these professionals joined the project teams, they were adept at developing their own self-directed learning strategies. Professional development readily becomes an integral part of the work environment (Schön, 1987).

All observation confirms that individuals, especially those considered to be knowledgeable, had extensive skills and experience in self-directed, independent learning. The architectural director in the RDA project was a good example of self-directed learning, motivated to learn from experience, his colleagues and environment. The submarine pipeline consultant in the INF project learnt as he went along, designing the submerged water mains using the horizontal directional drilling method, in fact a totally new exposure for him.

The work demands also required team members to constantly learn new technology and techniques. They drew on their professional experience to develop their own personal learning and information seeking strategies. These were very varied and included formal and informal educational programs, both within and outside the company network. A free and open work environment encouraged these activities, allowing individuals to move around and interact with anyone or anything they might need. Because of the complexity of the work, the needs for particular information and knowledge were unpredictable. The open work environment allowed individuals to decide how and when they should develop their own learning activities. A free and open work and learning environment is critical for effective and productive product innovation (Koning, 1988; Myers, 1996; Pelz and Andrews, 1976). It recognises that opportunities for learning can be both planned and unplanned.

Several team members confirmed that from time to time they would come across problems or designs that they had not encountered before. They had to establish where and how to acquire the skills needed, by consulting literature or people. It was not uncommon for team members to learn and discover new techniques to minimise or avoid serious environmental, time and cost impacts. They often toyed with several possible alternatives until discovering the best option to accomplish a particular task.

Team members also found that because of both the changing nature of the construction industry and the intensity of business competition, professionals had to constantly learn new technologies and techniques to continuously improve their own performance and offer their clients a high level of expertise and creativity. When this knowledge was not readily available, they were expected to locate it themselves. In the INF project, the landscape architect turned to the specialist design of large-scale water features in the hope that he could offer such services directly to a future client. Alternatively, he could use that experience to decide which specialists to employ in the future. In the RDA project, the clubhouse interior designer stressed the necessity of learning to avoid stagnation, with fashion, trends and materials constantly changing. Participants confirmed that each new project brought with it unexpected challenges. Some could be as simple as improving the way of doing things to increase efficiency.

Thus, research confirms the possibility of two systems of knowledge being used by the team members. One monitored new developments through reading and updating seminars. The other involved immediate and specific problem solving. It would appear that their learning pattern was sporadic, often problem-focused and self-directed, using social networks and work-related reading as the primary means of furthering their education.

In construction, the cost of experimenting is too high. Once something has been designed, it will be built accordingly. The chance of making mistakes should be kept to a minimum as some structural failures can cause fatalities and injuries. Other minor problems could cost money to rectify. However, all the team members agreed that they learnt more from failures and mistakes. The majority said they usually recalled failures over and above successes.

Learning from failure or mistakes requires a critical reflection on the problem and its assumptions. Argyris (1991) argues that professionals need to reflect critically on their behaviour and assumptions and then change the way they act or do things when a similar situation or problem arises. This seemed to be a standard operating characteristic of individuals in the project teams. They all explained that a construction professional learns from mistakes. They found that mistakes help one to better understand the technology so that one can produce good products. Critical reflection is an important component in this process.

Through personal reflection on past mistakes, team members would try not to repeat the mistakes they might have made. Of course, this is highly dependent on the memory of the team member. If he forgets about a transgression made in the past, the chances of repeating it are still great. The general consensus was the bigger the mistake, the less easy it would be to forget.

7.6.2 Team Learning

In contrast with the literature, the findings from both case studies reveal that it is the project teams themselves that encourage these activities independently of any directives. Current literature on team learning points to the need for work environments and resources to support and encourage unplanned spontaneous learning and sharing activities (Dixon, 1994; Guest, 1986; von Glinow and Mohrman, 1990). These sources generally address how the organisation can develop and support these interactions.

Both project teams had formal goals and project management structures. They were focused on producing new products - an infrastructure and a residential development. A lot of small informal, self-organising sub-teams seemed to be the main mechanism, with a small number of team members sharing and contributing their expertise to address a problem or issue at hand. Zuboff (1988) has described how professionals self organise into small focused teams for specific problem solving activities that require a specific blend of expertise. Team members were observed to be spontaneous and dynamic in forming team collaborations. As both project teams were self-organised, they did not have to account for how they got their work done. They were only accountable for accomplishing their commitment. This type of self-organising team behaviour more closely matched the descriptions of teamwork given by Zuboff (1988), where she examined professionals self-organising into teams to address information intensive problem solving activities. The nature of technology and information intensive work requires individual expertise to negotiate collaborative work activities as the situation demands (Wheatley, 1992).

In both cases, small team collaborations usually consisted of 3 to 5 team members. These sub-teams usually self-organised in response to problem solving needs and information exchanges, as the issues were not relevant to the whole team. When the individual team members had more extensive work experiences with each other, these small teams also seemed to emerge to brainstorm or re-examine the projects and issues at hand. Small teams are more effective in the learning and transfer of knowledge when their membership has a common, shared background that unites them (Brown and Campione, 1994). This spontaneous, self-organising team formation is described by Zuboff (1988). In her work, she describes how the immediacy of the work situation requires self-organisation of expertise. Formal team structures are at a disadvantage in these situations. These small teams typically pool their resources for learning and acquiring the skills and knowledge needed to solve problems. Individuals share their information seeking and learning strategies so the sub-team can learn in as many different ways as possible. Usually the sub-teams in both projects met in small clusters in large meeting rooms where team members were free to move around. Individuals shared information and knowledge, as well as results from work. It was an environment that let everyone openly discuss and comment on ideas. Jaques (1984) shows that this is required in effective product innovation teams. These collaborative discourses are characteristic of innovative teamwork environments (Jelinek, 1979).

The larger project teams followed stricter and more formal project management processes and had more formal procedures for sharing and interacting. These larger project teams were far more focused on formal business and product development issues. The overall project followed its formal management guidelines. Project goals were identified and implemented. Deadlines were met and quality standards achieved. However, the information flows and learning issues were almost invisible. No one talked in terms of knowledge flows or learning. However, the most interesting thing that occurred in both larger project teams was that the team members would informally break into smaller sub-teams to process and transform the information they needed. This could happen at any time or place. There seemed to be an informal 'shadow system' at work. Team members would self-organise into small teams. These smaller teams contributed directly to the work of the larger project teams, but they were not formally recognised in the organisational structure of the projects. They formed spontaneously, negotiated by the team members themselves. Most were temporary, lasting only until an immediate goal was accomplished. Savage (1990) has identified individual and group connections as a characteristic of knowledge intensive work and learning. These networks create a team of teams in which individuals self-organise and negotiate their work and learning responsibilities.

Almost all team members recognised that formal meetings could not deal with actual issues but were useful in setting milestones and goals for the two projects. Therefore large project teams were not conducive to learning. But they did provide occasions and places for team members to interact and share experiences.

As stated previously, the nature of consultancy work requires team members to continually engage in self-directed learning. Because of the complex and changing nature of technology and customer needs, they require team members to collaborate and share experiences and learning. No one person can learn and understand everything required for solving complex technical problems to create innovative new products. Therefore, team members have to collaborate and develop team approaches to their work and investigations. No one individual can effectively learn and create the new knowledge required. Therefore team members collaborate to work and learn together in small teams.

The social and professional interaction created in both projects a tacitly understood identity. As individual team members grew to know each other, they accumulated knowledge of how others worked and thought, and thus they developed working relationships. There was indeed a team learning process where team members developed a tacit understanding of their working relationships, the knowledge resources available to them, and the application of the team's expertise to their work. It was tacit because they could not describe how it worked, but these patterns were observed to repeatedly recur at work.

7.6.3 Inter-project Learning

Team members would carry over some of their new knowledge, both explicit and tacit, to new assignments as they frequently cited experiences gained from previous projects during team meetings or when they tried to convey proven ideas to other team members. They would carry what they have learned with them, thereby potentially transferring this newly created knowledge to the minds of their new co-workers. Working concurrently on several projects allowed team members to draw on other projects, possibly improving the team's perspective by helping them pinpoint what is important, yet seeing 'similar issues coming from different disciplines'.

In both cases, the most typical but unrecognised way of sharing knowledge and 'lessons learned' across projects was to work concurrently on several projects. Inter-project learning could be seen as transferring recently gained knowledge from one project to other subsequent or concurrent projects, directly or otherwise. As discovered in both projects, inter-project learning can happen both concurrently or sequentially. Nobeoka (1995) described the concurrent transfer as a new project beginning to transfer knowledge from a base project before it has completed its task. Whilst the sequential transfer happens, knowledge and experience are transferred from a basic project to a new one after the initial project has come to an end. This mode of transfer acknowledges the fact that repetitive tasks should be institutionalised (Lundin and Söderholm, 1995).

In both projects, inter-project learning was reported as a consequence of multiple team membership triggering the concurrent transfer mode to occur. Since the base project and the new project were being carried out concurrently, the knowledge does not have to be stored in order to be applied to the next project. The best scenario is when a participant works in both teams. Through overlapping participation, knowledge created in other projects is currently shared and utilised. In other words, project team members from the one project learn from others. This was found to be common to both project teams. In the INF project, the civil engineer shared knowledge he had learnt about pedestrian paving from another project he was also currently engaged in. The project manager was involved in another residential project, through which he learned of an approval problem relating to block paving on sloped road surfaces. Armed with such knowledge, the chances of a similar problem arising were avoided when submissions were made to the Highways Department. This learning exercise proved to save time, effort and frustration and showed how team members could directly apply successful practices - or avoided those that were not as successful. For the RDA project, one team member found that the experience he gained from a residential project in the Mid-levels could be learned and transferred to the concurrent case project.

All the project managers from the Project Management department of the case organisation met on a monthly basis to share their knowledge and learning from the projects they were working on. In this way team learning between projects was promoted in 'real time'. As the projects were in different phases, they could help each other. Any findings from these meetings would be channelled back to the project that they were managing. These would include both positive as well as negative lessons gleaned by other project managers while working on other projects. These lessons learned were shared openly by the project managers with the project teams concerned.

The sequential transfer mode was not mentioned specifically in either case. Previously gained experience would become part of the skills pool a person possessed and it was not easy to distinguish where a particular slice of knowledge came from. However, team members usually identified projects that they had gained certain experience from when needing to validate an idea or assertion. Team members individually learned from the projects they were involved in and the learning or knowledge acquired became part of their experiences. Alternatively, experience gained from past projects could be viewed as a form of inter-project learning. Team members who worked on previous projects gained experience and knowledge from them which, if positive, could be transferred to current projects. Negative experiences, like previously unsatisfactory building materials, could be acted upon also in the RDA project.

Team members suggested that a central prerequisite for inter-project learning was a certain degree of repetition in projects, since generally the similarity of aspects allows construction and refinement of procedures in projects, whereas the total uniqueness of a project hinders learning (Lundin and Söderholm, 1995; Partington, 1996). While much learning will be project-specific, some will be added to the knowledge base carried forward to future projects. The extent to which this longer-term learning occurs will depend both on the intellectual milieu of their work context and on their own personal disposition.

In both projects, the most common strategy used for inter-project learning was personalisation rather than codification. The codification strategy is generally characterised by the use of documents, guidelines, reports and databases, relying on the codification of knowledge as the prime trigger for learning. No inter-project learning, as described above, used the codification strategy. Instead, the personalisation strategy was used frequently to transfer knowledge and learning, usually relying on team members straddled across several projects, meetings and personal networks.

7.6.4 Summary of the Collective Project Learning Process

The project teams were select groups of professionals with extensive experience in self-directed learning that they used to access information and knowledge, both in and out of the projects. The team members had to constantly learn new technology and techniques in order to remain competitive in their work. Given that they were expert in self-directed learning, they created an environment where they could maximise their opportunities for individual inquiry and learning. Problem solving was the main goal of their work. To support this they recognised that failure was an opportunity for learning and understanding. Understanding failure is a primary mechanism in learning how new technology and systems operate, optimally avoiding repetitive mistakes. Therefore, considerable effort should be made to support an individual's critical problem solving and reflection processes. Individuals develop their own strategies based on individual thinking and learning preferences.

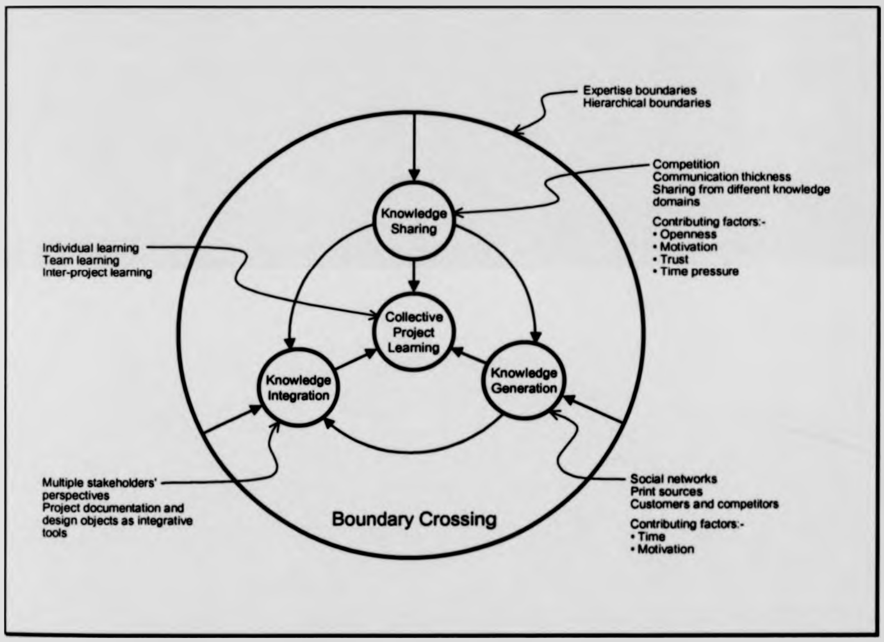
The findings from both projects revealed that it was the project teams themselves that encouraged the team learning activity, independent of any directives. These small sub-teams typically pooled their resources for learning, acquiring the skills and knowledge needed to solve problems in an open and permissive environment. Individuals shared their information seeking and learning strategies so that the sub-team could learn in as many different ways as possible. The larger project teams followed more formal project management processes and procedures for sharing and interacting. These smaller teams contributed directly to the work of the larger project teams, but they were not formally recognised in the organisational structure of the projects. They spontaneously formed, navigated by the team members themselves. Most were temporary, lasting only until the immediate goal was accomplished.

Inter-project learning can be seen as gaining knowledge from a project and transferring it directly or indirectly to other subsequent or concurrent projects. Inter-project learning can happen both concurrently or sequentially. In concurrent transfer, a new project begins to transfer knowledge from a base project before it has completed its task. The sequential transfer happened when knowledge and experience are transferred from a basic project to a new one after the initial project has come to an end. A central prerequisite for inter-project learning is a certain degree of repetitiveness between projects, since the similarity of aspects allows construction and refinement of procedures in projects, whereas the total uniqueness of a project hinders learning. It was found in both cases that the most widely used strategy for inter-project learning was personalisation rather than codification.

7.7 Interrelationships between the Five Processes of Knowledge Creation

Knowledge creation in multidisciplinary project teams starts with the pre-requisite boundary crossing process, which then leads to the three knowledge processes of knowledge sharing, knowledge generation and knowledge integration. Collective project learning is central to the three knowledge processes. This shows that knowledge creation processes within multidisciplinary teams are not linear. Instead, they are interwoven, occurring throughout the projects, as shown in Figure 7.1.

Figure 7.1 The interrelationships between multidisciplinary knowledge creation processes and contributory factors influencing the processes



Both cases found that the project teams needed to cross boundaries imposed both by the range of diverse professional disciplines and also by the hierarchical divisions of client, consultants and contractor before genuine work, problem solving or pertinent knowledge creation could occur. Without boundary crossing, team members could focus simply on their own disciplinary work without due regard for, or collaboration with, other disciplines. In crossing these two boundaries, they could initiate the three knowledge processes through joint problem solving. Once the design issues and problems influencing several disciplines have been identified, knowledge could be shared using their own experience and perspectives. This shared knowledge could include both positive as well as negative experiences. In this process, they also might examine various issues like assumptions, constraints, etc. If the team members possess insufficient knowledge to resolve the situation, or if the situation is not familiar, they could then proceed to the next circular process of knowledge generation where knowledge from various sources will be elicited to fill the knowledge gaps. This happens frequently in design situations where team members may not have the necessary expertise or experience to generate the pertinent knowledge. Individuals would draw on their own resources to generate new knowledge or through interactions within the teams. Once the required knowledge is elicited, knowledge integration will happen by combining all knowledge. In this respect, the knowledge sharing and generation processes are repetitive until sufficient knowledge is found to solve the issue at hand. In some situations where the design problems are familiar, team members can re-use existing knowledge. This implies that new knowledge is not needed to be generated. However, due to changing customer needs, unique design inputs, new technologies or regulations, continuous improvements and initiatives often may be required to generate new knowledge rather than re-use existing knowledge. Once team members have sourced new or emergent knowledge, they need to integrate their collective knowledge. This involves combining, modifying and negotiating among team members so that not only are their needs fulfilled but also the needs of stakeholders. Drawing this balance is in fact an intricate process, requiring the full appreciation of the multiple perspectives held by all stakeholders, including project team members.

The knowledge creation process does not stop here. Through the processes of knowledge sharing, generation and integration, a lot of the emergent knowledge, accessed by individual team members or the team as a whole, will be learnt, absorbed and turned into valuable experience that may be utilised again in the future. Collective project learning is the nucleus of all three knowledge processes (i.e. sharing, generation and integration). In addition, collective project learning can occur within individuals, teams as well as at inter-project levels.

The above discussion helps us understand how the processes of knowledge creation occurred in multidisciplinary project teams, as well as how the five knowledge-creation processes of boundary crossing, knowledge sharing, knowledge generation, knowledge integration and collective project learning are interwoven with each other. Through these interwoven processes, new or emergent knowledge is created within the project team or existing knowledge is combined to form new insights. It must be recognised, however, that inevitably there are some limitations to the present study. In Chapter Eight, we will offer a more detailed account of the theoretical and managerial contributions of this study, as well as acknowledging its limitations and briefly indicating some possible directions for further research.

Chapter Eight - Conclusion

8.1 Introduction

Successful technological innovation or problem solving requires successful knowledge creation. This thesis is fundamentally about knowledge creation, a critically important and enormously complex social process. Despite its importance and complexity, little is known about how this process occurs within multidisciplinary project teams, much less how to facilitate it most effectively.

Knowledge creation is important in creating and sustaining competitive advantage as well as in meeting organisational goals. It is through knowledge creation that new products and services are developed and introduced to the market and it is through knowledge creation that organisations meet and improve upon their performance. Multidisciplinary project teams are especially well suited to this type of inquiry because knowledge output, the main outcome of these teams, depends on knowledge creation. These teams are increasingly important actors in organisations, yet there exists a scarcity of scholarly research on knowledge creation within them, despite assertions that such research initiatives would contribute positively to an academic agenda on organisational knowledge growth.

This research has focussed on three major aspects: the key processes that underlie knowledge creation within multidisciplinary project teams, the interrelationships between these processes and the factors that influence them. To do this, the research empirically investigates the creation of new technical knowledge and develops a conceptual model of the knowledge creation process. It modifies Nonaka and Takeuchi's (1995) organisational knowledge creation theory into the area of multidisciplinary project teams. Two case studies were carried out to explore the processes taking place in multidisciplinary project teams, to understand their interrelationship and to highlight the factors enabling these processes. These led to a number of compelling findings, culminating in the conclusion that knowledge creation is intimately linked to the collaborative nature of project teams themselves.

In this chapter, the overall research findings are discussed by integrating them into a coherent theory and suggesting some interesting ways of viewing knowledge creation within multidisciplinary project teams. But first the major contributions of the research are outlined. In the following section on knowledge creation within multidisciplinary project teams, the major findings are examined by integrating them into a common theme. The development of a revised theoretical model regarding how knowledge is created in multidisciplinary teams is given next. This is followed by a discussion on the theoretical implications. Then, various managerial implications, specific to multidisciplinary project teams, are taken into account. The major limitations of the research, with suggested future research directions, are outlined.

8.2 Contributions of the Research

The research has contributed twofold to the literature on knowledge creation and team processes within multidisciplinary project teams.

Firstly a better understanding of knowledge creation within multidisciplinary project teams has been reached, with the research providing substantial empirical evidence. This has not been adequately examined by past researchers. Powell (1998), for instance, acknowledged that we know little about the processes of knowledge creation in collaborative settings. Previous work has focussed mostly on the organisational level, usually from the perspective of knowledge or technology transfer. Specifically, the fundamental processes have not been studied. This research provides a glimpse into how knowledge is created within multidisciplinary project teams involved in technological innovation or problem solving.

Secondly, this research has modified Nonaka and Takeuchi's organisational knowledge creation framework, resulting from its general inadequacy to deal with vital features of the research. Besides its underlying focus on individual knowledge, the primary distinction between tacit and explicit knowledge is problematic as tacit or personal knowledge is always a precondition for explicit knowledge. Tuomi (1999) also criticises the Nonaka and Takeuchi's model for taking culture and language as given, which may make its use difficult for multidisciplinary project teams. It is also not clear what happens when the knowledge-creating spiral expands outside a team - is knowledge still created the same way (Tuomi, 1999)? To overcome some of the shortcomings of Nonaka and Takeuchi's knowledge creation model, the knowledge conversion processes are re-grouped under 'knowledge sharing', 'knowledge integration' and 'collective project learning', as previously explained in the conceptual framework. By doing that, the limitations of Nonaka and Takeuchi's knowledge creation framework are overcome. Furthermore, this research does not utilise Nonaka and Takeuchi's (1995) conditions enabling organisational knowledge creation but instead generates its own from the case studies examined. By exploring knowledge creation within multidisciplinary project teams, this research has contributed to a better understanding of the interrelationships between several loosely connected knowledge-creating activities, previously not investigated together, as well as their importance in knowledge creation. The empirical results provide new insights into both the theory and management of knowledge creation. These insights are described in detail in the following sections.

8.2.1 Knowledge Creation in Multidisciplinary Project Teams

Beyond modifying Nonaka and Takeuchi's (1995) model of knowledge conversion processes, a major and significant finding is that the collaborative nature of multidisciplinary project teams is essential in creating new knowledge. With a traditional focus on professional specialisation, many facility projects may be managed with tasks being executed in parallel or in sequence, or by certain project team members in isolation. This is often counter-productive when projects are so designed that the success of creating new knowledge among diverse disciplines may suffer, with optimal value possibly not achieved.

The first process in knowledge creation involves boundary crossing, with two types of boundaries affecting the progress and success of multidisciplinary knowledge creation identified. The importance of boundary crossing is reflected in solving the 'boundary paradox' (Quintas et al., 1997), where team members are able to exchange and combine knowledge (Nahapiet and Ghoshal, 1998). The interactions across these boundaries can either foster or hinder knowledge creation. The first boundary identified was between team members of different disciplines. The second boundary existed between client, consultant and contractor. The expertise boundaries could be crossed, not only through knowledge redundancy among team members, but also through boundary objects. The most prominent project boundary objects were drawings and personal conversations among team members. The second hierarchical boundaries could be crossed through team members consciously breaking down any barriers by valuing the expertise of others. The example set by the project managers was also helpful in this regard. It must be stressed that crossing boundaries does not necessarily guarantee the creation of knowledge. It is seen, however, as a pre-requisite for all the four remaining processes to occur.

The second process relates to knowledge sharing, with project team members of differing knowledge domains more likely to discuss their uniquely distinct information and knowledge than those who possess information in common. It seemed to be an advantage to have a diverse pool of knowledge for team members to access and share in discussion. Despite the existence of little competition among team members, external competition could act as a double-edged sword in the knowledge sharing process. Sharing important market or design knowledge could lead to imitation by competitors, possibly even resulting in project poaching. In addition, the type of communication appeared more influential in the transfer of tacit rather than explicit knowledge. For tacit knowledge to be effectively transmitted, interpersonal communication seemed of the utmost importance. Four influences impacting positively and negatively on the sharing of knowledge were identified, including openness, motivation, trust and time pressures.

The third process to be considered is that of knowledge generation, in which teams create knowledge by generating new or 'emergent' knowledge through interaction and communication. New or emergent knowledge, not possessed before discussion, can develop through group discussion and interaction (Kogut and Zander, 1992). The development of emergent knowledge is vital for creativity and innovation. It is generated through various means, including those of social networks, printed sources as well as customer and competitor feedback.

Social networks were identified as the most important vehicle for information and knowledge exchange, with team members heavily reliant upon colleagues, friends and ex-colleagues as rich resources for generating design knowledge. The use of printed data in the design process appeared to be limited, viewed as time-consuming and used mainly to cross-check solutions offered. Social networks tended to recommend published materials, helping reduce research time and enhance usability. Comprehension of customer needs, insight into competitor products and an inspection of completed facilities seemed to all stimulate knowledge generation. Time and motivation were identified as two very significant influences and it is interesting to note that both of these impacted on the sharing of knowledge, as well as the generation of new knowledge.

Fourth is knowledge integration, realised by marrying the differing perspectives and knowledge of various disciplines in the design decision-making process. It enables different stakeholder views to be incorporated so that they can be considered and integrated. Facilities design requires multidisciplinary skills and knowledge input. Various team members brought different sets of assumptions about optimal ways to proceed, prioritising different values and perspectives to ultimately best meet stakeholder requirements as well as arrive at satisfactory design solutions. Project documentation, as well as various design objects, were used as tools to integrate the range of knowledge input from project participants.

The fifth process involves collective project learning, in which professionals with extensive experience in self-directed learning learn from the projects they are engaged in. Project team members had to constantly absorb new technology and techniques in order to remain competitive. Experts in self-directed learning, they created an environment maximising opportunities for individual inquiry and learning. Problem solving being central to their work, they also recognised that failure was an opportunity for learning and understanding. Understanding failure is a primary mechanism in learning how new technology and systems operate, optimally avoiding repetitive mistakes. Therefore, considerable effort should be made to support an individual's critical problem solving and reflection processes. Individuals then develop personal strategies based on their own thinking and learning preferences.

The project teams themselves encouraged team learning activities, independent of any directives. Small sub-teams typically pooled their resources for learning, acquiring the necessary skills and knowledge to solve problems in an open and permissive environment. Individuals shared their information seeking strategies so that the sub-team might learn in as many different ways as possible. The larger project teams followed more formal processes and procedures for sharing and interacting. The smaller teams contributed directly to the work of the larger project teams, but they were not formally recognised in the organisational structure of the projects. They spontaneously grouped and regrouped, navigated by the team members themselves. Most formations were temporary, lasting only until the immediate goals were accomplished.

Inter-project learning can be seen as gaining knowledge from a project and transferring it directly or indirectly to other subsequent or concurrent projects. Inter-project learning can happen both concurrently or sequentially. In concurrent transfer, a new project begins to transfer knowledge from a base project before it has completed its task. Sequential transfer happens when knowledge and experience are transferred from an initial project to a new one, upon the original's completion. A central prerequisite for inter-project learning is a certain degree of repetitiveness between projects, with the similarity of aspects enabling construction and refinement of procedures, whereas the total uniqueness of a project can slow learning, possibly hindering immediate progress. The most widely observed strategy in inter-project learning involved personalisation rather than codification.

Now that the major findings of the research have been discussed, their integration is attempted. This results in a new model specific to the multidisciplinary project team setting and is presented in the next section.

8.2.2 A Model of Knowledge Creation in Multidisciplinary Project Team Settings

The research has arrived at a new model of knowledge creation within multidisciplinary project teams, differing from the organisational knowledge creation theory developed by Nonaka and Takeuchi (1995). The research places primary emphasis on the processes rather than the outcomes of multidisciplinary knowledge creation as put forward by previous researchers.

The underlying processes of knowledge creation in multidisciplinary project teams are different to those proposed in the organisational knowledge creation theories. A new model of knowledge creation within multidisciplinary project teams is proposed and illustrated in Figure 7.1. In the model, the five processes of knowledge creation are identified, including the processes of boundary crossing, knowledge sharing, knowledge generation, knowledge integration and collective project learning. The interrelationships of these five processes are elaborated to enable their thorough understanding. It must be stressed that that these knowledge creation processes within multidisciplinary teams are not linear. Instead they are interwoven, occurring throughout the projects

This model provides a critical comparison with existing organisational knowledge creation modes and has tried to embrace past literature related to team processes and knowledge creation. The proposed model also highlights the factors that influence these five knowledge creation processes in both positive and negative ways. The next section details the theoretical implications of the research.

8.3 Implications for the Theory on Knowledge Creation

The modified model discussed in the research findings and in the previous section suggested at least two implications for the theory on knowledge creation. The first implication is that the theory should be contingent upon specific settings, e.g. a particular team or organisation. The findings suggest that the underlying processes of knowledge creation are different between the modified model and the one described by Nonaka and Takeuchi (1995). In addition, the factors influencing them are found to be different as well. This also suggests that different factors are associated with certain knowledge creation processes, highly linked to specific settings.

The second implication is that the theory must explicitly take into account the communication processes utilised by project team members in creating new knowledge. The research findings also agree with the assertion by Nonaka and Takeuchi (1995) that the knowledge conversion processes should be closely associated with strong communication. The two processes appear inter-linked, strongly supportive of one another. Orr (1996) finds that when documentation proves insufficient, photocopier technicians use face-to-face communication over breakfast and lunch meetings to share knowledge. Nonaka and Takeuchi (1995) suggest that individuals can also share knowledge through non-verbal means, such as observation, imitation and practice. While individual input is still important to the overall process of knowledge creation, communication would seem to be a vital component, especially at the team and organisational level. It may even be argued that individual knowledge creation is based on communication, as no person learns or masters knowledge entirely alone. Communication processes need to be central to any theory of knowledge creation. Research findings are used next to point out some specific implications for the effective management of multidisciplinary project teams.

8.4 Implications for the Effective Management of Multidisciplinary Project Teams

Project teams with diverse workforces can be seen as essential units in promoting and sustaining knowledge creation within organisations (Kanter, 1988; Nonaka, 1994; Spender, 1998; Starbuck, 1992). However, the diversity of team members can be problematic, posing a demand on the team to manage divergent thinking paradigms and basic assumptions, as well as the 'professional egos' of team members (Dougherty, 1992). This would suggest a need for proper management before the benefits of knowledge creation can be harvested. This would require the joint effort of teams and their management.

This research suggests four key lessons for multidisciplinary project teams and management. The theoretical insights discussed above lead to a number of practical implications and recommendations. These are illustrated anecdotally from the case-based research.

8.4.1 The Support of Intra- and Inter-organisational Social Networks

The analysis presented in Chapter Seven made it clear that project team members generate knowledge and learn from colleagues within their own organisations as well as from people in other companies. These social networks can comprise friends, former classmates or ex-colleagues. Team members may access them to generate knowledge or learn of new and unfamiliar practices. These social networks enable learning across projects, facilitating the transfer of knowledge from one project to another.

From an intra-organisational perspective, the current project-based culture appears to enable intra-project, rather than organisational, learning. One method increasing the internal transfer of knowledge and enhancing a firm's competitive advantage, is a managerial commitment to creating a relaxed environment where individual consultants can learn from each other internally, across project boundaries.

Broader personal networks are important for knowledge creation and consultants should encourage and support their formation. They should be considered an asset, particularly beneficial when consultants are faced with uncharted situations. Strong intra and interdisciplinary personal ties and contacts with professionals from the same or other specialisations should contribute to knowledge creation, enhancing learning across projects. After all, no one single person or professional can possess all the knowledge required for any construction project.

The development of personal relationships and the promotion of network building appear to be enhanced, with less emphasis on efforts to centrally collect and manage tacit forms of knowledge. Personal relationships, especially those based on trust, commitment and the expectation of reciprocity (as opposed to reward), seem the broadest distributors of knowledge - knowledge often unavailable elsewhere and critical to the work being performed. Supporting the formation of personal relationships could create unanticipated learning opportunities that could be missed when relying too heavily upon centralised electronic databases to solve all knowledge sharing challenges.

8.4.2 The Enhancement of Co-operative Teamwork

Lessons learnt from the two cases suggest that projects with open and regular communications tend to be better at creating new knowledge. While it could be time-consuming and potentially costly, the practice of holding regular and informal multidisciplinary meetings was a positive tactic used in both projects studied. Direct and open communication and reflection were encouraged in these meetings. This collaborative exchange of knowledge appeared to successfully diffuse important knowledge among project participants. While individuals might be expected to perform tasks on their own, management needs to design adequate mechanisms for collaboration within any project. The provision of informal meetings is an effective ploy to encourage collective resolution of design issues or problems. Furthermore, isolation of project team members through rigidly uncompromising task specifications should be avoided. Even if tasks are specialised, the responsible project members should communicate directly and regularly with other relevant project members rather than perform their work in isolation, hoping to merge their work together at some later stage.

8.4.3 Mechanisms for Easing Tension among Project Team Members

The creation of tension within any project is inevitable, more likely to be detrimental to knowledge creation than enabling. It tends to detract from collaborative effort. Tensions can be generated from temporally tight project programmes, unfamiliar work practices and priorities and variant project, personal and organisational goals. Mechanisms for reducing unwanted tensions should be introduced to the projects. In both projects, team members found that socialising encouraged the formulation of personal relationships and that this helped ease tensions that might have developed.

8.4.4 Concentration on Project Value Maximisation

It is evident from the case analyses that multidisciplinary projects are by nature unwieldy. For successful knowledge creation, project value maximisation is more important than efficiency. Project value maximisation must come before efficiency. This becomes clear when an efficiently designed project results in limited knowledge creation. Initially cheaper to manage, the return on investment can be very low. An example from both case studies was the adoption of an existing design solution. Project efficiency may have been increased through reduced design time but the outcome was less than ideal. Current needs were not entirely met and the feature in question lacked the unique distinction the development sought to achieve.

Within budgetary constraints, projects should be designed with appropriate resources. Traditional project management techniques can be used to help track progress but this should not be allowed to hinder flexibility in facing any significant changes that may enhance the project's value, as well as incorporating the latest needs of the stakeholders and customers.

Great care was taken in both projects to effectively deal with other contributory or stakeholder issues, as opposed to simply concentrating on efficiency. This was evident in the use of input from functional departments within the case organisation, regulatory authorities, customers or even competitors. From an efficiency perspective their involvement was not necessary. The facilities could be developed without them. The effective implementation of their needs in the design, as well as design features to attract potential customers, was paramount to success.

Rather than setting traditional goals, management should nurture knowledge and learning opportunities to enhance a project's unique and effective features. This was reflected within the Project Management Department where important lessons were distributed at regular intervals across the projects, rather than at completion when most previous lessons might have been forgotten. The chances of recurring mistakes were thus minimised, with the potential enhanced for an on-going commitment to sharing project knowledge.

8.5 Limitations and Future Directions of Research

As more organisations employ multidisciplinary teams to sustain or improve their competitive advantage through innovative products or services, more attention should be directed to highlighting their unique features and understanding how to turn the teams into an effective knowledge creation force.

Although this research has made significant theoretical and practical contributions, like any other study, it has limitations that call for further research. This section highlights these, alongside future opportunities for investigation.

Firstly, only a specific type of team was included in the research data. The research site provided an excellent opportunity to explore the processes, interrelationships and contributory factors to knowledge creation within a multidisciplinary setting. However the experience of these teams cannot be extrapolated to all teams. It is suggested that future research could attempt to conduct similar studies in more diverse settings. Since different team structures and cultures could differently influence the knowledge creation processes, future research could contribute to the development of a pluralistic, rather than normative, view of team knowledge-creation capability. This might include comparative studies of information-intensive teams versus production-oriented teams, and research versus product oriented teams. The current study was based on multidisciplinary project teams (architects, engineers, surveyors, etc.), with members sharing a lot of commonality by being located in the same industry - when compared with other settings. Future studies could examine teams in more complex interdisciplinary circumstances (e.g. biotechnology, genomics, etc.) where teams are brought together - even from quite different fields and industries. These might work on complex problems, pooling their diverse backgrounds and training - possibly to solve a complex business problem, design a new system, product or service or re-organise a company.

Secondly, given the formative nature of this research and the difficulty of gaining access to other firms due to competitor sensitivity and confidentiality, the study was limited to the two case studies within the case organisation. The findings, to a certain extent, may have very limited general applicability. Further research may attempt to replicate this study in different organisational settings in order to extend the value of the research findings.

Thirdly, the research on knowledge creation extends across multiple theoretical boundaries. However, this study emphasised primarily the areas of knowledge creation and team processes. Though other related literature has been discussed in this thesis, their review was not the main thrust. The ample information management and information systems literature, devoted to knowledge management or organisational knowledge, were not incorporated into the study. This limitation can be explained by the study's focus on the processes of knowledge creation within multidisciplinary project teams, rather than the effects of information systems on these processes. Such a limitation represents a major research opportunity through exploring the impact of information systems on knowledge creation.

The fourth limitation of this study lies in exploring knowledge creation solely during the project design phase rather than during the complete project life cycle. This leaves the knowledge creation processes over the construction phase relatively untouched.

Further research that aims to examine knowledge creation during the construction stage could be interesting, as the knowledge input from contractors, sub-contractors and suppliers would need to be taken into account.

Finally, the study did not measure the effectiveness or quality of the knowledge created by the multidisciplinary project teams. Such a measurement could facilitate a clearer understanding of any organisational competitive advantage that might result from knowledge creation. Clearly, future research aiming to tackle these issues might enable project teams and management to better understand and evaluate the potential impact of multidisciplinary project teams on knowledge creation.

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